Agriculture in Pakistan

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Foreword

The digital age has its preferences. The reading time has been encroached upon by a watching time. The access to information is easy and a plenty where Wikipedia has emerged as the most powerful encyclopedia ever. Yet, a book is a book! We wish to promote the habit of reading books. Finding books is not difficult or expensive (www.pdfdrive.com) but a local context and indigenous experiences could be missing.

The University of Agriculture, Faisalabad (UAF) has achieved global rankings of its flagship programs and acceptance as a leader in the field of agriculture and allied sciences. A competent faculty, the stimulating ecosystem and its learning environment have attracted increasing attention. Publication of books is an important KPI for any institution of higher learning. Hence, UAF has embarked upon an ambitious 'books project' to provide reference texts and to occupy our space as a knowledge powerhouse. It is intended that the UAF books shall be made available in both paper and electronic versions for a wider reach and affordability.

UAF offers more than 160 degree programs where agriculture remains our priority. There are about 20 institutions other than UAF who are also offering similar degree programs. Yet, there is no strong history of indigenously produced text/reference books that students and scholars could access. The last major effort dates back to the early 1990's when a USAID funded TIPAN project produced a few multiauthor text books. Those books are now obsoleted but still in demand because of lack of alternatives. The knowledge explosion simply demands that we undertake and expand the process anew.

Considering the significance of this project, I have personally overseen the entire process of short listing of the topics, assemblage of authors, review of contents and editorial work of 29 books being written in the first phase of this project. Each book has editor(s) who worked with a group of authors writing chapters of their choice and expertise. The draft texts were peer reviewed and language corrected as much as possible. There was a considerable consultation and revision undertaken before the final drafts were accepted for formatting and printing process.

This series of books cover a very broad range of subjects from theoretical physics and electronic image processing to hard core agricultural subjects and public policy. It is my considered opinion that the books produced here will find a wide acceptance across the country and overseas. That will serve a very important purpose of improving quality of teaching and learning. The reference texts will also be equally valued by the researchers and enthusiastic practitioners. Hopefully, this is a beginning of unleashing the knowledge potential of UAF which shall be continued. It is my dream to open a bookshop at UAF like the ones that we find in highly ranked universities across the globe.

Agriculture is the lifeline for the economy of Pakistan. Pakistani agriculture is characterized by agro-ecological diversities in soil, rainfall, temperature, and cropping system. However, the agricultural production is stagnant due to several barriers including a fixed cropping pattern, reliance on a few major crops, a narrow genetic pool, poor seed quality, and a changing climate. In addition, the high cost of production, weak phytosanitary compliance mechanisms, and a lack of cold chain facilities makes Pakistan agriculturally uncompetitive in export markets. Despite all these issues, agriculture is the primary industry in Pakistan and small farmers continue to dominate the business. Small farmers grow crops for subsistence under a fixed cropping pattern and a holistic approach is required to develop agriculture to improve the livelihoods of the rural populace. This book presents a comprehensive overview of agriculture in Pakistan.

Before concluding, I wish to record my appreciation for my coworker Dr. Muhammad Farooq who worked skillfully and tirelessly towards achieving a daunting task. Equally important was the contribution of the authors of this book. I also acknowledge the financial support for this project provided by the USDA Endowment Fund available to UAF.

Iqrar Ahmad Khan

Preface

Pakistan has an agriculture-based economy where the share of agriculture in the national GDP is about 24%. Agriculture provides raw materials to major national industries like textile, feed mills, flour mills, and sugar mills, etc. A diverse range of soil types and agro-ecological zones made Pakistan fit for a large number of food, fiber and cash crops. Both indigenous and introduced crops have been grown for food, fiber and cash. Pakistan is 3rd largest producer of chickpea, 4th largest producer of cotton and mango, 5th largest producer of sugarcane and date palm, 7th largest producer of onion and wheat, and the 11th largest producer of rice in the world. In addition to the contribution to food security, the agriculture sector also provides economic security to 45% of the country's labor force which is directly involved in agriculture as their major profession or as a side business.

With the development in agriculture research, a significant improvement in the cultivation and production of crops has been achieved. With advanced technologies, barren lands have been cultivated and water has been managed in drought-prone areas wither with drip or sprinkler irrigations. The yield of major crops has been boosted and has improved 3-4 times, especially after the green revolution. With the production of biotic and abiotic tolerant crops, dependency on pesticides has decreased. With such improvements, agriculture farming has become an industry.

Despite all these improvements, there is very less understanding of agricultural systems and policies. Due to these reasons, often Pakistan has a surplus of commodities in one year and a shortage of the same commodity in very next year. The present book is an attempt to provide an understanding of agricultural systems and policies. This book has been divided into five sections. The first section provides an overview of faith and science of agriculture. In this section, some achievements of Muslim scientists are presented. The second section describes a systematic overview of agricultural research, education and extension services at the national and provincial levels. The third section provides insight into agricultural production and marketing policies with the identification of problems and their possible solutions. The fourth section provides an overview of different sectors of agriculture like crop sector, livestock sector, agricultural machinery sector, seed sector, fertilizer sector, and pesticide sector. In the last section, water and land resources have been described with respect to availability for agriculture. In this section, major soil problems in different agro-ecological zones have also been discussed. Different cropping systems in various agro-ecological zones have also been described.

Overall, the book covers several topics, which at present are not normally dealt with in books on general agriculture. It is difficult to find a book with this diversity that deals with these topics together. While preparing this book; adequate consideration has been given to present the most recent and advanced information. In a constantly evolving field, this is always not easy; however, the contents are intended for students in all areas of agriculture as well as scientists and businessmen. In addition, the contributions of reputed experts in different areas of agricultural production and policies provide deep insight into the individual topics. We believe that the contents will enhance the knowledge and provide a fresh perspective on several issues in agricultural systems and policy development. The editorial team thanks all authors who contributed to this volume.

Muhammad Farooq

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Ideological and Historical Perspectives

Chapter 1

The Role of Faith in Science

Muzaffar Hussain♦

Abstract

Science and faith are part of nature, and both need research but in a practical sense, science is based on research, and religion is based on belief. Religious scholars defend their faith with discoveries of science. It is claimed that the cognitive science of religion deals with an empirically well-versed Reidian defense of religious beliefs. A systematic study of religion and science started in the 1960s, broadening the areas of research in both parts. In this chapter, a brief history of the formal and informal relationship between faith and science has been discussed. Views from religious books especially the Holy Quran and scholars about faith and science have been discussed. Religious laws disclosed through revelation are immutable whereas scientific laws discovered by the human intellect are ever-changing. However, the human mind cannot be divided into two different camps oscillating from one camp to the other at ease. This is not only against the basic principle of *Tawhid* but also simply impossible.

Keywords: Activism, Faith, History, Religion, Science

1.1. Introduction

Science has increased food production, controlled diseases, enabled global communication, alleviated man's miseries, and added tremendously to his physical comforts (Floros et al. 2010). On the other hand, it has also introduced the deadliest weapons, poisons and caused environmental degradation and pollution putting the

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very existence of mankind at stake (Fordon 2007). However, natural sciences have been devoted to religious meaning, with anti-religious inferences, and in many situations, without any religious worth at all (Brooke 1991). For both good and bad, science has become an inevitable part of everyday life in modern civilization. So, every nation in the world is willy-nilly trying to maximize its scientific efficiency and performance. Certain parameters have been set to determine a nation's scientific potential. The same parameters apply to individual scientific establishments and institutions also. These include (i) supply of scientific and technical manpower, (ii) technical and financial resources, (iii) supply of scientific and technical information, and (iv) and organization of the system.

These parameters or standards, if met adequately, are believed to provide a favorable environment for ensuring the scientific and technical growth of a country. The crucial importance of these material factors is universally emphasized in the management of corporate science enterprises. Circumstances may, however, vary from one country to another and accordingly emphasizes each of these factors shifts in their *inter se* prioritization. However, the cognitive science of religion studies the cognitive foundations of religious beliefs. Therefore, arguments in natural theology are impacted by evolved cognitive dispositions as well (Helen and Smedt 2013). For instance, the design argument may develop its innate appeal from an advanced, early developed tendency in humans to assign purpose and plan objects in their environment. This makes the natural theological projects more complex, which rely on a discrepancy among the origins of a religious belief and their explanation through logical argument.

Clark and Barrett (2011) claimed that the cognitive science of religion deals with an empirically well-versed Reidian defense of religious beliefs. However, Reid (1764) suggested that we are right in holding beliefs that arise from cognitive faculties collectively present in humans. Nonetheless, Nichols and Callergard (2011) argued that this defense only works for perceptual faculties, memories, and beliefs on testimony, not for the mix of culture and evolved biases that constitute religions, as that does not form a Reidian faculty.

1.2. Historical Perspective

In India, for example, Ranganathan never felt weary in stressing the importance of information. He conceived scientific activity as an essential information process and used to say very fondly, emphatically, and repeatedly that information is the raw material as well as the product of all scientific research. One of his books begins with a mention of "Research consultants" engaged by the United States Defence Department during world war-II (Kent et al. 1978). They were chosen from amongst the working scientists and were deputed to spend all their time in the libraries sifting and collecting information needed by their counterparts working in the laboratories. The provision of effective and quick information support to the researchers saved much of their time, which they previously used to spend in the libraries. They now utilized time thus saved in the laboratories, which paved the way to the early discovery of the atom bomb, by speeding up the discovery process. According to Ranganathan, high priority accorded to information in the name of research consultancy established the superiority of the United States in the domain of science and thus enabled this country to emerge as the leading "Big Power" in the world.

Then in the late fifties, the Russians took precedence over the Americans in space science by launching the first ever Sputnik into space. The United States took it as a big challenge, rather than a threat to its image as a world power. The American President immediately constituted a committee headed by Dr. Weinberg, to delve into the weaknesses of the US research system, which gave the Russians an edge over them. After a thorough appraisal of the US science system, the committee submitted a report entitled "Science, information, and government, popularly known as the Weinberg report, which pinpointed major weaknesses and shortcomings in the United States science system (Weinberg 1963). Most of these, according to the report, pertained to the information component of the system. These weaknesses were overcome soon, and positive results started accruing. Consequently, the Americans not only caught up with the Russian scientists in space science but also outstripped them in a very short period. Nonetheless, the systematic study of religion and science started in the 1960s, with authors like Barbour (1966) and Torrance (1969) who challenged the usual view that religion and science were either at war or uncaring to each other. Barbour's Issues in Science and Religion (1966) set out many lasting themes of the field, containing an evaluation of methodology and theory in both fields. *Zygon*, the 1st specialist Journal, on science and religion, was also started in 1966. The early study of science and religion was dedicated to methodological issues; however, the authors from the late 1980s to the 2000s set contextual methods, including complete historical considerations of the association between science and religion (e.g., Brooke 1991). Harrison (1998) challenged the warfare model by disagreeing that Protestant theological notions of nature and humanity assisted to strengthen science in the 17th century. However, Bowler (2001) drew consideration to a broad movement of liberal Christians and evolutionists in the 19th and 20th centuries who intended to merge evolutionary theory with religious belief.

These are, of course, interesting stories containing very valuable lessons for science policymakers. But still, these do not reveal the whole truth as these are focused on the material factors only. Improving creativity in scientific researchers certainly needs a congenial material environment and it flourishes and thrives within the empirical parameters already described. But in the ultimate analysis creativity sprouts and blooms in the minds of the scientists that give birth to new ideas. The psychologists, therefore, got interested in the creative process and their interest was quite natural, genuine, and fully justified.

Most psychologists have studied the creative process from a very broad perspective. For them, the creativity of a scientist or an artist is essentially the same kind of mental activity, you may call it an identical psychological process. This point was made out of an interesting interchange between two contemporary creative geniuses. Havelock Ellis, the great writer, is reported to have once remarked: "Einstein is a great artist!" On hearing such remarks from a great writer about himself, Einstein was piqued, and it stimulated his scientific curiosity. As a true scientist, he set out to discover the real intent of the statement made by Havelock Ellis and started reading his works. After reading some of his books, he too gave a cold judgment on him saying "Havelock Ellis is a great scientist". This exchange of statements with a counterstatement was neither just humor nor a mere reciprocation of courtesy. It was, in fact, their concord on the deep similarities existing between their innate psychological processes even though their fields of activity were so vastly different. I need not dwell on this point more than conceding that creativity of all kinds emanates from the unconsciousness and the diverse forms that it takes have marked resemblances and similarities.

Ghiselin (1963) compiled a book entitled "The Creative Process" containing first-hand information on the world's most outstanding men and women of his time. They were selected from various fields such as art, literature, and science. He recorded in this book the experiences of thirty-eight persons in their own words as to how they begin and complete their creative works. Analyzing how new creative ideas are born and developed he classified them into two main categories "intensive thinkers" and "intuition followers". It was interesting to note that most of them reported that sudden flashes of intuition and clairvoyance guided them.

In another book "The Way of the Investigator" by Cannon (1972), a chapter was devoted to "The Role of Hunches in Scientific Thought". That chapter concluded that creative scientists depended on two methods, the method of "intensive thinking" on the existing status to find out the next move or "seeking the assistance of a sudden and unpredicted insight". Both these methods according to him served the scientists in their discoveries equally well. Based on his personal experience, Cannon (1972) stated that he invariably had the unearned assistance of unpredicted insights during his research activity, which was a matter of routine from years of his youth, and he always trusted them. He remarked, "The process has been so common and reliable for me that I have supposed that it was at the service of everyone". In the above chapter, Cannon (1972) also quoted a study on an inquiry into the appearance of hunches among the chemists in their research work conducted by Platt and Baker in 1931. The inferences drawn were based on the answers received from 232 respondents. While recording their evidence regarding their experiences in finding solutions to the problems, 33% of the researchers admitted that they always received assistance from hunches and 50% reported that they had such assistance only occasionally whereas 17% of the respondents said that they never had any such experience. Among this last category of respondents, some researchers declared that the very idea of hunches was distasteful to them. Without going into detail, it would suffice here to say that psychologists have been grappling with the creativity question for a long and because of their studies, they have been advancing arguments in favor of one or both these methods just described i.e., the thought aided by intuition and the unaided thought.

According to psychologists, creativity is the capacity to produce ideas, and the ideas must be both new and workable or functional. Thus, creativity empowers a person to adjust to novel situations and to solve problems that unpredictably arise (Simonton 2001). Some psychologists have been merely listing the conditions favoring the creativity process e.g., good physical state, fresh mind, mastery of the subject, striving for results, confidence, enterprise, willingness to take chance, eagerness for action, readiness to break away from routine, etc. Certain conditions have also been indicated by a few of them that help in the creative process such as discussing the problem with other investigators, reading articles pertinent to the problem as well as pertinent the methods useful in finding the solution. Others have tried to correlate creativity to the IQ of the individual scientist. Wallas (1954) described four stages of creative thinking, *viz*. preparation, incubation, illumination, and verification that are widely accepted. Maslow (1968) differentiates between creativity associated with great tangible achievements and the creative potential of ordinary persons, which inheres to the self-actualization motivation of every individual.

There is a vast plethora of literature on the subject to which one may refer according to his interest and taste. It may, however, come as a great surprise to the psychologists and scientists belonging to the secular school of thought that some scientists of the highest stature talk about certain moral values and religious beliefs about scientific creativity. Hefner (1993) reported that the association between science and religion includes creativity, battle, and courage as *created Co-creators* (we contribute to creation by feeling the creativity of scientific vision and religious revelation). For example, Nobel laureate Krebs laid great emphasis on the value of humility saying, "perhaps the most important element of scientific attitude is humility because from it flows self-critical mind and continuous effort to learn and to improve". Similarly, Pakistani Nobel laureate Dr. Abdus Salam, a Qadiani non-muslim, stated before an interviewer that the Islamic concept of *Tawhid* provided him the basis and direction of research, which led him to a discovery that qualified him for the Nobel Prize (Yusuf 2017). Moses had an awesome experience when God, 'I AM,' spoke to him from a burning bush in the desert. This creative revelation resulted in Moses leading his people out of slavery in Egypt. This Quranic call, according to Dr. Rafi-ud-Din, has a special significance for the scientific community as he regards the concept of *Tawhid* as indispensable to science. He said:

"The concept of Allah *(Tawhid),* the most fundamental of all the truths is indispensable to science as a system of truths. It must be used to illuminate the paths of scientific observation and inquiry in the worlds of matter, life and mind to reveal new scientific truths which can never be known in its absence" (Rafi-ud-Din 1995).

The endless Mind of God is much vaster than our human understandings. Through the supreme Eureka moment, we observe the excitement of becoming created co-creators. Theologian Gordon Kaufman (1993) understood God as serendipitous (fortunate) creativity, the coming into being of new modes of reality through the directional movements or trajectories that emerge in the evolutionary development of the cosmos and life. For philosopher Alfred N. Whitehead, creativity was the "universal of universals" (Whitehead 1929).

1.3. Faith and Science

To the question, does Islam develop a special type of mindset that helps in sharpening and strengthening the creative faculty of the working scientists, the answer is yes. Before discussing the subject let it be very clear that religious motivations are no substitute for natural endowments or compensation for natural disabilities (Gopin 1997). For example, bravery and cowardice are inborn mental dispositions. As bravery is a natural endowment so is cowardice a natural disability. But Islamic motivations can certainly accentuate the bravery of the brave and attenuate the cowardice of the coward. Allah's promise of granting eternal life and bliss to the *Shaheed* immediately after his death makes a brave Muslim all the more brave. As narrated in the Quran "*And do not say that who are killed in the path of Allah are dead. No! Indeed, they are alive, but you do not know how"* (Al-Baqarah, 154). Similarly, Prophet Muhammad said: "*Indeed, in Paradise are a hundred levels which Allah has prepared for the Mujahideen in His Path. The distance between each level is that of between the heavens and the earth. So, when you ask of Allah, then ask Him for Firdaus, for it is the center of Paradise, and the highest part of Paradise, and above it is the throne of The Most Merciful, from whence, the highest Firdaus, the rivers of Paradise spring forth*" [Al-Bukhari].

Likewise, his admonishment for the cowardly behavior with punishment in the life hereafter helps a coward in overcoming his cowardice to a remarkable degree if he is a true Muslim. Similarly, the creative faculties of scientists are greatly augmented by Islamic motivations and Islamic teachings. In fact, all true believers in Allah among the scientific community, whether Muslim or Non-muslim, enjoy science as a God-seeking and God-appreciating activity. Some of them had a mystic experience during scientific activity. My father, who had a strong mystic propensity, used to relate a story about his going into ecstasy state in the classroom while listening to a lecture on the circulation of blood. The great legendary Negro scientist, George Washington Carver, known as the peanut-man in America, called his laboratory as "God's little workshop" and always prayed before entering it. A journalist wrote about him, "to me it was a delight to meet a man of such distinction as Dr. Carver who enjoyed religion as he does. When I talked about things of God, his eyes sparkled, and his soul caught fire" (McMurry 1981). In recording these remarks about Dr. Carver, the interviewer simply testified that the joy of science and the joy of religion had mingled together so completely in Carver's personality that it was difficult to separate them from one another. This aspect of his psychology was also reflected in his lectures. He used to describe his laboratory work as his conversations with God. Linda O. Me Murry gleaned one such lecture and gave its account in the following words:

"He often described his conversations with the Creator about the peanut". In one account, he told the Creator, "I would like to know all about the creation of the world" to which His reply was, "surely you have disappointed me. You are supposed to have reasonable intelligence". Then Carver asked to know only "all about peanuts" but still the Creator declared that "All about the peanut is infinite and you are finite" As the Professor narrowed his demands the Creator explained, "I would be glad to give you a few peanuts. I have given you a few brains. Take the peanuts into the laboratory and pull them to pieces". Carver broke the peanuts into their constituents and the Creator advised him to take parts 2, 3, 4, 5, 6 and put them together in any way you wish so long as you keep the law of compatibility. When Carver asked, "Can I make milk out of the peanut"? The reply was "Do you have the constituents of milk"? The professor would then note that the answer was yes, and hold up a bottle of peanut milk, followed by a dozen of other products. Audiences loved the story which revealed a sense of humor and belief in divine inspiration and he used it often.

Carver used to say that the universe is a grand broadcasting system of Allah if we only knew how to tune Him in. We can thus appreciate what a powerful motivation the love of God can generate for spurring up the creativity of the scientist (Yahya

2005). An example of this is the statement in the Quran that life has an aquatic origin ("*And I created every living thing out of water*" Quran 21:30). As a true believer, he enters the laboratory with reverence and conviction to understand things of creation as the "handiworks" of God (Moring 2017). The hunches of the creative scientists to which we referred earlier thus turn into mystic experiences as "broadcasts" from God. Frithjof Capra, another great scientist, earned worldwide fame for writing a book entitled, "Tao of Physics" (Capra 1991).

He too had a mystic experience mingling with scientific thought. But he could not relate it to God and was therefore led astray. In the preface to the first edition of this book published in 1974, he wrote about his mystic experience: "Five years ago I had a beautiful experience which set me on a road that has led me to the writing of this book. I was sitting by the ocean in late summer afternoon watching the waves rolling in and feeling the rhythm of my breathing when I suddenly became aware of a gigantic cosmic dance. Being a physicist, I knew that sand, rocks, water, and the air around me were made of vibrating molecules and atoms and that these consisted of particles, which interacted with one another by creating and destroying other particles. I knew also that showers of "Cosmic rays" particles of high energy undergoing multiple collisions as they penetrated the air continually bombarded the earth's atmosphere. All this was familiar to me from my research in high energy physics but until that moment I had only experienced it through graphs, diagrams, and mathematical theories. As I sat on the beach my former experiences came to life, I saw cascades of energy coming down from outer space in which particles were created in rhythmic pulses; I saw the atoms of the elements and those of my body participating in the cosmic dance of energy; I felt its rhythm and heard its sound; and at that moment I knew that this was "the Dance of Shiva", "the Lord of Dancers" worshipped by "Hindus" (Capra 1984).

Hindu mysticism waylaid Frithjof Capra because, as he admits, he was only familiar with Hindu mysticism or the Zen of Buddha. His intuition was perfectly right but he intellectually integrated his experience to "the Dances of Shiva" due to the limitations of his religious knowledge. Here one is reminded of Holy Prophet Muhammad (SAW) saying that every human being is a born Muslim but upbringing by his parents turns him into a Jew or a Christian, had Frithjof Capra been familiar with the *Tawhid* of Islam this grand dance of the universe would have surely appeared to him as the *Grand Tawwaf* of the entire creation of universe around Allah.

1.4. Faith and Activism

Coming to the Islamic view of scientific creativity, it is preferred to conceive it as a form of "faith activism". All sorts of creativity coming from insights, hunches or unearned inspirations are emanating from the same source i.e. deeper recesses of the unconsciousness. These have marked psychological resemblances and similarities and are essentially the manifestation of the same quest for reality in various forms. What the scientists and artists call "creativity" mystics and religious people name as "love for God" (Al-Karasneh and Saleh 2010). Let us now ponder on the following verse of the Holy Quran which points to a covenant between man and Allah (SWT), which is deeply rooted in the human unconsciousness: "*And (remember) when thy*

Lord brought forth the children of Adam from their reins, their seed and made them testifies of themselves (saying) "Am I not your Lord"? They said, "Yea, verily" (AI-Ar'af, 112). Reminding the same covenant, the precursor of faith, now lying dormant in human unconsciousness, the Holy Quran in another verse exhorts man to activate it at the conscious level: "*Read in the name of thy Lord who created*". (AI-Alaq, 1). This is the very first revelation, which flashed on the mind of the Holy Prophet Muhammad (SAW) through the medium of the angel Gabriel. This verse was shown to man as the way for activating the covenant presently lying dormant in his unconsciousness. According to the verse, the very first step towards the *ma'rifat* of Allah (SWT) is the study of His creation. This is what the allusion "*Who created*" in this verse signifies. It is through the knowledge of His creation, which we call science, that we develop an understanding of Allah (SWT) at the conscious level with whom an eternal covenant is already herein us. Science is thus simply a process of faith activation. Creativity in science is thus a means of coming closer to Him. All searches for knowledge, says Iqbal, is essentially a form of prayer. To explain this point, he quotes the following passage from the mystic poet Rumi:

"The Sufis book is not composed of ink and letters; it is not but a heart white as snow. The scholar's possession is pen marks. What is Sufi's possession and footmarks? For some while, the track of the deer is the proper clue for him, but afterward, it is the musk gland that is his guide. To go one stage guided by the musk gland is better than the hundred stages of following the track and roaming about" (Iqbal 1989; Munawwar 1988).

In the analogy of the mystic's method expressed as the "hunt of the muskdeer", Iqbal explains the process of creativity in science as coming closer to God and gaining power over nature. He says:

"The scientific observer of Nature is a kind of mystic seeker in the act of prayer. Although at present he follows only the footprints of the musk deer, and thus modestly limits the method of his quest, his thirst for knowledge is eventually sure to lead him to the point where the scent of the musk deer is a better guide than the footprints of the deer. This alone will add to his power over Nature and give him that vision of total infinite which philosophy seeks but cannot find" (Iqbal 1989; Munawwar 1988).

It is profoundly meaningful that by combining *Dhikr* and *Fikr* the Holy Quran integrates the act of (scientific) reflection on the things of creation with the act of remembrance of Allah (SWT) and establishes the vital relationship between the two. Just ponder over the following two verses from Sura Al-Imran:

"*Verily in the creation of the heavens and the earth and the succession of night and day, there are indeed messages for all who are endowed with insight (and) who remember God when they stand, when they sit, when they lie down to sleep and thus reflect on the creation of heaven and the earth: "Oh our Sustainer; Thou hast not created (aught of) this without meaning and purpose. Limitless art Thou in Thy Glory! Keep us safe, then, from suffering through fire!*" (Al-imran, 190-191)."

This ayah illustrates that thinking people will ponder the creations of Allah (the sky and the earth, the night, and the day) by using their hearts (*basirah*). Therefore, people will see the Great of Allah and become grateful to Allah every time. Imam Razi claimed that those who remember and believe in the Oneness of Allah use their *aqal* (think) and will achieve al-Falah (success). To achieve the level of *tadhakkur*, man needs to put something into summarization to help him understand it wisely. Therefore, the man may have an idea about something in a simple diagram or picture. The application of *Tadhakkur* is applicable to subjects such as Al-Quran and al-Hadith (Ashaari 2010).

For Muslims, then, remembrance of Allah and reflection on His creation are vitally bound to one another. By remembering Allah, a Muslim scientist invokes the source of all creation and creativity whereas by reflecting on His creation he discovers Him through His laws operative in the natural phenomenon of this universe. To remain in constant contact with Allah (SWT), through remembrance and reflection is for the Muslim scientist the be-all and end-all of all his research activities. *Dhikar* and *Fikar* are therefore indispensable to each other in the Islamic concept of Science (Hussain 1997).

In Islam, science may, therefore, be convinced as a process of faith activism, which on its culmination issues into a special type of religious experience termed as *Khashiah* by the Holy Quran. The whole process of scientific research in an Islamic framework may, therefore, be described as under (Hussain 1997).

1) It begins with man's eternal covenant with Allah (SWT) lying dormant in his unconsciousness and he seeks to re-affirm it at the conscious level through the pursuit of knowledge we call science.
2) The pursuit of knowledge is endless. As the island of knowledge in the limitless ocean of Creator's secrets of creation expands its frontiers with the unknown also goes on increasing in the same proportion. Man can never achieve or ever hope to achieve full comprehension and mystery over the secrets of creation. This means that the urge for scientific knowledge ingrained in the human mind has a far more subtle purpose of generating faith rather than mere conquest of nature, which is usually assumed by secular scientists.
3) In the pursuits of knowledge, man remains ever engaged in the endless game of "hide and seek" with his Creator, Who is both Manifest and Hidden. In playing with the elusiveness of Allah (SWT) lies the fascinating joy of science.
4) All sciences are based on the law of causality. But the chain of cause and effect is infinite in which Allah (SWT) acts as the First and the Last i.e. the ultimate causer of every cause and the ultimate producer of every effect in the infinite continuum of cause and effect relationship in nature. A Muslim scientist, therefore, recognizes two levels of causality *viz*. horizontal causality and vertical causality. At the level of horizontal causality, he discovers cause-effect relations, which he can comprehend and manipulate. But at the vertical level of causality, he can only attribute them to the omniscient and omnipotent Creator Who is the Creator and Sustainer of the universe.

5) In the "hide and seek" game of the scientists in the continuum of — k "cause-effect" relationship, he is rewarded with material advantages and spiritual elevation. Scientific activity, therefore, bestows on man not only power over nature but also a high-grade spiritual experience to which the Quran refers as *Khashiyah*.
6) This spiritual experience obtained through the scientific method is according to Iqbal the need for our time. The modern man, who ceased to live soulfully by developing "habits of concrete thought", demands a "scientific form of religious knowledge" and "concrete living experience of God". All scientific knowledge obtained from whatever source it may come from is valuable and has a religious significance for us. But the Muslims have their way of assimilation of scientific knowledge by integrating all knowledge with their concept of *Tawhid*.
7) The Holy Quran bids us to pray and the words used in this verse deserve special attention. The word means, "increase me" which implies "growth of personality" rather than "increase of knowledge". In another Quranic verse knowledge, has been referred to as a "donkey-load of books" if it does not become a part of the personality. Persons who fail to assimilate knowledge into their personalities have been likened to assess carrying books on their backs.
8) "God-consciousness" or *Taqwa* is the measure of personality growth in Islam. Scientific knowledge must therefore be assimilated in such a manner that it adds to the "God-consciousness" of the individual.

1.5. Conclusion

There is a genuine difficulty for some of us who insist on the dichotomy of science and religion and emphasize the incompatibility of the permanent nature of religion with the ephemeral nature of science. As per our beliefs, the religious laws disclosed through revelation are immutable whereas scientific laws discovered by the human intellect are ever-changing; but at the same time, the human mind cannot be divided into two different camps oscillating from one camp to the other at ease is not only against our basic principle of *Tawhid* but also simply impossible. This is desired for all Muslim researchers to grasp the basic classification of *muhkmat* and *mutashabihat* given in the Holy Quran to which Muhammad Asad, a modern exegete of the Quran refers to the "Key-phrases". Secondly, focus on the subject of *Tansikh-e-Ayat*, which applies most appropriately to *Mutshabihat* pertaining to scientific discussion. Always pray to Allah (SWT) that may He guide the Muslim scientists in coming closer and nearer to Him in their scientific pursuits and they serve humanity with the perpetual insights they receive from Him. In fact, faith is the gateway to science and science is nothing else but faith activism.

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Chapter 2

Role of Muslim Scientists in the Agricultural Development

Ejaz Farooq Akram♦

Abstract

Muslim scientists played a pivotal role in all fields of science and contributed many important inventions and discoveries. The teaching of Islam has promoted research and Muslim scientists dominated all fields of science during the 10th to 12th centuries. In this chapter, the importance of agriculture with respect to Al-Quran and the role of Muslim scientists in the field of agriculture has been discussed. The introduction of date palms in the Indian sub-continent and promotion of agricultural crops, the construction of dams, and the development of the silk and jute industry in Spain are also discussed in this chapter. In the last section, the contributions of eminent Muslim scientists in the field of agriculture are discussed.

Keywords: Arabs, Canals, Fruits, Irrigation, Spain, Vegetables

2.1. History of Agriculture

The word "*Falah*" has been used for the success of human beings. In Arabic "*Falahat*" is used for agriculture. A farmer can be successful if he performs his work with all principles and practices of this discipline along with utmost struggle. This work done by a farmer is not only beneficial for him but also for other human beings. That is why agriculture is the basic and important need for human life. Almost all other requirements of life are also dependent on agriculture. It is important to mention

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that man started agriculture right from his creation to meet his needs. Agriculture is, thus, impregnated in human nature. The men involved in agriculture are exploring the secrets of nature (Nadeem and Butt 2017).

This is interesting to note that agriculture started in paradise even before human creation, where Prophet Adam (*A.S.*) and Hawwa (Eve) tasted a fruit and then tried to protect themselves with leaves. These fruits, leaves and other products indicate the presence of agriculture. The human being might be absent on this planet if he had not tasted that fruit. This is also interesting to note that all blessings offered after death are all related to agriculture i.e. colorful, unique, tasteful fruits, trees, beautiful valleys, canals and rivers (for noble) and tasteless fruits, thorns, trees and leaves (for bad).

The history of Muslim agriculture expertise started from the travel of Prophet Ibrahim (A.S.) towards Makkah. Where he stayed in a desert valley along with her wife and child and did some efforts for their needs and security. That is why Allah (SWT) gifted them with "*Zam Zam*". They also prayed: "Oh Allah blesses the people of this desert valley with fruits, vegetables, and cereals" (Al-Quran).

There were also severe economic stresses for Muslims in Madina, the first developing Islamic state, where the only surety for their bright future was agriculture which made their economy so strong that nobody was a candidate for obligatory charity (*Zakat*) in the era of the Caliph Umar ibn al-Khaṭṭāb (R.A.).

1) Allah (SWT) is the real Lord of everything including agriculture who has discussed in many places in the Holy Quran that all the efforts, skills and achievements of agriculturists are only due to Allah (SWT) because their only duty is to drop the seed in soil and all other is for Allah (SWT). Similarly, all these creations like earth, air, light, temperature, weather, and atmosphere belong to Allah (SWT). It would be very pertinent to quote here some verses from the Holy Quran:
2) Who is responsible for seed germination, you, or Allah (SWT)?
3) Who is responsible for rain, you, or Allah (SWT)?
4) You cannot grow even a single plant.
5) Great Allah has created everything in pairs.
6) We can destroy a crop ready for harvest if we want, and you all can do nothing, and all your skills, research, experience, resources and findings go waste. It is simply Allah (SWT)'s blessings that He accepts our efforts (Al-Quran).

These all agricultural processes indicate that:

1) Allah (SWT) is the greatest and most powerful.
2) Nobody is sharing His powers.
3) Allah (SWT) has created this universe alone.

From this (moving from germination to harvest), one can understand that all of us will have to face the same phenomenon also. The Muslim agricultural experts should arrange their efforts in the same manner i.e., should be beneficial both for themselves and whole human beings.

2.2. Role of Muslim Scientists

Muslims have done a lot in political, social, educational, and scientific fields focusing their attention on human welfare. This all work helped a lot of humanity. Muslims worked in every field of life and set the principles through their efforts. The basics of today's research are based on foundations set by our forefathers. The role played by Muslim scholars and scientists in the field of mathematics, chemistry, astronomy, medicine, geography, and physics is quite evident and cannot be overlooked (http://www.islamtomorrow.com/science2.asp). However, the focus of this article is on the contribution of Muslims in the field of agriculture and allied disciplines as botany. Albukry and Omer Khayyam are famous for their work on botany.

Muslim agricultural scientists have done a lot in the field of agriculture. Agricultural skills and traditions (at least date palm culture) traveled along with Muslims wherever they moved. Some areas were suitable for its cultivation while others were not. Some agricultural reforms were also introduced during the era of Caliph Umar ibn al-Khaṭṭāb (R.A). These reforms resulted in the improvement of yield and the economy (Zaimeche 2001, 2002).

It is special to note the construction of 80 miles long canal during the era of Umar bin Alaas (R.A.). Moreover, the river Nile was connected with the Red sea. This canal contributed a lot to agricultural development. Other canals constructed in that period include the Abi Musa canal, the Maqal canal, and the Saad canal which were the base of the agricultural revolution in that period.

Many canals were constructed during the era of Ameer Mu'awiyah ibn Abī Sufyān (R.A.) including the Kuzama canal, the Arzaq canal, and the Shohda canal. This practice continued in the Umvi period also, especially during the Waleed Bin Malik period.

About 30 canals were constructed during the Abbassi era along with an agricultural school and farm. These canals irrigated millions of acres. During the Islamic era, Iran's progress was only due to the efforts of Muslim agricultural scientists. These scientists also compelled governments to spend money on agricultural research and extension. That's why agriculture was declared as an industry in that era.

More than 839 types of tulips were introduced by Muslims along with different varieties of other flowers. Different kinds of contests were held, and distinguishers were awarded for their work. Muslim authors wrote different kinds of books, especially on flowers.

The period (from the 9th to 13th century) witnessed a tremendous agricultural transformation which can be considered as an Islamic green revolution. The spreading economies of the Islamic world (including Arabs) allowed the diffusion of multiple crops and farming technologies. These agricultural innovations accomplished with improved farm mechanization led toward may change in the economy, vegetation cover, population distribution, household income, urban growth, population levels, labor force distribution, agro-industries, diet, cooking, and clothing in the Islamic world (Zaimeche 2001). The Muslim experiences in agriculture were introduced in the sub-continent along with Muhammad bin Qasim. Today's date palm varieties in Sindh and Baluchistan are due to those unknown agriculturists who came with Muhammad bin Qasim.

2.3. Role Played in Spain

Muslim agricultural scientists and experts did excellent work in Spain. They served with knowledge, literacy, cultural and social values. Well-known historian Watt reported that Spain was with poor agriculture, economy, and poverty before the arrival of Muslims. Muslims diverted their attention towards agriculture and a wide area of uncultivated land was brought under cultivation soon (Provençal 1953). Another Historian Ibne Hokal says that Spain was enriched with fertile land and a well-established irrigation system after the Muslim's arrival, which resulted in the progress and prosperity of the masses (Provençal 1953; Zaimeche 2001, 2002).

All kinds of fruits and vegetables became available due to the efforts of Muslim scientists. The specific areas were established for different crops. Wells were constructed at a distance of every mile, water storage dams at different sites, riverbanks (e.g., 264 feet long and 52 feet high bank at "Alkha" site, 750 feet long and 36 feet wide bank at Safoora River and 760 feet long band at "Balanseeda") constructed. These scientists also established an underground canal system e.g., 500 ft long underground canal at "Almanzoora", 1 mile long at "Mraveela", 5595 feet long and 30 feet wide at "Karikonut".

Agricultural education was also the main focus of Muslim scientists; so, an agricultural college, laboratories, and libraries were established. Evening classes were started in the villages and information regarding date culture, flowers, and other crop management practices were transferred to the farmers.

Abdur Rehman Addakhil (1st Umvi ruler) established a medicinal garden in Qartaba where different medicinal plants from Africa and Asia were introduced. Delegates were sent to different countries only to collect the plants and information regarding their management (Zaimeche 2001).

These scientists in Spain also introduced different storage techniques. Wheat was used to be stored for ten years, even for 50 (Almukarri) and 70 years (Alkazveeni). Some historians in "Ashbeelia fort" and "Sirkista" discovered some 80-100 years old bins full of wheat. Cold storage techniques were also introduced for fruits (Glick 2005).

The use of different fertilizers was also introduced to increase soil fertility. Most common among them were organic wastes. Pest control measures were also used against pests and diseases. This all was recommended after establishing a system of research. General crops of that area were wheat, rice, lemon, date palm, banana, pomegranate, spinach, and black peppers. Muslims also introduced different crops like chickpea and cotton. Different fruits, like pear, apple, almond, and grapes, were also cultivated (FSTC 2016).

Silk culture was also developed and extended by Muslim scientists (Jacoby 2004). Rearing of silkworms was declared as an industry and almost 800 factories were constructed where the finest silk of the world was prepared. About 3000 villages were under the “silk industry” in Jayyan. This expansion of the silk industry resulted in progress and prosperity of the area where 1/4th of people were with the finest silk clothes while in another world this “blessing” was only for Kings and their staff.

These scientists also introduced jute in Spain. This crop was used for manufacturing the world’s finest, strong, and better fiber and paper of that time. The finest variety of Jute was “Shahdanj” which was introduced by Muslim scientists. Olive was also cultivated and developed by Muslims. Olive oil was exported to other parts of the world. Olive plants were expanded throughout “Alshabeela” and some other areas.

The Muslim scientists also introduced methods for the management of pests, diseases, tree grafting, and the development of new varieties. For example, the Spanish Muslims used 08 different methods of grafting (Zaimeche 2001). Muslim scientists also paid attention to the rearing of animals along with the cultivation of crops; horses and sheep were of prime importance. A government department was working to look after the sheep rearing. Rearing of the honeybee was also declared as an industry and Spain was the world’s leading honey producer.

2.4. Some Distinct Scientists of Spain

2.4.1. Ibne-al-Awam Alshabeeli (Yahya bin Muhammad bin Ahmad ibne Awam)

He was the best agricultural scientist of the 12th century. He wrote a book on agriculture (*Kitab-ul-Falah*) focusing mainly on crops and also on animals, poultry, and honeybees (http://www.filaha.org) and has 35 chapters. Description of 585 plants and 55 fruits is included in the book. This book provides knowledge on a wide range of agricultural aspects e.g. soil formation, kind of manures and their benefits, types of irrigation water, gardening, and planting of trees, type of irrigation suitable for fruit trees, methods of the plantation, grafting techniques, trimming of grapevines, renovation of general plants, preparation of manures, the best time of irrigation for plants, diseases of plants and vegetables and their control and collection and preservation of many dried and fresh fruits. Moreover, the significance of plowing sowing methods of food grains, cultivation of rice, cotton, bhang, linseed, henna saffron, melon, and white poppy, selection of soil for growing vegetables, cultivation of bulbous vegetables, cultivation of flower plants, and garden plants, preservation of fruits, animals, their diseases, management, and animal breeding strategies were also discussed in this book (Ibn Khaldūn 1967). This book had been very popular in Europe. Urdu translation of this book had been published from Azam Garh (India). He also introduced the methods of preserving olive oil, fruits, and maize.

2.4.2. Ibn al-Bassal (Abu Abdullah Mohammad Ibn Ibrahim ibn al-Bassal)

Bassal means Onion in Arabic. Ibn al-Bassal was famous for onion cultivation. He also wrote a book on agronomy (*Deewan-ul-Falah*), which was subsequently edited into a single volume containing 16 chapters and was given the title "*Kitāb al-Qasd Wa 'l-Bayān*" (Book of concision and clarity). In the middle ages, it was translated into Castilian (Vallicrosa and Aziman 1955). Interestingly, this book contains no reference related to the early age agronomists and their work; thus, based on the personal experiences of Ibne Bassal, who traveled through East Africa, Egypt, and Saudi Arabia many times. This book is recognized as the most original and objective of all the Andalusian experts in botany, agronomy, and agriculture. The focus of that book was on soil types and the effect of different irrigation methods on it. In this book, he provided the distinction between the ten soil classes. Each class was given a different life-sustaining capability, according to the season of the year. He argued that the fallow land can be cultivated 4 times between January and May. However, for cotton grown under the Mediterranean coast, he suggested 10 cultivations (Vallicrosa 1960). He also wrote about the cultivation of almond, apricot, apple, cherry, chestnut, citron, date-palm, fig, grapevine, melon, olive, hazel and filbert, white mulberry, orange, peach, pistachio, pomegranate, quince, walnut, and watermelon. He also wrote about 10 forest and ornamental trees and shrubs, 27 flowers and herbs, and 16 different vegetables (Sarton 1956).

In 1085, the Alfonso VI of Castile captured Toledo, after which Ibn Bassal withdrew to Seville to the court of Al-Mu'tamid. There he established a royal garden. Besides Ibne Bassal, many other agronomists were present in Seville at that time. Among those, Ahmad bin Hajjāj al-Ishbīlī and Alī Ibn al-Lūnquh were the most prominent. Ahmad bin Hajjāj al-Ishbīlī authored many books on agronomy.

2.4.3. Abu-Al-Khair Alshabeeli

He was a well-known agricultural scientist of the 11th century. He got benefits from old books and wrote a book on agriculture (*Kitab-ul-Falaha*). He also discussed only his personal experience of gardens, field crops, and forests (http://www.filaha.org/author_Ibn_hajjaj.html). He also introduced four methods to collect rainwater. The process of sugar making was also introduced by him.

2.4.4. Ab-ul-Qasim Azahravi

He summarized the book (*Kitab-ul-Falaha*) of Abu-al-Khair Alshabeeli and published a summarized edition of that book (http://www.filaha.org/author_Ibn_hajjaj.html).

2.4.5. Abu Ubaid Albakri

Abu Ubaid Albakri was a famous botanist of Spain. He prepared a complete list of all plants in Spain and described their characteristics. He also wrote a book (*Aayan-a-Nabatat wa Shajarat Alundlusia*).

2.4.6. Abdullah Altaghneri

He wrote his observation and experiments in a book (*Zehr-ul-Bustan wa Nuzh-al-Ulazhan*) comprising 360 chapters and 12 volumes. This book discusses the matters related to soils, water resources, fertilizers, sowing of plants, and their subsequent growth, treatment of various plant diseases, and grafting. This book also describes the local practices adapted to grow the agricultural plants in Spain, the properties and uses of those plants. Topics of animal breeding have also been discussed in this book (Brill 2000; http://www.filaha.org/author_Ibn_hajjaj.html). He was originally from Tignar, which was a village several kilometers from Granada in the north.

2.4.7. Ibn-al-Hajjaj

Ibn-al-Hajjaj wrote a book (*Kitab-ul-Mukneh*) in which the detailed biography of 30 agricultural scientists was discussed (http://www.filaha.org/author_Ibn_hajjaj.html).

2.5. Some Distinct Muslim Botanists

2.5.1. Ahmad bin Daud

He wrote a book on plants (*Kitab-un-Nabat*), and also discussed some principles in the preface of the book and described 400 plants. This book is not available but is referred to by books (Khan 1954).

2.5.2. Muhammad bin Ahmad Alsaeed

This scientist of the 10th century wrote a book and added valuable information on plants and natural medicine (Moe et al. 2014).

2.5.3. Abu Jaffer ibne Muhammad Alhgafkee

He also carried out different experiments, wrote a book (*Aladviata Almafrdata*), and discussed different characteristics of African and Spanish plants. These plants were also named in Arabic and Latin.

2.5.4. Abdullah bin Ahmad

He moved throughout Asia and Africa for research purpose, and wrote two very important books namely "*Almaghni fil Advea Almafrdata*" and "*Aljame fil Advea Almafrdata*". These two books were the result of his research FOR many years. He discussed the beneficial effects of 1400 weeds and 2330 edible plant species. He also identified 300 new plants. These books were very much popular and became the basics of all research in botany.

2.5.5. Abu Ali Hassan ibne Alhashum

Ibne Alhashum is proud of Muslims for his work on the eyes and light. He provided very essential and basic information on the eye and light. In agriculture, he is famous as an agricultural engineer. He visited the river Nile several times and set a complete plan of work of “Uswan dam” based on his visits, observations, and analysis. Unfortunately, this plan could not be completed.

2.5.6. Abul Abbas al-RasuIi (Al-Malik al-Afzal al-Abbas ibn 'Ali)

Abbass bin Ali also wrote a book entitled “*Bughydt al-Fillahin fil Ashjar al-Muthmira wal-Rayahin*” comprising 17 chapters. This book includes topics on soils, fertilizers, waters, improvement of land, and crop seasons. This book also discusses who to from seeds of grains (sorghum, rice, millet, barley, spelt, barley, millet, rice, etc), pulses (lentil, mungbean, chickpea, beans, fenugreek), cucumber plants (brinjal, eggplant, vegetable marrow, melons), carrot, turnips, onions, fruit trees (vine, fig, date palm, apple, olive, pear, pomegranate, areca nut, banana, coconut), and cotton. He also described the pruning and grafting techniques with descriptions and primitive pictures of instruments, the qualities of plants, the prevention of damage to plants, medicinal plants grown in Yemen and the weights and measures (Sarton 1975). Europeans should be thankful for the knowledge, information, skills, inventions, and achievements made during the Muslim dynasty because their contributions provided the sound foundations for present-day agriculture (Bearman et al. 1994).

2.5.7. Al-Ishbili

He was an eminent Muslim agricultural scientist who wrote on water, trees, gardens, fertilizers, soils, fruits and their preservation, seeds, plowing, cereal farming, seasons and their tasks, livestock rearing, farming engineering, harvesting, and veterinary subjects, etc.

2.5.8. Ibn al-Wahshiya (Abu Bakr Ahmad Ibn Ali al-Wahshiya al-Kaldani or al-Nabati)

He was born in 860 A.D. and was an eminent Muslim agriculturist. He wrote a book on agriculture entitled “Al-Filahat ul-Nabatiyah” (Nabatean Agriculture) in 904 A.D., which is regarded as the first book on agriculture and served as a role model for other Muslim agricultural scientists who wrote books afterward. In this book, he discussed many topics including olive tree management, water resources, underground water recharge, wells digging, measures taken to enhance the water taste, aromatic flowering plants, pharmaceutical uses of bushes and trees, weather predictions, pollinated air and winds, fertilizer use, shrubs and grasses, improvement in the yield and quality of leguminous crops, storage of cereals, wild plants and their medicinal importance, and morphology of plants, various vegetable types, vine production and protection, wild trees, forest trees, fruit trees, grafting techniques, plant autogenesis and date-palm production (Rashed 1996).

Besides these scientists, several other Muslim agricultural scientists contributed to promoting agriculture in their era. For example, Ibn Wāfid (d. 467/1075) established the royal botanical garden which was comparable with the Jannat al-sultān in Toledo. Ibn Wafid, a Muslim scientist wrote a booklet related to agronomy which was later translated into Castilian. Ibn Mammati (d.1209), Djamal Eddin al-Watwat (d. 718/1318) and Riyad al-Din al-Ghazzi al-Amiri (935/1529) wrote on agricultural topics viz. manures/fertilizers, soil cultivation tools, and methods, types of agricultural lands suitable for various crops, springs/wells/irrigation channels, nursery plants, grafting and pruning of fruits trees, cereal/vegetable/flowers/tubers and bulbs/and legume cultivation, preserving of fruits and poisonous plants/animals (Vallicrosa and Aziman 1955.)

Some other books were also written and translated by Muslim scientists. A book on Roman agriculture was translated into Arabic and was published in Egypt. Similarly, different books having important agricultural information were translated into Arabic. In 1943, a book written by Mustafa Alshahbi was published. About 10,000 agriculture terminology was translated into Arabic.

In the 19^{th} century, a book (*Husn-al-Sinata fee Ilm Zarria*) was published from Egypt on modern agriculture. Mr. Ahmad Nida was the author. In past, the big centers of Muslim scientist’s research, experiments, and publications were Cairo, Damascus, Qartaba, Gharnata, Alshabeela, and Almarya, where all kinds of research and experiments were conducted, and results were published (Aftab 1995). In the modern age, several books have been published on different aspects of agriculture in Arabic and other Muslim languages.

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Section – II

Agricultural Research, Education and Extension Systems

Chapter 3

National Agricultural Research System in Pakistan

Iftikhar Ahmad, Ghazanfar Abbas and Shazia Iftikhar♦

Abstract

National Agricultural Research System (NARS) in Pakistan is spread over Research Institutes of the Federal Ministries, Provincial Departments, Agricultural Universities, and a number of Agriculture Colleges. The Pakistan Agricultural Research Council (PARC), as an Apex Federal Body under the Ministry of National Food Security and Research, administers and its main functions include conducting, promoting and coordinating agriculture research and development activities both at the national and international levels. It also extends financial support to projects of national importance. Human Resource Development (HRD) in the Agricultural Research and Development is also a major function of PARC. In the mid 70s, PARC was entrusted to introduce the National Coordinated Research Programs (NCRPs) as a mechanism for conducting joint research in the country. It started with the implementation of 33 National Coordinated Research Programs on major commodities/disciplines in collaboration with all the concerned provincial and federal institutions as participating units. The NCRPs provide the most effective mechanism for joint planning of research with a view to eliminate the wasteful duplication/repetition of research efforts and to improve the utilization of research resources in terms of man, money and materials. The development of agricultural resources was very much essential for national economic growth. Coordinated Programs were conceived that came into being as a means of helping the rural

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economy and developing and abundantly producing agriculture. Today, however, the farm problems and market needs are in many respects different and more complex from what they were about three decades ago. With the increase in population, physical resources available for agriculture are shrinking. We need to produce sufficient food and feed from less land, water and agrochemicals. There is an obvious need and ample justification to strengthen such useful programs. In fact, NARS should be strong enough to ensure long-term food security, improved nutrition, boost rural income and make agriculture cleaner and greener. This chapter, in general, elaborates background information on NARS in Pakistan, and also gives some data on the current status of the NARS in Pakistan.

Keywords: Education, Development, National Agricultural Research System, PARC, Reformation, Transformation

3.1. Introduction

The agriculture is Pakistan's largest single sector of the economy and accounted for 19.5% of the total Gross Domestic Product (GDP) in 2016-17 (Govt. of Pakistan 2017). The sector employs 42.3% of Pakistan's total labor force. About 59.46% of the country's population resides in rural areas and is directly or indirectly linked with agriculture for their livelihood (Govt. of Pakistan 2017). While on the one hand, this sector is a primary supplier of raw materials to downstream industries, contributing substantially to Pakistan's exports; on the other, it is a large market for industrial products such as fertilizer, pesticides, tractors and agricultural implements (Govt. of Pakistan 2015). The agriculture sector is an important source of foreign exchange earnings through exports of agricultural commodities and agricultural-based products. However, substantial foreign exchange is required for the imports of agricultural commodities and products. Pakistan's trade balance has been negative for most of its history as a nation (Nagy and Quddus 1988; Ali and Iqbal 2005).

Despite its critical importance to growth, exports, incomes, and food security, the agriculture sector has been suffering from secular decline. Growth in this sector, particularly in the crop subsector, has been falling for the past three decades. Productivity remains low, with yield gaps rising (Mellor and Malik 2017). Critical investments in new seeds, farming technology and techniques, and the water infrastructure are not being made. Without major new investments in agriculture, it is unclear how Pakistan would be able to tackle emerging challenges such as declining water availability, and climate change (Govt. of Pakistan 2009). Over the past eight years, agriculture has grown at an average rate of 2.17% per annum. However, volatility in the sector is high, with the range of growth varying between 3.62% and 0.23%. The fluctuation in overall agriculture has been largely dependent on the contribution of major crops (Govt. of Pakistan 2015).

During the fiscal year 2016-17, the overall performance of the agriculture sector recorded a growth rate of 3.46% compared to the previous year at 0.27%. Crops witnessed a growth of 3.02%, livestock by 3.43%, forestry by 14.49% and fisheries by 1.23%. In the crops sector, important crops (or major crops) have a major share of 23.85% of total agricultural value added during 2016-17. The performance of important crops compared to the previous year was attributed to enhanced performance of crops, particularly cotton and rice which were grown at 7.6 and 0.7% respectively. Other (minor) crops share 11.03% of total agricultural value addition recorded a growth of 0.21% in 2016-17. The production of chillies, onion and mungbean showed positive growth of 0.2, 2.7 and 27.4%, respectively, compared to the production of the corresponding period (last year). On the other hand, the production of pulses like mashbean and lentil, and potato showed negative growth of 15.3, 17.9 and 3.2%, respectively (Govt. of Pakistan 2017).

The livestock sector– the single largest contributor to overall agriculture (58.33%), grew by 3.43% in 2016-17 as against 3.36% last year. The Fisheries sector contributed 2.12% in agricultural value addition with a reduction of 1.23% against its previous year's growth of 3.25%. The forestry sector experienced positive growth of 14.49% this year with a total share of 2.33% in agriculture (Govt. of Pakistan 2017).

Pakistan's agricultural performance is closely linked to the supply of irrigation water. The water availability at canal heads is 106 million acre feet (MAF) per annum (Katyara et al. 2017). The availability of canal water during Kharif 2016 was 71.35 MAF which was 9% more than Kharif in 2015 and 6.4% more than the normal supplies of 67.1 MAF. During Rabi 2016-17, the estimated canal water availability was 29.66 MAF which was 10% lower than Rabi 2015-16 and 18.4% less than the normal availability of 36.4 MAF (Govt. of Pakistan 2017).

3.2. Evolution of Agricultural Research and Development in Pakistan

Agricultural research in Pakistan dates back to 1929 when the Imperial (now Indian) Council of Agricultural Research was founded to promote agricultural research in India. At the time of the partitioning of India in 1947, only one agricultural college and one research station remained, in Lyallpur (now Faisalabad). At independence, there was a considerable loss of scientific talent from these long-standing entities, which had been the premier agricultural college and research center for undivided North India. The inflow of scientists transferred from institutions in present-day India only partially compensated for this loss. The urgent need of a strong central agricultural research organization to complement and support the work of the provinces was recognized, and the government took a number of actions to develop this capacity. For the active development of Pakistan's research system, it is not surprising that many reviews of the agricultural research system have been made. Among the major reviews are those documented in 2010 (seemingly unpublished), an effort by PARC staff on a "Country Study on the National Agricultural Research System (NARS) in Pakistan–An Analysis of System Diversity":

1) Setting up the Food and Agricultural Committee in 1948 was the first step in that direction. It was reconstituted as the Food and Agricultural Council of Pakistan (FACP) in 1951.

2) It was renamed as Agricultural Research Council (ARC) in 1964; however, its scope remained limited as a funding agency. In the late 1950s, research and teaching institutions in the North West Frontier Province [now Khyber Pakhtunkhwa (KPK)], Punjab, and Sindh provinces were founded with assistance from the United States. These institutions laid the groundwork for the current agricultural education and public research system.
3) The joint Pakistan-American agricultural research review team, 1968.
4) The second joint Pakistan-American team on agricultural research, 1973.
5) The ARC's effectiveness and functionality were enhanced as a result of the recommendations that emanated from the joint review of the agricultural research system in Pakistan by a combined team of Pakistani and American scientists in 1968 and in 1973 given at (iii) and (iv).
6) The agricultural research development loan, USAID, 1974.
7) The joint review team for agricultural research in Pakistan under the loan agreement between Pakistan and the United States, 1976.
8) The year 1978 went down as an important landmark in the history of agricultural research. The ARC was given autonomous status in order to improve the management and effective coordination of research efforts. In 1979, the process culminated in the re-designation of ARC to PARC.
9) The World Bank agricultural research subsector review, 1980.
10) Agricultural Research Division (ARD) was established with chairman PARC as its secretary.
11) PARC Ordinance was promulgated in 1981.
12) One year later, the government announced its agricultural policy, which stressed equitable growth in all aspects of agriculture.
13) World Bank staff appraisal report of the (first) agricultural research project, 1981.
14) The Minnesota reconnaissance team report on the agricultural research system of Pakistan, 1982.
15) International Service for National Agricultural Research (ISNAR) in 1983 examined the relationships between PARC and the provinces, including those within and among the institutions of the center and the provinces, and made suggestions and recommendations for their improvement. The ISNAR also examined the concepts, organizations, and functioning of a selected group of National Coordinated Research Programmes (NCRPs). National Agricultural Research Centre (NARC) was established in 1984.
16) The Sixth Five-Year Plan (1983–88) also emphasized transforming agriculture from subsistence to export-oriented and making the country not only self-sufficient in agricultural commodities but also achieve a substantial exportable surplus to improve its foreign-exchange-earning capacity. This was supported by a second World Bank agricultural research project in 1987.

17) PARC planned its program in accordance with these exigencies and made concerted efforts to maximize agricultural productivity, through such measures as providing effective coordination, strengthening research facilities, improving the terms and conditions of researchers, creating adequate training facilities, funding research activities, diffusing improved production technologies, and by creating National Coordinated Research Programs in the commodities and disciplines that are of national economic importance. In 1998, the Pakistani agricultural research system was reorganized at the federal and provincial levels, and few changes have occurred since.
18) The Agricultural Research Division was abolished in 1993.

Agricultural research in Pakistan is performed by a considerable number of federal/central institutions;[†] provincial agricultural research institutes (ARIs), agricultural universities, and private sectors/companies. The federal research establishments are involved in basic and strategic research, provincial research institutes are focusing on applied and adaptive research, agricultural universities are working across the research spectrum from basic to adaptive, and private sectors/companies (agro-industry) cover fertilizer, pesticides, seed, and machinery, and are involved in adaptive research.

3.3. Establishment of Institutions (Ordinance, Acts) and their Reformation, Transformation and Development

Pakistan had a dual agrarian structure in which a feudal system coexisted with the peasant system. In a recent seminar held at PARC, Dr. Sohail J. Malik, President, Innovative Development Strategies, presented his data and revealed that percentage crop income share from more than zero but less than 3 acres of farm category is 27% while that of 50 acres and above is 9%. However, in the case of livestock, income share from these two categories was 48 and 3%. In the same presentation, he updated land holdings data while reporting that 42% hold more than zero but less than 5 acres while 4% hold 50 and above (Agricultural Census 2010).

In addition to land distribution, access to markets and institutions is biased toward big farmers. For example, the credit market for small farmers is constrained by collateral requirements. About one third of farmers in Punjab are located more than

[†]Institutions established at the federal level play their respective roles in the National Agricultural Research System (NARS). These institutions are (i) Pakistan Agricultural Research Council (ii) Pakistan Central Cotton Committee (iii) Pakistan Atomic Energy Commission (iv) Pakistan Science Foundation (v) Pakistan National Accreditation Council (vi) Pakistan Council of Scientific and Industrial Research (vii) Pakistan Council for Research in Water Resources (viii) Pakistan Institute of Development Economics (ix) Pakistan Forest Institute (x) Center for Applied Molecular Biology (xi) Center of Excellence in Water Resources Engineering (xii) International Water & Salinity Research Institute (xiii) Soil Survey of Pakistan (xiv) Federal Seed Certification and Registration Department (xv) Water and Power Development Authority (xvi) Agricultural Policy Institute, (xvii) Higher Education Commission.

15 km away from any fruit and vegetable market, and 8% have to travel more than five km to reach a metalled road (ACO 2000). Most of the extension system is biased toward big farmers. Skewed land distribution in land ownership and access to the institution (especially for education, information and credit) are the main source of income inequality in rural areas.

On the basis of access to land and institutions, the rural agriculture social structure can be divided into three broad layers (Ali and Ashraf 2006): (i) Large commercial farmers who have better access to research outputs in the form of improved technologies. They have financial resources to buy scientific inputs like fertilizer, pesticides, and information packages. They are well linked with agricultural institutions and markets, which lead them to successfully grow high-tech crops like potato, onion and fruit orchards. Their management level is quite intensive even for the production of traditional commercial crops like cotton, maize and sugarcane. Under the current agriculture structure, they are the main source of agricultural growth. (ii) Small-scale, resource-poor marginal farmers, including sharecroppers and tenants, who have little access to institutional credit and extension systems, and they are not connected with markets. This affects their ability to adopt research outputs in the form of improved technologies and inputs. (iii) Landless laborers who earn their livelihood from the farm as well as non-farm employment. Direct income earnings from agriculture account for approximately half of the total income of poor households, which helps to mitigate poverty and inequality in rural areas up to a certain extent. The public sector agricultural research (both at the strategic-end component and users-end component) should not only cater to large commercial farmers to stimulate agriculture growth but also meet the needs of resource-poor farmers and landless laborers to tackle abject poverty in the countryside and ensure food security (Ali and Ashraf 2006).

Summarizing the above, Dr. Sohail J Malik (2015 unpublished) is of the view that a few more factors hinder Pakistan’s agricultural growth and hence employment and rural poverty reduction:

1) Unequal land distribution and resultant skewed distribution of power and policy biases
2) Inefficient allocation and use of irrigation water
3) Government intervention in markets
4) Step motherly attitude to agriculture in all policy-making decisions and resource allocation except decisions that lead to elite capture
5) Serious disconnects between the center and the provinces in decision making and implementation, one size fits all policies that overly focused on wheat and fixated on 4 crops only
6) Regulatory environment that discourages investment and reduces the market efficiency

3.4. Main Components of NARS – Pakistan

National Agricultural Research System (NARS) in Pakistan is spread over Research Institutes of the Federal Ministries, Provincial Departments, Agricultural Universities and several Agriculture Colleges.

3.4.1. Pakistan Agricultural Research Council (PARC)

The PARC was established in 1981 as the major federal agency responsible for agricultural research and development under the Ministry of Food and Agriculture (MINFA) [now Ministry of National Food Security and Research (MNFSR)]. Its present charter, under the PARC ordinance of 1981, gives the authority to head a research system composed of strong provincial and central components that jointly plan and execute priority research programs in the country (ISNAR 1983). It is a semi-autonomous organization. The main functions of PARC are to conduct, support, coordinate, and promote agricultural research throughout Pakistan. The PARC also provides training for research staff and acquires and disseminates research information to improve the use of modern technologies in the country (Ali and Ashraf 2006). It has created research establishments to fill the provincial gaps and has to train high-level scientific manpower. It seeks to develop its research agenda in accordance with government policies.

The PARC previously reported to the Ministry of Food, Agriculture, and Livestock. With the introduction of the 18th Amendment to the Constitution of Pakistan in 2010, the Ministry was dissolved, and its functions were devolved to the provincial level or assigned to other ministries. In 2011, oversight of PARC was transferred to the Ministry of Science and Technology and then later that year to the newly established Ministry of National Food Security and Research.

The importance of agricultural science was recognized in the recommendations of the first joint Pakistan-American agricultural review team of 1968 who discussed thoroughly it at the provincial level. The proposal was approved by the inter-provincial coordination committee and the cabinet committee in 1968. The implementation of this proposal was delayed during the period of separation of East and West Pakistan. The first director general of the PARC was appointed in July 1972.

A major research development loan and grant was negotiated through USAID in 1974. This represented a significant step toward building the facilities and strength of the PARC, the establishment of the NARC at Islamabad, and the enhanced development of the nationally coordinated research programs for strengthening the provincial agricultural research systems. The developments in Pakistan's agricultural research system during the late 60s form a strong framework for the development of effective central leadership, as well as enhanced cooperation among provincial and national agricultural institutions (ISNAR 1983).

The development of effective provincial agricultural research establishments (Faisalabad, Punjab; Tandojam, Sindh; Sariab, Quetta and Tarnab, KPK), in close contact with farm conditions and problems of their respective provinces, with on-farm testing, evaluation, and feedback, and closely linked with the extension services, seems basic for Pakistan's research system. These provincial agricultural research institutions are served by a central research organization namely PARC as a complementary. The PARC as the Apex Federal body in Agricultural Research & Development has provided complementary services, such as germplasms, equipments, small amounts of financial resources, and access to a wider range of international contacts. The PARC is also providing genetic resources, facilitating and assisting with the improvement of staff competence as well as assisting with the coordination of programs common to more than one province of the country. Extending these facilities to all corners of the country has facilitated the development of various infrastructures, as well as many new varieties of many important crops.

The PARC also generates, acquires and disseminates agricultural information for expeditious utilization of research results. It also creates research establishments to fill in the provincial gaps, and trains high level scientific manpower. It develops its research agenda in accordance with the government policies thus keeping abreast with the requirements of national and international demands. Therefore, PARC has always been contributing toward a prosperous Pakistan where it plays its leading role in NARS, Pakistan (http://www.parc.gov.pk/index.php/en/).

3.4.2. Pakistan Central Cotton Committee (PCCC)

The Pakistan Central Cotton Committee emerged as an incorporated institution on the national horizon in 1948, with the broad objective to concentrate its efforts on bringing an improvement in growing, marketing and manufacturing of cotton and cotton by-products through an extensive program of Research and Development (R&D) in all its conceivable aspects. The committee is a semi-autonomous body with the Federal Minister of Food, Agriculture and Livestock as the president. It supports research on cotton production and genetic improvement in stations at Multan and Sakrand, and on fiber technology at a laboratory in Karachi. In addition, the committee does promotion and development work on cotton production and marketing. Punjab also has a research station devoted to cotton production and improvement at Multan, adjacent to the central station (http://www.pccc.gov.pk/home.html>).

3.4.3. Pakistan Atomic Energy Commission (PAEC)

The history of the Pakistan Atomic Energy Commission goes back to 1956 when the Atomic Energy Research Council was established. In 1964, 1965 and 1973, reorganization took place, and the Atomic Energy Commission was incorporated as a statutory body under an Act, with considerable autonomy. In 1972, the commission was transferred from the Science and Technology Research Division to the President's Secretariat.

The PAEC is now the largest Science and Technology (S & T) organization in the country, both in terms of scientific/technical manpower and the scope of its activities. Starting with a nuclear power reactor at Karachi (KANUPP) and an experimental research reactor at Nilore, Islamabad (PARR-I), the emphasis in the early years remained on the peaceful uses of nuclear energy. Consequently, research centers in agriculture, medicine, biotechnology and other scientific disciplines were set up all over the country. As the emphasis shifted towards concerns for national security, important projects were also initiated in this area. The PAEC is actively working in the field of agriculture employing Nuclear Techniques at its Agriculture Centers at Faisalabad, Peshawar and Tandojam (http://www.paec.gov.pk/index.aspx).

3.4.4. Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad

Nuclear Institute for Agriculture and Biology, Faisalabad, is a research and development center functioning under the auspices of PAEC. The project was approved by the Government of Pakistan in 1967 and research activities were started in 1970, and the institute was formally inaugurated on April 6, 1972. From the outset, the mandate was to create and maintain new genetic material for sustained agriculture development and to conduct research on applied problems in the field of agriculture and biology using nuclear and other related techniques. NIAB is located on Jhang Road, Faisalabad at a distance of 7 km from the city center. Its laboratories and related facilities are built on an enclosed area of 60 acres (24 hectares) with an attached experimental farm having an area of 140 acres (56 hectares) (http://www.niab.org.pk/research.htm).

The PAEC has clear mandates on the safe use of modern sciences with an aim to improve the socio-economic growth of the country. National Institute for Biotechnology and Genetic Engineering (NIBGE) is one of the main biotechnology institutes of the four bioscience centers of PAEC and was formally inaugurated by the President of Pakistan in 1994. It is located in Faisalabad. It is also an affiliate center of the International Centre for Genetic Engineering and Biotechnology (ICGEB). The institute is a focal point of modern biotechnology and provides a technology receiving unit to help the development of the country through applications of modern biotechnology and genetic engineering. The research programs at NIBGE are mainly aimed at improving agriculture, health, environment and industry and are supported by national and international financial grants. The institute's research facilities include state of the art equipments supported by technical services, an IT facility and a National Library for Biological Sciences. The institute now offers several services and marketable products. The educational programs leading to M.Phil. and Ph.D. degrees have also been incorporated into the institute's mandate for the development of human resources in modern sciences (http://www.nibge.org/).

3.4.5. Nuclear Institute for Food and Agriculture (NIFA), Peshawar

Nuclear Institute for Food and Agriculture, one of the four agricultural research institutes of PAEC was established in 1982 in Peshawar. The institute works for the enhancement of crop production and protection, soil fertility, water management and conservation, value addition of food resources, employing nuclear and other contemporary techniques (http://www.nifa.org.pk/).

3.4.6. Nuclear Institute of Agriculture (NIA), Tandojam, Sindh

The Nuclear Institute of Agriculture is the first agricultural institute of PAEC. It was established fifty years ago and was formally inaugurated as Atomic Energy Agricultural Research Centre (AEARC) on 22 November 1963. The institute has been conducting goal-oriented research on agricultural and biological problems, related to the improvement of major crops; physiology of plants from different aspects related to the enhancement of crop productivity; entomological studies related to the development of non-polluting techniques such as biological insect control of crop pests and disease; soil science studies related to chemistry, fertility of the soil and efficient use of fertilizer and irrigation. A biotechnology laboratory has been established at NIA in which the efforts are mainly focused on the production of virus-free plants of banana. The significant achievement of the institute is the evolution of sixteen high yielding, disease resistant and improved quality varieties of important crops such as wheat (7), rice (4), cotton (2), sugarcane (2) and mungbean (1). These varieties are very popular among the growers and are being cultivated in the majority of the area in the province of Sindh.

The research work of the institute is regularly published in renowned national and international journals and in comprehensive annual reports which is a regular feature of the institute since its inception. The present souvenir is being published for the celebration of the 40th anniversary of this institute. Every scientist, research worker and supporting staff member deserves congratulations on all the outstanding achievements of the institute, publication of this souvenir and celebration of the successful forty years of NIA (http://nia.org.pk/mai.html).

3.4.7. Pakistan Science Foundation (PSF)

Pakistan Science Foundation is the apex body for the promotion and funding of scientific and technological research and science popularization in the country. The PSF has two subsidiary organizations including the Pakistan Museum of Natural History (PMNH) and the Pakistan Scientific and Technological Information Center (PASTIC). The foundation functions as a link of PMNH/PASTIC agency for the establishment of comprehensive scientific and technological information dissemination centers, promotion of basic and fundamental research in the universities and other institutions/ centers, the establishment of science centers, clubs, museums, herbaria and planetaria, promotion of scientific societies, organization of periodical science conferences, symposia and seminars, exchange of visits of scientists and technologists with other countries and grant of awards, prizes and fellowships to individuals engaged in developing processes of consequence to the economy of the country (http://www.psf.gov.pk/).

3.4.8. Pakistan National Accreditation Council (PNAC)

Pakistan National Accreditation Council has achieved a milestone of Mutual Recognition Arrangement (MRA) with International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC). Now Pakistan is included in the list of countries having an equivalent status for accreditation of testing and calibration laboratories all over the world. The PNAC has been established under the administrative control of the Ministry of Science and Technology, Government of Pakistan as the national apex agency to accredit conformity assessment bodies such as laboratories and certification bodies. The accreditation services of PNAC were launched during the year 2001. To become the most competent accreditation body in the region. The PNAC strives for improvement, competence and integrity of conformity assessment bodies by providing them with an internationally recognized accreditation service and also promoting a quality culture, which ultimately benefits the consumers, producers, regulators and other stakeholders (http://www.pnac.org.pk/).

3.4.9. Pakistan Council of Scientific and Industrial Research (PCSIR)

Pakistan Council of Scientific and Industrial Research was established in 1953 under Societies Act to promote the cause of Science and Technology in the country. Since 1973, it is functioning under the Act of Parliament, which was amended in 1984. The Chief Executive of the Council is the chairman who is appointed by the Federal Government. The 21-member council is the policy making body of the PCSIR, which is composed of a chairman, three members of the governing body, three directors of PCSIR laboratories, four representatives from four ministries, four directors of industries, one from each province and six representatives of the industry. There are eleven laboratories/units and five HRD centers established throughout the country, headed by Director Generals/Directors who directly report to the chairman. In the head office, 150 officers/staff including 07 directors are working in different divisions/wings. There are 767 scientists/engineers/technologists working in different laboratories supported by 742 technicians/skilled workers/supporting staff and 1096 administrative staff (http://www.pcsir.gov.pk/).

3.4.10. Pakistan Council for Research in Water Resources (PCRWR)

The Pakistan Council of Research in Water Resources was established in 1964, under a resolution and named as Irrigation, Drainage and Flood Control Research Council (IDFCRC) within the Ministry of Natural Resources. It was brought under the control of the Ministry of Science and Technology in 1970. The council was renamed as PCRWR in 1985. The PCRWR is an apex autonomous body established with the objective to conduct, organize, coordinate and promote research in all aspects of water resources. Since its inception, PCRWR has played its role as a national research organization by undertaking and promoting applied as well as basic research in various disciplines of the water sector, more specifically, irrigation, drainage, surface and groundwater management, groundwater recharge, watershed management, desertification control, rainwater harvesting, water quality assessment and monitoring, development of innovative water resource management, and conservation and quality improvement technologies, etc. (http://www.pcrwr.gov.pk).

3.4.11. Pakistan Institute of Development Economics (PIDE)

The Pakistan Institute of Development Economics was established in Karachi in 1957, and in 1964 accorded the status of an autonomous research organization by the Government of Pakistan. It is devoted to theoretical and empirical research in Development Economics in general and on Pakistan-related economic issues in particular. In addition to providing a firm academic basis for economic policy-making, its research also provides a window through which the outside world can view the nature and direction of economic research in Pakistan. Other social sciences, such as demography, anthropology and interdisciplinary studies increasingly define the widening scope of research that must be undertaken for proper economic policy and development to have sound underpinnings. Over the past 50 years, PIDE has earned an international reputation and recognition for its research. The PIDE faculty is rich, and its advisory committee consists of world-renowned economists such as Nobel Laureate Robert A. Mundell.

The PIDE is located at the Quaid-i-Azam University campus in Islamabad, the capital of Pakistan. The campus rests against the backdrop of the Margalla hills on the Potohar Plateau, within a short distance of the remains of Taxila, which once housed the world's oldest university. Archaeological remains discovered in this area show that it has been a center of civilization for some 5,000 years. The Institute, a neighbor to several other academic outfits situated in this historic and scenic part of the green foothills of the great South Asian Mountain ranges, is the hub of economic and social science research in this part of the world. In November 2006, PIDE was granted the degree awarding status and hence its top priority now is to provide quality education that is affordable but of world class standard in this region along with a truly stimulating learning environment. The advice of PIDE's International Advisory Board is also sought on various aspects of the Institute's academic activities. This Board comprises outstanding scholars in the fields of Economics, Demography, and Anthropology (www.pide.org.pk).

3.4.12. Pakistan Forest Institute (PFI)

Pakistan Forest Institute was established in 1947 in Peshawar, KPK with a vision to conserve natural resources and protection of the environment. The mission of the PFI is to improve the quality of life by providing support for effective research and trained manpower for scientific management of forests, rangelands, biodiversity conservation, watersheds, wildlife and environment protection in Pakistan. Currently, it is organized into six functional divisions' *viz*. Forestry Research Division, Biological Sciences Research Division, Forest Products Research Division, Forest Education Division, Biodiversity Division and Sericulture Division are under the control of the Director General (http://pfi.gov.pk/about.php). It conducts research and imparts education and training in forestry sciences to the nominees of the Provincial Forest Departments and other agencies such as the Forest Development Corporation. The Forest Products Research Division is a Directorate of Pakistan Forest institute Peshawar, Ministry of Environment Government of Pakistan. This division is providing research and training services to the Government and Non-Governmental Organizations (NGOs) in the field of Wood Anatomy (wood identification), Timber Testing, Wood seasoning and Preservation, Composite Wood Products and Pulp and Paper Science and Technology. The PFI is aiming to help the local forest products industry in improving the quality of their products by disseminating the recent advances in the field of wood sciences. The institution has fully realized the fact that Pakistan is among forest deficient countries. Research must be focused on the economical and efficient use of our scarce forest resources for the benefit of the peoples of Pakistan (http://ilm.com.pk/admissions/pakistan-forest-institute-peshawar/).

3.4.13. Federal Seed Certification and Registration Department (FSC & RD)

After the independence, till 1961 there was no independent system for seed production and distribution. In 1961, Finance and Administration (F&A) Commission established the West Pakistan Agricultural Development Corporation (WPADC) for the procurement and distribution of seeds. In 1972, WPADC was dissolved, and the provincial government started the production, multiplication, procurement and distribution of seeds. The seed industry development project was launched in the country on the recommendation of the World Bank Appraisal Mission's Report ($ 23 Million) which provided legislative support through the promulgation of the Seed Act, 1976. This enactment provides requisite infrastructure like National Seed Council (NSC), Provincial Seed Councils (PSC), Federal Seed Certification Department (FSCD) and National Seed Registration Department (NSRD). The NSC addresses all the pursuits of seed both public and private seed sector organizations. The federal government entrusts the PSC function within the provincial territories for the purpose of this act. The department regulates and controls the quality of seeds through crop inspection and seed testing. Seed production/multiplication and distribution are carried out by public and private seed sector organizations like Punjab Seed Corporation, Sindh Seed Corporation (now as Foundation Seed Cell), Agricultural Development Authority, KPK (now as Department of Agriculture Extension and Research), Department of Agriculture Extension, Balochistan and private seed companies. Under the economic austerity measures, the FSCD and NSRD were merged in 1997 and the new organization has been designated as Federal Seed Certification & Registration Department (FSC & RD) (http://www.mnfsr.gov.pk/frmDetails.aspx?opt=misclinks&id=20).

3.4.14. Water and Power Development Authority (WAPDA)

The WAPDA was established through an Act of Parliament in 1958 which is an autonomous and statutory body under the administrative control of the Federal Government. This agency is responsible for the construction and operation of irrigation systems down to the watercourse outlets serving an average of around 150 ha each. The WAPDA has done considerable pioneering research in studying the problems of on-farm distribution and the use of irrigation water in such systems. Continued studies leading to the more efficient functioning of irrigation systems deserve increased attention and support, and the close cooperation of WAPDA and the central and provincial agricultural research agencies. Research on water management aimed at increasing crop productivity and efficiency of utilization of irrigation water should be accelerated through collaboration among WAPDA, PARC and provincial agricultural research institutions. The WAPDA was unbundled in the year 2007 whereby the functions of its power wing were redefined as Hydel Power Generation and Operation & Maintenance (O&M) of power houses. Following unbundling of its power wing, WAPDA's mandate is now the development of water and hydropower resources in an efficient manner (http://www.wapda.gov.pk/index.php/about-us/present-setup).

3.4.15. International Water and Salinity Research Institute (IWASRI)

The International Waterlogging and Salinity Research Institute) was established under the Ministry of Water and Power (MOWP) Government of Pakistan in 1986 to conduct and coordinate research pertaining to waterlogging, salinity, irrigation and drainage. Moreover, IWASRI coordinates with other institutes and manages supervision of its allied organizations namely Mona Reclamation Experimental Project (MREP), Bhalwal, Lower Indus Water Management and Reclamation Research Project (LIM), Hyderabad, International Sedimentation Research Institute, Pakistan (ISRIP) and SCARPs Monitoring Organization (SMO), Lahore (http://www.wapda.gov.pk/index.php/iwasri/introduction).

3.4.16. Centre of Excellence in Water Resources Engineering (CEWRE)

It is realized that training at bachelor's level is not enough to solve intricate and complex engineering problems being faced in the development and management of water resources. To solve water resources problems, a team of hydrologists, irrigation and drainage engineers, water resources managers, water resources engineers, geologists, economists, social scientists, agronomists, soil scientists and environmentalists is required. The basic training that an engineer receives during his initial degree is limited and cannot cope with the highly specialized and rapid technological advancement in the development and management of water resources. He cannot solve complex water resources problems with the knowledge of the elementary principles learned in the basic degree programs.

Centre of Excellence in Water Resources Engineering (CEWRE), generally called as "Centre" is one of the leading academic and research institutes in Pakistan, equally recognized nationally as well as internationally, imparting a high-level goal-oriented studies in water resources-related disciplines like Water Resources Management, Water Resources Engineering, Engineering Hydrology and Hydropower Engineering. The Centre has started two M. Phil degree programs in 1979 in the fields of Hydrology (HYD) and Water Resources Management (WRM). A 3rd M. Phil degree program was started in 1994 in the discipline of Water Resources Engineering (WRE). The degree program in Hydrology was redesigned as Engineering Hydrology (EHY). In addition, an M.Sc. degree was initiated in the fields of WRM, EHY, and WRE. The Centre offered a 4th postgraduate M.Sc. degree program in the discipline of Hydropower Engineering (HPE) in 2000. More than 250 students have so far successfully completed M.Sc., M. Phil and Ph.D. degree programs in different programs and presently 80 students are engaged either in course work or research thesis in the four-degree programs of the Centre. The Centre's graduates are highly demanding and are employed in the national and international organizations working in the water sector (http://www.cewre.edu.pk/).

3.4.17. Center for Applied Molecular Biology (CAMB)

In order to build national capability in the new bioscience, the University of Punjab established a nucleus Centre for Advanced Studies in Molecular Biology. In 1986, the Ministry of Education upgraded the University Centre into a National Centre of Excellence in Molecular Biology. In April 1987, the Federal Ministry of Science & Technology (MOST) approved the establishment of a Centre for Applied Molecular Biology (CAMB), located back-to-back with the laboratory block of the Centre of Excellence in Molecular Biology (CEMB) (http://www.camb.edu.pk/).

The twin component Molecular Biology Laboratory Complex is spread over 60 acres of land, with a covered area of 7,000 square meters including a Laboratory Block, a Teaching Block and a Hostel for Ph.D. Research Scholars. The Laboratory Block is divided into four separate research units comprising a total of 20 Research Laboratories and four Conference Rooms: one Production Unit and one Support Facilities Unit comprising a Lab-aid Section (for washing, autoclaving and media preparation), an Animal House, an Insectary, six large Plant Growth Rooms and storage space for research materials. The Teaching Block consists of a well-equipped Library, Seminar Hall, Photocopy, Photography, Computer Rooms, Conference Hall, Director's Office and Administration and Accounts section. There is a self-service canteen, a dining hall and 11 rooms in the research scholar's hostel. The objectives and functions of the centre are as under: (i) Teaching and training to generate a cadre of manpower specifically trained in molecular biology and recombinant DNA technology. (ii) To undertake goal oriented molecular biological research on specific problems related to economic needs of the country for agriculture, health and medicine, industry, energy and environment sectors. (iii) To create a repository of DNA modifying enzymes, DNA cloning vectors, novel bacterial strains and other such molecular tools for ready availability and use by various (iv) Research groups at this Centre and other DNA research laboratories in Pakistan. (v) To organize National and International seminars and conferences for detailed' discussions on scientific and technological developments, which will lead to new ideas and innovative applications of knowledge in gene cloning and recombinant DNA technology (http://www.camb.edu.pk/).

3.4.18. Agricultural Policy Institute (API)

The Agricultural Prices Commission (APCom) was established in 1981 through a resolution of the Ministry of Food, Agriculture and Livestock, Islamabad. It has been declared as an attached department of MINFAL in May 2006. The main responsibility assigned to the APCom is to advise the Government on the price policy of important crops. The agriculture commodity markets are not only imperfect but also fragmented. During the post-harvest period, commodity prices in the open market tend to crash to the disadvantage of growers. Small farmers who dominate the farm production system in the country neither have adequate storage nor sufficient staying power to hold on to their marketable surplus in hope of getting better prices, later on, and are forced to part with their marketable surplus immediately after harvesting the produce. In such a situation, the farmers, particularly small farmers, are at the mercy of middlemen who tend to exploit the situation to their advantage. In order to safeguard the interest of growers, the government announces the support minimum price of important crops. The support price acts as a minimum guaranteed price and is designed to provide a floor to the market, especially during the post-harvest period when the market prices tend to crash to un-remunerative levels, particularly in years of good crop (http://www.mnfsr.gov.pk/frmDetails.aspx?opt=misclinks&id=4).

3.4.19. Higher Education Commission (HEC)

The HEC is an independent, autonomous, and constitutionally established institution of primary funding, overseeing, regulating, and accrediting the higher education efforts in Pakistan. In 2002, it was formed under the leadership of Prof. Atta-ur-Rahman its founding Chairman, with additional executive reforms granted by the constitution. Under the leadership of the Chairman and Federal Minister, and administrative control of the Executive Director, the HEC is divided into various departments, which are headed by Members and Advisors. The purpose of the HEC was to investigate the problems and prospects of higher education in Pakistan which plays a significant role in leadership development among the peoples of the country. The functions of universities are to develop people physically, mentally and spiritually. It improves and promotes the economic, social, political and cultural life of the nation. Globally, the universities are guiding and co-operating with the industrial and agricultural development organizations and developing their economics rapidly and meaningfully. In Pakistan, after more than seven decades, the developmental indicators are not showing positive results. The participation rate in higher education is about 3% the of age group (17-23) and this is 16.2% of the world average for this age group. The advanced countries are achieving more than 40% participation rate in higher education. There are problems of lacking quality staff, students, libraries and laboratories, research facilities, financial crisis, weaknesses of examination, ineffective governance and academic results are not at par with international standards.

3.4.20. Punjab Higher Education Commission (PHEC)

Punjab Higher Education Commission was established under the mandate of the 18th Constitutional Amendment. The PHEC aims to improve the quality of higher education in Punjab. Instead of relying on the quantity of work, the central focus of PHEC is to enhance the quality of education in existing Higher Education Institutions (HEIs) in Punjab. It is determined to provide easy, affordable and equitable access to higher education for the people of Punjab. Since its inception (January 2015), the PHEC aims to build a prosperous Punjab by equipping students of HEIs with adequate facilities and by incubating a market-oriented and skilled workforce through proposed skill-development projects. This initiative would pave the path for students to excel within their respective areas of the profession.

The PHEC is resolute in its commitment to bridge the divide between public and private higher education institutions by establishing educational benchmarks compatible with the imperatives of the modern-day knowledge economy and developing a culture of rigorous pursuance thereof. In this regard, it has initiated several faculty development programs through which foreign scholarships and post-doctoral fellowships have been awarded to the deserving and competent faculty members of public sector HEIs in Punjab. The PHEC firmly believes and endeavors to strengthen the existing assets and introduce new initiatives to bring higher education at par with modern needs. Increasing equitable access is a top priority of PHEC along with bringing improvement in academic standards, emphasizing a focus on research relevant to the socio-economic needs of the province and introducing mandatory faculty development programs to improve the teaching standards. The PHEC also intends to contribute toward the province's economic agenda by creating a capable and employable workforce through the introduction of structural and technical skills programs in academia (http://punjabhec.gov.pk/).

3.4.21. Provincial Agricultural Research Systems

Pakistan is divided into five provinces. At the provincial government level, agriculture is divided into five fields: crops, livestock and fisheries, food, natural resources (soil water, forestry, and wildlife) and education. Research conducted by the federal government agencies is largely long-term priority research, while the research conducted by the provincial research system is mostly adaptive in nature. Each of the four provinces has a main Agricultural Research Institute (ARIs) under the administration of the Department of Agriculture. The ARIs are Ayub Agricultural Research Institute (AARI), Faisalabad in the province of Punjab, ARI, Tandojam province of Sindh; ARI, Sariab Queeta in the province of Balochistan and ARI, Tarnab Peshawar in province of KPK.

Ayub Agricultural Research Institute, Faisalabad: AARI is the apex research body at the provincial level. AARI came into being in 1962 on the bifurcation of the Punjab Agricultural College, Lyallpur (present, University of Agriculture, Faisalabad) into separate teaching and research establishments. The Institute has undergone evolution to build up infrastructure and human capabilities, which has played a vital role in boosting research efforts to meet the needs of burgeoning the population and accelerated industrial needs and serve the farming community.

The Agriculture Research Institute (ARI) Sariab, Quetta: ARI Sariab, Quetta, is the only multi-disciplinary institute functioning in the whole of the Balochistan. This institute was established in 1958 as a Potato Research Station, after the dismemberment of one unit in 1970 the research station was renamed ARI, Sariab, Quetta.

The Agriculture Research Institute (ARI) Tarnab Peshawar: In KPK, systematic agricultural research was started in 1908 at Tarnab, Peshawar by the then Government which was further strengthened and expanded to the entire Province over the years by the formation and establishment of new research stations and institutes.

What distinguishes the organization of agricultural Research & Development in KPK from Punjab and Balochistan is that livestock research in KPK falls under the umbrella of the Department of Agriculture. Second, during the 1980s, under USAID funded TIPAN project, the Agricultural Research Wing of the department was merged with the KPK Agricultural University Peshawar to become the KPK Agricultural Research System. The aim was to improve the quality of agricultural education and research to become more responsive to farmers' needs. Although collaboration between the agencies has increased, the merger of education and research has not been fully successful because of the dual administrative control. The provincial government not only has financial control over the research entities, but also interferes in administrative issues. The university falls under the Ministry of Education and receives its funding from the higher education commission of the federal government.

The Agricultural Research Institute (ARI), Tandojam: Agricultural Research under Sindh's Department of Agriculture is less consolidated than in the other three provinces. The ARI, Tandojam focuses on crop research except for rice, wheat, and horticulture for which separate commodity research institutes exist. Livestock research is also separate and falls under the provincial Department of Livestock and Fisheries.

All four provinces have a number of other government agencies involved in agricultural research on areas such as veterinary sciences, water resources, fisheries, wildlife and environmental issues. Unlike the provinces, Pakistan's federally administered areas (Azad Kashmir and Northern Areas) and the federally administered tribal areas do not have an official research infrastructure as such. Nonetheless, PARC has established its own Agriculture Research and Development Centers. In Azad Kashmir, PARC conducts research through a Technology Transfer Institute in Muzaffarabad.

3.4.22. The Agricultural Universities Systems

There are at present five agricultural universities in Pakistan, namely:

- The University of Agriculture, Faisalabad, established in 1961, on the separation of the Faculty of Agriculture from the Agriculture Research Institute.
- Pir Mehr Ali Shah Arid Agricultural University, established in 1985, on upgrading of Agricultural College Rawalpindi.
- The Sind Agricultural University, Tandojam, established in 1977, on upgrading of the Sind Agricultural College.
- The University of Agriculture, Peshawar, was established in 1981, with the separation of the Agricultural Faculty from the University of Peshawar.
- Muhammad Nawaz Sharif University of Agriculture, Multan, established in 2012 as an independent university

3.4.22.1. The University of Agriculture, Faisalabad

The foundation stone of the Punjab Agricultural College and Research Institute was laid in 1906 in Lyallpur and Sir Louis Dane, the then Lieut, and Governor of Punjab formally opened the college in 1909. Since its inception, the college has passed through many vicissitudes. It started with a three-year course of Licentiate of Agriculture covering lectures and practical classes in Agriculture, Chemistry and Agricultural Chemistry, Physics, Botany and Agricultural Botany, Zoology and Entomology, Mathematics, Land Surveying and Veterinary. A few years experiences proved this system unsatisfactory. The number of students seeking admission to the College began to decline and a crisis was reached in 1913 when no new class could be formed. Under the circumstances, in pursuance of the recommendations of the Board of Agriculture at its meeting held in Coimbatore (India) in 1913, a modified four year course of Licentiate in Agriculture (L. Ag) was adopted. This course comprised of two parts. The first part consisted of simple practical instructions in Agriculture and elementary courses in scientific subjects while the second part was related to systematic courses in sciences allied to agriculture. At the end of the first part examination, successful candidates used to a get a leaving certificate and were eligible for lower rank jobs in the Agricultural Department, and for such posts as Estate Managers. The candidates completing both parts of this course were awarded the Diploma of Licentiate in Agriculture. This course started in 1914, continued up to 1920 and met with some measure of success.

In 1917, as a result of a resolution passed at a conference held at Pusa (India), the College was affiliated to the Punjab University for four year degree of B.Sc. (Agri.) and the first batch was honored with B.Sc. (Agriculture) degree in 1921. However, a provision, for a leaving certificate at the end of the first two years, as practiced previously, was maintained for those not wishing to take a degree. The student’s interest in leaving certificate class, however, declined with time and it was decided to close this program in 1941. The college got affiliated with the Punjab University for M.Sc. (Agriculture) degree in 1923 and the first M.Sc. degree was awarded in 1928. Originally the M.Sc. (Agriculture) was purely a research degree but realizing the importance of theoretical understanding of the subject, it was decided to include course work also in the degree program. The college also got affiliated with the Punjab University for the degree of Ph.D. and the first doctorate degree was awarded in 1944. Punjab Agricultural College and Research Institute remained the premier seat of learning and training in tropical agriculture for a major part of the century and made great efforts to promote agrarian development in the country. After independence in 1947, the Government of Pakistan appointed the National Commissions of Food and Education with the terms of reference to review, in all its ramifications, the prevailing agrarian system and to formulate measures for developing the full potential of our agricultural resources. The commissions made a strong plea for establishing an Agricultural University, which could play a more vigorous role in promoting research and education in Agriculture. Pursuant to these recommendations, the University of Agriculture, Faisalabad was established by upgrading the former Punjab Agricultural College and Research Institute in the year 1961-1962 and the Faculty of Agriculture originated directly from the old Punjab Agriculture College in 1961 (visit: http://www.uaf.edu.pk/).

3.4.22.2. Pir Mehr Ali Shah Arid Agricultural University

In the past, the main emphasis on Agricultural Research & Development has been on irrigated agriculture, while rainfed agriculture remained neglected. With the rapid increase in population, the irrigated areas failed to provide sufficient food requirements and it became imperative to find out ways to make use of the huge part of cultivable land in the rained region. In the 1970s, the Government of Pakistan constituted a Barani Commission to review and recommend measures for the development of rained agriculture and uplift of the poor masses through education, research and development of technology and manpower. Pursuant to the recommendation of the Barani Commission, the Government of Punjab established Barani Agricultural College, Rawalpindi that was later upgraded to the level of university in 1994 (http://www.uaar.edu.pk/).

3.4.22.3. The Sind Agricultural University, Tandojam

Sindh, the fertile Mehran valley, is known for the production of a variety of agricultural commodities. This province was a net exporter of food supplies to the entire sub-continent during the 19th century. After the completion of the Sukkur Barrage system in 1932, a need was felt for a thorough agricultural education so as to develop a healthy interest in the millions of hectares of neglected capital thirsty and poorly managed farmland and to equip the people with the necessary technical know-how for maximizing agricultural production. Efforts in this direction culminated in the establishment of a premier seat of learning in 1939-40 with the name of King George V Institute of Agriculture of Sakrand, Nawabshah district. The institute was later on shifted to its present site in 1954-55 and was re-designated as the Sindh Agriculture College, Tandojam. It was in the mid 1960s that the vital importance of agriculture for economic development became crystal clear to the national planners and policy makers. To foster rural reconstruction, agricultural education and development resulted in the preparation and approval of a plan for the establishment of an agriculture university in Sindh. Subsequently, an agriculture college was upgraded to the status of an additional campus of Sindh University, Jamshoro, on July 01-1976 and finally raised to the status of a present full-fledged Sindh Agriculture University under the Act on March 01, 1977. The university possesses an academic complex of three faculties and a Directorate of Advanced Studies and Research. The three faculties are the Faculty of Agriculture, the Faculty of Agricultural Engineering and the Faculty of Animal Husbandry and Veterinary Sciences. Three graduate degree programms are offered in the three faculties. These include the Doctor of Veterinary Medicine (D.V.M), Bachelor of Engineering in Agriculture (B.E. Agriculture) and Bachelor of Science (Hons.) Agriculture in nine disciplines of Agriculture viz. Agronomy, Agricultural Chemistry, Agricultural Economics, Agricultural Education and Extension, Entomology, Horticulture, Plant Breeding and Genetics, Plant Pathology and Plant Protection. The university offers post-graduate programms leading to the award of M.Sc. in degree in Animal Husbandry and Veterinary Sciences, Agricultural Engineering and in all the above-mentioned disciplines of Agriculture. M.Phil and Ph.D. degree programms are also offered in selected areas where trained staff and other facilities are available. Besides, a modest number of short courses and training programme are regularly offered to meet the continuing and in-service education needs of agriculture officers, field assistants, bank officials, agricultural technicians, progressive farmers, small farmers, tenants, gardeners, housewives and other clientele groups (http://www.sau.edu.pk/about-us.php).

3.4.22.4. University of Agriculture, Peshawar

It was established in 1981, with the separation of the Agricultural Faculty from the University of Peshawar. The university caters to the needs of all disciplines of agricultural Research & Development in the area with under- to post-graduates studies of high quality. Since its establishment in 1981, this University has been playing a vital role in imparting agricultural education and conducting basic and applied agricultural research throughout the province and disseminating the results of agricultural research among the farmers and general public through its outreach/public service activities. Being one of the leading institutions in the country, the University has been enjoying the prestige of providing high quality agricultural education and research to its students. Other than degree programms, the University has been playing a vital role in training scientists and students of the allied institutions through short-term trainings in different areas of agriculture and relevant disciplines. Similarly, international trainings have been a regular feature of this University’s humanresource development programme where hundreds of Afghan nationals have been trained so far. The graduates of this university are serving in public and private sector organizations in key positions within Pakistan and abroad (http://www.aup.edu.pk/).

3.4.23. Civil Society Institutions

The Agha Khan Rural Support Program in Pakistan (AKRSP), the National Rural Support Program (NRSP) and the Punjab Rural Support Program (PRSP) are key civil society institutions with a long history and success record. To achieve the desired aggregate impact, their community structure will be greatly expanded to provide complete coverage of Punjab. The AKRSP was conceived as a unique approach to fostering the development of rural people. Its purpose is to involve the people of three remote districts of Northern Pakistan in their own self-sustaining development and to provide a model of rural development applicable in other settings. Filling a gap in government services, AKRSP has done a creditable job with limited resources in assembling and testing new agricultural technologies, but progress has been costly, difficult, and slow. More research and development specifically for the Northern areas is urgently needed. The AKRSP will need to continue its role as the main technology broker until government line agencies can adequately fulfill their appointed roles. Lack of adequate technology for introduction at the farm level and insufficient effort to develop the technology are among the commonest problems in rural development. Some bank-financed projects have relied almost exclusively on technical aspects, neglecting the incentives for farmers' participation. The broader-based AKRSP model is more balanced, but it needs improved technology as much as any rural development program.

3.5. Organization of NARS

Among the SARC countries, Pakistan has the 2nd largest agricultural research system with quite a large number of scientific manpower. The research system includes approximately 15,000 scientists. Although the total number of scientists working in agricultural research in Pakistan seems good, but this number is quite lesser than in India. The present agricultural research system comprises essentially four main streams, the PARC at the national level, provincial agricultural research institutes, the agricultural universities at the provincial level and several other agencies such as scientific organizations, scientific councils, centre of excellences and various ministries/departments at the centre and as well as private sectors participate directly or indirectly in the NARS activities in the country. The central role of PARC and the NARS institutes are given in the Figure 3.1 and Table 3.1, respectively.

3.6. The PARC System

Although agriculture is a provincial subject, PARC has established many central research institutions since 1981 in order to cater to the agricultural research needs of the country. These PARC research establishment are essentially meant to (i) undertake, aid, promote and coordinate agricultural research (ii) expedite utilization of research results (iii) establish research establishments (iv) train high-level scientific manpower (v) generate, acquire and disseminate agricultural information (vi) establish research library and (vii) perform any other related functions.

Currently, PARC conducts strategic research on emerging challenges in agriculture at national and provincial priorities. It conducts exploratory research on new commodities and fills the gaps in the provincial research agenda. It provides services to the provincial system in the conservation and supply of germplasm, agricultural informatics, and human resource development. It also ensures collaboration and linkages with the provincial and international research systems. Major areas of the Council’s research include crops, horticulture and floriculture, agricultural biotechnology, farm mechanization, natural resources, animal sciences, social sciences and agricultural informatics. The PARC has contributed tremendous1y through the NARS of Pakistan and has assisted in developing more than 264 improved varieties of wheat, rice, pulses, maize, sorghum, millet, fodder, cotton, sugarcane, oilseeds and horticultural crops. Many other varieties are in process as well. Special attention is being given to developing high yielding pest resistant varieties. Besides developing varieties, strengthening agricultural research programs at the provincial levels, promoting linkages between research, education and extension; and introducing cutting-edge technologies are other high priority areas of PARC.

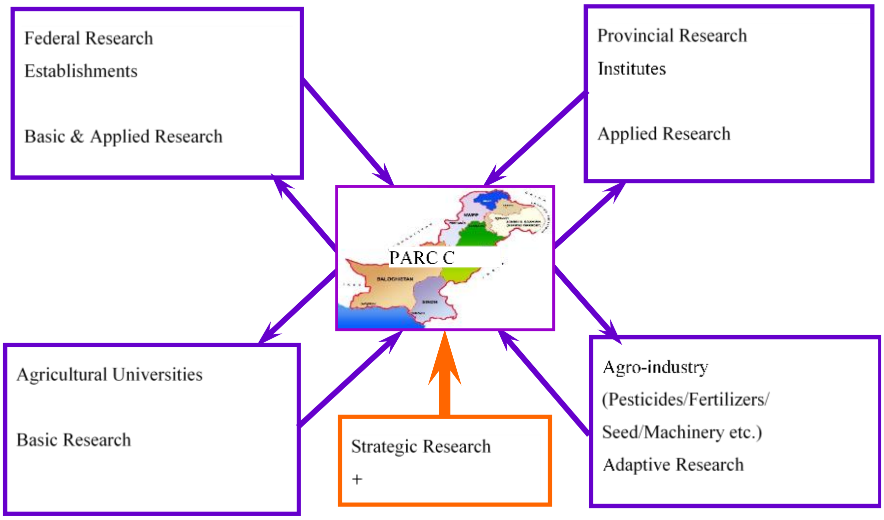

Figure 3.1 National Agricultural Research System

Table 3.1 The NARS institutes with their administrative status and headquarters

Institutes	Status and Ministry	Headquarters
The PARC System		
Pakistan Agricultural Research Council (PARC)	Autonomous, Ministry of National Food Security and Reseearch	Islamabad
National Agricultural Research Centre (NARC)	Establishment of PARC	Islamabad
Southern Agricultural Research Centre (SARC)	Establishment of PARC	Karachi, Sindh
Arid Zone Research Centre (AZRC)	Establishment of PARC	Quetta, Balochistan
Mountain Agricultural Research Centre (MARC)	Establishment of PARC	Gilgit, NAs
Technology Transfer Institutes (TTIs)	Establishment of PARC	Faisalabad, AJK, Tandojam, Quetta, Peshawar, Gilgit
Small Ruminants Research Institute (SRRI)	Establishment of PARC	Shoran, Balochistan
Shaheed Benazir Bhuttoabad Research Stations	Establishment of PARC	Nawabshah, Sindh
Neelibar Agricultural and Training Station	Establishment of PARC	Burewala

Institutes	Status and Ministry	Headquarters
Hill Agriculture Research and Technology Demonstration Station (HARTDS)	Establishment of PARC	Lehtrar, Rawalpindi
Other Scientific Organizations/Councils/Centres of Excellence		
Pakistan Central Cotton Committee (PCCC)	Ministry of National Food Security and Reseearch	Karachi
Federal Seed Certification and Registration Department (PSCRD)	Ministry of National Food Security and Reseearch	Islamabad
Agricultural Policy Institute (API)	Ministry of National Food Security and Reseearch	Islamabad
Pakistan Atomic Energy Commission (PAEC)	Autonomous body with President of Pakistan	Islamabad, Faisalabad, Tandojam, Peshawar
Pakistan Science Foundation (PSF)	Autonomous with Ministry of Science & Technology	Islamabad
Pakistan National Accreditation Council (PNAC)	Autonomous with Ministry of Science & Technology	Islamabad
Pakistan Council of Scientific and Industrial Research (PCSIR)	Autonomous with Ministry of Science & Technology	Islamabad, Lahore, Karachi, Peshawar, Quetta
Pakistan Council for Research in Water Resources (PCRWR)	Autonomous with Ministry of Science & Technology	Islamabad
Pakistan Institute of Development Economics (PIDE)	Autonomous body with Ministry of Planning	Islamabad
Pakistan Forest Institute (PFI)	Ministry of Environment	Peshawar
Center for Applied Molecular Biology (CAMB)	Autonomous with Ministry of Science & Technology	Lahore
Center of Excellence in Water Resources Engineering (CEWRE)	Autonomous body, Ministry of Federal Education and Professional Training	Lahore
Water and Power Development Authority (WAPDA)	Autonomous body Ministry of Water and Power	Lahore
International Water & Salinity Research Institute (IWSRI)	Autonomous body Ministry of Water and Power	Lahore
Soil Survey of Pakistan (SSP)	Ministry of Defence	Rawalpindi
Higher Education Commission (HEC)	Autonomous body, Ministry of Federal Education and Professional Training	Islamabad

Institutes	Status and Ministry	Headquarters
The Provincial Agricultural Research Systems		
Ayub Agricultural Research Institute (AARI), Punjab	Dept. of Agriculture, Government of Punjab	Faisalabad
Agricultural Research Institute (ARI) Sindh	Dept. of Agriculture, Government of Sindh	Tandojam, Sindh
Agricultural Research Institute (ARI) Balochistan	Dept. of Agriculture, Government of Balochistan	Sariab, Quetta, Balochistan
Agricultural Research Institute (ARI) KPK	Dept. of Agriculture, Government of KPK	Tarnab, Peshawar, KPK
The Provincial Agricultural Universities Systems		
University of Agriculture	Autonomous, HEC, Dept. of Agriculture, Government of Punjab	Faisalabad
Pir Mher Ali Shah Arid Agricultural University	Autonomous, HEC, Dept. of Agriculture, Government of Punjab	Rawalpindi
The Sindh Agricultural University	Autonomous, HEC, Ministry of Education, Government of Sindh	Tandojam
University of Agriculture	Autonomous, HEC, Ministry of Education, Government of KPK	Peshawar

3.6.1. National Agricultural Research Centre (NARC)

The NARC is the largest research institution of PARC and is one of the several research establishments of PARC functioning at the federal and regional levels. NARC was established to support the provincial system by conducting upstream research and providing raw materials and inputs that can be used in the provincial system to produce the finished products. The NARC coordinated programs serve as a common platform for the scientists working in different federal, provincial agricultural research, and academic institutions to jointly plan their research activities, avoiding unnecessary duplication of research efforts. Research that can best be addressed at a national centre rather than by provincial institutions is undertaken at NARC (http://www.parc.gov.pk/). In particular, research requiring sophisticated instruments like electron microscopes, ultracentrifuges, and elaborate analytical and quality testing facilities is undertaken at NARC, supported by highly qualified and trained manpower. The adaptation of technologies available from the international research systems is also managed by NARC in collaboration with the provincial research and extension institutions. The location of NARC in Islamabad facilitates liaison with international and national scientists. The goals and purposes of NARC are following:

1) The major goal of NARC is to conduct research in areas of national importance where such research is not currently being undertaken or is seriously inadequate and it can best be done at a well-equipped, properly staffed and funded central institution, where facilities are available to all scientists in the country.
2) The NARC will also have a Training School to impart theoretical as well as practical training in crop production and related techniques to provincial scientists. The training school will conduct special courses on important agricultural commodities and will have the necessary facilities including lecture rooms, laboratories, and experimental fields, besides a cafeteria and hostel for the trainees. Eminent national and international experts on different commodities will teach these courses, which will also include extensive field experiments to be done by the trainees.
3) The other facilities at NARC include a reference library and a centralized information service to provide the latest research information to all the research scientists in the country. A centralized facility for the repair and maintenance of sophisticated laboratory equipment is also being established at NARC, which will provide service to all the research institutions.
4) The repair and maintenance division will have adequately trained staff and technicians to undertake repairs of most of the laboratory equipment in the country. The division will organize training courses to build up the capabilities of the major research institutions to repair their equipment by training a large number of technicians for various institutions.
5) The Agricultural Machinery Division (AMD) will undertake research in developing designs for urgently needed farm machinery in cooperation with the relevant provincial institutions. AMD will develop linkages with the agricultural machinery manufacturers in the country so that the successful designs, after testing in farmers' fields can be manufactured in sufficient numbers and made available to the farmers within a short period.
6) The Plant Introduction Centre (PIC) and the National Unit of Plant Genetic Resources (PGR) will also be located at NARC. The main objective of these groups is to collect and preserve the genetic resources of various crops and animals to save them from extinction to transfer their desirable traits for the development of high yielding varieties with other desirable characteristics like resistance to diseases, insects and other environmental stresses. The group will also systematically (arrange to) test exotic plant and animal species under various ecological conditions prevailing in different parts of the country, to select those which could be directly used by the farmers with minor modifications. The successful strains/cultures selected by PIC will be passed on to the provincial institutions for adaptive research and large-scale introduction in their areas.
7) Research in Social Sciences related to agriculture will also be concentrated at NARC so that the social scientists could interact with biological scientists and undertake research on various socio-economic problems of distinct categories of farmers and the agro-ecological regions. In addition to a strong research group at NARC, small research groups on agricultural economics

will also be established in each province to interact and support the applied research on different aspects of agriculture in the provincial institutes.

8) NARC will provide a focal point for all the agricultural research scientists of the country to jointly discuss and plan their research activities on different commodities, and to undertake research on common problems, which can best be done at a National Centre rather than at each of the provincial institutions. In particular, research on problems requiring sophisticated equipment like electron microscopes, ultracentrifuges, and elaborate analytical and quality-testing facilities, will be undertaken at NARC.

NARC, Islamabad has the following sections / Institutes to achieve the above goals:

1) Animal Sciences Institute
2) Agricultural and Biological Engineering Institute
3) Agriculture Poly Technique Institute
4) Crop Sciences Institute
5) Climate Change, Alternate Energy & Water Resources Institute (CAEWRI)
6) Department of Plant & Environmental Protection
7) Crop Diseases Research Institute
8) Ecotoxicology Research Institute
9) National Institute of Bioremediation
10) Food Science and Product Development Institute
11) Food Security Research Institute
12) Horticultural Research Institute
13) Honeybee Research Institute
14) Institute of Microbial Culture Collection of Pakistan (IMCCP)
15) Land Resources Research Institute
16) National Institute of Genomics & Advance Biotechnology (NIGAB)
17) National Institute of Organic Agriculture
18) Olive Research & Development Institute
19) Plant Genetic Resources Institute
20) Social Sciences Research Institute

3.6.2. Regional Centers

3.6.2.1. Balochistan Agricultural Research & Development Center (BARDC)

The BARDC caters to the needs of the people of the province. Under BARDC Quetta, five institutes namely, Horticultural Research Institute Khuzdar, Coastal Agricultural Research Institute Lasbella, Agricultural Research Institute Turbat, Agricultural Research Institute Jafferabad and Agricultural Research Institute Barkhan at Rakhni (new) are working with the aim to enhance agricultural productivity through efficient management of natural resources (water, land, range lands, livestock, medicinal herbs and fisheries.

3.6.2.2. Southern Agricultural Research Center (SARC)

The SARC, one of the major research establishments of PARC is located in Sindh, Pakistan with its headquarters at the University of Karachi, Karachi. The main focus of SARC Karachi is on specialized disciplines of national and regional importance related to Coastal Agricultural Research, Crop Diseases Research, Grain Storage Research, Grain Quality Control, Livestock & Fisheries Research, Peri-urban Dairying, National Sugar Crops Research, Pesticide Research and the Vertebrate Pest Control Programs (http://www.parc.gov.pk/).

3.6.2.3. Arid Zone Research Institute (AZRI)

The AZRI Bahawalpur has been working for the last more than two decades for catering to the research needs of the Cholistan area. The AZRI, Bhawalpur, aims at a multidisciplinary approach with the main goals: to evaluate present constraints to agricultural productivity in the desert where the potential for irrigation is either undeveloped or does not exist, to establish a regional capability to trickle the problems of arid areas and develop suitable techniques for the best land use in the Cholistan desert, to assess the social and economic acceptability of proposed technological innovations and develop suitable methods for the rapid and effective dissemination of new agricultural information, and to ensure self-sustainability of biological systems and environmental protection of fragile arid ecosystems of the Cholistan desert (http://www.parc.gov.pk/).

3.6.2.4. National Tea & High Value Crops Research Institute (NTHRI)

The NTHRI is located in Mansehra. It is involved in standardized propagation techniques for efficient multiplication and distribution of improved planting materials of tea & high value crops.

3.6.2.5. Summer Agricultural Research Station (SARS)

SARS Kaghan, facilitates agricultural scientists all over the country, as well as from abroad turn up to conduct their off-season research trials on different crops.

3.6.2.6. Mountain Agricultural Research Centre (MARC)

The MARC is located in Gilgit. It is involved to conduct research in all sectors of agriculture and improving the agricultural productivity in Gilgit-Baltistan to generate opportunities for the livelihood of poor farmers of this least developed remote area.

3.6.2.7. Arid Zone Research Institute (AZRI), Dera Ismail Khan

It caters to the needs of the arid and semi-arid areas of KPK. It is situated in D.I. Khan which is lying in the extreme south western part of the province.

3.6.2.8. Arid Zone Research Center

Umerkot, Sindh works for enhancing the productivity of arid and semi-arid agriculture of Thar and surrounding areas by identifying crop, livestock and socio-economic constraints.

3.7. Provincial Agricultural Research Systems

All four provinces have agricultural research institutes which are supported and directed by the provincial ministries of agriculture. Main establishments are elaborated as under:

In Punjab, Punjab Agricultural Research Board (PARB) (http://parb.agripunjab.gov.pk/) was established to foster an integrated approach to research planning and efficient allocation of research resources so that the agriculture innovation system of the province can generate appropriate solutions to the issues faced by various stakeholders in the food and fiber chain. The vision of the PARB is to support scientific innovations for the prosperity of Agricultural Stakeholders in Punjab.

Punjab also has Punjab Agricultural Department (http://www.agripunjab.gov.pk/research) having wide-spread research establishments. These include:

1) Bahawalpur, Regional Agricultural Research Institute
2) Bhakkar, Arid Zone Research Institute
3) Chakwal, Barani Agricultural Research Institute and Soil & Water Conservation Research Institute
4) Faisalabad, Ayub Agricultural Research Institute (AARI), dealing in cotton, wheat, pulses, oil seeds, sugarcane, vegetables, and other agricultural research activities
5) Hafizabad, Soil Salinity Research Institute
6) In Lahore, Rice Research Institute (Kala Sha Kaku) and a Rapid Soil Fertility Survey & Soil Testing Institute cater to local farmers
7) Multan, Mango Research Institute
8) Sahiwal, Maize and Millets Research Institute and a Potato Research Institute
9) In Sargodha Fodder Research Institute as well as a Citrus Research Institute

In KPK, Agriculture Research Institute (ARI), Tarnab, Peshawar is a network of 13 Agriculture Research Institutes/stations with several substations, functioning in the province under the supervision of Director General Research (BPS-20). The Outreach Directorate is headed by Director Outreach. He is responsible for the promotion and transfers improved technology to the end users. Research institutes/stations can be split into two categories, one with the mandate of research on multiple disciplines, e.g., Agriculture Research Institutes in Tarnab, Dera Ismail Khan and Mingora, and Agriculture Research Station Baffa, Mansehra falls under this category. While the other category is commodity institutes/stations like Cereal Crops Research Institute, Pirsabak, Sugar Crops Research Institute, Mardan. In the 1980's, the Government of KPK according to an agreement signed with US-AID, under Project Transformation and Integration of Provincial Agricultural Network (TIPAN), handed over the Agricultural Research Wing of Agriculture Department to Khyber Pakhtoonkhwa Agricultural University, Peshawar, which was later called Khyber Pakhtoonkhwa Agricultural Research System. This agreement aimed to enhance the quality of agriculture education and research according to the need of the farming community. This System is working under Khyber Pakhtoon Khwa Agricultural University, Peshawar administration and is financed by the Government of KPK. The following Institutes/Stations are established in the Province under Agricultural Research System KPK:

- Agricultural Research Institute, Tarnab, Peshawar
- Agricultural Research Institute, D.I. Khan
- Cereal Crops Research Institute, Pirsabak, Nowshera
- Sugar Crops Research Institute, Mardan
- Agricultural Research Station Mingora, Swat
- Barani Agricultural Research Station, Kohat
- Agricultural Research Station, Baffa, Mansehra
- Livestock Research Station, Jaba, Mansehra
- Potato Research Centre, Abbottabad
- Agricultural Research Station, Chitral
- Agricultural Research Station, Serai Naurang
- Agricultural Research Station, Ahmad Wala, Karak
- Livestock Research and Development Farm, Surezai, Peshawar
- Directorate of Outreach, Khyber Pakhtoonkhwa Agricultural University, Peshawar

In Balochistan, the Agriculture Research Institute (ARI) Sariab, Quetta is the only multi-disciplinary institute functioning in the entire province. This institute was established in 1958 as a Potato Research Station, after the dismemberment of one unit in 1970 the research station was renamed Agriculture Research Institute, Sariab, Quetta. Presently this Institute has the following components:

- Directorate of headquarters
- Directorate of Agriculture Research Fruit
- Directorate of Agriculture Research Tropical Fruit
- Directorate of Agriculture Research Soil & Water Testing
- Directorate of Agriculture Research Water Management
- Directorate of Agriculture Research Oil Seed and Cotton Crops
- Directorate of Agriculture Research Vegetable & Potato Seed

- Directorate of Agriculture Research Cereal Crops
- Directorate of Agriculture Research Fodder Pulses and Cereal Crops
- Directorate of Agriculture Research Plant Protection
- Directorate of Agriculture Research Economics & Marketing

3.8. The Provincial Agricultural Universities System

The organizational structure of University of Agriculture, Faisalabad includes Faculties (Faculty of Agriculture; Faculty of Veterinary Science; Faculty of Sciences; Faculty of Animal Husbandry; Faculty of Agricultural Engineering & Technology; Faculty of Social Sciences; Faculty of Food, Nutrition and Home Sciences), Institutes (Institute of Horticultural Sciences; National Institute of Food Science and Technology; Institute of Soil & Environmental Sciences; Institute of Animal & Dairy Sciences; Institute of Microbiology; Institute of Physiology and Pharmacology; Institute of Business Management Sciences; Institute of Agricultural Extension, Education and Rural Development; Institute of Agricultural and Resource Economics) and Directorates (Directorate of Academics; Directorate of Graduate Studies; Directorate of Farms; Directorate of CABB; Directorate of Students Affairs; Directorate of External Linkages; Directorate of Research, Innovation & Commercialization; Directorate of Sports; Directorate of Water Management Research Centre and Directorate of Student Financial Assistance and University Advancement).

The University of Agriculture in Faisalabad (Punjab) is by far the largest of the four, employing over 500 faculty staff. They spent an estimated 25 to 40% of their time on research, resulting in around 200 full-time researchers. The university's research activities are coordinated through the Directorate of Research, Innovation and Commercialization, which is also responsible for communication with national and international partners and funding agencies and advises the university's management on all issues related to the promotion of research and its results.

Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi includes five faculties (Faculty of Crop and Food Sciences; Faculty of Veterinary & Animal Sciences; Faculty of Agricultural Engineering & Technology; Faculty of Sciences; and Faculty Social of Sciences), six institutes (University Institute of Information Technology, University Institute of Management Sciences, Institute of Soil & Environmental Sciences, Institute of Food and Nutritional Sciences, Institute of Hydroponic Agriculture and Institute of Geo-Information and Earth Observation) and directorates (Directorate of External Linkages; Directorate of Financial Assistance and University Advancement; Directorate of Advanced Studies; Directorate of Works; Directorate of Student Affairs; Directorate of Women Development Studies Centre; Directorate of Sports; Directorate of Planning and Development; Directorate of University Development; Directorate of Academics; Directorate of Quality Enhancement; Pak-Korea Capacity Building Centre).

Sindh Agriculture University, Tandojam includes five faculties (Faculty of Agricultural Engineering; Faculty of Animal Husbandry and Veterinary Sciences; Faculty of Agricultural Social Science; Faculty of Crop Production and Faculty of Crop Protection) and two institutes (Information Technology Centre and Institute of Food Sciences and Technology). Sindh Agricultural University (SAU) in Tandojam is the second-largest university in Pakistan in terms of agricultural research and development (R&D) staff and expenditures. In 2003, the university employed 73 full-time researchers involved in a wide range of crop, livestock, and socioeconomic research themes.

University of Agriculture, Peshawar includes six faculties (Faculty of Crop Production Sciences; Faculty of Crop Protection Sciences; Faculty of Nutrition Sciences; Faculty of Animal Husbandry and Veterinary Sciences; Faculty of Rural Sciences; Faculty of Management and Computer Sciences) and two institutes (Institute of Business and Management Sciences and Agricultural University Peshawar Schools and Colleges).

In Sindh, the Agriculture Department (http://sindhagri.gov.pk/) is working through Agriculture Research, Agriculture Extension, Agriculture Engineering and Water Management, Sindh Seed Corporation and Cane Commissioner. For the development of the agriculture sector and sustainable agricultural economy the department is taking efforts for the modernization of agriculture research, advancement of mechanized agriculture, strong market information system, improved agriculture extension services, water management, supply of good seeds and other facilities.

3.9. Status of Autonomy and the Governance of the NARS Organizations, Status of Autonomy

PARC, PAEC, PSF, PNAC, PCSIR, PCRWR, PIDE, CAMB, CEWRE, WAPDA, IWSRI, HEC and four agricultural universities in provinces are autonomous organizations where PCCC, PSCRD, API, AARI-Faisalabad, ARI-Sindh, ARI-Balochistan and ARI-KPK are running as government organizations.

3.9.1. Governance of the Institutions

As far as the governance of the NARS institutions is concerned, there are many non-uniformities among them. The governance system of these organizations is described briefly here.

3.9.1.1. Governance of PARC

The overall decision-making body of PARC is its Board of Governors (BOG) responsible for the control, direction and superintendence of affairs of PARC. The Board is assisted in its operation by a number of Committees. The Federal Agricultural Minister is the President of the Board. The executive committee comprising the Chairman and Members of the Council is the principal administrative body responsible for executing all policies and discharging the functions of the

Council. Matters relating to research planning, coordination, budget and policy formulation are referred to the Board of seeking its guidance and general direction.

3.9.1.2. Governance of PCCC

The Chief Executive of the Committee is full-time Vice President of grade-21 of the Federal Government. He is assisted by the Secretary of PCCC in Administrative & Financial matters, the Directors at the Headquarters and the Institutions in all Technical Aspects. The PCCC is supported by a CESS on marketed cotton.

3.9.1.3. Governance of PAEC

PAEC is incorporated as a statutory body under an Act, with considerable autonomy. In 1972 the commission was transferred from the Science and Technology Research Division to the President's Secretariat. This is run by the Board of Governors. The President of Pakistan is the Chairman of the Board of Governors.

3.9.1.4. Governance of PCSIR

In PCSIR, the Governing Body is the executive organ of the Council and comprises the Chairman and three full-time members *viz.* Member (Science), Member (Technology) and Member (Finance), nominated by the Government. The Head Office of the PCSIR is functioning in Islamabad where the offices of the Chairman, all members and Secretary PCSIR are located. The Science Wing is headed by Member (Science), who supervises matters relating to Research & Development, Training, International Affairs and Scientific Information Services. The Technology Wing is overlooked by the Member (Technology), who looks after the matters relating to Technology, Industrial Liaison and Civil Works. The Finance Wing is headed by the Member (Finance) who is in charge of activities in the Finance and Audit and Accounts Divisions. The Chairman is assisted by the Secretary and Administration and Establishment Wings, working directly under him.

3.9.1.5. Governance of PCRWR

The overall decision-making body of the Pakistan Council of Research in Water Resources (PCRWR) is its Board of Governors (BoG), responsible for the control, direction and superintendence of the affairs of the PCRWR. Technical and Executive Committees assist the Board in its operation. The Federal Minister and Secretary (Scientific and Technological Division), Ministry of Science and Technology are the President and Vice President of the Board, respectively. PCRWR undertakes research on the development, management, conservation, utilization and quality of water resources and also develops and maintains National Water Resources Database.

3.9.1.6. Governance of IWASRI

The administrative control of IWASRI was given under WAPDA. The Member (Water) WAPDA is Chairman of the Executive Committee of IWASRI. The Institute works under the general supervision and guidance of the Board of Directors. The Secretary Ministry of Water and Power (MOWP) is the Chairman of the Board.

3.9.1.7. Governance of CEWRE

The Government of Pakistan established CEWRE in 1976 as a semi-autonomous institution of higher learning under the control of HEC and the Ministry of Education, Govt. of Pakistan. The Centre is academically affiliated with the University of Engineering and Technology, Lahore, which awards degrees to the Centre's graduates.

3.9.1.8. Governance of HEC

The HEC is an independent, autonomous and constitutionally established institution of primary funding, overseeing, regulating and accrediting the higher education efforts in Pakistan. Under the leadership of the Chairman and Federal Minister, and administrative control of the Executive Director, HEC is divided into various departments, which are headed by Members and Advisors Education Commission of Pakistan. (https://en.wikipedia.org/wiki/Higher).

3.9.2. Governance of Provincial Agriculture Research Institutes

The agriculture research institutes in all provinces are the government departments. The Secretary, Agriculture Department in each Provincial Government is the policy decision maker. The provincial research institute is headed by a Director General and has a Research Management Committee (all the Directors of the institutes) as its Governing Body. The basic budget for each provincial institute is provided by the respective provincial government.

3.9.3. Governance of Provincial Agricultural Universities

Each provincial agricultural university is an autonomous body. The governor of the province is the ex-officio chancellor of the university. In Punjab, the Minister of Agriculture is pro-vice-chancellor, while the Ministers of Education are pro-vice-chancellors in the Sindh and KPK provinces. All the universities are headed by a Vice Chancellor and have a syndicate as their governing body. The basic budget for each university is provided by the central government through the HEC, which in turn obtains the funds from the federal government through the Ministry of Federal Education and Professional Tranining. The faculties of the agricultural universities constitute the largest single pool in the national agricultural scientific manpower with advanced academic training from abroad.

3.10. Role of PARC in NARS

The PARC is committed to providing leadership to NARS of the country. Since agriculture is a provincial subject and mainly undertakes applied research through provincial agricultural research institutes and basic research through provincial agricultural universities. The PARC through its research establishments spread all over the country undertakes strategic research on national and provincial priorities and emerging challenges in agriculture. The PARC also conducts exploratory research on new commodities and gaps in the provincial research agenda to provide solutions to the existing gaps and emerging problems of national importance.

It provides services to the provincial system in the conservation and supply of germplasm, agricultural informatics, and human resource development. It also ensures collaboration and linkages with the provincial and international research systems. The PARC is managed by a Board of Governors and is responsible for the overall control and direction of the PARC. The Board is assisted by the Research Advisory Committee, which includes representatives from PARC, farmers, politicians, and the agricultural business community. The day-to-day activities of the council is run by the Executive Committee which is consisted of PARC Chairman and five Members of the Council. The five members do not correspond to the above functions of PARC, rather heading the discipline-based Division, i.e., Crop, Natural Resources, Livestock, Social Sciences and Finance & Administration. The central management of the PARC is supported by several units, including general administration; personnel; physical plant construction, management and maintenance; procurement; financial management; planning, monitoring, and review; international liaison; scholarships & training; and publication & information. In addition to its headquarters, various institutions under PARC's umbrella conduct agricultural research in the wide number of agro-ecological zones within the country.

3.10.1. Role of PARC in Research Coordination

The PARC closely coordinates research activities with special emphasis on: Knowledge Sharing; Germplasm Sharing; Resources Sharing; Joint Planning; and Joint Implementation. The PARC coordinates with Federal Institutions and Provincial Research Institutes in different ways; some of which are presented below:

1) Board of Governors of the PARC constituted the Inter Provincial Agricultural Research Coordination Committee (IPARCC); with Chairman the PARC as its Convener and Secretary of this Committee.
2) The PARC coordinates with other Federal Research Organizations like PSF, HEC, PAEC, etc. through combined research projects.
3) The PARC also coordinates with all the provinces as well as AJK by funding different agricultural research projects through a competitive grant system which is mainly financed through Agricultural Linkages Program (ALP) and Research for Agricultural Development Program (RADP)
4) The PARC works in various provinces through the Government Funded Projects, Pakistan Sector Development Project (PSDP) and Memorandum of Understanding (MOU), etc.
5) The PARC having its own research centers in various provinces. Details are mentioned in this Chapter elsewhere.
6) The PARC also has its Technology Transfer Centers in all four provinces as well as AJK, through which the PARC shares its technologies with the provincial extension departments as well as directly with the farmers.
7) The PARC's International and National research coordination is given below in Figure 3.2:

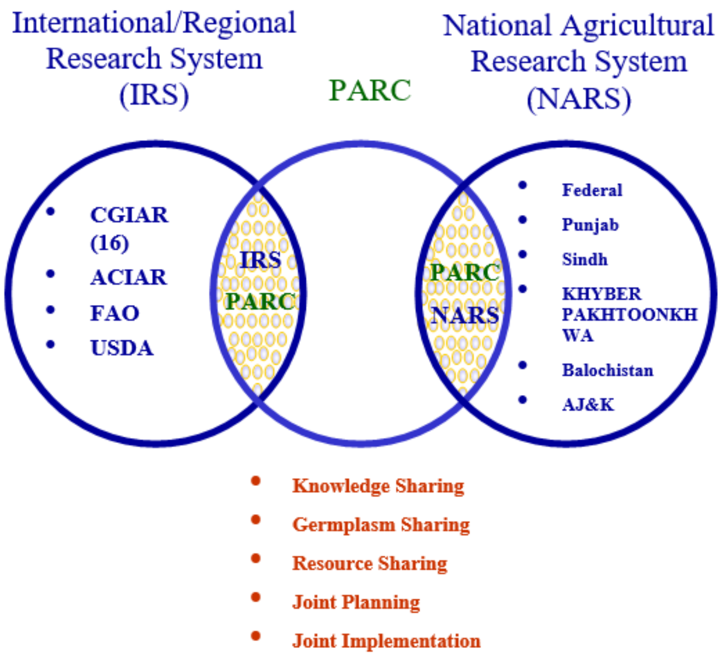

Figure 3.2 National and International Research Coordination

3.10.2. Research Extension Linkages

The basic function of agricultural extension is to transfer the latest production technologies generated at research institutes and universities to the farmers. During the MTDF, the Provincial Governments were responsible to improve and strengthen the agriculture extension services. The electronic media are supposed to be extensively used for broadcasting/telecasting special production packages of different farm operations. A section on the transfer of technology is usually established as an integral part of all research institutes to ensure that the latest research findings and packages are disseminated to the farmers. Extension services in each district were established for adaptive research farms having their own team of mobile extension experts, which undertakes crop maximization/adaptive research programmers.

Trainings/refresher courses are organized for the extension staff to enhance their knowledge and latest technologies. The Punjab province is implementing a new approach to farmer's group participation in four districts which were extended to the whole province in phases. The new system involves a "Group Participatory Approach" aiming at integrated crop management through Training of Trainers (TOT) and Training of Facilitators (TOF). Based on the successes of a pilot project on IPM, one of the authors of this Chapter (Dr. Iftikhar Ahmad) introduced Farmers Field Schools (FFS) in Pakistan. The FFS concept was so popular that neighboring Afghanistan approached Pakistan to train their Agricultural Extension Staff for adopting FFS in that region. In this technique, farmers are trained and demonstrated various practices in the actual field like a family or a closed classroom. The success of the new approach lies in its focus on the farmers as decision makers in soil, crops and pest management techniques and the use of non-formal methods using the farmer's fields for training and learning process. Women farmers benefitted more when the FFS technique was adopted in agriculture extension activities.

Being an important instrument to provoke new knowledge for the expansion of agricultural productivity, research has been given prime importance. Several MOUs have been signed with China for collaborative research programs which will be undertaken by PARC. New research institutes such as Benazir at Benazirabad (Nawabshah), Neelibar (Vehari), Organic Agriculture (Islamabad), Cotton (Rahim Yar Khan), Mountain Research (Gilgit-Baltistan), Plant Tissue Culture Labs Network, Participatory Research and Development (Sulman Range), Salinity Research (Islamabad), Agriculture Research (Muzzafarabad) and Teaching Research (Balochistan) will be established in coming days. To popularize research technologies, technology transfer units will be established in Research and Development institutes.

3.11. Education – Link with Agricultural Universities

National Agriculture Education Accreditation Council (NAEAC) was established in 2006 by HEC with the mandate to carry out a comprehensive program of accreditation of agriculture degree programs in private and public-sector agriculture education institutions in Pakistan. The overall objective of accreditation is to improve the capacity of institutions in the form of academic and physical infrastructure in relation to the set targets. Accreditation is a mandatory process for all relevant academic programs offered by public and private sector institutions. The purpose of such accreditation is to enhance recognition of the institution in the agriculture community and prospective students/employers. All institutions in Pakistan which provide a recognized agriculture degree are required to apply to the Council to have such degree programs accredited. NAEAC is responsible for the accreditation of educational programs leading to degrees in the agriculture disciplines. All agriculture degree programs (except veterinary sciences) comprising about fifteen (15) disciplines of agriculture fall under the purview of the Council. The major functions of the NAEAC are:

i. Organize and carry out a comprehensive program of accreditation of agriculture programs leading to degrees/diplomas based on approved policies, procedures and criteria, and publish a list of ranking of degree programs.
ii. Develop accreditation policies, processes, guidelines and procedures for the program evaluators.
iii. Approve the list of evaluators selected through an approved criterion

iv. Participate in the process of accreditation of academic programs and constitute Accreditation Inspection Committees (AICs) from the approved list of evaluators.

v. Develop program evaluator's training manual/self-study material, questionnaire, forms and templates.

vi. Collect information and statistics on accredited programs of higher education in agriculture and its respective institutions and publish them as deemed necessary.

3.12. Linkages between Federal, Provincial and Private Sector Research System

Although both components have different responsibilities, they are synergistically linked with each other to produce the system-level outputs. In fact, the efficiency and success of the Strategic End (SE) of the research system depend on how effectively the Users End (UE) of the research system utilizes its materials, methodologies, models and inputs, while the success of the UE also depends on the relevance of the materials supplied by the SE to the problems of the agriculture sector in different ecologies of the country (Figure 3.3). To improve the efficiency of each component, it is important to draw boundaries of each component to avoid duplication and confusion and suggest ways to improve the synergistic links between the two components. The agricultural research system is just like a service industry with its defined inputs, activities and outputs. Like any service industry, the structure of the system should be organized on scientific lines so that its employees are motivated, and its resources are fully and efficiently employed. For this purpose, inputs (or resources), activities (or functions), and outputs (or targets) of each production line of the system needs to be clearly specified. This study was designed to analyze the structure and operation of the SE component at the federal level that drives the whole system and to draw boundaries between the federal, provincial, and private continuum of the research system. It is expected that such analysis will improve the efficiency of every component as well as the overall efficiency of the whole system.

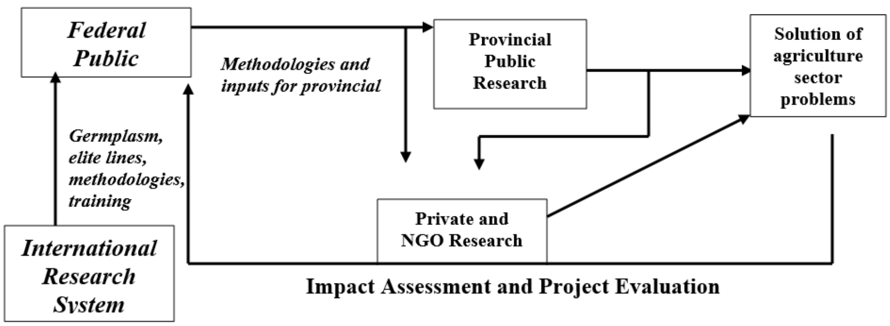

Figure 3.3 Interaction among various components of agriculture research system

Source: Ali and Ashraf (2006)

3.13. Management Information System (MIS)

Management Information System (MIS) has also been institutionalized and a web-based 'Project Monitoring and Evaluation System' (PMES) has been developed in the Planning Commission for effective implementation through continuous sharing of e-information amongst all stakeholders.

Following progress has been made in MIS during 2009-10:

- Evaluation, Result Base Monitoring (RBM) and Working Paper modules have been incorporated in PMES
- PMES software has been successfully operationalized in 21 ministries/divisions while other ministries will be looped within two years.
- 1477 Project Directors / Project Officers got the training on PMES
- PMES currently houses a database of 1600 development projects and is available online
- Cash / Work Plans of 592 projects were processed online through PMES
- PMES facility has also been endowed to the Government of Sindh for reporting implementation on the provincial ADP projects

As NARS Leader, the PARC has established a National Agricultural Information System (NAIS) and audio-visual communication facility to pass on research results to farmers. The PARC website has been established and Home Pages containing vital information about the organization have been developed. It has linkages with all important Agricultural Research & Development establishments. The PARC has also published more than 125,000 copies of scientific publications during the past 35 years including periodical publications. The Audio-Visual Communication facility of the PARC is passing on research results to farmers effectively.

3.14. Monitoring of Research Programmes during Implementation

Based on the funding sources, a review process is adopted for the evaluation of activities performed. Review means checking the design and work plan by the concerned ministry. If during the review, some activities are not according to the plan then on the recommendations of the review committee, these activities are shifted to the next quarter. After completion of the first year, the project annual review is conducted. These reviews are initiated by the planning division, concerned members and Chairmen PARC, and the concerned Ministry representatives.

The planning directorate/agriculture linkages program secretariat of the PARC organizes an annual review. The project in-charge prepares an annual report of the project consisting of progress, achievement and result of the project for the period under report. The planning directorate organizes a review meeting that is attended by the members of the Technical Advisory Committee (TAC) of ALP. The TAC reviews the annual progress reports of the projects and offered their observation and suggests recommendations for modification. The planning directorate then prepares and compiles a one- or two-pages summary of each project showing the project's outcome, observations and recommendations of TAC. These are submitted to the members of the board of directors (BOD) of ALP for final recommendation and decisions. The planning directorate and concerned technical division of PARC in collaboration also review the progress on their own and observe their farm field or lab activities in the concerned institutions. Similar reviews are done by other projects, such as RADP, or the Italian Government funded Olive Project titled "Technical Assistance and Support to Line Ministries in the Agriculture Sector with Emphasis on Olive Production-Afghanistan, Nepal and Pakistan". In short, all projects running in the NARS and its establishments review these according to the time / frame mostly indicated in project documents/PC-1.

3.15. Conclusion

Because of the significant role of the agriculture sector in Pakistan's economic growth, a strong NARS is needed on a sustainable basis. Keeping in view the growing population pressure and the future food needs of the nation, Pakistan should remain abreast with the latest production technologies for obtaining higher production of cereals by using our limited resources of land, water, energy, and labor. For this purpose, we look forward to our NARS which must focus on these issues under the umbrella of the PARC. However, emphasis should also be given that the new technologies that are generated through NARS must reach end users through a well-mobilized and efficient delivery system. All these goals will be achievable if the government commits itself that a sizeable budget is set aside to run the NARS in a smooth and interrupted way. The role of agricultural universities in producing state of the art agricultural graduates, their enhanced employment opportunities, and their in-job career development are the main ingredients of a sustainable NARS, else there is a likelihood that this brain will also be drained overseas.

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Chapter 4

Agricultural Education in Pakistan

Zahid Ata Cheema and Aman Ullah♦

Abstract

Education is the first brick to construct a sound and peaceful nation. Character building and ethics are the decoration material as cement in building material to decorate a building. Without decoration a building is ugly and doesn't attract the attention of the passerby. Likewise, ethics, character building and morality are the foundation of the personality of an educated person. The way of dealing and addressing the masses depicts one's persona and educational institution background. In our existing education institutes, these basic values donot exist. Students get the education just to earn money to fulfill their bellies. The direction of education is completely diverted towards this valueless money. There is a dire need to teach the students that education does not mean to earning money, the true spirit of education is to make one a human. The only difference between a man and an animal is ethics. This chapter highlights the need for ethics, character building and the existing educational system and their improvement with a focus on agriculture.

Keywords: Curriculum, Education, Policy, Teachers, Training

4.1. Introduction

All problems in Pakistan are created by the educated class (a statement commonly made by a retired professor). If we look into the history of Pakistan, this

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statement sounds correct. The education imparted during the past-half century had been lacking in a very basic and essential aspect, as there had been entirely no emphasis on character building and ethics (Huitt 2004). Moreover, it had been aimless and directionless. Good education brings changes in attitude, behavior, builds character and motivates to work for higher ideals of life but unfortunately our education has produced, incompetent, selfish, coax and corrupt human resource (Hackman 1980). For competing with the advanced nations and for fulfilling national needs and objectives, drastic changes in the entire education system are inevitable. The whole educational system had to be reorganized/re-structured keeping in view the ideology of Pakistan and the social, cultural, religious values and it should be aimed at producing patriotic, dedicated and honest selfless Pakistani citizens (Mahmood et al. 2016).

The syllabi have to be changed/modified, the dilemma regarding the medium of instruction has to be decided once forever, the teachers have to be trained accordingly and the nation had to give top priority to education, which should be reflected in our national budgets. The scope for improvement always exists. In this chapter, some of the basic defects of agricultural education have been identified and highlighted with focus a on character building.

4.2. Ethics and Character Building

Education regarding ethics, good norms and morality is lacking in our entire system. The education based on such values leading to character building could be the major driving force for enhancing the efficiency of every individual at all levels (Trevino 1986). This type of education could inculcate the spirit of devotion, selflessness, sacrifice and patriotism. Therefore, much more emphasis should be on character building (Ryan 1999).

4.3. The Teachers

The chief justice committee has recently demanded the appointment of honest judges in the courts. The appointment of honest, dedicated and fair teachers is rather more important than judges because the teachers teach judges as well. Better grades, salaries, respect and environment could attract intelligentsia towards this noble profession. It is the teacher who makes men, not the books. The teacher should be a role model because the character and behaviuor of teachers could be the most important tool in the character building of the students (Justi 2002). The students learn more by deeds than words (Stokes 2002).

Teaching is an art, which could be improved by dedication and experience (Dawe 1984). The teacher should be aware of current affairs, innovations and knowledge and should use the latest teaching aids such as audio-visuals, PowerPoint slides, etc. He should involve the students in class discussions and should develop better relations with the students by being sympathetic and helpful (Al-Mamun 2014). The medium of instruction greatly influences the teaching capability of the teacher and learning capacity is much higher in national/local languages (Teo 2009). The medium of instruction up to graduation must be Urdu, however for higher education the learning of a foreign language as Arabic and English should be mandatory.

4.4. Education and Training of Para Field Staff

The para field staff (field and stock assistant) play a basic and fundamental role in disseminating the information and displaying the latest techniques to the farming community and providing basic information to the decision-makers.

The existing education and training of para field staff are extremely weak, both in theory and practical, moreover due to low pay scales (BPS-11) only the third-rate matriculate students join as para field staff. The education and training facilities for para field staff are inadequate. For improving the standard of their education, the two-year course should be changed to a three-year diploma and students only matric with science should be admitted. Highly qualified teachers should be recruited. Provision of the latest laboratory equipment and field implements, and better library facilities can improve the quality of education of para field staff. To attract intelligent students, the basic pay scale for para field staff should be at least (BPS-14). By adopting these measures, the efficiency and contribution of para field staff could greatly be enhanced.

4.5. In-service Training

The importance of in-service training is recognized in all societies. It is essential to keep abreast of the new techniques and developments in specific fields. By providing proper in-service training at regular intervals (3-5 years), the efficiency of all concerned (para field staff, officers, researchers and administrators) can be enhanced tremendously. A list of in-service agricultural training institutes working in Pakistan are given in Table 4.1.

4.6. Farmer's Education and Training

The education and training of farmers are necessary because it is the farmer who could serve as an important agent for achieving self-reliance. Proper education and training could motivate and involve the farmers in developmental activities leading to a self-sufficient nation in food and other related products. The use of mass media particularly television could be very effective in educating the farming community (Wakefield et al. 2010). Special attention should be paid to improving the socio-economic conditions of farmers. Provision of credit in kind as seed, fertilizer machinery, pesticides, etc. should be encouraged instead of cash.

4.7. Heads: Their Education and Training

The role of a head of any institution or department is vital in enhancing the efficiency of his colleagues/subordinates. The character, attitude and behavior of a director/principal officer/chairman, etc. greatly influence the working efficiency of his section. An honest and polite officer/head can enhance the output of his department manifold than a corrupt and toady (Aldrichand and Herker 1977).

Table 4.1 In-service agricultural training institutes

Province		Diploma
Punjab		
Affiliated with		
University of Agriculture Faisalabad		
1.	In- Service Agricultural Training Institute, Rahim Yar Khan	Diploma in Agriculture Sciences-DAS
2.	In-Service Agricultural Training Institute, Karor Lali-E-Son, Layyah	Diploma in Agriculture Sciences-DAS
3.	In-Service Agricultural Training Institute, Sargodha	Diploma in Agriculture Sciences-DAS
4.	Pak-German Institute of Co-operative Agriculture, Multan	Diploma in Agriculture Sciences-DAS
Per- Mehar Ali Shah, Arid Agriculture University, Rawalpindi		
5.	Barani Agricultural Training Institute, Rawalpindi	Diploma in Agriculture Sciences-DAS
6.	Barani Agriculture Training Institute, Khushab,	Diploma in Agriculture Sciences-DAS
Khyber Pakhtunkhwa		
University of Agriculture, Peshawar		
7.	Agricultural Training Institute, Tarnab	Diploma in Agriculture Sciences-DAS
Sindh		
Sindh Agriculture University, Tando Jam		
8.	Sakrand Agricultural Training Institute, Nawabshah	Diploma in Agriculture Sciences-DAS
Balochistan		
Balochistan Agriculture College, Quetta		
9.	Agriculture Research Institute Sariab Quetta	Diploma in Agriculture Sciences-DAS

Azad Jammu & Kashmir		
University of Poonch Rawalakot		
10.	Extension Services Management Academy (ESMA), Garhi Dopatta, Azad Jammu & Kashmir	Diploma in Agriculture Sciences-DAS

All sectional heads/principal officers should be provided with special training and education for dealing with administrative matters. A fair and efficient administration would definitely improve the working and efficiency.

The administrative head should be generous enough to provide a congenial atmosphere in his department, by awarding special awards, prizes and writing letters of appreciation to efficient/dedicated officers/staff. The sectional head should be able to resist unnecessary political pressures in promoting or recruiting lower staff and should follow only merit and justice.

4.8. Government Policy

Priorities of government (federal/provincial) would rapidly and greatly improve education. If a government gives priority to education, it will certainly be improved. Very good reports/suggestions were made by different committees/commissions on education but are never implemented. If a government decides to improve education only then good recommendations could be implemented. The government should strictly follow the policy of merit in appointments, selections, promotions and transfers from lower staff to high-ups, particularly the secretaries and institutional heads. Discipline should be maintained at all levels (Steinberg 1990). Officers or staff involved in corruption, negligence, malpractice and coaxing should be strictly dealt with. The merger or integration of teaching/research and extension of agriculture department and related fields has been recommended at different fora, so the government should take necessary steps in this direction. Funds needed for this purpose be generously allocated to the larger interest.

4.9. Educational Institutions

The standard and quality of education in most of our institutions had declined steadily. The main reason for this decline is the negligence of government and society as a whole. The appointment of unsuitable institutional heads and teachers had further stimulated this decay. Lack of funds, particularly the shortage of laboratory equipment and chemical has also reduced the quality of education. Similarly reduced emphasis on practical and field work has led to poor quality graduates. The admissions are not according to the facilities. The quality of post-graduate research has gone down due to a shortage of funds and space. The administrative control of some educational institutions is under general universities which restricted the proper development. The separation of teaching from research has also aggravated the problem (Khan 2016).

The existing educational institutions should be strengthened by encouraging an interdisciplinary approach, for instance, Department of Animal Sciences may be established at D.I. Khan, D.G. Khan, Quetta and similarly Department of Crop production, Crop protection, Agri-business and Information technology, and Farm machinery be established at University of Veterinaryand Animal Sciences, Lahore.

Moreover, at each divisional headquarters an agriculture college should be established where courses on Forestry, Fisheries, Animal production, Health care and Agri-business should be taught in addition to courses on Crop production and protection and Farm machinery, etc.

The Department of Agricultural Sciences at Allama Iqbal Open University, Islamabad should be raised to the status of Faculty of Agricultural sciences. This department/faculty could effectively educate the farmers, who are the end users of all innovations in Agricultural sciences. A degree program for in-service para field staff and master program for in-service officers/researchers working in agricultural institutions could be initiated to improve their skills and efficiency. The list of educational institutes working in Pakistan is given in Table 4.2

Table 4.2 Institutions of agriculture in Pakistan

Province	University name	Faculties/Institute/ Department
Punjab	University of Agriculture, Faisalabad	1. Faculty of Agriculture 2. Faculty of Veterinary Sciences 3. Faculty of Sciences 4. Faculty of Animal Husbandry 5. Faculty of Agricultural Engineering & Technology 6. Faculty of Social Sciences 7. Faculty of Food, Nutrition & Home Sciences
	Sub-Campus (University of agriculture Faisalabad)	
	Burewala /Vehari Toba Tek Singh Depalpur, Okara	
	Allama Iqbal Open University	1. Department of Agricultural Science
	University of Sargodha, Sargodha	1. Faculty of Agriculture
	Muhammad Nawaz Shareef University of Agriculture (MNSUA), Multan	1. Faculty of Agricultural Bio System Engineering & Technology

	2. Faculty of Agriculture & Environmental Science
	3. Faculty of Social Science & Humanities
	4. Faculty of Veterinary and Animal Science
Bahauddin Zakariya University, Multan	1. Faculty of Agriculture Sciences and Technology
Sub-Campus (Bahauddin Zakariya University, Multan)	
BZU Sub- Campus Layyah	
Islamia University, Bahawalpur	1. Faculty of Agriculture & Environment
	2. Faculty of Veterinary and Animal Science
Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi	1. Faculty of Crop & Food Sciences
	2. Faculty of Veterinary & Animal Sciences
	3. Faculty of Agricultural Engineering & Technology
	4. Faculty of Sciences
	5. Faculty of Social Sciences
Sub-Campus (Pir Mehr Ali Shah, Arid Agriculture University)	
Khushab	
University of the Punjab	1. Faculty of Agricultural Sciences
Ghazi University, Dera Ghazi Khan	1. Faculty of Agricultural Sciences
	2. Faculty of Arts
	3. Faculty of Management & Social Sciences
	4. Faculty of Science

Sindh	Sindh Agriculture University, Tando Jam	1. Faculty of Agricultural Engineering
		2. Faculty of Animal Husbandry & Veterinary Sciences
		3. Faculty of Agricultural Social Science
		4. Faculty of Crop Production
		5. Faculty of Crop Protection
	Sub-campuses (Sindh Agriculture University)	
	Umerkot	
	Khairpur	
	Dokri	
	University of Karachi, Karachi	1. Department of Agriculture and Agribusiness Management
Khyber Pakhtunkhwa	University of Agriculture, Peshawar	1. Faculty of Crop Production Sciences
		2. Faculty of Crop Protection Sciences
		3. Faculty of Nutrition Sciences
		4. Faculty of Animal Husbandry & Veterinary Sciences
		5. Faculty of Rural Social Sciences
		6. Faculty of Management and Computer Sciences
	Gomal University, D. I. Khan	1. Faculty of Agriculture
	University of Haripur, Haripur	1. Faculty of Physical and Applied Sciences
	University of Agriculture, D. I. Khan	1. Faculty of Agriculture
		2. Faculty of Veterinary and Animal Sciences

		3. Faculty of Agricultural Engineering 4. Faculty of Smart Agriculture 5. Faculty of Basic Sciences 6. Faculty of Forestry, Wildlife and Ranage Management 7. Faculty of Management Sciences 8. Faculty of Fishries 9. Faculty of Food Sciences
	Hazara University, Mansehra	1. Faculty of Biological and Health Sciences
	University of Swat, Charbagh, Swat	2. Faculty of Life Sciences
	University of Swabi, Swabi	1. Faculty of Agriculture
	Abdul Wali Khan University, Mardan	1. Faculty of Agriculture
Balochistan	Balochistan Agriculture College, Quetta	1. Division of Crop Production 2. Division of Crop Protection 3. Division of Horticulture & Crop Improvement
	Lasbela University of Agriculture, Water and Marine Sciences	1. Faculty of Agriculture 2. Faculty of Marine Sciences 3. Faculty of Water Resources Management 4. Faculty of Veterinary & Animal Sciences

Azad Kashmir	University of Poonch, Rawalakot	1. Faculty of Agriculture 2. Faculty of Veterinary & Animal Sciences
	Mirpur University of Science and Technology, Mirpur	1. Faculty of Veterinary & Animal Sciences

4.10. Conclusion

At presently, none of the institutions in Pakistan comes under world standards. The entire education system should be restructured. For this purpose, government must give top priority to education which should be reflected in national budget. The "*Iqra*" fund should immediately be diverted to education sector. The aims and objectives of education must be clearly defined; hence the curricula and syllabi be modified accordingly and the dilemma of medium of instruction must be settled. There should be much more emphasis on character building and ethics. At the time of appointment of teachers and heads of educational institutions, their character and aptitude must be determined. To attract intelligentsia in education, better grades, attractive salaries and facilities must be ensured. For enhancing efficiency and improving the skills, better facilities for libraries, laboratories should be provided, and permanent monitoring and strict discipline must be established at all levels. A three-dimensional approach of advice, reward and punishment, could be the most effective means for enhancing efficiency.

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Chapter 5

Agricultural Extension System in Pakistan

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Abstract

Agriculture extension services are considered the prime vehicle to disseminate agriculture-related information which encourages technology transfer, capacity building, human resource and social capital development. These services are cost-effective and environmentally sustainable agricultural policies for uplifting crop productivity and increasing economic gains of growers for sustainable livelihoods. In Pakistan, various agricultural extension and rural development programs were initiated to accelerate the agriculture sector. Since the inception of the extension department, agricultural professionals on different levels are working on the

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facilitation of farming communities and boosting the agriculture sector. However, they are provided with scanty incentives and resources as compared to the private sector. Moreover, the public agricultural extension services sector is running with insufficient funds, bureaucratic approaches, poorly motivated staff and ignoring the women and poor farmers in the decision-making process. In the country, particularly in Punjab, appointments of agricultural professionals are made on "contract basis" under contract policy 2004 for the period of three years initially which imposes the risk on employees, hence cannot perform their duties efficiently. Similarly, front-line workers like Field Assistants (FA), Agriculture Officers (AO) are lacking the facilities to work smoothly in the field. A conducive environment with sufficient funds at the gross root level is seldom available. Following the principles of participatory extension services, the new policy needs to be effectively implemented in order to require extension officials to work in cooperation with the farmers. The agricultural extension policy needs to be revamped and then effectively implemented according to the farmers' needs and problems encountered. GIS has an important role in improving agriculture extension agents' capacity. The blueprint decentralized extension policy needs to be effectively implemented. The chapter recommends that agricultural extension is the lifeline for agricultural development. Under the complex scenario, when agricultural productions are at risk pertinent to a number of internal and external factors, it is mandatory to form a concrete extension policy in Pakistan.

Keywords: Basic Democracy System, Integrated Rural Development Program, Peoples Works Program, Rural Works Program, Training and Visit System, Village Aid Program

5.1. Introduction

Pakistan is the 6th most populous nation on earth with a population of 203 million after China, India, The United States of America (USA), Indonesia and Brazil (PRB 2016). Agriculture is the prime feeding source of increasing mouths nationwide. Pakistan is a developing country in terms of economy but yet self-sufficient in food production pertinent to highly fertile lands and productive agriculture (FAO 2015). However, the landscape of agriculture is changing with the passage of time and approaching change seems bitter. In the recent past downfall of agriculture is well documented and in the coming year's wide production gap may unleash hunger, food insecurity and poverty threats.

Agriculture shares 19.5% of the national Gross Domestic Product (GDP) and provides employment for 42.5% labor force, involved in different operations (Govt. of Pakistan 2016-17). During 2015-16, agriculture embarked on negative growth putting immense pressure on the economy. But, during 2016-17, agricultural growth was recorded at 3.46% against the target of 3.50%. Extensive growth was subject to the availability of inputs, agricultural credit and favorable environmental conditions. Pakistan is graced with a distinct position globally in terms of crop production. For instance, Pakistan is the 4th largest producer of rice after China, India and Indonesia. Pakistan is also graced as 4th largest producer of cotton after China, US and India.

The main crops (wheat, sugarcane, rice, maize and cotton) account for 23.85% of the value added in overall agriculture and 4.66% of GDP. The other crops account for 11.03% of the value added in overall agriculture and 2.15% of GDP. Livestock contributes 58.33% to agricultural value addition and 11.39% to GDP. Forestry contributes 2.33% to agricultural value addition and 0.46% to GDP. Fisheries contribute 2.12% to agricultural value addition and 0.41% to GDP. Overall, it can be concluded that agriculture is playing a pivotal role in national development, though; attained production potential is not enough for sustainability. Agriculture in Pakistan is being challenged by multiple contrasting factors. For instance, climate change, insect pests and diseases, natural disasters, shifting of cropping patterns, shrinking cultivable lands, increasing rate of migrants, absence of farmers led policies, sluggish marketing, high postharvest losses, inflation, poverty, food insecurity, poor rural road infrastructure, low preference to modern mechanization and conversion of fertile lands into residential colonies are some of the leading attributes militating agriculture directly or indirectly. The direct impact of these factors is resulting in low yields which put pressure on the socio-economic development of stakeholders. Friendly policies do well while the support of extension services facilitates farmers in terms of natural resource management production enhancement and socio-economic boom. Therefore, extension services are the part and parcel of agricultural operations and are collaterally important for the country.

This chapter describes different agriculture extension models in Pakistan, the present extension system, current reforms by the Government, different bottlenecks in the system and appropriate recommendations for improving the extension model to improve the agriculture sector.

5.2. Agricultural Extension (AE) Services in Pakistan

Agricultural extension services emerged as a vital institutional offer, particularly after the green revolution. Agricultural Extension remains the noteworthy pillar of Agriculture Knowledge and Information System (AKIS) along with two further pillars of research and education. The involvement of the extension was to bring desirable changes in the behaviors of target audiences like farmers. Researchers unveil and document their agreement that a strong association between research, extension and education would have exerted more effectiveness (Ashraf et al. 2007). With the passage of time, extension education embarked more worth and established itself as a full-fledged discipline with a specifically owned philosophy, set principles, and esteemed objectives of farmer’s education, technology sharing and facilitation. Extension staff employees multiple teaching techniques are in the best interest of the agriculture community (Bajwa et al. 2008). Pertinent to this significance, agricultural extension graced the community with a positive role in poverty alleviation and achieving food sufficiency and security (Farooq et al. 2010).

History is evident of the colonial government in Sub-continent and major agricultural institutions were established by the British Colonial Government with a primer of colossal canal network during the start of the 20th century. A number of standing departments interrelated with irrigated agriculture is the heirloom of colonial government. Agriculture, livestock, forestry and fisheries sectors were headed by the Secretary of Agriculture. Regional Directorates of Agriculture in Lahore (Punjab), Peshawar (Khyber Pakhtunkhwa) and Hyderabad (Sindh), and the Bureau of Agricultural Information situated in Lahore were major institutional components of agriculture. These directorates were more emphasized improvement in area under cultivation, inputs supply, seed and fertilizers storage, training of staff and plant protection. The agricultural extension wing was part of regional directorates. Each regional directorate was assisted by Deputy Directors Agriculture (DDA) at the divisional level. Extra Assistant Directors Agriculture (EADA) and supporting staff were adjuncts to DDA's. The animal husbandry wing was liable for development in the livestock sector (like breeding, animal nutrition and control of diseases). The veterinary sector has a complete organization of extension services in the whole country like AE (Table 5.2).

The beginning of the 20th century (1905) framed agricultural education in Punjab with the inception of Punjab Agriculture College and Research Institute in Lyallpur (now Faisalabad). The Bureau of Agricultural Information was upheld in 1962, which was accountable for the dissemination of information through audio-visual aids and print media.

Agricultural extension service in Pakistan has been public since independence. The extension has never been the responsibility of the federal government in Pakistan. Provinces across the country are delegated for the provision and execution of extension services. However, it is widely debated that the execution of extension services is traditional and based upon old-fashioned methods followed by top-down and technology-driven approaches (Ashraf et al. 2007). Research-extension linkage is meager as reported by a number of researchers. But, still, it is crystal clear that the role of extension in the uplifting agricultural economy in Pakistan is inevitable. Since the inception of the country in 1947, extension offerings are a component of rural development plans and strategies. The emergence of different agricultural extension programs like Village Cooperative Movement, Village Agriculture, and Industrial Development Programme (Village-AID), Basic Democracy System (BDS), and devolution plan are proof of the worth lying behind the agricultural extension.

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5.3. Structure of Agriculture Extension Services in Pakistan

The agriculture extension services are public in Pakistan and across the country provincial system is in trend; as the extension has never been under the control of the federal government. Pakistan employed different structures of extension. The Government of Pakistan has recently (in 2017), abolished “Decentralization” and implemented the “Basic Democracy System”. According to this recent approach in Pakistan, the extension system is controlled by the Director General Agriculture (Ext. & AR) at the provincial level, while on the divisional level the Director of Agriculture (Ext.) is the main correspondent with the Deputy Directors of Agriculture Extension (DDA) working at the district level. The Assistant Directors of Agriculture (ADA) (Extension) are appointed at the tehsil level for the correspondence with DDA. Agriculture Officer (AO) is appointed at Markaz (a particular area containing a number of villages) level followed by the field Assistant (FA) (afterward promoted as Agriculture Inspector) at Union Council (UC). AOs and FAs are change agents, being in frequent contact with farmers. A total number of AOs and FAs working in all provinces of Pakistan are given in Table 5.1. FA facilitates AO in technology dissemination. Generally, this system is a reflection of the top-bottom approach where information floats from higher-ups to subordinates working in the field for the dissemination of agricultural innovations. The organogram of the current extension system in Pakistan is presented in Figure 5.1.

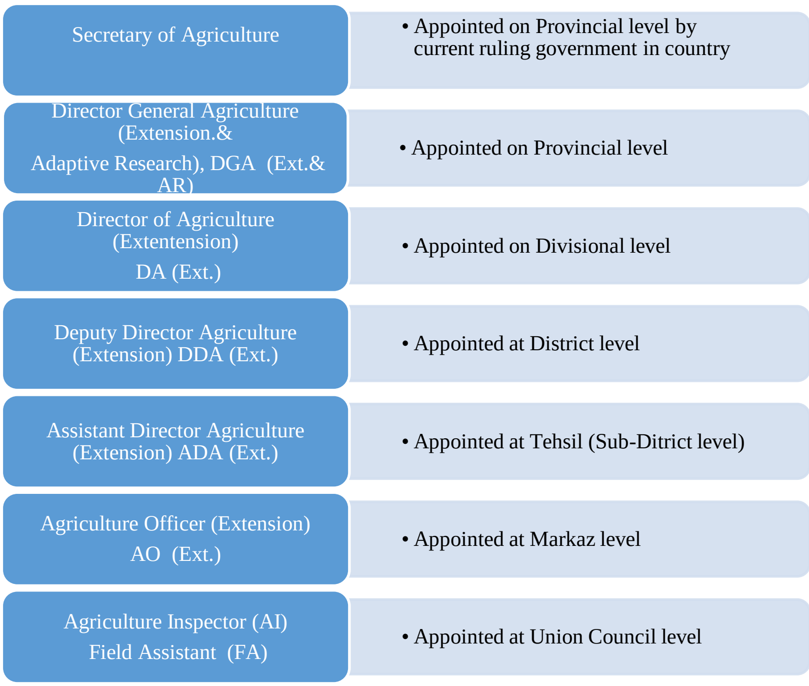

Figure 5.1 Organogram of current extension system in Pakistan

Division: Administrative "Division" is further sub-divided into the district.

District: In Pakistan, a "District" is a local administration unit inherited from British Raj. Districts were usually clustered into administrative divisions, which in turn shaped provinces.

Tehsil (Sub-District): Second lowest layer of local government. Each tehsil is part of the "District".

Markaz: On an average 6-8 union council makes one "Markaz"

Union Council: The smallest part of local government. Tehsil is subdivided into union councils.

Table 5.1 Agricultural extension agents in Pakistan

Province	Agriculture Officer (Front line extension agent)	Field Assistant
Punjab	763	3264
Sindh	573	1026
Baluchistan	586	1016
Khyber Pakhtunkhwa	222	539
AJK, GB, FATA. ICT*	180	673
Total	2324	6518

*AJK: Azad Jammu & Kashmir, GB: Gilgit Baltistan, FATA: Federally Administered Tribal Areas, ICT: Islamabad Capital Territory

Source: http://siteresources.worldbank.org/PAKISTANEXTN/Resources/AgricultureResearchandExtensioninPakistan.pdf

Table 5.2 Livestock Extension Infrastructure in Pakistan

Province	Veterinary Officer (Front line extension agent)	Veterinary Assistant
Punjab	1403	2271
Sindh	358	748
Baluchistan	631	1153
Khyber Pakhtunkhwa	338	1600
*AJK, GB, FATA, ICT	323	1346
Total	3053	7118

*AJK: Azad Jammu & Kashmir, GB: Gilgit Baltistan, FATA: Federally Administered Tribal Areas, ICT: Islamabad Capital Territory

Source: http://siteresources.worldbank.org/PAKISTANEXTN/Resources/AgricultureResearchandExtensioninPakistan.pdf

5.3.1. Provincial Directorates General of Agriculture Extension

After the abolishment of the devolution plan in 2016, the BDS of extension is a recent implementation. A separate Directorate of Agricultural Extension and Adaptive Research exists at the provincial level. This office is headed by Director General. This office transmits numerous duties including assistance on agriculture to the ruling provincial government, execution of provincial projects, and up-keeping relationship with the provincial government for agricultural extension matters. Information received from the research also floats from this office to extension agents performing duties on the district, sub-district and Markaz levels.

5.3.2. District Level Extension Organization

With the implementation of the devolution plan in 2001, the agricultural extension department was under the direct control of the District Coordination Officer (DCO). At that time, the Executive District Officer of Agriculture (EDOA) coordinates with DCO. However, BDS brought some modifications as Executive District Officers (EDOs) were turned to the Director of Agriculture, and control of DCOs was restricted. Now, the Director of Agriculture followed by DDA (Extension) is responsible for the implementation of projects at the district level and coordinates with Director General Office and AD at the tehsil level.

5.3.3. Tehsil Level Extension Offices

Under the DDA (Extension), ADs Agriculture (Extension) are based at the tehsil level. Their number corresponds with the number of tehsils in the particular district. The ADs handle agricultural extension activities in their respective tehsils.

5.3.4. Markaz Level Extension Offices

Agriculture Officers are based at the Markaz level. These AOs are frontline workers and responsible for the implementation of agricultural innovations at the grass root level. These AOs correspond with the number of Markaz in the particular tehsil. The AOs are responsible for carrying out agricultural extension responsibilities in their respective Markaz. Each Markaz consists of 6-18 union councils and approximately 6000-8000 (Govt. of Pakistan 1971) people which indicate that the AOs have to cover a huge area.

5.3.5. Union Council Level Extension Offices

Under each AO, are several FA placed at the UC level. Their number corresponds with the number of UC in the particular Markaz. The FAs are frontline agricultural extension workers. Extension advice is provided in the areas of major and minor crops, fruit and vegetables, livestock, fisheries, and agricultural marketing. Under each FA are two Beldars (laborer) who are field workers. They are more laborers than technical persons and help the FA in daily agricultural activities.

5.3.6. Institutional Extension in Pakistan

For field services, extension staff is working on different levels and facilitating farming communities at their doorstep through diversified approaches. These extension officers are agriculture graduates, qualified from different agricultural universities. These universities across Punjab are emphasized extension education and producing graduates to serve the field. These graduates are trained regarding crop production, protection, harvesting, post harvesting, marketing and technology transfer, etc. A general extension model looks like this as indicated in Figure 5.2. These institutions not only produce students but also carry out updated research to prove the solution to reported problems. Developing agricultural innovations for the farmers is also the main function of these institutions.

5.3.7. Public Sector Universities

Just like agricultural research, Pakistan has a vast network of universities. Main agricultural universities are the following:

- University of Agriculture, Faisalabad
- Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi
- Muhammad Nawaz Sharif University of Agriculture, Multan
- Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan
- Faculty of Agriculture & Environment, Islamia University, Bahawalpur
- College of Agriculture, University of Sargodha, Sargodha
- Faculty of Agricultural Sciences, Ghazi University, Dera Ghazi Khan
- Sindh Agriculture University, Tandojam
- University of Agriculture, Peshawar
- University of Agriculture, D. I. Khan
- Faculty of Agriculture, Gomal University, D. I. Khan
- Faculty of Agriculture, University of Swabi, Swabi
- Abdul Wali Khan University, Mardan, University of Swabi, Swabi
- Balochistan Agriculture College, Quetta
- Lasbela University of Agriculture, Water and Marine Sciences
- Faculty of Agriculture, University of Poonch, Rawalakot

Most of the above universities have department of agricultural extension and offer undergraduate and graduate programs. The University of Agriculture, Faisalabad (UAF) is the oldest and leading institution in Pakistan among agricultural academic institutions.

5.4. Training Options for Extension Professionals

Trainings are inevitable for boosting the knowledge of extension professionals. With the passage of time, challenges to agriculture and the needs of farmers are increasing and to fulfill these needs it is imperative for extension professionals to update their knowledge accordingly. Therefore, trainings are inevitable and for this purpose, across the country, a number of training institutes are working for in-service trainings of extension professionals. Some major training institutes located in different regions are listed below.

- In-service Agricultural Training Institute (IATI), Sargodha
- Barani Agricultural Training Institute (BATI), Dahgal, Rawalpindi
- IATI, Rahim Yar Khan
- Pak-German Institute of Co-operative Agriculture, Multan
- Agricultural Training Institute (ATI), Karor Lal Eson, Layyah
- Extension Services Management Academy (ESMA), Garhi Dupatta, Azad Jammu & Kashmir (AJK)

5.5. Agricultural Extension Programs in Pakistan

Since the independence of Pakistan, extension work is in progress. However, at that time, there was not an independent identity of the extension department in the country. Extension work was carried out under the arms of different community development programs. During 1952-53, a number of community development programs were initiated in Pakistan and India with the assistance of the USA (Holdcraft 1978). Approximately 50 million dollars were invested by the USA in these community development programs in 30 countries. Nevertheless, 50% of this investment was ensured in Pakistan, India and the Philippines. The World Bank rendered more financial resources as compared to any other financing source. Gustafson (1994) described that extensive support of the World Bank was in gratitude of extension and development significance in developing countries.

In the early 1950s, in the Punjab, Pakistan efforts were executed to uplift rural income through cottage industries and improved farming practices. Efforts were further made to boost self-help, cooperation among rural people and offering required services to rural communities. Implemented programs were multipurpose (Waseem 1982). Different programs launched in Pakistan were Village Agricultural and Industrial Development (V-AID) Program, (2) BDS, (3) Rural Works Program (RWP), (4) Integrated Rural Development Program (IRDP), (5) People Works Program (PWP) and Decentralization.

5.5.1. Village Agricultural and Industrial Development (V-AID) Program

During 1952, the first formal effort towards rural development was launched. This formal effort was named as V-AID Program (Mallah 1997). The V-AID based upon community development and extension service approach to formulate solutions of rural community problems. The offered solutions were pertinent to mobilization of governmental resources and active engagement of rural people. The V-AID obliged as extension agency of entire nation building departments persisting on village level. Within scope of extension services under V-AID, demonstration method approach was adopted to inspire growers for adoption of site specific and improved varieties of crops, farming practices, fertilizers, resources management and livestock production, and management practices (Chaudhry 2002).

5.5.1.1. Working Procedure of the V-AID Program (1952-1962)

The village Aid approach was kept under the control of government officials as development officers, supervisors, and specialists to support and supervise the working of front-line workers. About 150-200 villages (approximately 140,000 people) were structured in each district as development areas to be administered by the development officer. The development officer was selected by the government and was detained and accountable to Deputy Commissioner (DC) (Waseem 1982; Muhammad 1994). The development officer was facilitated by two supervisors strained from different provincial departments for the assistance of villagers to promote self-help. Improvement in crop production and livestock production, construction of roads, culverts, wells, bridges, and drains, plantation of trees, and alleviating health hazards were the main activities undertaken under the V-Aid program (Malik 1990).

Active involvement of people paved the way for V-Aid toward success. The V-Aid raised arms to allied departments as well. This collective action gave birth to “Zarai Taraqiati Bank Limited (ZTBL)” in 1961, for extending credit facilities to rural people. Before the inception of ZTBL, in 1952, Agricultural Development Finance Corporation and “Agriculture Bank” started rendering loans to small farmers. Later on, the integration of these two departments laid the foundation of ZTBL in 1961. Agricultural education, extension and research were further expanded. In 1959 under “Land Reforms/Zarai Islahaat”, the land was allotted to small farmers. In 1956, small industries corporation initiated the development of handicrafts at the domestic level.

5.5.1.2. Strengths of the V-AID Program

The village Aid program embarked on success and established vital relationships between governmental organizations and villagers. Village Aid worked recognized themselves as multipurpose extension agents. Government Village Aid Training Institutes imparted one-year training to V-Aid extension agents (Waseem 1982). The solitary aim of V-Aid was to emphasize uplifting the living standards of rural people across the country through education, motivation, structuring of village councils, expansion of health facilities, promoting modern agriculture, construction of roads, building farmers' access to credit, enabling agricultural marketing and promoting self-help among farmers (Malik 1990; Chaudhary 2002).

5.5.1.3. Weaknesses of the V-AID Program

Soon after the implementation, the V-Aid gained ample acceptance among rural people and met with partial success. V-Aid documented more success in creating awareness among the rural community regarding self-help and self-reliance to combat problems. However, this achievement appeared temporary as the program remained unsuccessful in maintaining standards owed to the poor cooperation of allied departments (Muhammad 1994). The weak structure of V-Aid was the prime reason behind its failure. Inadequate inter-departmental cooperation adopted a top-down approach in administrative decisions, and scanty technically trained staff were other plights of failure (Waseem 1982; Mallah 1997). Village Aid workers were multipurpose extension agents and hence remained unable to gain the confidence of specialists. Moreover, extensive work was anticipated from rural people on a voluntary basis without their empowerment at the village level (Malik 1990; Chaudhry 2002).

5.5.1.4. Abolishment of the V-AID Program

Considering the partial success and magnitude of the problems, the government of Pakistan abolished the V-Aid program in 1962. It was unveiled that the program was not producing desired outcomes (Malik 1990). The decision to the abolishment of V-Aid was not made on recommendations of any formal or systematic assessment or evaluation (Govt. of Punjab 1983; Chaudhry 2002).

5.5.2. The Basic Democracy System (BDS)

The BDS was established in 1959 across the country. A major concern of the system was to strengthen the relationship of the community with political development, particularly at the local level. Waseem (1982) and Chaudhry (2002) illustrated that BDS emphasized economic, social, and political development. Mallah (1997) has documented that BDS was an ample opportunity for the rural community to actively participate in community development programs.

5.5.2.1. Working Procedures of BDS

Government administrative and development tiers were systematized into five levels. UC was the least tier comprising 5-6 villages and a group of villages consisting of 12-15 village councilors. Approximately, one UC enclosed a population of 8000 people (Govt. of Pakistan 1971). These respective councilors conducted economic and social development work in their particular areas. Waseem (1982) and Chaudhry (2002) iterated that councilors were mainly concerned with improvements in education, agriculture, sanitation, and infrastructure.

5.5.2.2. Strengths and Weaknesses of BDS

The major strength of BDS was developing awareness and local leadership within the local community (Chaudhry 2002). On contrary, the major weakness of the BD system was that the system failed to emphasize agricultural development and fetching autonomy in local government. Insufficient local leadership and inadequate funds for development were other major reasons behind failure (Waseem 1982; Chaudhry 2002). Furthermore, the bureaucracy subdued BDS as they didn't compromise their hold on administration and active participation of the people. Malik (1990) also reported scanty funds provision for BDS.

5.5.2.3. Abolishment of BDS

The basic democracy system enjoyed the same fate as its prototype the V-Aid and as result, BDS was also abolished in 1970 by the Government of Pakistan (Govt. of Pakistan 1971).

5.5.3. Rural Works Program (RWP)

Rural Works Program (RWP) was propelled in 1963 in East and West Pakistan. The RWP exerted efforts to boost the maximum involvement of local people in the planning and implementation of development projects and to boost self-help awareness among community members (Mallah 1997; Chaudhry 2002). Furthermore, RWP intended maximum participation of local people in development programs to uplift their social and economic well-being, enhanced opportunities for employment through small-scale projects not requiring huge investments, and build infrastructure like roads, irrigation channels and bridges. The program was further aimed at building the operative nucleus of planning and development at the UC level and to comrade increasing a chunk of the population in development efforts (Waseem 1982; Mallah 1997; Chaudhry 2002).

5.5.3.1. Working Procedures of RWP

The RWP was initially apprehended by Pakistan Academy for Rural Development, Comilla. The strengthened purchasing power of rural communities rendered encouragement to the rural economy. Institution of local government, particularly at Thana (Police Station) and UC levels were accountable for planning developmental projects. The RWP was sprung at once nationwide to reinforce the new establishment of basic democracy and enable local officials to commence substantial development programs relating to their particular areas. Further, it intended to develop a pleasing working system towards that end (Waseem 1982; Mallah 1997).

Literature is evident that basic democratic institutions implemented the program with the sound association of government. The government rendered entire administrative decisions, control, and monitoring of the involved official at all levels. The government established directorates of projects in provinces for rural work programs in the department of basic democracy and local government. The DCs were appointed as controlling officers to manage and administer the implementation of programs at the district level. Tehsil (sub-district) and UC were kept under the control of Sub-Divisional Officers (SDOs). Chairman UC was the elected representative of approximately 10,000 people in rural works programs. The report of the Government of Pakistan (1983) unveiled divergence in the context of people's participation that RWP weakened the participation of rural people at the village level extensively. The report further elaborated that all decisions were made on the UC level with the coordination of government officials while the participation of rural representatives was minimal.

5.5.3.2. Strengths and Weaknesses of RWP

The success and strengths of the RWP program have been reported by several researchers (Waseem 1982; Mallah 1997; Chaudhry 2002). They confirmed that about 60,000 rural infrastructure and services-related projects were completed in RWP and the approximate cost of projects was significantly lower than those built in other relevant programs. Alleviating unemployment and job provision at the doorstep were the main aspects of RWP. The RWP further raised awareness among rural masses regarding developmental needs and persuaded them to formulate plans.

Participation of rural masses in the formulation of plans and execution of projects was ignored. Elected Chairmen of UCs were not accountable to their voters who elected them for their representation (Waseem (1982; Government of Pakistan 1983). The project was kept more emphasized on small-scale projects rather than long-term projects as the result of the spending of project funds during the presidential election held in 1965. This act was the mockery theme highlighting rural people's participation in the planning of projects (Mallah (1997; Chaudhry 2002). Furthermore, scanty efforts were made to maintenance of the completed projects.

5.5.3.3. Abolishment of RWP

After conceiving several missing links RWP was abolished in 1972 and replaced with the “People’s works Program” to provide participation of the people in the planning and execution of developmental plans (Chaudhry 2002).

5.5.4. The Integrated Rural Development Program (IRDP)

Integrated Rural Development Program (IRDP) was another effort of the government to improve rural people’s lives. Although the program was comprehensive but comprised theoretical discrepancies and operational misperceptions. Waseem (1982) and Muhammad (1994) disclosed that the IRDP approach was technocratic within the confines of rural life and the traditional approach of technocrats. The prime concern of the IRDP approach was to enhance rural lives with the collaboration of public officials and the envisioned beneficiaries (Govt. of Pakistan 1983; Malik 1990; Mallah 1997). IRDP further entailed leading motive of enhancing agricultural output through the adoption of modern techniques, farm management and planning, and offering storage, credit, and transportation and marketing conveniences.

5.5.4.1. Working Procedures of IRDP

Markaz was the core organizational and geographical point of IRDP activities. It was a production area comprising 50-60 villages to improve the socio-economic status of the target group through an intensive rural development program. The initial thrust shall be to increase agricultural production and productivity by intensification, diversification, and commercialization of agriculture based on sound physical organizational and institutional infrastructure. This requires upgrading of skills through appropriate technology, provision of supervised credit, inputs, machinery, tools, storage, marketing, health, education, etc. as a package deal from a focal point. The complex "Markaz" was recognized on the village level to reflect the growth point to be established into an agro-village and a platform for gathering departmental officials under one roof. The "Markaz" was anticipated as an administrative unit of local government across the districts. IRDP approach developed multipurpose cooperative societies at the village level since there were no elected local councils. The cooperative society at the village level and the Markaz committee at the Markaz level became the two tiers of the IRDP organization. The government officials (some newly appointed and others pinched from different provincial departments) were employed as guardians of the described two tiers of management and administration to deliver guidance and obligatory services (Waseem 1982; Malik 1990; Govt. of Pakistan 1983; Mallah 1997; Chaudhry 2002).

5.5.4.2. Strengths and Weaknesses of IRDP

The IRDP approach delivered some vital strengths like integration of nation-building departments which were intricate in uplifting farming communities, devolution of staff and services from district and tehsil (sub-district) to Markaz level. Furthermore, the development of farm information and dissemination system was another strength owned by the IRDP approach (Waseem 1982; Govt. of Pakistan 1983). Poor response from line departments in the wake of services and their adequacy was the leading weakness of IRDP as reported by Chaudhry (2002). So, IRDP failed in bringing improvement in agricultural practices as independent public organizations and private establishments were involved in providing seeds, fertilizers and agriculture loaning to rural people.

5.5.4.3. Abolishment of IRDP

The IRDP stayed for a decade but partial success restricted replication of IRDP (Govt. of Pakistan 1983) and the implementation approach was terminated in 1977. Poor cooperation among officials was the major reason for the failure of IRDP (Waseem 1982; Malik 1990; Chaudhry 2002).

5.5.5. The Peoples Works Program (PWP)

The government of Pakistan initiated yet another effort, naming as Peoples Works Programs (PWP), in 1972, as an element of land reforms and rural development projects (Govt. of Punjab 1983). The scope of PWP was much different from the rural works program (RWP). PWP emphasized on development of infrastructure schemes with the involvement of local minds in both rural and urban regions (Mallah 1997; Chaudhry 2002), ensuring maximum involvement of local people in the planning and implementation of development projects, which was the core objective of PWP. It was anticipated that the maximum involvement of local people will give them confidence and raise awareness among rural communities to manage their domestic liabilities without dependence upon government bodies (Mallah 1997; Chaudhry 2002).

5.5.5.1. Working Procedures of PWP

Both rural and urban areas were integrated with the PWP approach. Report of Govt. of Punjab (1983) and findings of Waseem (1982) augmented that PWP engaged a wider number of groups and was also with the support of adhoc groups of public representatives and local elite at district and village level. The PWP approach was laid on extensive administrative grounds for the implementation of activities. About 60% of wages were paid in cash to employees in most of the schemes of PWP. However, Mallah (1997) intimated that 80% of activities undertaken under PWP were voluntary and 20% were paid in cash.

5.5.5.2. Strengths and Weaknesses of PWP

The PWP approach was mainly concerned with increased local participation in the planning and implementation of developmental efforts. However, according to the researcher's findings, this effort appeared partially fruitful (Malik 190; Mallah 1997; Chaudhry 2002). The Planning Commission of Pakistan evaluated the PWP approach in 1975 and unveiled several serious gaps in scope and implementation (Mallah 1997; Chaudhry 2002). More involvement of politicians in PWP was also discovered which suppressed the local participation and put them relying on the government. Approximately 90% of the PWP projects lacked local engagements. Preferences were given on large-scale projects which were also implemented with the involvement of contractors and utilization of funds remained a mystery.

5.5.5.3. Abolishment of PWP

Literature is insufficient to prove the exact date of the abolishment of PWP. However, it seems that PWP was terminated immediately after 2-3 years of implementation. Termination was pertinent to the lack of government support. During the mid-1970s, this approach was termed the Peoples Works Program but in the late 1970s was replaced by Rural Works Program (Mallah 1997). Literature is evident that all the applied extension programs were under criticism because of the adoption of the top-down approach to agricultural innovation sharing. Likewise, in PWP required packages were not disseminated based on the felt needs of the people and this aspect appeared major cause of the failure of PWP. Syed (1991) identified that mistreatment of available funds and inadequate participation of local minds in planning and implementation were other reasons for the failures of PWP.

5.5.6. Barani Area Development Program (BADP)

The Barani Area Development Program (BADP) was initiated in 1975 for the development of rain-fed areas of Punjab. The major focus of the program was agricultural development in rain-fed areas. In 1977 another organization "Agency for Barani Area Development (ABAD) was established (Waseem 1982). This newly developed agency holds the same operational area with a wider magnitude of responsibilities. Operational control of BADP was also in the hands of ABAD. The BADP was advanced to other areas with the same mission. However, the scope of the program was condensed to the production of crops in rain-fed areas (Govt. of the Punjab 1978). This program entirely lacked people's participation in planning and implementation and the execution of the program was not according to the felt needs of the people (Malik 1990; Mallah 1997). The program was also under the bureaucratic control of government officials.

5.5.7. Traditional Agriculture Extension System

The traditional Agricultural Extension System was launched in 1961. This system is the oldest system of extension across Pakistan and remained operational till 1978. Later on, the "Traditional Agricultural Extension System" was replaced by Training and Visit (T&V) System which was funded by the World Bank (Shah 1990). Mallah (1997) stated traditional extension system as one of the historical systems started in 1902 with the introduction of the canal irrigation system in the Indo-Pak-continent. The traditional extension system was fundamentally a "technology transfer" from the government to the people reflecting the Top-Down Extension System (TDES). The traditional system alleged that practical and relevant information is available and the mandate of agricultural extension lies in disseminating this particular information to the farming communities (Axinn 1985). Disseminating information among farmers, transfer of innovative technology, introduction of new varieties, fertilizers application and awareness of crop management are some leading functions of agricultural extension. Though, some researchers agreed that Traditional Extension System principally emphasized technology transfer from top-to-bottom (Waseem 1982; Malik 1990; Mallah 1997). The traditional extension approach was top-to-bottom concerned but decisions were usually formulated at the top by the responsible authorities, who were dealing with the matters of implementation of the traditional extension system (Ali 1991).

5.5.7.1. Strengths, weaknesses and Abolishment of Traditional Agriculture Extension System

Dissemination of new varieties, improving fertilizers use efficiency and crop protection management were some noteworthy strengths of the traditional extension system (Mallah 1997; Chaudhry 2002). Multifarious duties were allotted to extension workers (Lodhi 2003); hence program reflected intrinsic weaknesses which hindered working efficiency. Resultantly, partial impact and success of the traditional extension system are documented. The traditional extension system failed in developing research and extension relationships.

5.5.8. Training and Visit (T&V) Extension System

The Training and Visit System (T&V) replaced the traditional agricultural extension system in Pakistan (Benor and Harrison 1977; Mallah 1997). The T&V was initially launched in 5 districts of the Punjab and Sindh provinces of Pakistan in 1978 and 1979 respectively. Project districts in Punjab were Sargodha, Jhelum, Vehari, Sheikupura, and Rahim Yar Khan (Gondal 1989). According to Rehman (1992), T&V was appreciated by the bureaucracy because of sound internal communication in agriculture. The T&V was an attempt made by developed countries with the involvement of donor agencies for announcing new models of extension for alleviation of deficiencies posed by traditional extension systems in developing countries. The triangular relationship between research, extension, and farmers was the core philosophy of T&V. T&V program further emphasized technology transfer and minimizing modern technologies developed at research farms and adopted by the traditional growers. The top-down approach was adopted in transferring technology in the T&V system. T&V further intended to modernize agricultural extension services in replacement of conventional extension to uplift rural dwellers. Under the T&V approach, farmers were the extension clients. Extension workers working under T&V executed their efforts in educating contact farmers of their prescribed area. Khan et al. (1984) narrated that 10% of farmers of the total jurisdiction of extension workers were the contact farmers. These contact farmers were assumed to act as opinion leaders and to perform as volunteer extension workers in the rural community.

The organization of this model was constructed on the total figure of farming families that an extension worker could rationally be projected to cover. Each extension worker functioned according to the static fortnightly schedule, which was acknowledged to rural farmers, extension agents, and supervisory staff. The extension agent received one day of training each week. Extension agents visited four groups of contact farmers (about 6 to 8 farmers in each group) in the 1st week and another four groups during 2nd week (Jalvi 1981; Khan 1992).

5.5.8.1. Strengths and Weaknesses of T&V Extension System

The T&V approach embarked on some dominating success. Jalvi (1981) revealed that the T&V approach updated the traditional extension system and established a strong relationship between research, extension and farmers through adaptive research constituents. Akhtar (1990) also unveiled that field assistants argued that the T&V was much better than the traditional extension system. The efficiency of extension field staff was improved in T&V as compared to the traditional agricultural extension system. On contrary, despite notable strengths, T&V also evolved some weaknesses. Khan et al. (1984) cited that T&V enjoyed the same fate as its predecessors and was dogged by poor performance. Khan (1992) narrated that the T&V approach reflected repetition of extension messages over a longer period, unsuitable contacts farmers selection, selection of incompetent extension workers, majority of contact farmers were unable to perform voluntarily and selection of trainers who have never received a single event of training were the leading missing links in implementation of T&V. The system was excessively top-to-bottom oriented letting agricultural information float from research to growers through extension agents without assessing the needs of the local community (Howell 1983). However, the T&V approach delivered closer association with growers. T&V was further inclined to institutionalize hierarchical leanings prevailing for top-to-bottom centralized management (Antholt 1990). Howell (1982) opined that basic suppositions of the T& V system were wrong.

The inadequate knowledge on part of farmers was the prime production constraining factor and the T&V didn’t permit local people participation in the planning of the program (Lodhi and Khan 1984). The system also faced huge criticism for a fortnightly schedule of extension agent visits, particularly during looming seasons (Lodhi and Khan 1984; Antholt 1990). Hayward (1989) described that focus of T&V was more on procedural features as compared to important issues like the dissemination of messages to the rural community.

The T&V system appeared expensive being much labor intensive and encompassing a large number of extension agents as compared to the traditional extension system which posed a question of affordability (Howell 1982; Hornik 1988; Antholt 1990).

Additionally, the T&V remained to fail to embark any significant impact on overall agriculture and crop production in Pakistan (Hayward, 1989; Antholt, 1990). These findings are in contradiction to those of ARW (1982) where the report revealed the extensive contribution of T&V in improving crop production and overall agricultural development. The report further cited that though the investment cost was higher as compared to the traditional extension system, the output was also greater. A similar trend was observed by Bindlish and Evenson (1993) in Kenya that the T&V embarked significant contribution to boosting agriculture. Insufficient use of mass media techniques by extension agents in the communication process was another criticism of the T&V system (Lodhi and Khan 1988); despite mass, media tools are full of potential to facilitate development (Singhal and Rogers 1989).

Poor selection of contact farmers is well documented (Howell 1983) and the selfish behavior of contact farmers raised criticism over T&V. Contact farmers monopolized the extension advice and did not let it pass to farmers properly (Howell 1982). This was the probable reason for the limited opportunity for small and needy growers to earn benefits from the T&V. Furthermore, the youth and women of rural areas were ignored entirely. Extension agents generally established contact with elderly male household heads. Rolling (1988) interpreted that the T&V system was completely focused on the information needs of the growers and brought into consideration that all the requirements are met, which was a wrong impression indeed. T&V put scanty emphasis on the development of technical and managerial skills in farmers (Byerlee 1988). Rolls (1984) presented the same opinion that our indulgence of knowledge dissemination as a social transaction had not been forward-looking by the system. Considering the number of weaknesses lying with the T& V system Government of Punjab took responsibility and terminated this system in 1999. The main features of the AE system after termination of the T&V are as below:

- Crop and area-specific Farmers Training Programme (FTP) in which master trainers train the growers at the village level according to a permanent annual schedule in different phases. Literature is distributed among growers. At the end of the training, there is a question and answer session for growers where they are motivated for feedback from the field for onward transmission to R&D institutions. Mostly the AO is a trainer and AI/FA is a facilitator for wide publicity of training schedule and gathering of farmers.
- Demonstrations of different modern technologies by laying out demonstration plots of different crops on farmer's land.
- Farmers Field Schools (FFS) on different horticultural crops like mango, citrus and some vegetables under horticulture extension.
- Training of master trainers (TOT) for different crops before the schedule of FTP is started to update the knowledge of the latest technologies.
- Seminars, farmer’s gatherings, mega gatherings during the season of different crops for wide publicity of technologies and policies.
- Enactment and quality control of inputs like seed, pesticides and fertilizers for provision of standard quality inputs for higher yields.
- Implementation of different development projects, interventions, etc.

- Reporting different researchable issues from the field with close liaison with farmers and observations.

5.5.9. Devolution Plan/Decentralization

The military regime led by General Pervez Musharraf introduced a new plan named “Decentralization/Devolution of power” to decentralize administrative power at the grass root level. This plan aimed to boost the economic status of local people by bringing all resources to the grass root level (World Bank 2002; Luqman et al. 2005). According to the report of SPDC (2000) devolution is permanent and comprehensive and enables to strengthen of different roles and rendering more power to elected representatives (FAO 2011). Devolution of authority introduced administrative deviations in the entire public sector department and the department of agricultural extension was no exception (Saeed et al. 2006). Districts across the provinces were awarded autonomous powers of planning and implanting development programs.

5.5.9.1. Working Procedure

Institutional reforms were brought in all associate departments including the agricultural extension department after the inception of the devolution plan (Luqman et al. 2004). This updated system of the extension sector performed functions under “District Government” where each district is managing extension-bound tasks. Across the country, allied departments like fisheries, water management, livestock, forestry, and soil conservation worked under a single authority named “Executive District Officer of Agriculture (EDOA)” (Lodhi et al. 2005). The designation of DDA was changed to District Officer Agriculture (DOA) who performed duties under the administration of EDOA. The EDOA was bound to report to DCO who was accountable to elected representative District Nazim (Administration). Furthermore, line departments delivered technical guidance and monitoring of cross-district agricultural development projects. The DOA and Deputy District Officer of Agriculture (DDOA) at district and tehsil levels respectively were liable for backing EDOA. AOs performed their duties at the Markaz level followed by FAs at the UC level for backstopping AOs (Figure 5.3; World Bank 2003).

Under decentralization plan, the DCO was decidedly involved in financial matters, execution of the work plan and monitoring of extension service providers. District Nazim was actively engaged in the intra-district transfer of staff. Unfortunately, the executive district officer of agriculture who was the head of the extension department was behind the scenes.

Though devolution was the delegation of power to local people, outcomes appeared were sluggish. Memon (2004), Farooq and Ishaq (2005) augmented that the devolution plan didnot reflect any significant efficiency in extension services. Bajwa (2004) identified that extension staff was poorly motivated, funds were inadequate, centralized management, a top-down approach in planning and meager accountability system were reasons behind poor performance of the devolution plan. Khushk and Memon (2004) reported a 25-30% reduction in budget after the introduction of devolution. Luqman et al. (2005) opined that the administrative changes in the extension system laid more negative influences than positive improvements. The negative influence was on the rise because of multifarious duties, political involvement, and inadequate administrative staff and amplified paperwork (Farooq et al. 2007). On contrary, Ashraf et al. (2007) was of the view that extension-farmer linkage was improved under decentralization and dissemination of information from extension agents to farmers was better than the previous programs. Access to information by farming communities got height and devolution presented sound system of feedback on problems of farmers to extension staff (Ashraf et al. 2009). However, Saeed et al. (2006) reported that in the post-devolution scenario, the availability of inputs for farmers was increased. Lodhi et al. (2005) praised the working of extension staff regarding sharing information about crop production, but information sharing on crop protection faced criticism. Under this mixed response, the devolution plan was replaced by BDS recently in 2016 by the current democratic Government of Pakistan. However, literature is not evident of evaluation study of devolution plan conducted by the government or non-government institutions.

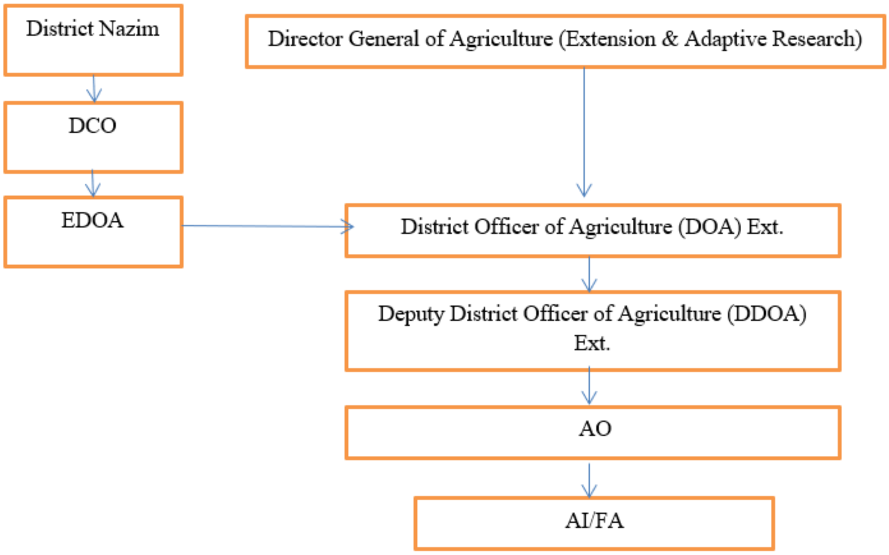

Figure 5.3 Organizational Structure of Extension under Devolution Plan

5.5.9.2. Challenges

i. Abundant Bureaucratic Involvement

Bureaucratic and political involvement is the major challenge influencing agricultural extension since inception. Outlook on extension programs implemented in different years in different regimes is evident that political involvement affected the performance of the extension field staff and outcome of the implemented program appeared meager. This heavy political involvement always hindered local people’s participation in the planning and execution of different projects. Politicians have been found influencing extension work badly. The major reflection is the transfers of working officers on political grounds (Ahmad et al. 2016). Political involvement also raises nepotism in the agriculture department. Effective extension work is based on the rendered services through extension field staff. Furthermore, smooth working is associated with convenient working rather than pressure building by political forces. So far, despite repeated agricultural programs implementation and identification of political involvement no serious policy interventions are seen in Pakistan. The recent examples persist in devolution plans were political involvement marked heights (Farooq et al. 2007).

ii. Non-Extension Tasks

The involvement of extension field staff in non-extension activities is a highly debated and unresolved issue of the extension system. The basic objective of the extension department is the facilitation of farmers and serving them at their doorstep. This is possible only by letting extension staff work independently according to their specified duties. Unfortunately, in the history of extension programs is evident that extension field staff is never allowed to work in line with their duties, even kept involved in non-extension-related duties. Involvement of extension field staff in “Ramzan Bazar”, “Sasti Roti Scheme” and “Wheat Procurement” are the leading examples. These kinds of duties are non-extension and an extra burden on extension field staff, despite EFS being under the huge burden of contacting a large number of farmers in the area of their jurisdiction. Resultantly, the role of extension field staff in conducting extension work faces criticism that their working efficiency is poor and not in best entrust of farming communities (Davidson et al. 2001). Ahmad (1999) presented the same thoughts that public sector extension in Pakistan has failed to address the needs and problems of farming communities.

iii. The Inception of Private Sector Extension

Until 1988, the role of private sector extension was limited in Pakistan. The government of Pakistan employed National Commission on Agriculture (NCA) to probe the poor growth of the agriculture sector and cater recommendations for strengthening the agriculture sector. In 1988, NCA advocated the inclusion of the private sector in the extension system under the objective of inputs provisions and marketing of insecticides to combat insect pest infestation (Govt. of Pakistan, 1988). The integration of the public and private sector produced significant results across the world, but in Pakistan outcome appeared sluggish. Private sector extension overwhelmed public sector extension and promoted business model extensively. The private sector has turned to major businesses and selling insecticides and pesticides are on the rise. The dependence of farmers on these chemicals is increasing day by day which not only increased the cost of production but also makes insects pests resistant. Private sector extension also damaged the trust of public sector extension in the mind of the farming community.

The working approach of the public and private sectors is entirely different. The public sector aims to facilitate farmers and the private sector tends to grab money by selling chemicals. Public sector extension agents are less in number and have a number of constraints including mobility and scanty resources. On contrary, private sector extension agents are enriched in resources and possess four-wheel vehicles for approaching farmers even in remote areas. Hence, the private sector builds a new dimension of trust and services at the doorstep. Private sector extension staff is provided with annual bonuses, foreign trips, and gifts for the achievement of their targets while public sector extension lacks these facilities and their work is undermined.

iv. Absence of Service Structure

Since the inception of the extension department, agricultural professionals on different levels are working on the facilitation of farming communities and boosting the agriculture sector. However, agricultural professionals are provided with scanty incentives and resources as compared to private sector extension staff (as discussed in the above section). The extension department lacks in service structure. Once the “AO” is appointed in Grade-17 and more often he retires in the same grade after serving the department 25-30 years, which is entirely unjustified. Agricultural professionals have been protesting and negotiating with government officials but so far service structure of the extension department has not been approved. On contrary, allied departments like livestock and research possess service structures and parallel opportunities for promotions. Furthermore, particularly in the Punjab province, appointments of agricultural professionals are made on a “Contract Basis” under contract policy 2004 for the period of three years initially which imposes the risk on employees. More often it happens that contract employees are not notified as “regular employees” in spite of three years of completion and these employees face severe hardships while granting extension in contract or regularization by the government. This injustice lowers the devotion, dedication and overall performance of extension field staff working in the field. A number of research studies like Jan et al. (2008) concluded that the lack of devotion, motivation and sense of responsibility of extension workers are major drawbacks behind poor performance. Effective working of extension field staff extensively demands the provision of service structure, job security and serious considerations of government.

v. Inappropriate Placement of Agriculture Officers/Change Agents

The AOs and the FAs are front-line workers of the extension system in Pakistan. The AOs and the FAs held vital positions and responsibilities in each community/extension development program implemented in different years. They conduct frequent contacts and meetings with the farmers and facilitate them with agricultural innovations at their doorstep. Since the development of the extension system, the AO is working on the “Markaz” level and FA is performing the function at the UC level. It is worth noting that one “Markaz” comprises 6-8 UCs and each UC comprises 6-8 villages approximately. With the passage of time population of the country is increasing and according to estimates, it may reach 302 million by 2030. Currently, the population of Pakistan is nearly 207 million. With the increasing population, the burden on AO is increasing and it is not possible to approach each and every farmer for facilitation and solving their problems. Similar circumstances persist for coverage of a huge chunk of the farming community on the UC level by the FA. A number of researchers augmented the dire need of switching AO on the UC level rather than “Markaz” and FA on the village level rather than UC. This switchover could boost working efficiency and generate more employment opportunities for agricultural graduates. Contacting and meeting farmers could become an easy act for technology sharing and solving farm-related problems.

vi. Induction Trainings

Trainings are imperative for the development of skills and organizing induction trainings are mandatory for newly recruited officers to stabilize their working in the department. Unfortunately, there is not a single particular department for the induction training of newly appointed agricultural professionals. Lets' take an example of a newly appointed "Instructor/Demonstrator" who is an agricultural graduate and not familiar with employment protocols and regulations until he is not imparted with induction training. The newly appointed instructor receives appointment orders through courier service and instructions as well to join the concerned department within the stipulated time. The officer does the compliance of orders and joins the department at the earliest, where he meets with innovation that one of the "clerical staff members" joins him. Shortly, the head of the department calls him and pays him a warm welcome with a list of duties to perform from the same day of joining. Now the question arises, how can he start performing well immediately after joining, while he is not familiar with the department, rules, dress code and staff members? More interestingly, he awaits a couple of months to grab an office for proper functioning. This world is entirely contrary to what he has been taught in university that you are about to qualify for the white-collar respectable job once your degree is completed. This pity situation persists in the agriculture sector which is the lifelines of the economy of Pakistan.

On another side, what happens in civil service departments? Once the individual qualifies Civil Superior Services (CSS) examination, he or she is sent to Management and Professional Development Department (MPDD) Lahore for 3-6 months, where he or she is taught each and every conduct of job that he or she is supposed to perform. Participants are trained by "Bureaucrats" and upon finishing training; the officer becomes enriched in office management. This comparison and insight on ground realities reflect that a significant aspect of the agriculture department is missing. For improvement in the functioning of agricultural professionals, it is imperative to develop specific institutions to impart induction training to newly appointed officers. For in-service training, 5 in-service training institutes are working at, Sargodha, Rahim Yar Khan, Rawalpindi, Layyah, and Garhi Dupatta Muzaffarabad (AJK), which organize trainings for improving the technical knowledge of agriculture staff. Ali et al. (2009) suggested that there is a need to establish a system of boosting competencies of EFS regarding attitude, knowledge and skill. The establishment of an induction training institution could serve the purpose.

vii. Research-Extension Linkage

Research-extension linkage is assumed imperative for authenticated communication of agricultural innovations among farmers. Strengthening research-extension linkage has been a top priority of policymakers for ensuring agricultural knowledge and information system (Ashraf et al. 2007). However, despite of implementation of multi-sectorial programs research-extension linkage is under criticism. Luqman et al. (2013) augmented that lack of linkage between research-extension had been a problem throughout historical development approaches of extension. Davidson (2001) highlighted no coordination between the research sector and extension. Khan (2006) criticized the poor involvement of local people and extension professionals in the planning and execution of implemented plans.

The poor research-extension linkage is a fundamental weakness in the extension system of Pakistan. Extension services in Pakistan are usually outdated and the relationship between research and extension is isolated. Furthermore, agricultural universities uphold meager bonding with research and extension units. Khan (2006) made an endorsement that the isolation of agricultural universities from research and extension is prominent. Universities are more focused on education and research conductance autonomously. Siraj (2011) documented relationship disparity among different departments within the agriculture department which made rendered services ineffective. The urgent need for restructuring research-extension linkage is imperative for the effectiveness of extension and outreach services in Pakistan. A strong relationship between research and extension could harness the potential and retain credibility for future courses of action.

5.6. Recent Developments in Pakistan Agriculture Extension

The importance of access to information and improved communication for sustainable agriculture development is obvious in this modern age of Information and Communication Technology (ICT). Sharma (2006) stated that modern communication technologies when applied to conditions in rural areas can help to improve communication, increase participation, and disseminate information and share knowledge and skills. The ICT generally means internet, computers, telecommunications infrastructure, cell phone, radio, television, newspapers and digital libraries. The internet revolution on the one side has proliferated information access to its users, on the other hand, it has played a role in the increase of information (Siraj 2011).

The Agriculture Department, Government of Punjab-Pakistan has felt the need to implement ICT for agriculture development and started a mega program for enhancing the capacity of the present agriculture extension system. The following interventions/ activities are being executed with a very positive response from growers and other stakeholders.

- Development of soil attributes database and its GIS mapping through soil sampling by field staff of extension wing reporting on android cell phones.
- Provision of android cell phone to the AOs, the AIs and the FAs under Agri-smart Program for better service provision to growers through monitoring on the dashboard (Monitoring of extension service at different levels).
- Farmer's registration for Kissan cards and android mobiles for provision of different interventions announced by Govt.
- Interest-free E-Credit by registration on LMRS.

- Provision of the internet at the grass root level.
- Provision of tablets to field staff (the AOs, the AIs and the FAs) under the Connected Agriculture Platform Punjab (CAPP) programme.
- Provision of laptops at different levels.
- Use of social media like Facebook pages, WhatsApp groups at different levels, and SMS for E-reporting and prompt updates.
- Plant clinics run by well-trained Plant Doctors with the collaboration of CABI PlantWise. Monitoring, evaluation and database of different crops, diseases area through internet software. Collaboration with different national and international analytical labs for any new issues observed in the field. Use of PlantWise Knowledge bank on the CABI website.
- Radio and TV talk shows are regular features.
- Web page of Agriculture Department and uploading different crop production technologies, database, literature and activities of all ongoing projects.
- Horticulture Extension (HE): Previously there was no separate setup for HE in the Agriculture Extension wing in Pakistan. The agriculture extension agents of the department performed the HE activities. Due to the tremendous potential of the Horticulture sector, the Punjab agriculture department started a project named “Fruit & vegetable development project (FDVP)” in 2001. The activities of the project were focused on mango, citrus and vegetables. Now the project is being transformed into non-development and an independent directorate of HE has been established. The Director of Agriculture Horticulture Extension heads at the provincial level. The Deputy Directors Horticulture/Horticulture Officers have been appointed on the regional basis. However, the complete setup has not been started and is in the pipeline for approvals at different levels. This is a good step of Govt. if the set up is completed and horticultural activities are started independently.

5.7. Role of Geographical Information System (GIS) in Agriculture Extension Services

The agriculture extension services are vital for profitable and sustainable agriculture. The services rely on the availability and prompt access to information on the physical and human aspects in spatial dimensions. The innovations in information technology (IT) skills, especially in geospatial technologies in recent years have offered new tools and capabilities for extension services for managing spatial data. Geographic Information System (GIS) provides mapping and spatial analysis capabilities by integrating spatial and attribute data for so many purposes. The agriculture extension data is associated with specific geographic features e.g. the qualitative and distributional aspects of water are associated with information on crop yield, and its impacts on the soil chemistry. The GIS enables the information to analyze relationships between the available data. The technology is widely used in central and western European countries especially in Hungary for precision agriculture (Pecze et al. 2001). It is a type of farming that is carried out by the operation in-field variability, where the seeding, nutrient replacement, spraying, etc. is practiced according to the local circumstances of a given field. The GIS runs analytical functions and presents visual results in the form of maps and graphs, allowing decision-makers to virtually analyses issues and then select the best course of action. GIS is helping in the decision-making capacity of agriculture extension staff ultimately helping farmers to increase production, reduce costs, and manage the natural resources, inputs and land more efficiently. This ability helps in the generation of new sets of information helpful for agriculture extension agents. The GIS operations are based on two main views given as under.

5.7.1. The Map View

The map view shows the ratios between real-world geographical aspects on paper and computer. GIS help to design a set of intelligent maps that show features and feature relationships on the earth's surface. This information is in the form of sets of layers of confined geographical boundaries. For example, geographical boundaries of urban and rural areas, built-up areas, domestic, commercial, and official areas, demographics and socioeconomic aspects of the population, agricultural lands, experimental farms, orchards and gardens, water bodies, rainfall, temperature, soil conditions, insects, weeds, infrastructure, forests, natural land cover and landscapes. The given information is shown in the maps in the form of points, lines and polygons of different standard colors. Maps of the underlying geographic information can be constructed and used as "windows into the database to support queries, analysis, and editing of the information" (Parthasarathy 2014). In this way, the set of information is developed and manipulated in the form of different types of maps according to the interests of decision and policymakers.

5.7.2. The Model View

There is a variety of models helping in the scenario development and future prediction of the situation. GIS models help the spatial and temporal alignments of the processes, phenomena and events. GIS software operates the set of information transformations and creates new datasets from the existing geographic information. The GIS function of geo-processing, process the existing information, analyzes it, and derives new information (Parthasarathy 2014). The GIS operations and creation of artificial intelligence in agriculture extension services are important for work efficiency, improved accuracy, task automation, access to government data, time and cost savings, a collaboration between the stakeholders and departments, resource management, and enhancements of the public participation (ESRI 2006).

5.8. The Way Forward

Agricultural Extension is the major instrument for technology dissemination, uplifting crop productivities, and doubling economic gains of growers for sustainable livelihoods. Public sector extension is ensuring agricultural innovations familiarity and adoption among end users since the inception of the country. Currently, BDS is in vogue after the termination of the decentralization system. The approach of BDS is the same has been in past and the working mechanism is not improved. Though, the nomenclature of the seats is changed. District level extension is still under influence of the local government. Front line workers (AO & FA) are bound to cover a large geographical area and a number of growers. On contrary, frontline workers are resource deficient and under a load of irrelevant duties.

Linkage with agricultural institutions and research centers is still meager. Though, the history of extension work in the form of community development programs is old. This chapter further summarized that extension is full of potential and amicably capable of improving the agriculture sector in the country but is victimized by the exploitation of management and assigned duties. Considering the laid significance and scope of the extension sector, the government launched a number of extension programs which resulted in partial success. Different programs embraced failures after one another. Interestingly, the reasons behind failures are almost alike which are still persisting in the system. The top-down approach to the extension, political involvement, and poor participation of local people in planning focus on short-term projects, biases, nepotism, inadequate funding and poor working efficiency of extension field staff were the prominent barriers to success. Scanty assessments and evaluations of implemented programs are conducted by government organizations to formulate predecessors with concrete planning.

Under the challenging circumstances and overarching penetration of private sector extension, public sector extension is working with zeal and vision of farmers' development. The working of extension agents is confronted with widely addressed and ignored barriers. These barriers comprise abundant bureaucratic paperwork, involvement in non-extension tasks, political involvement, weak research-extension linkages and confusion regarding their roles under varying environments and extension models. Extension agents are resource deficient and poorly trained. Extension agents are appointed without induction trainings, non-availability of mobility means and lesser chances of promotion. Engagement in non-extension tasks is heavily distressing their working efficiency. Despite full fledge department of extension in Pakistan, outcomes of extension-based activities are sick. The majority of services are biased toward large and progressive farmers.

In the end, it is recommended that agricultural extension is a lifeline for agricultural development. Under the complex scenario, when agricultural productions are at risk pertinent to a number of internal and external factors, it is mandatory to develop a concrete extension policy in Pakistan. Providing funds, mobility means, service structure, induction and in-service training could persuade frontline workers. Lucrative incentives could be another trump card to render encouragement to working field staff and agricultural graduates who are likely to join the agriculture department. There is a dire need to modify the hierarchy of the extension department. Keeping the constraints of extension staff, it would be an amicable option to switch the AO on UC from the Markaz level and FA on the village level. Policy on private sector extension working must be placed in reflections to sanitize biasness and business model which is not the aim of public sector extension.

The innovations in IT skills, especially in geospatial technologies in recent years have offered new tools and capabilities to extension services for managing spatial data. The GIS provides mapping and spatial analysis capabilities by integrating the spatial and attribute data for so many purposes. The inclusion of ICT in the present extension is a bold step of the Punjab Agriculture Department; however hectic efforts are needed to adopt this latest technology which is prone to changes with the passage of time and developments. The provision of funds well in time, proper facilities for staff, and provision of the latest tablets, cell phones, and laptops with replacements are very important for the success of this intervention. Efficient and continuous provision of the internet is key to efficient working in which we are still far behind. A strong and frequent training system is direly needed to build the capacity of field staff in ICT.

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Section – III

Agricultural Policies and Marketing

Chapter 6

Agricultural Policies in Pakistan

Aamer Irshad[♦]

Abstract

Agriculture has a central role in the economy of Pakistan with a pivotal influence on the socio-economic set-up. It accounts for over 21% of the gross domestic product while employing 45% of the country's labour force. Furthermore, the economic growth of the country is directly linked to the agriculture sector as it provides raw materials to the agro-based industries of the country and also earns a substantial amount of foreign exchange for the country. Better policies are the fundamental determinants for the success of a sector in achieving the desired goals. The policy is a course or principles of action adopted or proposed by an organization or individual. Therefore, policy-making institutes or organizations are also of great importance in setting up suitable policies for the country. However, in Pakistan, the government is the entity that imposes policies on the agriculture system. Agricultural policy is influenced by so many factors such as political, social and economical nature, and a number of characters such as politicians, bureaucrats, traders, consumers, etc. also influence the policy to be formulated in its final shape. In the end, after consulting with analysts, politicians choose a better plan that can bring efficiency to the system. However, the circumstances are always not ideal due to restrictions or suggestions from the political economy, stakeholders, ideological demands, and public choices to achieve the desired goals at times. Agriculture policies are not the only tools that influence the food system but also there are economic policies (monetary, exchange, fiscal, and wage rates) that have huge implications. However, when framing policies, one should keep in mind the economic, political, legal and social setting in which the policies will be executed. Policies, as a rule, should be adapted to economic laws so that the functioning of those laws is supported or controlled but not stalled. Policies in different fields of economic activity should be properly coordinated with one

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another to avoid conflicts and inconsistencies. Since agriculture policy is generally considered a public instrument, therefore, this chapter only focuses on governmental policies, legislations, programs, and plans affecting the agriculture sector of Pakistan.

Keywords: Agriculture, Policy making, Traders, Consumers, Agricultural policies, Legislations

6.1. Introduction

Agriculture is the single largest sector of Pakistan's economy accounting for a 21% share of GDP and providing 45% of employment to the labour force. Moreover, it contributes to the economic growth of the country as a supplier of raw materials to industry, a market for industrial products, and acting as the main source of foreign exchange earnings (Pakistan Economic Survey 2015-16). Open weather activity, the association of generally poor people, the source of tradable surpluses, and the importance of food production always steered agriculture to be a pivotal part of public and economic policies for governments around the globe. The objective of agriculture policy has been on increasing production by supporting farmers, providing cheap and quality food to consumers and earning foreign exchange for the countries. With technological advancements and the adoption of good policy packages, food has never become a short supply to feed the ever-increasing population of the world thus defeating the Malthusian theory which always echoed the exhaustion of production resources to meet the food demands of the population. The challenge is not over yet. The global food crisis of 2007-08 has exposed the fragility of the agricultural production system and policies around this subject. This is more applicable where agriculture is a subsistence activity, food supply-demand balance is precarious, and the climate change phenomenon is facing front to degrade the endowments. It is equally important where agriculture is an industrialized activity in the face of new technological advancements like GMOs, nexus with energy and climate change has become reality. Formulation of appropriate policies, therefore, has got importance to ensure food supplies no matter what time in the history of mankind is going through.

he government is the entity that imposes policies on the agriculture system. Behind the scene, however, is a plethora of characters (politicians, federal ministries, provincial governments, bureaucrats, technocrats, academia, experts, traders, producers and consumers) and conflicts (political, economic, and social) that shape the final product to take effect and guide the agriculture system of the countries. Policy analyses inform politicians to make the right choices which are expected to bring efficiency to the system. The situation is, however, always not ideal because of wants and compulsions of stakeholders, ideological demands, political economy, public choices and ethics restricting to bringing desirable results at times. This situation put a disadvantageous situation for many while creating advantages for some thus creating rent seeking opportunities. Agriculture policies are not the only instruments that affect the food system but also there are economic policies (fiscal, monetary, exchange and wage rates) that have huge implications.

A policy is a course or principles of action adopted or proposed by an organization or individual (Oxford Dictionary). Agriculture policy then is a course of action adopted either by the governments or the private sectors for the agriculture sector in their respective countries or globally. It helps to achieve certain policy objectives and goals by setting regulations and incentives across various steps from field to fork. Since agriculture policy is generally considered as a public instrument; therefore, the chapter will only focus on governmental policies, legislations, programs and plans affecting the agriculture sector of Pakistan.

The cornerstone of agriculture policies in Pakistan has been ensuring maximum returns to farmers especially the smaller ones, providing cheap food to the consumers and raw materials for industry and exports. A major part of the country’s economy has been contributed by the agriculture sector thus its performance influences overall economic growth. Since independence, Pakistan's economy has gone through structural adjustments and the share of agriculture has reduced from half to less than a quarter. However, it is still an important sector that has strong vertical and horizontal linkages with the economy of the country. Major exports of the country are still agriculture-based. About two-thirds of the rural population relies on agriculture for their livelihood. The matter of concern is that the growth rate of agriculture could not be sustained in recent times (Govt. of Pakistan 2014-15). From 1960 to 2000 growth rate was about 4% which simultaneously decreased below 3% in the first decade of this century (Anonymous 2013-14).

To effectively implement the policy framework, the governments has set up institutional mechanism or governance structure. Such a mechanism has also been established in Pakistan as explained in this chapter.

6.2. Agriculture Governance and Institutional Framework

Constitutionally, Pakistan is a federation. It has three tiers of government. At the national level, there is a federal government supported by various ministries/divisions and subordinate offices. Provincial departments form a government in the provinces whereas the third tier at the district level is called local governments.

At the federal level, there is a Ministry called National Food Security and Research responsible for policy planning and coordination on the subject of agriculture. This is the successor of interest of the Ministry of Food, Agriculture and Livestock (MINFAL) which was abandoned on June 30, 2011, as a consequence of the 18th Amendment to the Constitution of 1973. Certain departments of MINFAL were wound up in 2011. Presently, MINFAL is supported by the Department of Plant Protection and Quarantine, Animal Quarantine, Agriculture Policy Institute, Federal Seed Certification & Registration Department, Pakistan Agriculture Research Council, Pakistan Oilseed Development Board, Pakistan Agricultural Services and Storage Corporation and Water Management Cell. Pakistan Central Cotton Committee, Marine Fishers Department and Soil Survey of Pakistan were previously with the MINFAL, but now have been given to Ministries of Textile Industry, Ports and Shipping, and Punjab Government respectively under devolution. Likewise, Pakistan Forest Institute was given under the control of Khyber Pakhankhawa Government. The function of agriculture development is rest with the Planning Commission that formulates development plans and strategies in the country and allocates financial resources (Annual Plan 2011-12).

Provincial governments have the function of implementing and executing policies with the help of local governments and several departments including food, agriculture, marketing, irrigation, cooperatives, fisheries, livestock, dairy, forest, and wildlife. The combination and nomenclature of these departments may be different in four provinces. Provincial departments have several subordinate institutions such as research, extension, education, water management and field engineering to support the working of main departments. The role of the private sector has increasingly become important in Pakistan over time. Several private companies are involved in inputs (seed, fertilizer, pesticides, and machinery) production, supply and support services to farmers. Many private banks are providing credit to farmers having a share more than state-owned banks e.g., ZTBL in total agriculture credit disbursement. Under the policy, the government is gradually pulling itself out of agriculture business activities. One important part is, however, under government control which is marketing except for part of livestock such as poultry, milk, and meat. The government has a high influence on agriculture markets which distorts business activity. There is an active consideration to deregulate this activity as well.

In 2010, the Government of Pakistan undertook a massive devolution process where seventeen Ministries along with several functions of some Ministries were reshuffled and transferred to provinces. For example, the MINFAL has been abolished. In a major shift, the task of policy, planning, and coordination with regard to food and agriculture was assigned to Planning Commission. Food handling activities were entrusted to Commerce Ministry. Similarly, International cooperation was given to Economic Affairs Division. Several functions such as economic studies for framing agricultural policies, farm management research, crop forecast, and insurance, marketing intelligence, commodity research, soil survey, special crops, under-developed areas and cooperatives were devolved to provinces. This division of labour, however, could not sustain resulting in the establishment of a new Ministry of National Food Security and Research at the federal level and most of the functions and departments have been reallocated to it as explained above.

6.3. History of Agriculture Policy in Pakistan

The government of Pakistan has adopted several policies and strategies to handle the agriculture system along with the supply chain including production, post-production, marketing and trade of produce. However, such policies with one exception of 1991 have never been approved as a consolidated document to become available. All issues of the agriculture sector were addressed separately as and when emerged by the respective institution of the federal or provincial government. Since agriculture has been an important part of the national economy, so Government made concerted efforts to arrive at policy options to boost its growth, increase the profitability of the farmers, sustain food supplies, get raw materials for the industry and meet export needs.

The first formal effort was made by the setting up of “The Food and Agriculture Commission 1959” headed by Malik Amir Muhammad Khan, the Governor of West Pakistan. The Commission made recommendations on taxation, cooperative farming, land tenure, irrigation, drainage, water logging, salinity, and construction of big water reservoirs and grain storage. It also addressed the livestock issues, especially the pricing mechanism. Improvement in forest cover was recommended along with tea plantations to utilize the mountainous regions (Food and Agriculture Commission Report 1959). In 1988, “National Commission on Agriculture” was constituted under the leadership of Mr. Sartaj Aziz, the Minister of State for Food and Agriculture. This Commission followed the economic growth approach and recommended an agriculture growth rate of 5% for the next 12 years. To achieve such a growth rate, several recommendations were made to increase crop and livestock production with backup support from policies and institutions. It recognized the role of rural infrastructure especially farm-to-market roads for agriculture development in the country. Land reforms were also suggested to address the issues of tenants and the computerization of land records. The Commission also recommended devolving the sector’s responsibilities to the lowest tiers of the Government in a phased manner (National Commission on Agriculture Report 1988).

Along similar lines, Prime Minister’s Task Force on agriculture was constituted in 1993 to resolve the sector’s issues, enhance agriculture development and raise the profitability of farmers. It suggested different measures on sector reforms in institutions and land, production, infrastructure, support services like research and extension, credit, and smallholder and commercial farming. Water and drainage arid agriculture was also highlighted in the recommendations along with focusing on horticulture, livestock poultry, and fisheries development (Prime Ministers Task Force Report 1993). The food crisis of 2007-08 resulted in the formulation of another Prime Minister’s Task Force on Food Security in 2009 under the leadership of Mr. Sartaj Aziz. This was the first time in the history of Pakistan when the government adopted a comprehensive approach addressing the full value chain from field to fork covering the production, procession, marketing and consumption of agricultural produce. It also addressed the issues of economic access and affordability of food items for consumers. It means that the scope of the report was not only confined to the supply side but also the demand side of the food. Most of the present day’s policies have reference to the recommendation of this task force (Prime Minister's Task Force on Food Security 2009).

National Agriculture Policy of 1991 was the only document adopted by the government as a comprehensive policy package for the agriculture sector. The National Commission on Agriculture 1988 provided the basis for this policy. It emphasized achieving a high growth rate, enhancing productivity without damaging much the natural resources and increasing exports. Modernization of agriculture was given importance for enhancing the system efficiencies. Corporate agriculture also got policy support. Water again was given due importance for enhancing storage, conveyance and field use efficiencies (API 1991). Another policy “Agricultural Perspective and Policy 2004” was also drafted by the Ministry of Food and

Agriculture. This document contained all the subjects covered in the Policy of 1991 but with a modern look. In addition, it also touched upon new subjects such as World Trade Organization (WTO) and climate change. This was a good effort; however, it could not get the approval of the Government (Agricultural Perspective and Policy 2004). Along with these policy documents several other policies have been formulated and drafted in allied sectors of agriculture such as the Livestock Development Policy 2006, Natural Management Policy 2010, and National Forest Policy 2005 and 2009 (Anonymous 2013). Since agriculture is a provincial subject, therefore relevant governments also made efforts to produce some policy documents to implement the national agricultural policies in sub-sectors of agriculture such as crops, livestock, poultry and fisheries.

In 2011 devolution hit, the agriculture sector among others and MINFAL was dissolved. A new establishment i.e., Ministry of National Food Security came into being in the same year and took up the assignment of formulation of food policy for the federal government. This document is still in the process and under review and improvement with the federal government.

The government of Pakistan follows a mid-term development strategy translated into five-year development plans. For the implementation, Annual Plans are formed with budgetary allocations. The first Five Year Plan was conceived for the 1955-60 period for overall economic growth and development including the agriculture sector in Pakistan. By passing through several plans and non-plan periods, the 11th Five Year Plan is in vogue that covers the period of 2013-18 (Anonymous 2013-14). This plan got guidance from Vision 2025. The Vision contains seven pillars and five enablers. Though agriculture in one way or another has been mentioned in full documents of Vision 2025 but Pillars four and six put special emphasis on the agriculture sector and provide guidelines to be adopted in the formulation of plans, programs and policies for the development of the agriculture sector (Anonymous 2014).

For long, livestock thrived on its own without much policy support from the public sector. Most policy focus however was on crop sub-sectors including inputs, outputs and support services. The following sections of the chapter cover it in detail.

6.3.1. Land Policy

The contribution of land resources to agricultural development depends upon the quantity and quality of land resources and the efficient use of such resources by the farmers. The availability of land per capita in Pakistan has been falling over time primarily due to an increase in rural population and limited out-migration of farmers to urban areas and/or non-agriculture activities in rural areas. In addition, the phenomenon of land degradation has adversely impacted the quality of land resources in Pakistan. The land reforms have to serve three purposes; increased production, efficiency and equity through redistribution of land and security of tenure. However, these reforms did not succeed in changing the status quo in Pakistan and thus had no significant impact on production (Naqvi et al. 1989). Chaudhry et al. (1985) focused on the size-productivity relationship in Pakistan during the seventies in the wake of the Green Revolution. The study concludes that the traditional inverse relationship between farm size and productivity exists in Pakistan precluding the possibility of a positive relationship. This study concluded that the rate of growth of productivity in the seventies was more pronounced in the case of small farmers compared with large farmers. The authors are of the view that the reasons why the traditional inverse relationship remains intact are higher labour input, more intensive land use, greater manorial application and greater irrigated area of the small farmers in relation to the large ones.

Changing the profile of land ownership, operational holdings and land fragmentation has profound implications for the efficient use of land and access of small farmers to employment opportunities. Security of tenure and proof of conclusive titles to land are essential pre-conditions for encouraging farm investment and optimal use of resources within the agricultural sector. Correct and updated land records help in prompt dispute resolution of land litigation matters and facilitate access to credit as land is often used as collateral by the lending agencies. This section provides a brief description of the existing system and policy and the institutional issues impinging on the efficient use of land and the access to land by tenants and small farmers (Qureshi and Qureshi 2004).

The major objective of current land administration is the registration and management of land rights, use allocation, valuation and taxation. This system is based on land registers and cadastral maps maintained by the local land administrator (Patwari) under the oversight of senior revenue officers at the district and provincial levels. Historically land ownership, as well as distribution of operational holdings in Pakistan, is highly skewed. The pattern of distribution has become more unequal over time. The Gini coefficient of ownership as well as operational holdings has continuously been increasing over time. The share of small holdings in the area relative to their number of land holdings is declining (Table 6.1).

In view of the increasing preponderance of small holdings with the increasingly declining size of holdings, the threat of small farmers being forced into poverty is a real one. The phenomenon of increasing land fragmentation in Pakistan has also been noticed. The increasing incidence of land fragmentation is costing the farmers terms of unnecessary time needed in moving from one fragment of land to other fragments of land.

The increased inequality in land distribution is primarily due to the inheritance laws as land is rarely sold in rural areas. The increased inequality in land ownership is found in Pakistan despite the provisions with respect to maximum ceilings on the land that can be owned by an individual and the stipulation on the minimum holdings sizes with respect to subsistence holdings in Land Reform Acts enacted in 1959 and 1972 (Dawan News 2010). Data on land holdings larger than legally prescribed limits and operational holdings less than the subsistence holdings are reported in different census reports. This shows that the provisions in the Land Reforms Acts have not been fully implemented. The weak implementation of reforms was due to faulty design of the implementation process as well as collusion between the affected landowners and the government machinery. The implementation of land reforms was entrusted to the Federal and Provincial Land Commissions. These administrative bodies were not under the land revenue administration. The legal process of resumption of land over and above the fixed land ceilings was complex in design and was subject to judicial determination which delayed the implementation of reform. Corruption was rampant and it is not surprising that census data picks up holdings that are larger than the permissible size of holdings. The land reforms provisions with respect to the security of tenure have also not been fully implemented. The terms of the contract between a landowner and the tenants operating the land are often oral in Pakistan and diverge from the legal provisions included in various Land Reforms Acts. Tenants rarely challenge their grievances in courts of law.

Table 6.1 Number of farms and farm size in Pakistan

Size (ha)	Farm number				Farm area			
	1972		2010		1972		2010	
	Million No.	%	Million No.	%	Million Ha.	%	Million Ha.	%
Under 2	1.06	28.1	5.35	64.7	1.04	5.2	4.12	19.2
2 to under 5	1.50	39.9	2.05	24.8	4.99	25.2	6.16	28.7
5 to under 10	0.79	21.1	0.56	6.8	5.29	26.6	3.79	17.7
10 to under 20	0.29	7.7	0.21	2.6	3.73	18.8	2.72	12.7
Above 20	0.12	3.2	0.09	1.1	4.81	24.2	4.61	21.6
Total	3.76	100	8.26	100	19.85	100	21.41	100

Source: Govt. of Pakistan (2010)

The proper implementation of Land Reforms Acts (Land Reforms Regulations Act 1972) as well as dispute resolution of land matters assumes the existence of reliable land records. The nature of land records and the mechanism for their updating were designed by the British mainly for the collection of land revenue and preservation of peace, and law and order in rural areas. The objective of land management for rapid agricultural growth was never a primary concern of British rulers. An elaborated system of preparation of land records with respect to land ownership, its operation, transfer through sales and inheritance was evolved by the British. This system was continued in Pakistan. However, it has decayed with the passage of time primarily due to assigning other duties to the revenue officials.

The basic flaw in the land management system was that it was not designed to give a conclusive title to a piece of land. The entries in the land records gave only presumptive titles and these entries could legally be challenged in a court of law. This shortcoming is at the core of the problem of land disputes in Pakistan. The frequent disputes and land litigation has deterred incentives to improve the land. The gains in land improvement could be wiped out if the land could be taken away by other parties through the courts.

The overriding objective of accurate land records is to promote greater efficiency through faster information retrieval, transparency, and reduction of transaction costs for the owners of the land. The present system of land records is deed based. Entries in the deed are not checked for the legality of transactions and in no way are proof of title to the land. Some experts suggest the need for shifting to the “Torrens” system which is a title based rather than the current practice of ‘deed’ based system. A shift to the ‘Torrens’ system can enable the government to give a conclusive title guarantee to holders of land. The land markets would also easily develop as the purchase of land could not be contested by other parties. In recent times, Sindh and Punjab governments made good progress in the computerization of land records. It may be hoped that the longstanding issues of land ownership documents will be streamlined to give a boost to investment in the sector, make the land market more liquid and solve the issues of collateral for credit needed by the banks.

6.3.2. Pesticide Policy

After independence in 1947, the government made concerted efforts to increase the yield of agricultural crops to feed its population. In this regard, the government imported seeds and plants of exotic varieties which brought insects along with significant importance due to the non-existence of quarantine measures. Likewise, the government introduced new varieties which were highly responsive to fertilizer so making vulnerable to pests. This situation actually increased the pest prevalence in the country which made it impossible to control them with cultural practices. A need was felt to adopt external plant protection measures as agrochemicals were gaining popularity around the globe for agriculture. Initially, pesticides were used in Pakistan to control locust attacks in the 1950s. So, the first consignment of formulated pesticides was imported in 1954. Pesticide usage gradually increased, and business remained under government control. There was no legal framework to regulate pesticide activities in the country until 1971 when an agriculture pesticide ordinance was promulgated. Subordinate legislations were undertaken in 1973 and relevant rules of agriculture pesticides were framed.

Agriculture Pesticide Ordinance/Act 1971 made provisions to regulate pesticide-related activities in Pakistan. The Ordinance 1973 was formulated by the President of Pakistan to import, manufacture, formulation, pack, storage, labeling, distribution, sale, and use of pesticides and ancillary matters in Pakistan. Registration is to be allotted to each pesticide that will be valid up to 30th June for up to 3 years and is renewed for another 3 years on expiry. Penalties including fines and impressment have been described in the ordinance to check the adulteration of pesticides (Saleem and Shah 2010). To assist the government regarding pesticide registration, Agriculture Pesticide Technical Advisory Committee (APTA) was established which included members from Pakistan Agriculture Research Council (PARC), Universities, Government Departments and Central Cotton Committee (Feenstra 2000).

According to Agriculture Pesticides Rules 1973 (Amended), 294 pesticide adulteration cases were registered in Punjab, one in NWFP. Out of the 48 from Punjab and one from NWFP were decided by the court, five persons in Punjab and one person in NWFP were arrested, while 43 were imposed fines (Rs. 500-3000) (MINFA 1993). Likewise, Quarantine Act 1976 provided check cross-border movement of agriculture commodities. The plant protection department had been made custodian of these two important laws related to pests and pesticides in Pakistan, which provides facilities, such as locust survey and control, pest control by air on field crops, quarantine of agricultural commodities, and monitoring of pesticides imports, manufacture, formulation, repacking, advertisement, sale, use and quality. Until the year 1980, there was strict control of the government over this business. By that time most of the pesticides were used for aerial spraying to control locusts, pests of sugarcane, cotton, rice, tobacco and fruit crops, etc. (Habib 1996). There was a subsidy on pesticides and aerial spraying was done by the federal government without any cost. Afterward, the government started charging but a very nominal to farmers, which was later increased up to 25% of the total pesticide application cost. Farmers started growing more crops which resultantly increased pesticide use i.e. 665 tons in 1980 to 14,773 tons in 1990 and 61,229 tons in 2000 worth about 7.7 billion rupees (Ahmad et al. 2002). Better plant protection practices along with high-yielding varieties caused to increase the cotton production from 4.2 to 12.50 million bales from 1981 to 1992 (Govt. of Pakistan 1991-92). The Plant Protection Department had the responsibility to import and distribute insecticides in the country through a national agricultural extension network (Habib 1996). Resultantly the subsidy was however totally abolished in 1980 and 1982 in Punjab and Sindh, respectively and trade was shifted from the public to the private sector (Ahmad et al. 2002). Multinational companies got hold of the pesticide business and almost all major agro-based companies of the world did business in Pakistan (Jabbar and Mallick 1994). It took another 12 years to introduce liberalized import policy in 1992. An important intervention of this policy was that the generic pesticide chemicals were allowed to register and import. This step was taken to break the monopoly of big companies which were exploiting farmers and minting money. The stride gave results soon and prices of pesticides fell down significantly. The policy shift opened a lot of opportunities for the private sector which took full advantage, consequently, many domestic agrochemical companies emerged as important players in the market.

Presently there are three types of pesticide registration options available in Pakistan. Three types of Forms have been devised to handle the registration process. A pesticide product having a trade name is registered under Form 1. A generic name of the pesticide can be registered by the name of active ingredient/molecules on Form 16. Similarly, Form 17 is used to register a product that is in use and registered abroad in Economic Corporations and Development (OECD) countries and China (Anonymous 2017).

With the advancement in science and technology, it became evident that pesticides are important plant protection tools in one way and pose health threats in the other way due to their hazardous nature (Anonymous 2017). Previously human life losses along with biodiversity were reported, so some protective measures were adopted like application care and even banning of chemicals. Countries of the world reached a consensus and adopted several conventions and agreements to mitigate the ill effects of pesticides. In line with the world community, Pakistan had also joined and ratified those agreements. In conformity with good agricultural practices and international obligations, Pakistan banned 23 pesticide products in the country between 1989 and 1993. Relevant international agreements along with their dates of signing and ratification by Pakistan are given below.

- Rotterdam Convention on Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides (signatory since 1992)
- Stockholm Convention on Persistent Organic Pollutant (POPs) (signatory since 2001)
- Basel Convention on the Control of Trans-boundary Movement of Hazardous Wastes and their Disposal (signatory since 1994)
- Montreal Protocol on Substances Depleting Ozone Layer (ratified on 18.12.1992)

The involvement of the private sector in pesticide activities made this a vibrant business. It had far-reaching effects on the overall agriculture of Pakistan. Private companies provided many incentives to farmers including credits and their farmer's contact was far better than provincial Agriculture Extension Departments. It posed pesticides as a single control measure for plant protection against insect pests and hence played an important role in increasing the overall use of pesticides (Qureshi 2015). The aggressive media campaigns especially on national television channels at prime-time enhanced product promotion and subsequently usage by the farmers. Overall consumption touched its peak in the year 2004 when 129,598 metric tons were consumed (Khan et al. 2013). Afterward, the consumption has been reduced significantly and went down to 40,463 metric tons in 2009 (Govt. of Pakistan 2014-15). The main reasons are the reduced pest pressure due to the introduction of resistant varieties, especially BT cotton, and the lowering productivity of cotton and other cash crops (Nazli et al. 2010). Initially, the business was in the grip of multinational companies, so they preferred to import their products from their already manufacturing facilities abroad. Later when some local companies emerged, they installed formulation facilities, especially with the technical assistance and investment of China. From the year 2000 onward, the ratio of import to local manufacturing skewed towards local production (Ahmad et al. 2007).

6.3.3. Credit Policy

When the personal funds of a farmer erode, he looks for external support to complete the farm operations. In such a situation, relatives and friends become the first choice for small farmers' from where he meets his financial need without any interest and collateral. If that does not become available, his obvious choice would be the source that is cheap, fast and convenient. Since formal credit has policy support therefore ensuing paragraphs will cover only the institutional credit.

The Loans for Agricultural Purposes Act, 1973, provides a legal framework for all types of credit facilities for persons engaged in agriculture. The State Bank of Pakistan is an institution that makes a regulation to achieve the target fixed in consultation with all stakeholders included in the "Advisory Committee on

Agriculture Credit". For disbursement of the loan, there is a widespread network of specialized, as well as commercial banks in the country having close to 11000 branches in Pakistan of them over 4000, are dealing in agri. credit. About 4000 mobile agriculture credit officers are working in credit disbursement for farming communities all over Pakistan (Irshad 2012). Agricultural credit demands for the farming community are enormous. The current total agriculture credit demand in Pakistan has been estimated at around Rs. 1000 billion. With aiming to promote agriculture in the country, the State Bank of Pakistan has allocated agricultural credits of Rs. 385.5 billion for the year 2016 which is 64.3% of the overall target of 600 billion and 20% higher than the previous year. A total of 36 banks were involved including 20 Commercial banks, five Islamic Banks, nine Microfinance Banks, and two specialized Banks which are engaged in the provision of agriculture credit facilities to the farming community (Pakistan Economic Survey 2015-16). The country's meager financial resources and competing demands from various sectors of the economy do not allow providing such an amount to the farming community. State Bank of Pakistan makes always strenuous efforts to meet the demands. The efforts and governmental focus yielded dividends in recent times and in the year 2014-15 an amount of Rs. 516 billion has been disbursed against 391 billion last year (Pakistan Economic Survey 2014-15). The 32% increase depicts the efforts made this year compared to the increase last year. This increase can be attributed to the high targets given to the banks, high appetite, and innovative loaning products. Another important change that occurred in recent years was the increase in the number of banks for agriculture credit disbursement. Previously the public sector ZTBL was the main shareholder in the agri. credit market (Pakistan Economic Survey 2015-16). Its share has decreased in relative terms from 56% in 2001-02 to 19% in 2015 due to the participation of commercial banks in 1995, domestic private banks in 2001 and microcredit banks in 2011 in the agriculture credit market of Pakistan. The outreach has been however a challenge as the numbers of borrowers are not increasing but contrarily, they have decreased by 2.8% i.e., from 2.15 million borrowers to 2.09 million compared to last year. It shows a clumsy effort made by the banks to touch the new borrowers and rather banking on the clients who are already on the net.

The disbursement target for the year 2015-16 has been fixed at Rs. 600 billion which is over 50% of the total credit need of the country. In the last five years increased credit growth gradually reduced the demand-supply gap as the credit disbursement was 37% in 2010-11 which increased up to 52% in 2014-15 against the requirements (Pakistan Economic Survey 2014-15).

Though agriculture is being done all over Pakistan, however, its concentration is high in Punjab, a food basket for the whole country. Out of the total cropped area, about 71% is in Punjab followed by Sindh (16%), Khyber Pakhtunkhwa (7%), and Balochistan (1.2%). In line with farm activities, agriculture credit disbursement is high in Punjab and is 82% of the total credit disbursed in the year 2014-15 (Pakistan Economic Survey 2014-15). Sindh, Khyber Pakhtunkhwa, and Balochistan received 11%, 2.6% and 0.2% share in total agriculture credit respectively. In the rural economy, along with the farm, several non-farm activities run side by side. Both sectors get an almost equal share in the total agriculture credit disbursement. In the year 2014-15 about 50.2% of the credit was disbursed as farm credit compared to 49.8% as non-farm credit (Table 6.2).

Table 6.2 Supply of agricultural credit by institutions (Rs in billions)

Bank	Target 2014-15	2014-15 (July-March)			Target 2015-16	2015-16 (July-March)		
		Disbursed	Target achieved (%)	Share in total disbursed (%)		Disbursed	Target achieved (%)	Share in total disbursed (%)
Major Commercial Banks (5)	252.5	167.4	66.3	51.4	305.7	198.8	65.0	51.6
ZTBL	90.0	56.2	62.4	17.2	102.0	55.3	54.2	14.3
DPBs (15)	115.5	72.1	62.4	22.1	131.8	84.8	64.4	22.0
PPCBL	11.5	5.8	50.9	1.8	12.5	6.1	48.8	1.6
MFBs (9)	28.2	20.7	73.6	6.4	40.1	34.5	86.0	8.9
Islamic Bank (5)	2.3	3.8	134.7	1.2	7.9	6.0	75.9	1.6
Total	500.0	326.0	65.2	100	600.0	385.5	64.3	100.0

Source: State Bank of Pakistan

The performance of a loan has been considered as the most important indicator with regard to lending institutions. Participation of private banks enhanced the competition in the rural credit market (SBP 1990-2000). It led to the improvement in the portfolio quality of traditional and specialized institutions. The percentage of non-performing loans (NPL) has been going down very consistently. The NPL was 18% in 2011 which has been reduced to 11% in 2015. A major reduction was noted in non-farm NPL (SBP 1990-2000). To reach and provide services to small farmers has always been a prime focus of the credit schemes in Pakistan. The size of farm and non-farm credit is almost equal. During the fiscal year 2014-15, about 60% of the farm credit was utilized by the subsistence or small landholders. From the non-farm credit, about 23% was disbursed to small farmers. Under the regulation of the State Bank of Pakistan (SBP) the lending financial institutions have been launching several products to service small farmers. In the recent past credit, schemes have been launched focusing on small farmers that include financing schemes for small farmers, credit guarantee schemes for small farmers, Crop loan insurance schemes and microcredit for smallholders (State Bank of Pakistan Working Paper for ACAC).

6.3.4. Agriculture Research, Extension & Education

Agriculture research, extension, and education are very important to support services for overall agriculture development. They are mainly considered a public good and the government takes them primarily the responsibility of the state. To cope with the future food and fiber demand in the country such good support services hold the key to making the system more effective (Röling and Pretty 2016).

6.3.4.1. Education

The agricultural education is being administered mainly by specialized universities working under the administrative control of provincial governments. The Higher Education Commission (HEC), a restructured body of the University Grants Commission provides a common framework for maintaining uniform quality standards and equality in the country. Since the inception of the HEC, the curricula of the agricultural universities have consistently been revised after every three years to make it discipline-wise harmonious among the universities, conversant with the prevailing and upcoming needs of the sector and match the international standards. In addition, the HEC has put a lot of money into universities to improve the academic and allied facilities.

6.3.4.2. Research

National Agricultural Research System in Pakistan includes federal research establishments, provincial research institutions, and agricultural universities. The private sector though insignificant but is a part of the system. At the federal level, various institutions are doing agriculture research irrespective of their affiliation with the federal ministry. All provinces have a central multidisciplinary research institute on crops as well as on dairy and livestock including poultry and fisheries. These institutes are supported by many research centers depending on the commodity and agro-ecological requirements (Planning Commission 2006). Private companies working in fertilizer, pesticides, seed, farm machinery, food processing and some commercial banks are also doing some research work to maximize their profit margins. However, their research programs are very limited. Local companies do not have well-developed infrastructure and trained manpower. Whereas multinational companies depend on their foreign research establishments while in Pakistan they only do marketing. The role of the Pakistan Agriculture Research Council is central to the National Agricultural Research System. Its mandate is to undertake aid, promote and coordinate agriculture research in Pakistan.

6.3.4.3. Extension

All provincial governments have maintained an extension system for outreach activities. They also help to implement agriculture laws, rules and regulations and provide feedback to scientists on researchable problems. Sometimes developmental projects also develop temporary extension services to execute the projects. There are several public sector companies such as ZTBL, Pakistan Horticulture Development and Export Company (PHDEC) and Pakistan Dairy Development Company (PDDC) doing extension services in Pakistan. They have strong linkages with the farming community. Agriculture universities and research institutes have also extension programs for their adjoining areas. All organizations invariably try to build linkages with provincial agriculture extension departments as they have grass root level access to the farming community. The private sector extension services system consists of seed, pesticide, fertilizer companies, banks dairy, poultry, livestock, oil, sugar, tobacco, maize industry, etc. They provide specialized extension services and emphasize the promotion of their products. Rough estimates suggest that about 70-80% of the advisory services are provided by private companies. They have better transportation facilities and operational budgets. Non-

Governmental Organizations such as rural support programs are another important component of the agricultural extension system. Their main focus is on a community-based approach to bringing change in society (Malik 2003; Bajwa et al. 2008).

Most of the faculty of the agricultural universities in Pakistan besides teaching conduct research and to a limited extent perform outreach activities. The agricultural universities in the country have the best human resource but weak infrastructure and resources for applied research. On the other hand, Provincial Research System has a well-expanded infrastructure of research institutes, stations and sub-stations spread all over the province but de-motivated stagnant scientific staff. The past experiences of integrating education and research were quite useful but could not sustain for long (Bajwa et al. 2008). The USAID-funded Transformation Integration of Provincial Agriculture Network (TIPAN) project in Agriculture University Peshawar did excellently in the development and release of varieties, research and provision of research facilities (Agriculture and Rural Development Division 1994). However, the Provincial Government de-merged the research system from Agricultural University Peshawar in 2005. Similarly, in the late 1970s, the Punjab Agricultural Research Coordination Board (PARCB) was instituted which too was attached to the Provincial Secretariat Lahore in 1991. With it, the super-structure of a good working relationship between agricultural education and research was disrupted. However, the research system with de-motivated scientific staff started sinking and has almost dried out from the motivated human resource. Recently the government of Punjab has established a body namely Punjab Agriculture Research Board (PARB) to support the research agenda of the provinces. This model proved very successful and was considered for replication in other provinces (Irshad 2012).

6.3.5. Seed policy

Historically, the seed production and distribution system in the country has passed through various developmental phases. It remained with the Department of Agriculture from 1947 to 1960. Farmers use to grow their own saved seeds and share it with their fellow farmers. An institution namely West Pakistan Agricultural Development Corporation (WPADC) was set up in 1960 and was however dissolved in 1972 and the functions to handle agriculture-related activities including seed; were handed over to the provincial input organizations (Hussain 2011). The main aim of WPADC was to initiate systematic seed production and distribution among the farming community through its own mobile marketing network. This system failed due to high seed procurement than the farmers need. In 1976, with the assistance of the World Bank, a seed industry project was launched and the Seed Act, of 1976 was promulgated. Two public seed corporations in the Punjab and Sindh were established in addition to Provincial Seed Councils in the four Provinces, and National Seed Council at the federal level. To execute the seed quality regulation, the following Federal Seed Certification and National Seed Registration Agencies (merged thereafter and presently known as Federal Seed Certification and Registration Department) were established (Hussain 2011).

1) National Seed Council (NSC) at Federal Level
2) Provincial Seed Councils (PSC) at each provincial level

3) Federal Seed Certification Department (FSCD)

6.3.5.1. National Seed Registration Department (NSRD)

Pakistan's seed sector is undergoing a major transformation. A momentum is in progression as important adjustments have already been made and a number of initiatives are at various levels of implementation. There is increased understanding and commitment to turning around this sub-sector of agriculture by creating enabling environment for the seed sector and concentrating on technology and knowledge-based interventions. The Seed (Amendment) Act, 2015 has been promulgated and an inclusive approach has been adopted for the implementation of this new Law (The Express Turbine 2015). Similarly, the Plant Breeders' Rights Bill, 2016 has been introduced in Parliament. National Standing Committee on the Cabinet Secretariat has approved the draft of the Bill (Ahmed 2016). It is hoped that it would be implemented soon. These new arrangements would not only give more space for the national private seed sector but also give required confidence to the multi-nationals and overseas entrepreneurs to invest in research and development of the seed sector. With the entry of GMOs into the seed market, the Government of Pakistan adopted safety measures and biosafety guidelines. A mechanism was established in the Ministry of Environment to take the stakeholders on board. This mechanism was however disrupted due to devolution. Recently efforts are in progress to restore this mechanism under the newly established Ministry of Climate Change.

6.3.6. Corporate Farming Policy

To realize the potential of the agriculture sector in the economy, the Government of Pakistan introduced Corporate Agriculture Farming (CAF) policy with the objective to seek efficiency of production and increase incomes/revenues by bringing together agricultural production, processing, and marketing activities at one place under the management of a corporate entity. This policy focuses to improve agricultural productivity and profitability through the use of the latest production technology and adequate expertise particularly for exports, to produce high quality agricultural products due to a favorable resource base and to achieve/maintain an internationally competitive unit cost of production for all major crops, fruits and vegetables (Abbasi 2012).

The policy package for CAF was approved by the Cabinet in 2004 and the Board of Investment was made responsible for its implementation. Under the policy, only such local and foreign companies were entitled to Corporate Agriculture Farming those are incorporated in Pakistan under the Companies Ordinance, 1984 (Abbasi 2012). There is no upper ceiling limit on land holding for CAF by amending relevant laws. The size of the proposed corporate farm may be left to be determined by the prospective investor. Agriculture income tax, a regime applicable in provinces on income from agriculture would be applicable to CAF. Tax relief in the shape of an initial depreciation allowance at 50% of machinery cost is allowed to set off provincial agriculture income tax. Labor laws may not be applicable to corporate agriculture companies (Abbasi 2012). Due to special circumstances of the agriculture sector, however, appropriate labor laws be developed for this sector within five years. Import of agriculture machinery and equipment is exempted from custom duty and sales tax. Machinery items for wheat/grain storage and cool chain are importable at zero import duty. Wherever possible, state land may either be sold or leased to the investors for 50 years, extendable for another 49 years. Preference in this respect will be given to cultivatable wastelands, which are otherwise fit for cultivation. Transfer of land for CAF will be exempted from duty and 100% foreign equity is allowed. No government sanction is required for undertaking CAF except registration with BOI. Exemption of the dividends of CAF companies from tax was also agreed (Abbasi 2012).

The areas of investment for CZF have included land development and reclamation of barren land, desert and hilly areas for agriculture purposes and crop farming, reclamation of waterfront areas/creeks, crops, fruits, vegetables, flowers farming, integrated agriculture, processing of agriculture products, modernization and development of irrigation facilities and water management and plantation, forestry, dairy, small ruminants and other livestock farming.

Provincial governments had identified over 6.74 million acres (Punjab 6.6, Sindh 0.029, Balochistan 0.1, and KPK 0.002) of land for the CAF. According to media reports, some tracts of land have been purchased by corporate entities especially those coming from the Middle East to safeguard their future food demands. Later however the scheme got criticism from civil society and political parties arguing the deprivation of small farmers' interests and portrayed the impression of land grabbing and against the national interest. It was also argued that issues like poverty, inequality, environment and food security in Pakistan have not been taken care of while framing the policy. This made the CAF controversial which disrupted the momentum of development and the policy hence could not achieve the anticipated objectives (CAF 2014).

6.3.7. Fertilizer Policy

Fertilizer is the agriculture input that provides the highest economic returns to the farmers and the country. It always remained at the central place in agriculture policy since the realization of its importance. The government of Pakistan paid attention to the supply as well as the on-demand side of the fertilizer. On one hand, fertilizer use development was promoted while the supply was ensured either by local production or imports on the other hand (Chaudhry and Chaudhry 1997). The use of nitrogenous fertilizer in Pakistan was started in 1952-53 through FAO-Pakistan's "Freedom from Hunger" program. Phosphorus came seven years later in 1959-60 and potassium in 1966-67. In the early 1950s, all supplies were imported which however swelled up in ensuing years mainly pushed by subsidies. Fertilizer use development in Pakistan can be divided into three phases with regard to subsidy and price control policy (Chaudhry and Chaudhry 1997).

The regulated and subsidized regime extended from 1952 to1986**.** During this time span, the public sector had a major share in production and marketing with incentives such as zero duties and sales tax and a 20% guaranteed return on equity at the utilization of 90% capacity. Prices were controlled by the government with heavy subsidies. The distribution of imported and domestic fertilizer was as per provincial quotas. Manufacturers were allowed fixed marketing incidentals which were being revised from time to time. When the cost of production plus marketing incidentals exceeded the government-fixed retail price, then the producer received the difference as a subsidy. However, when the retail price exceeded the cost of manufacturing plus marketing incidentals, then the Government received the difference as a development surcharge. Agriculture Development Corporation was entrusted to import, which was however later replaced with the Fertilizer Import Department (FID) under the administrative control of the Ministry of Food, Agriculture and Livestock (Chaudhry and Chaudhry 1997).

From 1987 to 1995 partial deregulation was practiced. The government announced its first fertilizer policy in 1989 to encourage new investment in fertilizer production. There was gradual decontrol of prices, market, and imports. Guaranteed return for local manufacture was abolished but incentives such as gas on priority/price freeze and duty-free machinery were continued. The government deregulated straight nitrogen fertilizer prices and abolished fixed marketing incidentals and subsidy or development surcharge mechanism in 1996. However, phosphate and potash and compound fertilizers continued to be regulated and subsidized. The fertilizer producers were allocated import quotas after fulfilling the requirements of provincial distribution agencies. The deregulation of nitrogen fertilizer prices decreased the subsidy burden and provided an incentive to urea producers to improve efficiency, decrease cost, and improve production to get a high return on equity. This reduced the burden on the public exchequer on the account of subsidies (Chaudhry and Chaudhry 1997).

The deregulated phase started in 1996 and still is in vogue. The positive outcome of deregulation of nitrogenous fertilizers encouraged for deregulation of phosphate and potassic fertilizers in 1993 and 1995 respectively. The FID continued imports until the private sector became able to handle import requirements. The first ever import of di-ammonium phosphate (DAP) was jointly done by FFC and ECPL in 1994 which paved the way for the abolishment of FID in 1999-2000. The second fertilizer policy was announced in 2001 containing incentives, like gas prices at $ 1.10 m BTU or prevailing Middle East price. The price of feedstock gas was equated to the Middle East price on the date of signing the general sales agreement or the US $0.77 per million BTU whichever is higher (a discount of 10%). Duty-free import of phosphate rock and phosphoric acid allowed new investments in the sector (Fertilizer Policy 2001).

The last twenty-year period from 1996 to 2016 can be divided into two phases with regard to subsidy policy. From 1996 to 2006, there was a subsidy on imported urea in the shape of the price difference between the international and local markets. Thereafter, a subsidy on phosphate and potassic fertilizer was provided. In 2008, because of the hike in prices, the subsidy rate was further increased. This subsidy program ended in 2009 because of a stabilization in the international market. Subsidy program on imported urea was however continued to fill the gap between domestic and international markets. Subsidy on phosphatic fertilizers was started again in, 2015 to improve the balanced use of fertilizers (Pakistan Economic Survey 2015-16).

6.3.8. Marketing and Trade Policy

In Pakistan, agriculture marketing is a provincial subject while trade is regulated by the federal government. Agriculture marketing regulations in Pakistan come from pre-partition time. In United India, there existed unregulated agricultural produce markets which did not favor producers thus reducing their net returns. The exploitation of farmers by the middlemen and money lenders had affected food production and damaged revenues for the government. The consumers were also at the losing end as there were no standard weighting and adulteration mechanisms. To improve the situation, the "Punjab Agricultural Produce Marketing Act of 1939" was formulated for the province of Punjab. This act was designed to provide better regulation of the purchase and sale of agricultural produce and the establishment of markets for agricultural produces in the province of West Pakistan. The Act made the difference by fixing the rate on any service provided by the market agents and money lenders and setting up a mechanism for monitoring market operations and trade services such as weighing, adulteration, auctioning, etc. through the establishment of an institution called Market Committees (MC) (Act No. IV *1939*). The MC was like a semi-autonomous body given under the function of local administration for fair and transparent trade. Farmers and consumers among others were taken into the MC as members for decision-making. After independence, this Act was adopted with some amendments through West Pakistan Ordinance XXXII of 1969 (Act No. XXXII 1969). This system remained operative in Punjab till 1978 when the Punjab Agricultural Produce Markets Ordinance (XXIII of 1978) was introduced to provide better regulation of the purchase and sale of agricultural produce and the establishment of markets for agricultural produce in the province of the Punjab (Act No. XXIII *1978*). Agriculture Produce Market Act 1939 continued in other provinces which created some differences in market management and fee structure across provinces. A Market Committee Fund Board (MCFB) was created in provinces to arrange the funds and lead the development works in agriculture markets. Required institutions such as the directorate or department of agriculture marketing were created in Punjab and Sindh to effectively implement the provincial laws. However, the market regulations and related institutions though promulgated but could not become effective in the provinces of Khyber Pakhtunkhwa and Balochistan. In recent years several attempts have been made to loosen the control of the government over the markets to bring in private sector investments but could not succeed in a big way, especially in Punjab.

The federal government has some authority for price monitoring and control under the Price Control and Prevention of Hoarding and Profiteering Act, 1977. This function falls under the purview of the Ministry of Industries and Production but actually, Finance Division has taken the charge of price monitoring for consumers in the country (Act No. XXIX 1977). Along with this, there are several laws regarding foodstuff and quality for food safety to protect consumers mainly implemented by the provincial governments.

Under the Constitution of Pakistan, trade is a federal subject. The Ministry of Commerce has been assigned the task of trade promotion. For this role, the Ministry of Commerce formulates trade policy to achieve the policy targets. This Ministry also implements the Imports and Exports Control Act 1950 by issuing export and import policy orders whenever becomes desirable (ACT No. XXXIX 1950). The last such orders were issued in 2013. It contains all details regarding trade for all practical purposes. Trade policy was formulated on annual basis. However, this practice was improved in 2009 when a three-year "strategic trade policy framework" was adopted for the period of 2009-12 which mainly emphasized the improvement of regulation and export development. The second framework was developed and adopted after its expiry in 2012-15. The Ministry of Finance has a role both in inter-provincial and international trade. Domestic trade has however been less focused and all attention has been diverted toward international trade. Ministry of Finance through the Federal Board of Revenue and SBP has a major role in controlling cross-border movements of merchandise goods. All financial barriers and taxes to trade such as customs duty, regulatory duty, federal excise duty, provincial excise duty, sales tax, and withholding tax come under the purview of FBR at least for collection. The FBR also issues Statuary Regulatory Orders to amend the existing tariff regimes whenever some needs emerge. Likewise, there is another forum called Economic Coordination Committee which makes key decisions on trade on strategic items such as food (e.g. wheat, sugar, and pulses) and agriculture inputs including fertilizers. For sanitary, there is an arrangement called quarantine both plants and animals under the Ministry of National Food Security and Research which works to implement the Quarantine Act 1976 for plants and 1979 for animals (Ordinance No. LXXV 1976; Ordinance No. XLIX 1979). The plant protection department also has a role in regulating trade for food safety. Recently Ministry of National Food Security and Research is trying to establish a new department by the name of National Animal and Plant Health Inspection Services to do all such services in one department. It will take all related departments under one umbrella institution. There is a Grading and Marking Act of 1937 that deals with the grading and marking of agricultural produce for domestic and international trade (ACT No. I 1937). During the Uruguay Round of WTO negotiations, Pakistan agreed to join the trade liberalization regime along with other countries. Under the Agreement on Agriculture (AoA), the countries were required to reduce domestic support and remove the restrictions on trade. Along with AoA the Trade Related Intellectual Property Rights (TRIPS), Technical Barrier to Trade (TBT), and Sanitary and Phytosanitary (SPS) agreements have huge implications and are largely affecting international trade. For implementation, both federal and provincial governments have a role in their respective jurisdictions. Since major exports are coming from agriculture therefore trade policy has always had implications for the agriculture sector in the country.

6.3.9. Agriculture Pricing Policy

Farmer's profitability especially of small farmers has always been a matter of concern for the government in the situation of wide fluctuations of input and out prices. Likewise, the supply of food at affordable prices for consumers is also a priority. For such purposes, the government has been making interventions in the market to stabilize the prices by offering good prices to producers and consumers through price support and input and food subsidies (Chaudhry and Sahibzada 1995). To execute this function several adhoc arrangements were made until a specialized institution by the name of Agriculture Prices Commission (APCom) was established in 1981 through a resolution apparently as an autonomous body under the Ministry of Food, Agriculture and Cooperatives. Keeping in view that the prices of agriculture commodities usually tend to crash in the post-harvest period and resulting in a big loss to growers, especially to small growers, if there is no state intervention. With this intention, APCom was tasked to suggest/advise on the price policy of wheat, rice, cotton, sugarcane, gram, onion, potatoes, oilseeds and such other commodities specified by the government from time to time. On the input side, it has to suggest/advise on the issue of farmers' price of fertilizers, pesticides, quality seeds, and such other inputs as the government may specify from time to time, keeping in view, among other things, the need to phase out subsidies on agricultural inputs.

In 2006 after discharging very successfully the role of the price stabilization function of the government this institute was restructured and adopted the name of the Agriculture Policy Institute (API) thus enhancing the scope of work from only pricing to other policy matters in the agriculture sector. The API was established with the following aims; i) the focus will be on broader agriculture policies and will be general and adjustable keeping in view growing needs, ii) to conduct studies on emerging policy issues with processing, storage and marketing costs of agricultural commodities and recommend policies and programs to reduce such costs and improve the competitiveness of commodities, and iii) analyze the impact of important agricultural policies on groups such as consumers, processors and exporters and advise on policy adjustments needed for greater efficiency and equity (API 2006). The price policy has been curtailed to only four crops i.e. wheat, rice, cotton and sugarcane. Whereas the support price is announced only for wheat while for the remaining three crops indicative prices are announced.

To develop policy, the API annually conducts a field survey in major producing areas of these crops in order to review the crop situation and collect input prices and cost of farm operations. The API convenes a meeting of the API, s committee to solicit the viewpoint of all stakeholders before the price policy formulation. The parameters such as world supply and demand situation, domestic supply-demand situation, international prices, export and import parity prices and cost of production are being taken into consideration. After receiving the relevant analysis, the Ministry of Food Security and Research finalizes the summary in consultation with provincial governments and other stakeholders before put up to the ECC for approval of the support price. It is generally announced before the sowing season enabling the growers to allocate their resources to the optimal level. After the announcement of price, the procurements targets are fixed to be achieved by the Pakistan Agricultural Storage and Services Corporation (PASSCO) and provincial governments.

In the case of cotton and rice, the private sector plays a major role in marketing. However, the government regularly monitors the market situation and only announces the intervention price in case the price falls below the breakeven level. Only in case of urgent need, the government intervenes as an alternate buyer to cushion the market at a reasonable level. In the case of sugarcane, price fixation is the mandate of the provincial governments under the sugar factories control act. The API is the professional institute at the federal level that analyzes the factors of price determination and forwards its analysis to the provincial governments who announce the indicative price of sugar cane. The sugar mills primarily in the private sector procure sugarcane at the announced price.

6.3.10. Agriculture Water Policy

Water got a central place in all agriculture-related policies explained above in the policy review section of this chapter. Other than that, several exclusive efforts have also been made on the subject of water which includes task forces, policies, strategies and agreements. Likewise, water was also covered in national policy documents on forestry, conservation, rangeland and the environment because of its cross-cutting nature in the economy of Pakistan. The situation changed over time, but policy focus remained around the increase in storage capacity, improving conveyance both off and on-farm and use efficiency at the farm level.

Pakistan's water system mainly comprises glaciers, rain, and aquifer water storage (Qureshi 2011). The natural conveyance system includes river systems comprising rivers such as Indus, Jhelum, Chenab, Ravi, Sutlej and Beas (Ali 2013). At the time of partition control barrages (situated very close to the border) were awarded to India, while 90% of the command area lay in Pakistan. The use of river water remained an issue between Pakistan and India until Indus Basin Treaty was signed in 1960 for the distribution of water resources in the Indus Basin through the facilitation of the World Bank. According to the terms of the treaty (Anonymous 1960), India was given the exclusive use of the water of the eastern rivers namely Ravi, Sutlej, and Beas. Under the agreement, Pakistan agreed to embark upon a gigantic project nicknamed “Indus Basin Replacement Works”. The extensive undertaking involved the construction of two major dams, five barrages and eight link canals. Pakistan has the world's largest irrigation network. The salient features of the current irrigation system are as: major reservoirs 3 (12.5 MAF storage), Barrages 19, link canals 12, main canals 44, distributaries 4000, and water courses 135,000. The gross command area of the system is 14.6 million hectares. Around 142 MAF becomes available while near 48 MAF of groundwater has been removed by the system annually. However, the net water availability for crops is around 76 MAF. Compared to this, the annual water requirements of the country are around 93 MAF resulting in 17 MAF shortfalls without rainfall contributions. The rainfall contribution is however around 13 MAF while the total rainfed area of Pakistan is 16%. Water reservoirs of the country are under the control of the Federal Government (Ministry of Water and Power) which releases water as per demand and allocated shares to the four provinces. In the provinces, irrigation departments administer off-farm water movement (canal and distributaries) while mandated to improve field efficiency by on-farm water management i.e. watercourse improvement and field application methods come under the purview of the Agriculture Department. The flood irrigation method is a common practice in Pakistan for all types of crops including rice. The government is endeavoring to improve the watercourses by brick lining, popularizing precision land leveling, furrow irrigation for field crops, and high-efficiency irrigation system for high-value crops through different development projects (Kamal et al. 2012). On the other hand, the government is providing huge subsidies for tube wells that worked in several provinces which have now been discontinued for some period. This however is still being given in Balochistan where groundwater pumping has a huge cast due to deep water tables. The government is also launching a solar tube well scheme on subsidy for small farmers to reduce energy usage by replacing with it renewable resources.

Pakistan is moving to become a water deficit country (per capita water availability: 1026 m^3/year) under changing climate and increasing population scenario (Kahlown and Majeed 2013). During the previous many years, the water deficit increased due to the lack of any significant addition to storage capacity and disruption of River flows by India in violation of the Indus Water Treaty. However, with the dwindling resources situation, prime attention has been paid to managing water efficiently by adopting the triple prong strategy i.e. enhancing storage capacity of both mega and small dames, improvements of irrigation water conveyance infrastructure (canals, distributaries, and water courses) and on-farm water use efficiency. Any significant increase in storage capacity is not anticipated in the near future given the long gestation period of mega storage projects. The shortfall in water availability is expected to widen. In this state of affairs, efforts have been focused to utilize the available water resources efficiently by minimizing conveyance losses and by augmenting water availability through judicious use of ground water, rainwater harvesting, demand management, and resource conservation technologies. The impact of these interventions and rainfall contribution will bridge the projected supply-demand gap to facilitate the achieving of crop production targets in the country.

Until the nineteenth century, irrigation management was participatory in the parts which become Pakistan after the partition of India. In the twentieth century, large-scale irrigation and drainage schemes were introduced by the public sector and farmers became a passive recipients. To bring back the community in the irrigation in the country, drainage, and management system on modern business and sustainable practices, institutional reforms with the financial assistance of the World Bank were introduced in 1997 with the promulgation of the Provincial Irrigation and Drainage Act (PIDA Act). The reform objectives focus on autonomy and decentralization, farmer participation and empowerment, and efficiency and sustainability. The new institutions under the reform framework include PIDAs (provincial level), Area Water Board (main canal level), Farmers Organization (distributary level), and Khal Panchayat (water course level). After the promulgation of the PIDA Act in 1997 relevant rules were framed. The new arrangements take off very slowly in provinces. It is now that participatory irrigation has gained momentum. Provinces are now on and are working to inculcate new traits. After significant time passed, a study has recently been carried out to assess the impact and status of reforms. The farmer's feedback was very positive, and they consider that the reforms improved water distribution, better maintenance of irrigation system, reduction in water theft cases and conflict resolution. However, the issues such as ownership of reforms, policy issues (project design, change management, administrative control), institutional issues (leadership, staffing, turf sharing, M&E, rules regulation), empowerment and capacity issues (administrative, legal and financial) were identified. Other relevant issues like gender balance, political interference, gaps in social mobilization and sustainability of FOs were also highlighted.

6.3.11. Farm Mechanization Policy

Mechanization of farm operations has become necessary due to the shortage of labour and animal power at the planting and harvesting stages of crops. It helps in timely sowing, cultural practices and harvesting of crops and reduction in post-harvest losses (Sims and Kienzle 2006). The most popular forms of mechanization are tractors with cultivators, drills, wheat threshers, sprayers, power rigs, tube wells, and bulldozers. In the late 1950s & early 60s tractors were introduced in Pakistan primarily for the cultivation and haulage of farm produce. Tractorization has been accepted as mechanization as only cultivators became popular while other farm implements could not become popularized. The fact remains that it is not the tractor but the equipment that it pulls which improves infield efficiency & productivity (Sim et al. 2016). A total number of operational tractors in the country could be estimated near 700,000 thus making the total horsepower close to 1.4 hp per hectare, as recommended by FAO for developing countries. However, there is no substantial change occurred for tube wells and their number is almost constant i.e. around one million. To popularize farm mechanization, the government always used the policy of subsidy by linking it with agriculture credit from banks at cheap rates. This policy proved very effective and brought mechanical horsepower to the agriculture sector of Pakistan. It also created incentives for the investors by creating a sustained demand in the market. Two big tractor manufacturers namely FIAT and Messy Ferguson got to hold in Pakistan and indigenized the technology by the names of Millet and Ghazi, respectively. They are producing over 60,000 tractors annually depending upon the demand and electricity availability. Sometimes governments announced special promotion schemes. For example, in 2011-12 because of such schemes around 71,000 tractor units were sold indigenously. Along with this several models and makes of tractors and other agriculture machinery items were also being imported to meet the specific needs of the farming community. This is still going on and the annual import value may be around the US $100 million. The agricultural machinery loaning scheme also played a vital role in bringing the combine harvester to Pakistan in the 1980s. Because of that presently major portion of wheat and rice are harvested by machines. However, in recent years no addition of new machines have been added and import policy for old machines as scrap flooded the market with low-quality machines thus causing loss to farms and the country. For the local production government, farm machinery institutes played a very important role in developing local variants of farm implements for manufacturing by local industry. Quality of the machinery remained however a problem for the farmers because of the no quality standards and checks by the government and the poor affordability of the farmers.

The agriculture is a provincial subject in Pakistan. The above policy review however shows that the policy, planning and coordination function of the agriculture sector is rest with the federal government. Provincial governments have a major role in the execution and implementation of plans and policies within the national framework guided by the federal government in consultation with the provincial stakeholders.

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Chapter 7

Agricultural Marketing: Problems and Possible Solution

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Abstract

Marketing of agricultural produce begins on the farm, with the planning of production to meet the specific demands and market prospects, and is completed with the sale of fresh and processed agricultural products to end users. It includes the timely supply of essential farm inputs to farmers at reasonable prices as well. In Pakistan, both the private and public sectors are involved in the marketing of farm produce. Private sector enterprises operate freely in buying and selling agricultural commodities. Government intervenes in the marketing system through fixation of floor prices, procurement quotas, and prices, export quotas, regulation and control of markets, etc. Lack of market intelligence, insufficient infrastructure, the exaggerated role of middlemen, adulteration, hoarding and profiteering, remoteness from the market, excessive rates of various services, collusion amongst traders to suppress prices, etc. are the major pitfalls in agricultural marketing. Moreover, the meager marketable surplus of small farmers tied with their weak financial position makes it difficult for them to withhold the produce for better prices. In consequence, farmers in Pakistan get 65% of the consumer price for their non-perishable commodities and 25-55% for perishables commodities. The role of middlemen acting as a link between producers and consumers is very complex and needs in-depth analysis before concluding. An efficient marketing system, ensuring the availability of quality inputs and outputs at the desired place, at right time, and in the suitable form, is direly.

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7.1. Introduction

Marketing is referred to as a total system of inter-acting all the business activities, to plan, price, promote, distribute, and satisfy foods and services to household consumers and industrial users (Armstrong et al. 2014). Marketing of agricultural produce begins on the farm, with the planning of production, to meet the specific demands and market prospects, and is completed with the sale of fresh and processed agricultural products to consumers (or to manufacturers in the case of raw materials to industry). It also includes the timely supply of essential farm inputs to farmers at reasonable prices.

The agricultural marketing system in Pakistan is fairly diversified. Both the private and public sectors are involved in the marketing of farm produce. Private sector enterprises operate freely in buying and selling many agricultural commodities. The farmers bring their produce to the markets themselves or through market intermediaries where buying and selling of these commodities take place on the demand and supply equation (personnel observation). Government intervenes in the marketing system through fixation of floor prices, procurement quotas, and prices, export quotas, regulation and control of markets, etc.

The subject of agricultural marketing is entrusted to the provincial governments in Pakistan. However, some of the institutes related to agricultural marketing operate at the federal level whereas others function at the provincial level. At the federal level, Agricultural Policy Institute (API) previously known as Agricultural Prices Commission (APCom) formulates agricultural policies including those on agricultural prices and marketing. Quality and grading assurance in the domestic markets is a concern of the Department of Agricultural and Livestock Product Marketing and Grading (DALPMG). This department provides advisory services to the Federal Government on all matters relating to agricultural marketing in the country. It also guides the provinces on marketing and coordinates provincial activities at the national level. Similarly, Pakistan Horticultural Development and Export Board (PHDEB) is the supreme institute that deals with the issues related to export, particularly for horticultural products.

At the provincial level, especially in Punjab, agricultural marketing is managed by the Directorate of Agricultural Marketing working under the Ministry of Agricultural Marketing. Pakistan Agricultural Storage and Services Corporation (PASSCO) and Food Departments are apex bodies and procure many agricultural commodities especially staple foodstuff like wheat. In addition, Punjab Government has established the Punjab Agricultural Marketing Company (PAMCO) which works on a Public-Private joint initiative and is entrusted with the task to enhance storage, processing and transportation facilities in Punjab. The Punjab Institute of Agricultural Marketing (PIAM) has also been established for training the stakeholders and suggesting policy recommendations for improving the agricultural marketing system in the province.

In Punjab, the existing scenario is managed under two legal documents. Punjab Agricultural Produce Market Act 2006 under which market committees control the working and management of wholesale markets, whereas grading and quality certification in the domestic markets is legally controlled under Punjab Agricultural Produce Grading and Marking Act 1972 (Baddar and Mustafa 2008).

The potential of Pakistan's agriculture is much more than its existing status but the marketing inefficiencies like lack of market intelligence, insufficient infrastructure, the exaggerated role of middlemen, adulteration, hoarding and profiteering, excessive rates of various services, collusion amongst traders to suppress prices, and mismanagement of input and output markets are the main shortfalls which leave a small amount of marketable surplus. The meager marketable surplus of small farmers together with their weak financial position makes it difficult for them to withhold the produce for better prices. Likewise, the remoteness of the organized markets generally influences farmers' decision to sell locally at comparatively low prices. It is estimated that producers of farm products in Pakistan get 65% of the consumer price for their non-perishable commodities and 25-55% for perishables commodities (Badar and Mustafa 2008). The role of middlemen acting as a link between producers and consumers is very complex and needs in-depth analysis before concluding. Middleman is the person who provides many services to farmers and on the other hand, he is considered one of the major "institution" exploiting farmers. It is assumed that middlemen get very high margins but their share is generally justified by considering the provision of additional services and risks, which they usually undertake at each stage of marketing. When judged in this context, the marketing structure for agricultural products may not be seen as necessarily exploitative and inefficient. It is very difficult to draw a line between the responsibilities of the middlemen and the government in the agricultural marketing system because the middlemen provide those services to the task entrusted with the government viz. provision of credit, over height stay in the minds, settlement of social disputes, etc. (Chau et al. 2009). The government must ensure a timely supply of credit and information to lessen the extra burden, otherwise imposed by middlemen upon farmers. The interests of small farmers should also be safeguarded by procuring their produce directly by the government, which will enable farmers to receive fair prices and safeguard them against advance purchases made by the commission agents.

An efficient marketing system means the availability of quality inputs and outputs at the desired place, at right time, and in the suitable form, which is not possible without strong infrastructure support, efficient transportation (especially for perishables), processing, grading and storage facilities. Generally, these physical marketing facilities lack in our country and agricultural products have to be handled for a considerable time by various marketing agencies before reaching ultimate consumers. Even in the case of non-perishable commodities like food grains, it is estimated that the entire marketed surplus passes into the trade channel in two to three months, coupled with a lack of suitable storage methods and the principles of good storage management, which increase post-harvest losses. Authentic market monitoring on regular basis is necessary for maintaining meaningful interaction between producers and consumers to ensure a smooth and effective flow of agricultural products. Farmers and all other stakeholders in the market should have accurate information about demand, supply, and market prices for all agricultural commodities. Pakistan lacks a strong monitoring network due to which irregular trends in the market arrive for many agricultural commodities at different times is noted (i.e., glut of one commodity at one time and shortage for the same at another time). To put the agricultural marketing system back on the right track, there is a need to undertake surveys for collecting information regarding all agricultural commodities (Tyagi et al. 2005).

The major problems of agricultural marketing system in Pakistan and their possible solutions are discussed in this chapter.

7.2. Marketing and Economic Development

Economic development tends to mean rapid growth improvement achieved "in decades rather than centuries" and is most commonly defined today (Kenen 2000). Economic development is generally understood as a mean increase in national production that results in an increased average per capita gross national product (GNP). An increase in average per capita GNP alone however is not sufficient to denote the implied or expected meaning of economic development. Besides an increase in average per capita GNP, most interpretations of the concept imply widespread distribution of income as well. The strategies of economic development among others include industrialization, which incidentally, is the fundamental objective of most developing countries. Certainly, most countries see "economic growth" with the achievement of social as well as economic goals which among others include the following: satisfaction of such non-material needs as better education for all, better and more effective government, the elimination of social inequalities; as well as improvements in moral and ethical responsibilities of both public and private sectors of the economy. To achieve the above objectives, naturally, one should be concerned with the basic institutions of industrial society in general and with the management of the business enterprise in particular. One cannot accomplish such activities without direct concern with marketing (Ifezue 2005).

Marketing directs the flow of goods and services from producer to consumer or user. There are various technical, economic, and commercial functions, which are performed to satisfy consumer demand and ensure supply. The marketing process re-allocates scarce resources, set signals for demand and supply, and guides future economic activities. Marketing has a mobilization as well as a coordination function, steering production and supply with respect to place, time, forms and ownership utilities. It can, therefore, be termed as an integral part of the entire productive function (Tsipouri et al. 2010).

7.3. Relationship between Production and Marketing

The scope of marketing extends beyond the usual channel from farms to consumers; it includes harvesting, assembling, processing and distribution of agricultural products and also various inputs by farmers. Agricultural production, the supply of farm inputs, and the marketing of farm products are, therefore, not separate but part and parcel of a continued productive process (Debertin 1986).

The agricultural marketing system is inter-connected with every other segment of the national economy through a circular flow of goods and services that are measured in national and product accounts. It is a part of a larger agricultural business complex, which has no well-defined bounds, because of the inter-dependence of many sectors of the economy and there are no precise criteria marking out the bounds of agricultural marketing.

7.4. Agricultural Marketing Problems

Typical problems faced by the small farmers in Pakistan in dealing with the marketing of their comparatively small quantities of produce are briefly discussed in the following lines. These problems are categorized as (i) Techno-economic problems; (ii) Natural problems; (iii) Socio-economic Problems; (iv) Financial problems.

7.4.1. Production Orientation

Pakistan is rich in fertile land, yet the land is being wasted in different ways. About 52.91 million acres of land is culture-able whereas 42.62 million acres is cultivated. Other land remains uncultivated (Table 7.1). The reason can be described in two points.

- A major area is owned by feudals. It is difficult to manage such a huge area so only that part is cultivated which is easy to manage, the rest is left ignored.
- The rise of industrialization has given a threat to this sector. People are migrating to cities and cities are expanding, thus fertile lands are being wasted by the construction of new towns and colonies.

Many farmers, especially small farmers (< 5 Acre), are traditionally production-oriented and adapt more slowly to changes in marketing (Kahan 2013). They produce crops or products that they have been producing traditionally for a long but this traditional way leads to low production. Naturally, they try to find markets for them only when the changing or changed market structure requires improved or entirely different produce. It is essential that the marketing of produce be considered along with production planning. This is particularly relevant for highly perishable products such as fruits and vegetables where variety, quality and timings of supplies matter much. The attitude that the market already exists or of thinking about marketing only when the produce is ready to market leads to failures in marketing that cause frustration among farmers and ultimately adversely affect the rural development programs. Table 13.1 shows the land utilization of farm area reported in the latest census of agriculture 2010. It is shown that about 20 percent of farm area is still uncultivated.

7.4.2. Storage Capacity

Pakistan is facing grain storage problems at a large scale throughout the country, due to either traditional methods of seed storage or short commercial grain storage and their management. The people often store their grains in *godowns* due to protection from hidden enemies like birds, rats, and insect pests, which cause the time to time damage to the seed (Table 7.2). Some storage problems result in an increasing number of dormant seeds, sprouting, molding and rotting, and an increase in insect damage and bird contamination. However, chemical and biological changes like loss of germination, development of acidity, gluten deterioration and loss of nutritive quality may also occur. These storage problems are given below:

- Low capacity stores.
- Use of local Mud bins for storage.
- Un-cleaned and filthy store houses.
- Improper ventilation, leaky and dampness in store houses.
- Inconvenient storage (with broken walls, ceilings and floors).
- Un-proof store houses to insect pests, rodents and birds.
- Stores are un-proof to gas.
- Improper spray and fumigation to store houses.
- Use of old gunny bags.
- Seed storage in open bulks and heaps.
- Hazards such as rains and floods.
- Insect nest and disease problems in store houses.
- High temperature and humidity problems in stores.
- Storing seeds with high impurities (including inert matter, dead bodies of insects and fungus).
- Unhygienic conditions of stores.
- Unaffordability; for private farmers it is the main problem as more than 90% of farmers are smallholders.

Table 7.1 Land utilization of farm area in Pakistan (Million acres)

Area Distribution	Farm Area
Total Farm Area	52.91
Total Cultivated Farm Area	42.62
Uncultivated Farm Area	10.29
Culture-able Waste Area	8.88
Un Culture-able Including Forests	1.41

Source: Census of Agriculture (2010)

Table 7.2 Permanent and temporary storage options in Pakistan

Storage System	Bag System	Bulk System
Permanent storage facilities	Standard warehouses (shed type godowns) *Ganjis* (outdoor storage with bags stacked on plinths and covered by tarpaulins)	Concrete silos Steel silos, Bulk warehouses Open bulkheads (grain held outdoors between prefabricated steel walls and covered with PVC sheeting)
Temporary storage facilities	Flexible containers (cocoons) (airtight, unsupported rectangular structures made of lightweight ultraviolet-resistant PVC)	Silo bags (heavyweight plastic tubes, usually about 8–12 feet [2.4–3.6 m] in diameter and of variable length)

Source: FAO (2013)

About 65-75% of the total wheat produced in Pakistan is stored at the farm. Smaller farms generally keep more grains for consumption, so the quantity of wheat entering commercial channels from farms of up to 4.5 ha is insignificant. The breakdown of stocks held by various public and private sector actors from 2007/08 to 2009/10 is given in Table 7.3.

Table 7.3 Grain storage by the public and private sectors in Pakistan

Public/Private sectors	Million tones	Percentage of average wheat stored
Government procurement	5.23	30.00
Retained for seed (farmers, seed companies)	0.83	4.75
Stored at farm for own consumption	5.08	29.14
Stored by flour millers as buffer stocks	3.31	19.00
Stored by large farmers (≥ 20 ha) and private traders	2.98	17.10
Total	17.42	100.00

Source: FAO (2013)

Table 7.4 shows the storage capacity of public sector storage houses, it is 5.23 million tons out of which Punjab Food Department occupies 2.45 million tons; 0.71 million tons with the Sindh Food Department; 0.16 million tons with the KPK; 0.58 million tons with the Balochistan Food Department; and 1.3 million tons with PASSCO (FAO 2013).

Table 7.4 Public sector storage capacities in Pakistan

Agency	Million tons	Percent
PASSCO	1.3	25.0
Punjab Food Department	2.45	47.1
Sindh Food Department	0.71	13.7
KPK Food Department	0.16	3.1
Balochistan Food Department	0.58	11.2
Public sector total	5.2	100.0

Source: FAO (2013)

Shortage of storage houses creates the time utilities and losses are sustained by storing produce in open sub-standard stores. The total storage capacity with the government for food grains at present is unable to handle the volume of production and private storage costs an extra price. Due to a lack of financial reserve, the small farmers have to sell their produce at harvest time or a little after it; as a result, they do not receive a fair price. It is estimated that producers will get 10 to 15% more returns, if necessary, storage facilities with credits are provided. This will result in a better standard of living for producers and better investment power for productive farming.

7.4.3. Fraudulent Practices

Some of the fraudulent practices are, "*Arhtya*" and "*Dalal*" acting for both buyers and sellers, settlement under the case, false weighing and a variety of charges. The growers have no voice in the regularization of various fees charged to them. Many of the illegal dues are deducted. Excess weights are also in vogue in various markets. Illegal deductions are also made especially from fruits and vegetables. These obstacles are almost prevalent all over the markets, which reduces the grower's outcomes.

The rates charged by the *arthi* demonstrate that there is money to be made in agriculture lending to small and medium farmers. With operational costs at less than 2.5% of the total volume of lending, nominal write-offs and interest rates ranging between 62% and 80%, profit margins for the *arthi* are quite significant. In addition to earning from the credit, the *arthi* also earns commission from the sale of the produce of his borrower, calculated as a percentage of the sale price of the produce ranging from 2 to 4% depending upon the crop and his terms with the client (Haq et al. 2013).

7.4.4. Price Instability

Due to the seasonal nature of agricultural commodities, instability condition prevails in their market prices, and it is very difficult to regulate them according to the demand due to various physical, technical and market uncertainties (Trostle 2010). Seasonal price fluctuations are severe in developing countries because most growers are compelled to sell their produce immediately after or even before harvest to meet essential living expenses or to repay their debts. Clearly, a price guarantee can exercise its effect on production only to extent that the prices are actually received by the producers, the condition which is not always fulfilled. Figure 8.1 shows the price instability of major agricultural commodities. It is clear from the figure that cotton and rice, the main exporting commodities showed more variation in prices than other crops.

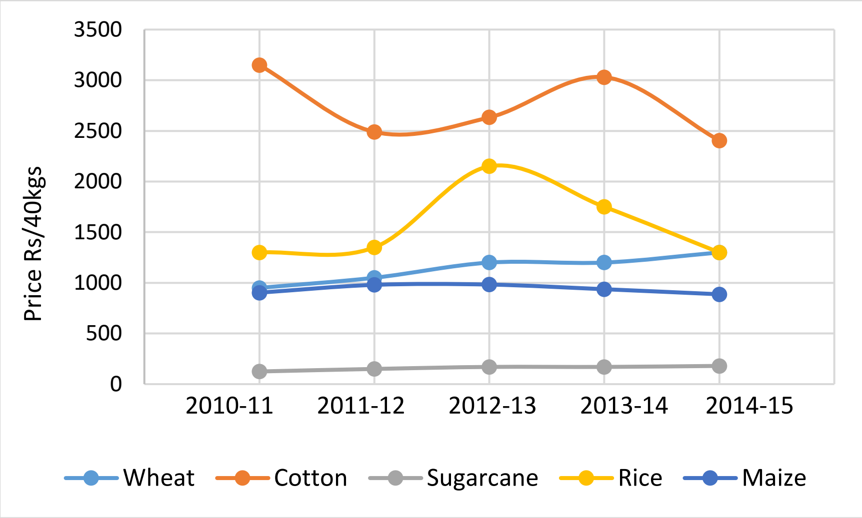

Figure 7.1 Trend in price of major commodities from 2010-2015
Source: AMIS (2015)

7.4.5. Small Marketable Surplus

A serious marketing problem for small farmers is their small marketable surplus. Mostly, he is unable to produce sufficient grains for the consumption of his own family or has only a small surplus to sell. However, for fruits, vegetables, livestock and livestock products greater marketable surplus is available with the farmer but still, this is not sufficient for efficient and effective marketing. The farmer may produce cash crops for the market such as sugarcane, tobacco, oilseeds, etc. however the quantity harvested from his small landholding, is still too small. For effective marketing, the scale of the economy is a critical element. A small marketable surplus implies a weaker basis to bargain with assembly merchants or wholesalers. Direct marketing by small farmers thus becomes impracticable because of high marketing costs. Therefore, small farmers have to depend traditionally on village assembly traders or itinerant merchants to market the produce. Even when the farmers are aware of an opportunity of getting a better price by selling their produce somewhere else, the traditional “customer relationship” established with certain other traders, prohibits the farmers from seeking a more advantageous alternative opportunity.

7.4.6. Inefficient Produce Preparation

Partly due to the small marketable surplus and partly due to lack of awareness, the inefficient marketing practices employed by the small farmers result in higher post-harvest losses, higher marketing costs, and lower prices. Further, fruits and vegetables packed in larger straw baskets or larger jute bags and transported by bullock carts on bumpy roads are subject to a physical loss of 20-40% by the time they reach the market (Hanif et al. 2004). Efficient methods for harvesting, sorting, grading, storage and packaging are essential. Without such efficient methods, the small farmers are bound to receive lower prices resulting in their weak competitive position.

7.4.7. Ineffective Rural Assembly Markets

At various places in Pakistan, periodic (weekly) rural markets are held which are mostly patronized, per force by circumstances, by small farmers. Such markets serve as assembly points that are linked with large secondary markets or urban wholesale markets. Some larger farmers with larger marketable surpluses bypass the rural periodic markets.

The small farmers remain the main users of rural markets, both for disposing of their small marketable surpluses to meet immediate cash requirements as well as for procuring daily necessities such as clothing, salt, shoes and other consumer items. In most cases, these markets are owned and managed by local authorities or by private contractors. The itinerant merchants and assembly traders also visit these rural markets to obtain small farmers’ produce at cheaper rates and selling it at remunerative prices in the secondary or urban wholesale markets.

Most rural markets have no marketing facilities such as storage and many do not even have shelters. Malpractices such as under-weighing, dubious sale and weighing practices are freely used against the interests of the farmer-sellers. Towards the end of the day, the bargaining power of the farmers becomes weaker as the market turns into a “buyer market”. The market authorities controlling these markets do not bother about the malpractices rampant in these markets. They are only interested to collect the market fees.

7.4.8. Skewed Distribution of Land Ownership

One common feature of our agriculture is the high concentration of landed wealth (70%) is controlled by 5% of landowners. The bottom 20% of households receive about 5% of the total income while the top 20% receive more than half of the total income (Table 7.5). On account of 70% of the small farmers, their marketable surplus is quite less, and the small farmers are not in a strong bargaining position and therefore, cannot influence the price structure. According to the Census of

Agriculture (2010), there are 8.3 million farms in Pakistan of which more than 96% of farms have landholding less than 25 acres. This small farmer predominance is very alarming because small farmers face a lot of hurdles to market their agricultural produce.

Table 7.5 Percentage distribution of farms

Farm Size (Acres)	Percent of Total Farms
Under 5	64.7
5 to under 12.5	28.8
12.5 to under 25	6.8
25 to under 50	2.6
50 to under 150	1.0
150 and above	0.2

Source: Federal Bureau of Statistics (2015)

7.4.9. Inadequate Communication and Transportation Facilities

The main physical infrastructure in a country is transport and communication (Soneta 2010). The transport in Pakistan included roads, railways, ports and communication networks consisting of postal services, telecommunications, etc. The development of a country's transport system is a pre-requisite to its economic growth. There is a close relationship between transport communication and the level of economic activity. Economic development requires a highly organized system of transport and communications. A planned and organized system of transport and communication is one of the indications of a country's development. If we economically compare advanced countries with backward countries, we will find a better system of transport and communication in advanced countries, while traffic jams and other irregularities are in the system of transport and communication in a backward country. Our economic development is conditional on a strong network of transport and communication.

Road transport in industrialized, developing and transition economics continues to grow at 1.5 to 2.0 times the growth of GDP. This is significantly higher than the rate of growth of the government's tax revenue; thus, making it increasingly difficult for governments to fullfil the finance needs of the road sector maintenance, upgrading, modernization of outdated networks, and expansion through the consolidated fund. At the same time, countries all over the world are realizing that roads are big business. Some transportation problems are given as:

- The transports are generally late, and passengers are finding inconvenience.
- Pakistan's transport is operating on a single track system while the double-track system is limited in rural areas.

- Railway organization is over-staffed, which is a financial burden and affects the position of the railway.
- Pilferage of goods in transit has become a common feature. Due to dishonesty railways has to pay compensation in thousands.
- Corruption and misutilisation of funds have also affected transportation development projects.
- The wages paid to workers are low. The majority of workers live from hand to mouth.
- Inadequate facilities have been provided to passengers.
- There is a shortage of funds to start development projects and to provide facilities to passengers.
- Road infrastructure is of low quality.
- High fuel consumption.
- Lack of well-equipped containers.

Although a lot of work has been done by developing roads from farm to market, yet there is an acute shortage of road networks and transport facilities especially, in rural areas.

7.4.10. Lack of Marketing Extension Service

Of various agricultural marketing problems, the most critical one is the lack of marketing extension service. Although crop production extension services do exist at the village and farm level to a certain degree, but marketing extension work designed to provide guidance to small farmers particularly, is non-existent. To establish and strengthen field-level marketing, extension service is an important priority area so as to make government efforts in effective marketing at the village level and to provide direct benefit to the small farmers.

There are many questions which extension workers are feeling problems to answer, such as:

- How do prices vary across seasons?
- From where we can search for technical support?
- What is the quality of inputs sold?
- Where can we look for credit support? What are the conditions attached to the credit?
- What is the price trend of the crop which the group is going to cultivate?
- What is the potential profit of cultivating one product unit?
- Who are the competitors? What are their strengths and weaknesses?
- What is the price which target buyers can pay?
- Who will insure our produce in contrast to any natural calamity?
- What are the factors responsible for price variation?

7.4.11. Credits availability

Zari Taraqiati Bank Limited (ZTBL) and commercial banking institutions are the two main sources to obtain credits by farmers for various agricultural operations for completing a number of formalities against acceptable collaterals. In principle, such loans are available to small farmers as well. But in practice, it is pretty difficult for them to obtain the required loan on time with the result that small farmers are unable to bring any improvement in their operations and ultimately enhance their countervailing power and incomes. The two main loan-giving agencies indicated above, perhaps have no provision in their respective charters to advance marketing loans. Thus, the farmers, in particular, the small ones, make dealings with the commission agents and wholesalers to obtain the marketing credits from them usually on terms unfavorable to the farmers. Large farmers, however, have access to marketing loans from commercial banks as well. Table 7.6 shows the agricultural finance flow and target achieved during the years 2013-14 and 2014-15. The main supplier in finance flow is ZTBL. Five Commercial banks (e.g., HBL, NBP, MCB, UBL, and ABL) provide more than 50% of agricultural finance to the farmers.

Table 7.6 Supply of agricultural credit by institutions (Rs in billions)

Banks	Target 2013-14	2013-14 (Jul-Mar)			Target 2014-15	2014-15 (Jul-Mar)		
		Flow	Achieved (%)	Share in total (%)		Flow	Achieved (%)	Share in total (%)
5 Major Commercial Banks	188.0	133.5	71.0	52.2	252.5	167.4	66.3	51.3
ZTBL	69.5	45.9	66.0	17.9	90.0	56.2	62.4	17.2
DPBs (15)	90.4	54.2	60.0	21.2	115.6	72.1	62.4	22.1
PPCBL	10.0	5.4	54.5	2.1	11.5	5.9	50.9	1.8
MFBs (7)	21.6	16.2	75.1	6.3	28.2	20.7	73.6	6.3
Islamic Banks (4)	0.5	0.5	94.6	0.2	2.3	3.7	162.2	1.1
Total	380.0	255.7	67.3	100.0	500.0	326.0	65.2	100.0

Source: *Govt. of Pakistan (2015a)*

Haq et al. (2013) concluded that informal sources of credit like the *arthis* still dominate the agriculture finance landscape in Pakistan. This is not because the farmers, at least in the irrigated heartland of Punjab, do not have access to formal financial institutions like banks. All farmers met during this study had bank accounts and many had at least one experience of borrowing from either a public or private bank. The issue seems to be that of appropriate products and processes: the informal lender remains the most convenient and flexible source of finance for the farmer. Despite charging rates of interest that range anywhere between 70 to over 100% compared to the banks' rates of 12 to 18%, the farmer chooses to deal with the *arthi*. Any serious attempt on channeling bank finance to the farmer, especially the small and medium farmer, needs to learn from the *arthi*. This study has attempted to provide such information.

7.4.12. Lack of group action

For obtaining more economic benefits, group action is a critical factor in successful small farmers' marketing. In Pakistan, small farmers can become members of primary agricultural co-operatives, although many such co-operatives are no more active. The most common function performed by these co-operatives is to act as agents of agricultural credit, fertilizer, and other inputs-providing institutions or government food/cash crops procurement agencies. Unfortunately, in Pakistan, the cooperative effort has not been successful in the agricultural field due to various reasons. Traditionally, farmers have no hesitation in joining group action for various socio-religious activities or for various crop production operations such as labor-sharing in planting and harvesting. But when it comes to economic functions such as marketing, it is not much encouraging where group action should be better understood by its members and management should be relatively more "sophisticated". Distrust among farmers, distrust of the management group, and lack of managerial skill and technical know-how of marketing, all together make group action in marketing a bit difficult.

7.4.13. Lack of vertical co-ordination of marketing channels

The success of small farmers' marketing depends on the degree of vertical "coordination in the marketing channels". Some marketing functions often focus only on one link of the marketing system, therefore, such un-coordinated marketing channels are a great constraint on small farmers' development (Figure 7.2). It is important to involve "channel captains"; often the wholesalers and assembly traders also induce them to orient their marketing strategies to small farmers' development.

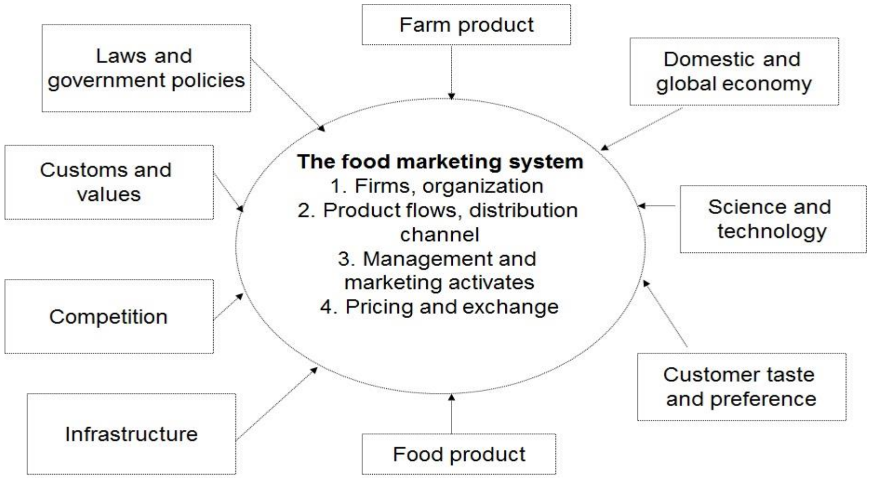

Figure 7.2 Channels of distribution in food processing marketing system

7.5. Possible Solutions

7.5.1. Creation of a Market Authority

A marketing authority should be created in all provinces as well as at the federal level. The provincial authorities should be made responsible for making overall marketing improvements within their own jurisdiction while the federal authority shall be primarily responsible for export marketing. In its advisory role, it shall have close liaison with the provincial authorities. While creating such an authority both at the federal and provincial levels, the desirability of involving the private sector may also be examined. This marketing authority may be an autonomous body quite distinct from the existing government marketing department/cells. For working out the necessary details of composition, constitution, functions, etc. an expert group shall have to be formed. Presently, there are 244 agricultural wholesale markets in Punjab, for grains, fruits and vegetables. Additionally, there are also 81 feeder markets to feed the main agriculture produce markets as shown in Table 7.7.

Table 7.7 Markets in Punjab, Pakistan

Type of Market	**Numbers**
Grain Markets	149
Fruits and Vegetable Markets	95
Feeder Markets	81
Total	325

Source: Govt. of Pakistan (2015a)

Unlike at present (when the marketing staff is working under the provincial agricultural directorates (Figure 7.3), although it has to deal with the marketing of livestock products, and is also used for agricultural extension work resulting in less effective role to handle the purely marketing problems), the agricultural marketing directorates in the provinces should have a specific entity. Their functions must include:

i. Marketing surveys.
ii. Marketing intelligence service.
iii. Grading for internal consumption and trade.
iv. Regulation of commodity markets.

7.5.1.1. Duties of the market committee

1) The market committee shall enforce the provisions of the ordinance and the rules (and by-laws) made thereunder in the approved market area. Therefore, the government shall establish a market therein providing such

facilities for persons visiting it in connection with the purchase, sale, storage, weighing, pressing and processing of agricultural produce.

2) Subject to such rules that government may make on this behalf, the market committee shall issue licenses to brokers, weigh men, measurers, surveyors, warehousemen, changers, *palledars*, *boriotas*, *tolas*, *tokrewalas* and *rehriwalas* for carrying on their occupation in the market area in respect of agricultural produce and to renew, suspend or cancel such licenses.

3) No broker, weigh man, measurer, surveyor, warehouseman, changer, *palledar*, *boriota*, *tola*, *tokrewala* and *rehriwala* is allowed to carry on his occupation in a notified market area in respect of agriculture produce unless duly authorized by a license (Govt. of Pakistan 2015b).

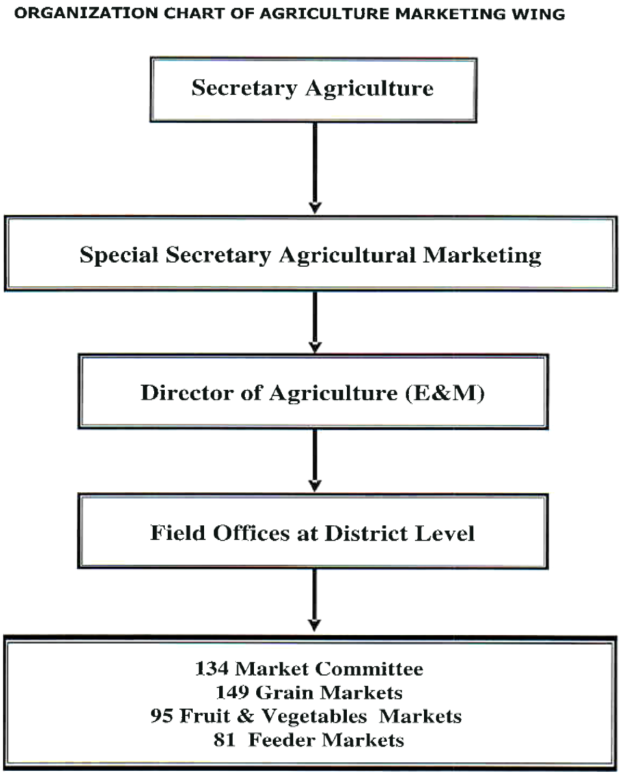

Figure 7.3 Organization chart of agricultural marketing wing
Source: Govt. of Pakistan (2015b)

7.5.1.2. How the commodity market works

The basic objective of the agriculture commodity markets is to facilitate the farmers by providing a platform to sell their agricultural produce at a fair price. The commodity markets of Pakistan especially in Punjab and Sindh provinces are spread across the province with an average distance of about 30-50 km between each market. One market can have more than 100 *arthis* doing business in it while there are more than 250 *arthis* working in the large markets (Haq et al. 2013). There is a whole range of players that come together in the market (called a *mandi* locally) (Figure 7.4), the key ones being:

- **Farmers:** A large number of farmers directly market their produce at the *mandi*. However, the majority of marginal farmers (< 5 acres of holdings) sell their produce through the *beopari* (village dealer). Moreover, some large farmers (having > 25 acres of holdings) make direct bulk supply to downstream industry and traders/exporters.
- ***Kacha Arthi* (commission agent):** The farmer has only two cash inflows during a year because there are two cropping cycles annually. The *kacha arthi* acts as the farmer's bank: in dry periods he relies on the *arthi* for funds to meet his day-to-day expenses and more particularly to purchase agriculture inputs (Aftab 2007). This advance or credit account is then settled when the farmer's crop materializes. The farmer is bound to sell his crop at the *arthi's* shop. The *arthi* does not take the title of the produce and only arranges auctions for the sale of the farmer's produce brought into the market. The *arthi* will deduct the agreed farmer or retain it for the farmer to withdraw on a need basis. The *kacha arhti* is thus the central point for the farmer and he maintains relationships with other players such as the *pukka arthi* and input dealers on terms and conditions that often the farmer is not privy to. It is thus upon the kacha *arhti* to fulfill the farmer's credit needs in cash or kind.
- ***Pukka Arthi* (wholesaler):** He is an important market intermediary. He often purchases in bulk either for storage (sale in later at higher prices) or supplies directly to the processing industries, mills, traders and exporters at some margin on prices. He may himself be a mill owner or in some cases take the role of an exporter, supplying international buyers. He may also borrow from formal or informal sources.
- ***Beopari* (village level trader):** This is an important village level intermediary for making small-scale purchases and sale of agriculture commodities. He buys from the farmer in the village and either directly sale to the processing unit or takes the produce into the *mandi* and sells it through a *kacha arthi* to the *pukka arthi*. He uses either his own or the factory owner's/*kacha arthi's* capital. He also advances inputs on credit to farmers and binds the recovery with the purchase of produce.
- **Broker:** He does not take title to the produce but takes responsibility for selling the produce. He usually acts as an agent of the *pukka arthi* or the processing industry/mill. He usually charges a commission for his services.
- ***Palledars* (labor):** These workers are associated with the *kacha arthi* and usually offer their services to farmers and *pukka arthis*. Their main services are loading, unloading, weighing, etc. and are paid by both the farmer and the *pukka arthi*. They also form their own elected associations in the market.
- ***Dallal* (auctioneer):** Dalal (licensed by the market committee) manages the auction process and takes his fee from the *kacha arthi*, who in turn deducts it from the farmer's sale revenue.

- **Input dealers:** They operate either in the market or the area adjacent to the market. Depending upon how his *arthi* operates the farmer may either purchase inputs directly from an input dealer who in turn has a contract with the farmer's *arthi* or the farmer buys directly from the input dealers on credit or cash.

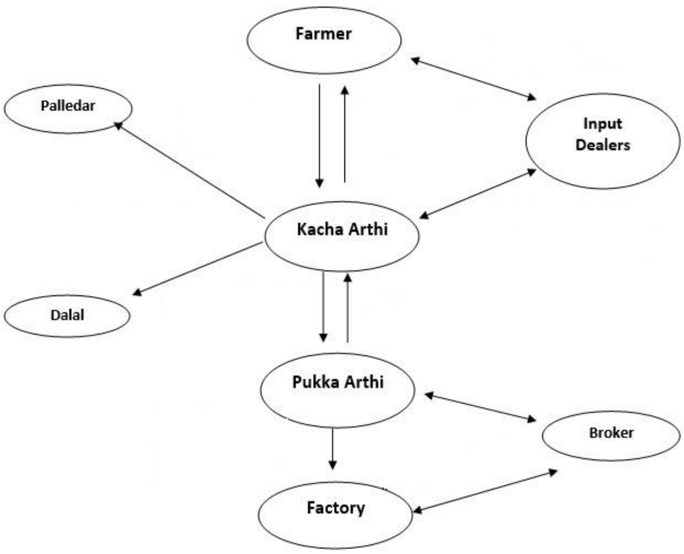

Figure 7.4 Agricultural Market Actors and their Roles
Source: Haq at al. (2013)

7.5.2. Marketing Boards for Agricultural Commodities

As the growers at present are not getting a fair deal in selling their produce through the wholesalers/commission agents, there is a need for creating alternate agencies like a marketing board with the active participation of growers to provide healthy competition to the existing market intermediaries.

7.5.3. Regulation of Wholesale Markets

In order to save the growers from exploitation by the commission agents and other market functionaries, the element of regulation of agricultural wholesale markets has been introduced. But the objective has not been achieved due to various reasons. It is, therefore, suggested that the working of the existing regulated markets be improved, and new ones are established with the proper control to minimize the market functionaries' exploitative role.

7.5.4. Network of Storages

A network of storage, at the focal points in the producing areas, is considered a sine-qua-non for the linkage of credit with marketing. A warehousing corporation should be established which may, under a phased program, set up storage across the country, with credit facilities against stock stored. The proposed storage program being capital-intensified, participation of commercial banks, ZTBL, and other loan-giving institutions shall have to be sought. Some precautionary measures for safe storage are:

- The seed to be stored should be sound, healthy and free of the trash.
- Store house should be in such a place where grains remain safe from insect pests, rats and humidity.
- The proper ventilation for air crossing should be maintained in store houses.
- The seed and storage area should be kept dry before use.
- The storage area should be safe from rain.
- Pest control must be ensured at an adequate level.
- Use of rodent and bird-proof *godowns* having controlled ventilation, high plinth and leakage-free floors, doors and windows should be encouraged.
- The slope should be given to the floors of the store for removal of water.
- The bags should be kept on the raised floor or high plinth of the stores. The bags should not come in direct contact with the floor which may damage the seed.
- The spray and fumigation of the storehouses should be done well before grain storage. Before storage of grain, the *godown* must be disinfected by spraying Malathion (50% EC).
- The wheat grains stored in bins and bags should be added with neem leaves as natural repellant, which must be dried first under shade before use.
- The stores should be provided with electricity, offices and staff facilities.
- There should be an adequate capacity for storage so that there is not any hypocrisy or ill-mannered act of store keepers or management.
- Store houses should be proper and provided with the latest technology, so that there is not any issue regarding food safety and security that causes the low export quality of grains.

7.5.5. Farm Services Centers

The concept of the farm service centers is based on giving a package deal in respect of various services to the farmer under one umbrella. The establishment of such centers in the rural areas may provide the facilities of storage, credit, small processing units, purchase of inputs like fertilizers, pesticides, diesel oil and repair of agricultural machinery of the farmers. Arrangements for the sale of farm produce through these centers may also be made.

7.5.6. Farm to Market Roads and Transportation

Due to the absence of village to *mandi* link roads, appreciable quantities just cannot reach the market and goes waste in the rural areas. It is, therefore, necessary that high priority should be given to the construction of these roads. Other difficulties (e.g., non-availability of refrigerated vans on railways for perishable commodities, delay in availability of wagons for other commodities) also need to be removed. There are some suggestions for the improvement of the transportation system:

- For easy and quick transportation, there should be a double track system.
- Efficient and hardworking employees should be selected because our present employees are generally inefficient as the selection is made on a kinship basis.
- To attract technical persons and qualified people, high wages should be offered.
- There should be control on corruption, misutilization of funds and leakage of revenue.
- There should be a provision of high-tech containers, andtrucks for proper transportation on lease by commercial banks.

7.5.7. Marketing Information System

It needs no emphasis that an efficient marketing information service can greatly help in dispatching of produce more profitably. Besides, it also assists the farmers in planning their production program. It shall also provide dependable statistics on prices and also other market information to the planners, research workers and decision-making authorities. Presently market information services provided at the federal level or by the provinces are by no means adequate. These need to be broad-based. For this purpose, adequate staff and other facilities such as telex, small printing and photo-copying equipment, etc., should be provided to the market information collecting and disseminating agencies.

7.5.8. Provision of Marketing Credit

Institutional credit facilities for agricultural produce have so far been production oriented. Certain allocations are, however, made for marketing credit, which is generally made available to the trading concerns in the urban area. Such credit facilities do not in any way help the producers. The credit-giving agencies should, therefore, allocate separate funds for marketing at the primary level and see that the credit actually reaches the farmer’s doorsteps, particularly the small farmers.

7.5.9. Grading of Agricultural Commodities

Grading commodities greatly helps in improving the overall marketing efficiency. It also expands the total market even with a given quality by meeting various quality demands and satisfying a large number of consumers (Jayne et al. 2014). Presently, the federal agricultural marketing department is grading some 20 commodities for export on a compulsory basis. It requires more attention both for increasing the number of exportable commodities and the quality of performance of those already subjected to grading. As for grading for internal trading and consumption being the responsibility of the processors, is conspicuous by its absence as the processors have yet to start it. It needs to be taken up urgently.

7.5.10. Farmers Organizations/Cooperatives

The farmers are generally unorganized and largely depend on the market functionaries for the sale of their produce (Minot and Roy 2007). Some efforts were made in the past for organizing the farmers into cooperative societies. But the success of these co-operatives has been by no means encouraging for various reasons which may be identified, and necessary steps should be taken to get the farmer's cooperative effort to succeed. According to the marketing wizards, co-operatives in Pakistan have failed but they must succeed. To make them viable, it is suggested to start with steps that may be taken for the formation of grower’s associations for making a collective effort in matters such as transport of produce from farm to market, storage and primary processing, etc.

7.5.11. Trained Marketing Personnel

There is a dearth of qualified and trained staff in the marketing field. It is, therefore, necessary that arrangements should be made for undertaking marketing research and imparting training to marketing personnel.

7.5.12. Retail Marketing Cooperation

A retail marketing corporation with commercial talent may be established for setting up a chain of supermarkets and departmental stores. The working of the existing utility stores needs to be streamlined and more items of essential consumption should be brought under their purview.

7.5.13. Cold Storages

A chain of cold storage may be established for storing perishable commodities, including fruits, and vegetables.

7.5.14. Pricing and Export Policy

The pricing policy should aim at providing an adequate return on investment. The procurement/support prices of different crops may be announced one season earlier to elicit adequate production response from the farmers. There is a need for the timely announcement of the export policy, particularly for commodities the export of which is subject to quantitative restriction. The export market for various export commodities may be diversified as far as possible.

7.5.15. Re-structuring the Organizational Setup

Marketing improvements in Punjab may be made distinctly at three levels (i) policy (ii) managerial, and (iii) grass root/farm levels. At the policy level, it is necessary to formulate an effective medium-term policy on agricultural marketing under which various components of marketing programs and activities can be integrated and coordinated. At the managerial level, the management and technical capabilities of technical bodies, involved in the implementation of the marketing policies, should be improved to enable them to work more efficiently and economically.

While fulfilling the socio-economic objectives of government policies at the grass-root/farm level, the marketing policies and programs should assist farmers in selling their produce, purchasing their inputs, and raising their incomes. At this level, the effectiveness of government policies and programs often loses its impact; especially for those farmers whose marketable surplus is too small and least oriented to marketing requirements.

7.5.16. Specifics

i. Modern rice mills in the public sector should be set up at places where milling facilities are inadequate/non-existent.

ii. Sugarcane assignments to the grower by the sugar mills should be on a quality basis instead of an acreage basis. Late lifting of sugarcane by mills should be discouraged.

iii. Modern fire-proof *godowns* should be constructed at Multan and Karachi to provide proper protection to cotton during storage.

iv. Green belts for growing fruits and vegetables around big cities should be revived (which have since become extinct due to rapid urbanization) to increase their production and supply to the urban centers at reasonable prices.

v. Both floor and ceiling prices may be fixed for minor crops like potato, onion, chickpea, etc. to safeguard the interests of both the growers and consumers.

vi. For in-time input availability there should be no malpractice with input or its shortage by large seller's brokers.

vii. For better agriculture marketing, efficient input marketing should also be managed by government authorities. The only focus is on agriculture produce marketing. But the marketing problems start from the input marketing mechanism.

viii. Efforts should be made to export fruits and vegetables in semi-processed form and bulk.

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Chapter 8

Prospects of Crop Insurance in Pakistan

Sarfraz Hassan, Muhammad Siddique Javed and Asad Naseer♦

ABSTRACT

The rapidly increasing population and over-riding need of raising the living standard of the population necessitate that the agricultural economy should be on a well-built foothold. Agriculture in Pakistan's economy accounts for 20.9% of GDP, employs 43.5% of the labor force, and generates about 65% of export earnings, including processed agricultural exports. In the recent past, due to several economic, agronomic, and climatic factors, the performance of the agriculture sector has not progressed up to the mark in a good manner. The yield of most crops is either stagnant or declining. The low productivity accompanied by the high cost of production is causing huge losses to the farming community, particularly to small farmers. To safeguard the interest of small farmers, strong public policies and public-private partnerships in agriculture supply chains are needed. In Pakistan, the concept of crop insurance is debated for a long, but progress on it is very small. An effective crop insurance scheme may provide essential elements like high and sustainable income for agricultural development. Thus efforts are needed to strengthen the public-private partnership for providing the farmers with crop insurance.

Keywords: Agriculture, crop insurance, risks and uncertainties, productivity, Pakistan.

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8.1. Introduction

The predominance of the agriculture sector is usually one of the main characteristics of developing countries in the sense that agriculture is not only the largest contributor to the national income but also the major source of employment, raw material for the industrial sector, and foreign exchange earnings. It is also the provider of food grains especially for the growing urban population and for the generation of the investible surplus to finance development efforts (UN 2013).

Agriculture in Pakistan's economy accounts for 20.9% of GDP, employs 43.5% of the labor force, and generates about 65% of export earnings, including processed agricultural exports. Although its relative share in GDP has declined over the years due to diversification towards industry and infrastructure, the absolute share of agriculture has increased and it continues to remain the most important sector of the economy, as it is providing livelihood to about 65% of the rural population. Since the advent of the green revolution, agriculture has advanced rapidly and has maintained an average growth rate of well above 3% per year. But since 2007-08 the performance of the agriculture sector has been very poor and erratic, the average annual growth rate remained well below 3% and the sector experienced the growth rate of 0.2% in the year 2009-10, while crop sector has experienced even negative growth rates as shown in Table 8.1 (Govt. of Pakistan 2015a).

Table 8.1 Average annual growth rate of agriculture and its subsectors

Sector	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
Agriculture	3.5	0.2	2.0	3.6	2.7	2.7	2.9
Crops	5.2	-4.2	1.0	3.2	1.5	3.2	1.0
i) Important crops	8.4	-3.7	1.5	7.9	0.2	8.0	0.3
ii) Other crops	0.5	-7.2	2.3	-7.5	5.6	-5.4	1.1
iii) Cotton ginning	1.3	7.3	-8.5	13.8	-2.9	-1.3	7.4
Livestock	2.2	3.8	3.4	4.0	3.5	2.8	4.1
Forestry	2.6	-0.1	4.8	1.8	6.6	-6.7	3.2
Fishing	2.6	1.4	-15.2	3.8	0.7	1.0	5.8

Source: Govt. of Pakistan (2015a)

Another major shift within the agriculture sector is that the share of the livestock sector (56%) has surpassed the crop sector (40%) as shown in Table 8.2.

Table 8.2 Share of subsectors in Agricultural GDP

Sector	**Share in Agri. Value Addition**
Agriculture*	20.9%* = 100.0
Livestock	56.3%
Important Crops	26.6%
Wheat	10.0%
Cotton	7.1%
Rice	3.2%
Sugarcane	3.1%
Maize	2.1%
Other Crops	11.1%
Fishing Sector	2.1%
Forestry	2.0%

Source: Govt. of Pakistan (2015a)
**This share is in total GDP*

8.2. Agriculture: A Risky Business

Agricultural production is typically a risky business. Traditional agriculture was practiced meeting the subsistence of the farming community i.e., to fulfill the food, clothing, and shelter needs of the society. The risks in traditional agriculture were confined to climatic risks i.e., production/yield losses due to extreme climatic conditions like heavy rainfall, floods, windstorms, droughts, pests, and diseases to crops and livestock. Now traditional agriculture has been transformed into commercial agriculture or becomes a business. In this scenario, we need an integrated approach that can identify and quantify risks involved in agriculture supply chains. To access these risks and uncertainties involved in agriculture, Agriculture Risks Management Teams (ARMT) of the Agricultural Rural Development (ARD) department of the World Bank has developed a holistic approach to analyze and quantify the risks in the agriculture supply chain and it is named as Rapid Agriculture Supply Chain Risk Assessment (RapAgRisk). In the agriculture supply chain, there are different players and those are input suppliers, farmers, output traders, processors, transporters, and other service providers (Jaffee et al. 2010). Table 8.3 represents basic classifications of risk along with the examples that are involved in the agriculture supply chain. All these risks are not covered in crop insurance schemes in the world. The US Federal Crop Insurance Program (FCIP) is the only program that covers both yield and price loss for specific crops i.e., maize, wheat, and soybean.

Table 8.3 Categories of major risks in agricultural supply chain

Type of risk	Examples
Weather related risks	Periodic deficit and/or excess rainfall or temperature, hailstorms, strong winds.
Natural disasters (including extreme weather events)	Major floods and droughts, hurricanes, cyclones, typhoons, earthquakes, volcanic activity.
Biological and environmental risks	Crop and livestock pests and diseases, contamination related to poor sanitation, human contamination and illnesses, contamination affecting food safety, contamination and degradation of natural resources and environment, contamination and degradation of production processes and processing.
Market related risks	Changes in supply and/or demand that impact domestic and/or international prices of inputs and/or outputs, changes in market demands for quantity and/or quality attributes, changes in food safety requirements, changes in market demands for timing of product delivery, changes in enterprise/supply chain reputation and dependability.
Logistical and infrastructural risks	Changes in transport, communication, energy costs, degraded and/or undependable transport, communication, energy infrastructure, physical destruction, conflicts, labor disputes affecting transport, communications, energy infrastructure and services.
Management and operational risks	Poor management decisions in asset allocation and livelihood/enterprise selection, poor decision-making in use of inputs, poor quality control, forecast and planning errors, breakdowns in farm or firm equipment, use of outdated seeds, not prepared to change product, process, markets, inability to adapt to changes in cash and labor flows, etc.
Policy and institutional risks	Changing and/or uncertain monetary, fiscal and tax policies, changing and/or uncertain financial (credit, savings, insurance) policies, changing and/or uncertain regulatory and legal policies, and enforcement, changing and/or uncertain trade and market policies, changing and/or uncertain land policies and tenure system, governance related uncertainty (e.g. corruption), weak institutional capacity to implement regulatory mandates.

Source: Jaffee et al. (2010)

To manage agricultural risks, the farmers either adopt formal or informal strategies. Jaffee et al. (2010) further classified these formal and informal risk management strategies in the ex-ante (before the event) and ex-post (after the event) risk minimization actions, and these are presented in Table 8.4.

Table 8.4 Informal and formal risk management strategies in agriculture

Informal risk management strategies		
	Farm household (mitigating risk)	**Community-level (sharing risk)**
Ex-ante	Savings, Buffer stocks	Food crop sharing
	Enterprise diversification	Common property resource management
	Low risk, low return, cropping patterns	Social reciprocity
	Production techniques	Rotating savings/credit
Ex-post	Sale of assets	Sale of assets
	Reallocation of labor	Transfer from mutual support networks
	Reduced consumption	
	Borrowing form relatives	
Formal risk management measures		
	Market-based (share/transfer risk)	Publicly-provided (transfer-absorb risk)
Ex-ante	Contract marketing	Pest/disease management
	Financial hedging tools	Physical crop/food stocks
	Traditional agriculture insurance	Price guarantees or stabilization funds
	Weather index insurance	Input subsidies
	Contingent funds for disaster relief	Public agricultural insurance
Ex-post	Savings	Disaster assistance
	Credit	Social funds
		Cash transfers
		Waiver (cancellation) of crop loans

Source: Jaffee et al. (2010)

In the developing countries like Pakistan where majority of the farmers are small and they are already caught up in the vicious circle of low productivity and poverty, the agricultural risks are mostly managed by the informal strategies, which cannot provide protection against high risks that are caused by the extreme climatic events and severe pest and disease losses. So, in case of repeated and big losses, the farmer has to sell his productive assets i.e., livestock and even farmland.

A large proportion of the population in Asia including Pakistan is dependent on government ex-post disaster relief assistance programs. For this purpose, in Pakistan, National and Provincial Disaster Management Commissions are working since the 2005 earthquake. Under these commissions, relief, rescue, recovery and reconstruction operations were performed on many occasions e.g., Floods in 2010, 2012 and 2013.

In 2015, the farmers in Pakistan suffered huge losses due to low market prices, and low yield of crops due to disease and climatic factors. To compensate for the farmer's losses, the federal government along with the assistance of the provincial government has announced a historical *Kissan Package* worth Rs. 341 billion. The package includes immediate cash grants for rice and cotton farmers (Rs. 5000 per acre), cuts in fertilizer prices (Rs. 140 billion), and a government scheme to pay insurance premiums for the small farmers having land less than 12.5 acres.

In all, its aspects and relationships, agriculture is subjected to a considerable element of uncertainty. As a business enterprise, that is, as a system of production, distribution, and exchange, it is susceptible to all the social and economic uncertainties. Again, as a mode of living, it has to reckon with all the personal uncertainties arising from death, impairment of health of farmers through sickness and accident and also the inability of agricultural labor to effectively employ its labor power. On top of these, agriculture is especially susceptible to the physical uncertainties of nature. As it has direct and continuous contact with the forces of nature. Indeed, one of the important features that distinguish a farm as a business unit from a manufacturing plant or commercial enterprise is that the major operations and manufacturing have to be carried on in the open and the operator must be prepared to deal with what are known as "Acts of Allah (SWT)", that is, extreme weather conditions i.e. high rainfall, floods, fire, wind storms, hurricanes, droughts, etc. and biological and environmental risks i.e. pests and diseases to crops and livestock. These risks not only affect the crop production/yield directly but also affects the farmer's demand for farm inputs and its loan repayment capacity indirectly; thus, impacting the supply chain downstream (i.e. input supplier) and upstream players (i.e. the buyers and processors of agriculture products). Extreme weather conditions also create hindrances in transport, communication and energy supply. Consequently, all such uncertainties make agriculture a very risky enterprise.

The types of risks confronting farmers vary with the farming system and with climatological factors and the institutional setting. Nevertheless, agricultural risks seem to be prevalent throughout most parts of the world. They are particularly burdensome to small farmers in developing countries like Pakistan.

Over time in Pakistan, the number of farms is increasing while the farm size is decreasing. According to the Pakistan Census of Agriculture 1960, the total number of farms was 4.86 million. The fear of land reforms, on one hand, availability of tractors, tube well, and better seed and fertilizer (due to the green revolution) on the other hand forced the landlords to self-cultivation and eject tenants. So, the number of farms in Pakistan reduced to 4.07 million in 1980 showing a reduction of 16%. But since then, the number of farms is increasing. Now according to the Pakistan Census of Agriculture 2010, the total number of farms in Pakistan is 8.26 million, showing an increase of over 100% from 1980. As the number of farms is increasing, the farm size is decreasing. Currently, the small farmers in Pakistan constitute over 90% of the farming community. Information on the farm numbers in Pakistan is given in Table 8.5.

Table 8.5 Total number of farms (1960-2010)

Census Year	Total Farms	Index %
1960	3326217	100.00
1972	2375369	71.40
1980	2544417	76.50
1990	2957453	88.91
2000	3864167	116.17
2010	5254804	157.98

Source: Govt. of Pakistan (2015b)

The incidence of risk in farming is important to policymakers for three reasons.

1) Fluctuations in farm income and particularly the risk of catastrophic losses may pose welfare problems for rural people. For household operating small farms in developing countries, these losses can too easily translate into miserly and malnutrition. Poor farmers may lose their land in catastrophic years because of indebtedness to local money lenders.
2) Farmers are typically risk averse and seek to avoid risks through management practices. The average returns to their resources are reduced due to many agricultural risks. This not only reduces the average farm income but also leads to smaller supplies of riskier agricultural commodities. Important food or export crops and the curtailment of their production can affect the consumer's welfare directly, by reducing the foreign exchange earnings. It also leads to lower national income.
3) Farmers exposed to severe risks are more likely to default on bank loans, particularly in the years of natural catastrophes.

The terms "risk" and "uncertainty" are often used interchangeably but have different technical connotations. Knight (1921) first makes a distinction between these terms. According to him, in an uncertain environment, the possible outcomes and their respective probabilities are not known. However, in a risky environment, both the outcomes and their respective probabilities of occurrence are known. Some economists say that risks can be handled by insurance cover while uncertainty cannot be dealt with easily. Debertin (2012) said that it may be more appropriate to think of the risks and uncertainty continuum. At one end of the continuum lies the risky events and on the other end lies uncertain events. "Uncertainty" is subjective probability; "risk" is an objective probability. There is again a difference between the terms "risk" and "hazard". The former denotes the property subject to lose and the later refers to the factor, which causes loss.

Risk creates a direct cost to the farmers. It is the amount of income he forgoes on average in order to pursue strategies that reduce his risks to an acceptable level. Farmers in the risky agricultural environment have evolved several measures to deal with production risks. These measures have been observed with minor variations in several small farming systems in developing countries. Broadly, there are three principal ways of meeting or managing agricultural risks.

1. Risk avoidance
2. Risk prevention, which includes several measures for the management of agricultural risks. Especially these comprise:
    i. Traditional methods of handling risks
    ii. Spatial diversification
    iii. Tenancy and intercropping
3. Assuming the risk

8.3. Insurance

According to Alfred Manes, "the essence of insurance lies in the elimination of the uncertain risk of loss for the individual through the combination of a large number of similarly exposed individuals who each contribute, to a common fund, premium payments, sufficient to make good the loss caused to any one individual (Manes 1944)". The primary function and essentials of insurance are as follows:

1) The primary function of insurance is the elimination of the uncertain risk of loss for the individual.
2) The first essential condition for the insurance is that the risk must be uncertain, that is, accidental or fortuitous.
3) The second essential condition is that the uncertainty is to a large extent eliminated through the combination of a large number of similar risks.

Insurance in a more precise manner can be defined as "a social device which aims at reducing the uncertainty of loss through a combination of a large number of similar uncertainties and, through the use of accumulated funds, distributing funds and distributing the burden of loss, should there be any, over space and time" (Chaudhry and Aslam 1993).

8.3.1. Necessary Conditions for the Insurability of Agricultural Risks

To be insurable, a risk should satisfy the following basic conditions:

i. A risk must be one which, when considered in the aggregate, has some uniformity of behavior so that it is possible to measure and predict the probability of loss in the future.

ii. The peril should be one that cannot be willfully caused to occur without involving some sacrifices on the part of the insured. The insurance is not meant for earning profit by the ensured, it is a device for security against an "Act of Allah (SWT)".

iii. The loss following the risk should be large enough to cause a substantial reduction in the income or investment. In other words, the risk should be measurable in large numbers.

iv. The cost of insurance or premium should be within the means of the average farmer. In a country, where a great majority of farmers are poor and illiterate, the scope for farm insurance is limited unless the state is prepared to bear a substantial part of its cost.

v. There should be a psychological urge amongst the farmers for insuring their crops against possible risks and they should be mentally and technically capable of satisfying that urge.

The salient features of Pakistan's mandatory crop loan insurance scheme are as follows as documented by the State Bank of Pakistan (SBP 2008).

i. ***Participation:*** All commercial and private banks and insurers registered with the Securities and Exchange Commission of Pakistan (SECP).

ii. ***Eligibility:*** All borrowers receiving agricultural loans from banks. Insurance Cover is mandatory for loanees.

iii. ***Period of Insurance:*** From the time of sowing or transplanting till harvesting.

iv. ***Insured Perils:*** (a) Natural calamities: Excessive rain, hail, frost, flood and drought. (b) Crop-related diseases such as viral and bacterial attacks or damage by locusts.

v. ***Sum Insured:*** Sum insured is based on per acre borrowing limits prescribed by the State Bank subject to a maximum of Rs. 2 000 000 per farmer per crop season.

vi. ***Premium***: Maximum 2% of the amount insured per crop per season plus applicable levies. Banks will be responsible for the collection and payment of premiums to the insurer.

vii. ***Basis of Indemnity***: Claims for damage directly caused by the insured risks to be based on the declaration of calamity by the competent authority (provincial or federal) in the area where the insured risk is located, and such declaration is notified in the Gazette and the final yield of the subject risk is less than 50% of the reference of that area. Indemnity is also subject to the name of the farmer/borrower and the insured crop has been earlier declared.

viii. ***Reference Yield:*** Three-year average yield of the particular area. The three years will be from the five preceding years discounting the best and worst years.

ix. ***Claims Payment***: Claims shall be payable to the banks by the insurers for credit to the insured borrower loan account. The maximum amount payable is the outstanding loan or the assessed amount, whichever is the lesser amount.

x. ***Special Condition Aggregate Limit of Liability:*** The maximum annual aggregate limit of liability of the scheme would be limited to 300% of the total premium. Insurers reserve the right to review the terms annually.

xi. ***Exclusions**:* War, civil war, strikes, riots, terrorism, etc. Non-utilization or wrong utilization of loan; Earthquake or volcanic eruption; Loss before risk declaration or after harvesting; Price fluctuations and loss of market.

8.3.2. Cost of Agricultural Insurance

Even if an agricultural risk is of fortuitous character and measurable, it may not be ensured unless the cost of insurance is within the means of the average farmer. This would require at least the following two things:

i. Premium must be reasonably low in proportion to the protection available.

ii. There must be an effective demand for insurance amongst a sizable section of the farming community so that the administrative and operational expenses must be low per unit value of insurance.

However, insurance, even though beyond the means of the average farmers, may be available if the government subsidizes a part of its cost as well as expenses, e.g., “all-risk” insurance in the United States, Canada, Israel, Sweden, Sri Lanka and other countries. The Government of Pakistan in 2008-09 paid to banks rupees 183 million (USD $ 2.2 Million) as premium subsidies for small farmers. This amounted to 58% of the premium cost (SBP 2010). In *Kissan Package 2015,* which has a worth of Rs. 341 billion, a significant amount has been allocated for premium subsidies for small farmers.

8.3.3. Objectives of Crop Insurance

The chief and foremost important objective of crop insurance, as compared to relief and concession, is that the ensured farmer, in case of loss, can claim indemnity as a matter of right. Secondly, the farmers themselves share the losses wholly or partly. A contractual right to assist the farmers further enables them to improve their credit worthiness due to crop failure in general and more particularly by using the insurance policy as collateral for loans. Furthermore, people in the rural communities and trade centers also find an opportunity of improving the stability of their income due to the stabilization of farmers’ income on which they depend so much. The farmers also gain great confidence in venturing into the adoption of new and improved farming practices and a making higher investment in agriculture for improving crop yields and increasing agricultural production. Finally, the government obligation, whenever undertaken, to provide relief in case of crop disaster is reduced.

The benefits of crop insurance are thus derived not only by farmers but also by other actors in the agriculture supply chain. It is a key measure to secure stabilization in the agriculture industry. It is complementary on the one hand, to activate and strengthen the base of agriculture, and on the other hand, to provide price and income support measures. So, crop insurance offers the process of stabilization of the agriculture industry through all stages of production, making such process more comprehensive, effective and sustainable.

8.4. Need for Crop Insurance in Pakistan

Recognizing all the risks to agricultural production, governments usually have a range of policy options for stabilizing farm income. The government of Pakistan has also taken substantial measures to increase agricultural production and stabilize the farmer's income by arranging a supply of inputs at subsidized rates and introducing modern technologies. No doubt, these measures have brought good results, but in the event of loss, the damage to crops is so heavy that farmers sometime could not get anything out of their fields. At the same time there is no consistency in the government relief and support measures, and most of the time (as mentioned earlier) these measures served as temporary rescue and relief packages. The risks associated with social, economic and natural calamities are beyond the control of the farmer's ability and efforts, particularly for small farmers that constitute over 90% of the farming community in Pakistan. It is necessary to secure farmers against natural calamities. Crop insurance may provide a more efficient alternative to stabilize the farm income and provide financial security to the farmers when their crop is damaged by natural hazards. It appears to be a simple and humanitarian concept. Its aim is to help the farmers in bad years. An effective crop insurance scheme may provide essential elements like high and sustainable income for agricultural development. By reducing risks, crop insurance can make small farmers more willing to try new technologies. In case of crop failure at any time, the protection provided by crop insurance payment serves to shorten the time that farmers take to recover from a bad year.

8.5. History of Crop Insurance in Pakistan

The introduction of the crop insurance scheme in Pakistan has been engaging the attention of the Government of Pakistan for a long time since 1948. But this theme could not be materialized. The question of the introduction of crop insurance came up in 1959, 1968 and 1971, when it was decided to set up a pilot project on a modest scale with a view to gain experience in crop insurance for its subsequent multiplication. The working group decided in May 1973 that a beginning should be made with a pilot project to cover Basmati rice in the Gujranwala district. The scheme did not, however, come up for further action for a number of years. In 1986, the ZTBL took an initiative with the collaboration of *Ademjee* Insurance Company and launched a pilot crop insurance scheme for cotton crop in a few areas, but the scheme did not bear fruit. In June 1987, the government announced a new scheme for crop insurance in the country. To start with, only two crops i.e., wheat and paddy were to be insured during the first phase of the scheme and only the farmers obtaining loans from ZTBL were to get their crops insured on a voluntary basis. This facility was also to be made available to the borrowers of Commercial banks and Cooperative loanees during the second phase. In the third and final phase, this facility was envisaged to be extended to all farmers. The program was planned to be launched in 1988, the details of which were to be worked out by the implementing agency i.e., ZTBL. The government also announced in its budget of 1989-90 to introduce crop insurance on a pilot basis and a sum of Rs. 30 million was allocated to this project. But no success was obtained in any case (Chaudhry and Aslam 1993).

Agriculture insurance is relatively under-developed in Pakistan. Livestock insurance was first introduced on a pilot basis in 1983 by two private insurers, *Adamjee* Insurance Company and the Eastern Federal Union Insurance Company. In 2008, under a public-private partnership, a national crop loan insurance scheme was introduced. Livestock and poultry insurance have been written on a small-scale in the past by various private insurance companies. Since *Rabi* season 2008-09, a group of ten insurance companies in conjunction with 20 commercial banks has been involved in the implementation of the national crop loan insurance scheme.

In this scheme, multiple peril crop insurance has been available for the individual grower for selected cereal crops, cotton and sugar cane. The present insurance schemes provide a unique two-trigger indemnity procedure: 1) catastrophe losses as a result of an insured peril that exceeds 50% of normal average regional (e.g., block) area yield must first be declared by a competent authority, and 2) this opens the policy for a loss adjustment at the individual farmer level (FAO 2010).

According to SBP in 2008-09, the crop insurance scheme's written premium was Rs 330.9 million or the US $ 3.8 million against paid claims up to December 2009 of US $ 0.28 million with an implied loss ratio of about 73%. The resulting outcome of the National insurance scheme 2008-09 is presented in Tables 9.6 and 9.7. Pakistan also faces severe floods in 2010, 2012 and 2013. But no formal details about these losses and the corresponding insurance cover are available. The 2008-09 crop loan insurance penetration rates are given in Table 8.6. Crop loan insurance scheme results (2008-09) are given in Table 8.7.

Table 8.6 Crop loan insurance penetration rates during 2008-09

Crops	Wheat	Rice	Cotton	Maize	Sugarcane	Total
Estimated cost of production (USD million)	4407.0	1613.0	1 955	508.0	771.0	9254.0
Estimated premium potential (USD million)	88.0	32.0	39.0	10.0	15.0	185.0
2008/09 actual premium (USD million)	1.4	0.5	1.2	0.1	0.6	3.8
Penetration rate (%)	1.6	1.6	3.1	1.0	4.0	2.1

Source: FAO (2012)

Table 8.7 Crop loan insurance scheme results 2008-09

Item	Premium	
	PAK Rs (million)	US $ (million)
Total premium	330.9	3.8
Premium subsidies	183.0	2.2
Premium subsidies	58%	58%
Claims	23.0	0.28
Producer premium	147.9	1.6
Producer loss ratio	73%	73%
Premium rate	1.4%	1.4%

Source: FAO (2012)

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Section – IV

Sector-wise Outlook

Chapter 9

Crop Sector in Pakistan

Masood Amjad Rana♦

Abstract

Pakistan has been naturally gifted with diverse climatic regimes and geographic terrains, which result in a wide array of agro-ecological zones in the country. The climate of the country ranges from tropical to subtropical, arid and semi-arid to temperate and alpine forests. The geographical landscape ranges from 1000 km along the coastal belt of Arabian Sea in the south, Indus delta in southern Sindh to Indus plains stretched up to northern Punjab, the Thar Desert in Sindh and Cholistan, Thal deserts in Punjab, Balochistan plateau in the west and the Karakoram Mountain range in the north. The climatic regions are coupled with contiguous agro-ecological pockets extending from the south to northwards covering a distance of 1700 km. Thus, the climatic conditions and topography of the country provide the potential opportunities for the cultivation of a wide range of food and non-food crops throughout the year. Most of these crops are grown in two main seasons, i.e., the winter season (called Rabi season in the local language) and the summer season (known as Kharif season). Wheat, gram, rapeseed, and alfalfa are Rabi crops, whereas cotton and rice are Kharif crops. Sugarcane is grown as a full-year crop, while maize is cultivated twice a year as Kharif and spring crops. Some fodder and pulse crops are grown in Rabi season, while some others are cultivated in Kharif season. At present, a net area of 15.4 million ha is devoted to crop production annually. Out of the total area, 7.33 million ha is cropped more than once bringing a total of 22.73 million ha under crop production every year with 147% cropping intensity. Wheat is the largest crop and is grown on more than 9.0 million ha each year followed by cotton (3.0 million ha), rice (2.8 million ha), fodders (2.0 million ha), and sugarcane, pulses, and maize each on about 1.2 million ha. The area under

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these crops fluctuates a little bit from year to year in response to market prices and weather conditions.

9.1. Crop Production Scenario

Indigenous production of staple foods by the agriculture sector caters >90% of the country's needs. Some crop commodities are produced in excess of the country's needs and, therefore, exported to other countries. The export commodities include rice, wheat, sugar, tobacco, vegetables, potatoes, chilies, mango, citrus, apples, and dates. If we analyze the production patterns that emerged after 1970-71, it is evident that the production of various crops has increased by many folds since 1970-71 (Table 9.1). Wheat and cotton lint production increased by 300% from 1970-71 to 2013-14. Wheat production increased from 6.476 million tons in 1970-71 to 25.98 million tons in 2013-14 and cotton lint production increased from 3.188 million bales to 12.77 million bales. Rice production increased by 3.1 folds, i.e., from 2.20 to 6.79 million tons; sugarcane by 2.91 folds from 23.167 million tons to 67.46 million tons; potato by 12.5 folds from 0.229 to 2.88 million tons; and onion enhanced by 7.0 folds from 0.247 to 1.74 million tons. The production of rapeseed, however, declined from 269,000 tons to 248,000 tons and the production of chickpea also dropped by 19,200 tons during the same period.

Table 9.1 Quantum of change in production of major crops during 1970-71 and 2013-14

Crop	**Production (million tons)**			**Increase/ decrease over 70-71 (%)**	**Annual growth rate (%)**
	1970-71	**99-2000**	**2013-14**		
Wheat	6.48	21.10	25.98	301.0	3.21
Cotton lint (million bales)	3.19	11.20	12.77	300.0	3.20
Rice	2.20	5.16	6.79	209.0	2.59
Maize	0.72	1.35	4.94	588.0	4.48
Sugarcane	23.17	46.40	67.46	191.0	2.46
Rapeseed-mustard	0.27	0.29	0.25	- 7.8	- 0.18
Chickpea	0.49	0.58	0.40	-19.2	- 0.48
Tobacco	0.09	0.11	0.13	49.4	0.92
Potato	0.23	1.87	2.88	1157.6	5.92
Onion	0.25	1.63	1.74	604.0	4.54

Source: Govt. of Pakistan (several issues)

The increase in crop productivity during this period (1970-71 to 2013-14), however, remained nominal (Table 10.2). The maximum increase was recorded for maize which improved by 284% at an annual rate of 3.1% followed by wheat, which increased by 162% at a growth rate of 2.21% per year. Cotton yields per ha enhanced by 146%, whereas potato and rice registered an increase of 93.8 and 66%, respectively during the same period. The increase in productivity of other crops, such as sugarcane, tobacco, rapeseed, potato, and onion ranged between 10.6 to 54.2%, whereas the productivity of chickpea decreased by 22.8% (Table 9.2).

Table 9.2 Quantum of change in productivity of major crops during 1970-71 and 2013-14

Crops	**Tons per hectare**			**Increase (%)**	**Growth rate (%)**
	1970-71	**99-2000**	**2013-14**		
Wheat	1.08	2.45	2.82	162.0	2.21
Cotton lint	0.31	0.64	0.77	146.0	2.07
Rice	1.47	2.05	2.44	66.0	1.16
Maize	1.13	1.73	4.32	284.0	3.10
Sugarcane	36.40	45.90	57.50	58.0	1.04
Rapeseed-mustard	0.53	0.84	0.95	81.0	1.44
Chickpea	0.54	0.61	0.42	- 22.8	- 0.59
Tobacco	1.72	1.90	2.65	54.2	0.99
Potato	11.30	16.60	21.90	93.8	1.52
Onion	10.40	14.90	11.50	10.6	0.23

Source: Govt. of Pakistan (several issues)

In spite of appreciable production gains achieved during the last 44 years, still there exist a large unachieved crop production potential (Table 10.3). The crop yields realized by progressive farmers are much higher than the national average and actually obtained by the majority of the farmers. This yield gap can be filled by the use of appropriate inputs, proper resource management, the use of area-specific and site-specific production technologies and by improving crop management practices. The unachieved gaps range from 72% in the case of paddy, 67% for sugarcane, 49% for wheat, 45% for cotton and 42% for potato. The yield gaps are almost of the same magnitude for other crops (Table 9.3).

Table 9.3 Yield gaps of major crops

Crop	Yield (Tons per hectare)			
	National average	Potential [(a)]	Gap	(%)
Wheat	2.80	5.50	2.70	(49)
Rice	2.40	8.50	3.6 o	(72)
Sugarcane	57.50	177.00	119.50	(67)
Cotton lint	0.77	1.40	0.63	(45)
Potato	21.90	38.00	16.10	(42)

(a): Yields obtained by progressive farmers

Over the past 25 years, some important value-added changes have taken place in the agriculture sector. The contribution of the crops sub-sector to national and agricultural gross domestic product (GDP) has reduced drastically, whereas livestock has emerged as an important major sub-sector. The contribution of the crops sub-sector to agricultural GDP has reduced to less than 40% in 2014-15 from 64% in 1990-91 and the contribution of the livestock sub-sector has increased to 56% in 2014-15 compared to 32% recorded 25 years (1990-91) ago. During this period, meat (mutton and beef) production has increased at a rate of 4.1% per year, poultry at 8.7%, and milk production at an annual growth rate of 3.2%. The entire meat consumption requirements are met through local production and local milk production is meeting more than 90% of domestic requirements.

9.2. Major Crops Grown in Pakistan

The details regarding the production, consumption trends and uses of major crops grown in the country are discussed in detail in the following sections.

9.2.1. Cotton

Cotton is an industrial crop and one of the main pillars of national and rural economies. Its value addition constitutes 8% of the agricultural GDP and 2% of the national GDP. It is grown on about 3.0 million ha mainly located in Punjab (78.4% of the area) and Sindh (20.2% of the area) provinces. It is also grown in a small area in Khyber Pakhtunkhwa and Baluchistan provinces accounting for about 1.5% of the total area under cotton crop in the country. Mostly small farmers having land less than 5.0 ha grow cotton (Anonymous 2015a). It is generally planted in April and May and harvested from September to December. New genetically modified Bt cotton varieties, however, are planted in the months of February and March. These varieties occupy more than 90% of the cotton area.

Pakistan stands at 4^{th} position in the world for cotton production after China, India, and USA (Emeka 2009). Cotton production during 2014-15 was 15.0 million bales (375 lbs or 170 kg each) which are the highest ever production in Pakistan (The

Dawn, April 2015). Punjab production stands at 10.9 million bales followed by Sindh with 4.0 million bales. Earlier, another bumper crop of 14.27 million bales was harvested in 2004-05. During the in-between period, cotton production hovered around 11 to 13 million bales (Anonymous 2015b). The Federal Committee on Cotton set cotton production and area targets at 15.48 million bales and 3.1 million ha, respectively. Whereas the forecast made by USDA Foreign Agricultural Service for cotton crop 2015-16 in Pakistan is 13.8 million bales (Anonymous. 2015c), which is 8% lower than that of 2014-15. Pakistan mostly grows medium and medium-long staple cotton varieties. Small quantities of short staple varieties are also grown by farmers in Sindh province which are mostly used for making quilts. However, fibre quality has been a concern of the textile industry. The quality of cotton fibre has deteriorated during cotton picking and ginning practices. Picking early in the morning with dew drops on lint and leaves, an intentional sprinkling of water on picked cotton to increase weight and careless picking leads to the mixing of foreign matter with cotton lint. Moreover, poor ginning practices, the absence of quality control measures, and the non-existence of a marketing mechanism based on premium price for clean cotton are the other reasons for quality loss. All these factors adversely affect the lint quality, increase textile production cost by 10%, and lead to depreciation of the value of raw cotton and textile products. To overcome this issue, the Government of Pakistan started producing a contamination-free cotton program in 2004. Pakistan Cotton Standards Institute was established to: (i) promote quality control through the introduction of standardization of cotton; (ii) establish cotton standards and recommend measures to Provincial Governments for the production of contamination-free cotton; (iii) devise quality control measures for export and domestic use, and handling procedures for contamination-free cotton in ginning factories; (iv) conduct grading of seed cotton and classification of lint cotton through its classes or the approved private inspection companies; (iv) conduct training in cotton grading and classing for growers, ginners, spinners, exporters and other persons of public and private sectors; and (v) ensure payment of the premium price for clean cotton through textile mills under the umbrella of All Pakistan Textile Mills Association (APTMA). The cotton crop provides the raw material for a large textile industry, which comprises1000 ginneries (350 in Sindh), 425 textile mills (105 in Sindh), and 300 cotton seed extracting mills and oil refineries. Fiber is used to manufacture cotton lint, yarn, thread, cloth, and garments, whereas cotton seed is used to produce, cotton linter, edible oil for human consumption, and animal cake. The cotton sector has been completely de-regularized, and no subsidy is provided by the government for its production and marketing. Spot prices for seed cotton are determined in the open market on daily basis. Pakistan is the 3rd largest consumer of raw cotton in the world. Domestic consumption of cotton has increased appreciably after the award of the EU Generalized System of Preferences “Plus” (GSP Plus) status to Pakistan in 2013. Provision of this status allows tariff and quota-free access to Pakistan textile products to enter European Union countries. Pakistan's textile sector usually consumes 5 to 7% more raw cotton than its local production. The consumption of raw cotton by the textile industry remains between 12.5 and 13.5 million bales. The forecast for 2014-15 consumption, however, is 15.36 million bales (Anonymous 2015a). The production-consumption gap is met through imports. In a normal production year, Pakistan imports 100,000 to 300,000 tons of raw cotton

(Table 9.4). During low production years, the import may exceed 500,000 million tons. The forecast of raw cotton imports for the year 2015-16 is more than 500,000 tons as the size of the next cotton crop is expected to decrease by 15% than 2014-15. Usually, fine and long-staple cotton such as extra-long staple (ELS) American Pima/Upland and Egyptian fine cotton are imported. These are used for improving the fabric quality for export markets. Demand for high-quality fabric is increasing in the domestic and export markets; therefore, substantial quantities of fine quality long-staple cotton will continue to be imported every year. Medium staple cotton is also imported to supplement domestic needs. Pakistan also exports raw cotton, as the cotton policy does not impose any restrictions on exports and imports. Raw cotton exports ranged from 100,000 to 250,000 tons during 2010-11 and 2013-14 (Table 9.4). In addition, quite large quantities of finished value-added textile products such as cotton yarn, cloth, thread, canvas, towels, garments and other textile products are exported. The value of these exports ranged between 10.1 and 11.42 billion US $, which constitutes 48 to 52% share of the total export earnings of the country (Anonymous 2015c). The textile industry usually maintains stocks of raw cotton enough for 2 to 3 months of use. The ending stocks remain in the range of 2.5 million bales to 3.0 million bales every year (Table 9.5).

Table 9.4 Export of raw cotton and cotton products

Particular	2010-11	2011-12	2012-13	2013-14
Raw cotton (000 tons)	144.3	256.5	92.5	114.7
Manufactured products of cotton (000 tons)	3513.6	3195.4	3495.6	3842.9
Value of cotton and its products exports (Rs billion)	1097.0	1018.5	1163.2	1291.1
Value of total exports of Pakistan (Rs billion)	2120.8	2110.6	2366.5	2583.5
Share of raw cotton and its products (%)	51.7	48.3	49.2	50.0

Source: (i) Govt. of Pakistan (2013-14) (ii) Govt. of Pakistan 2014-15, (iii) USDA Foreign Agricultural Service No. PK 1516 (2015)

Cotton production faces threats of insect pest attacks such as pink bollworm, aphid, mealy bug, and white fly, and disastrous diseases such as cotton leaf curl virus (CLCV) which are impeding the realization of the genetic yield potential of cotton. The new Bt cotton varieties released so far in Pakistan have been produced by backcrossing local cotton varieties with the exotic Bt gene source (Monsanto GMO: MON531 having Bollgard I, Cry 1Ac gene). In the process, full recovery of expression of the Bt gene at the appropriate time and for a suitable duration of plant growth and appropriate level of toxin production may not be possible. The gene expression, therefore, may remain weaker than the gene source. In such cases, the gene expression appears very late in plant growth when considerable insect damage has already occurred to the crop, its duration is too short that could not sufficiently control the insect attack, or toxin production is lower than the appropriate level thus its impact for insect control remains suboptimal.

Table 9.5 Cotton production, trade, supply, domestic consumption and stocks

Particular	Quantity (billion bales of 170 kg each)		
	2012-13	**2013-14**	**2014-15**
Beginning stock	3.47	3.17	2.61
Domestic production	13.03	12.77	15.00
Import	0.41	0.26	0.14
Exports	0.09	0.12	0.11
Total availability	16.82	16.08	17.64
Domestic consumption	13.65	13.47	15.36
End stock	3.17	2.61	2.28

Source: (i) Govt. of Pakistan (2013-14), (ii) USDA Foreign Agricultural Service No. PK 1516 (2015)

Multinational seed companies have introduced insect-resistant Bollgard II (Cry 2Ab) and herbicide-tolerant 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) genes in their cotton varieties to achieve better and wider insect control along with better weed control. These companies have got patented their Bollgard II gene in Pakistan, therefore, the local seed companies will be able to use these genes only after signing a licensing agreement with the parent seed company. In the absence of proper regulatory mechanisms and appropriate Intellectual Property Rights (IPR) protection laws (Seed Act Amendment and the Plant Breeder's Right Bill), multi-national seed companies are hesitating to market their products in Pakistan. This situation will further delay the introduction of new seed technologies in the country and the availability of improved varieties.

The Center of Excellence in Molecular Biology (CEMB), Punjab University, Lahore, and the National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad claimed the discovery of locally developed genes of Cry 2Ab and Cry2 Ab and EPSPS genes, respectively. If both of these institutions make new genes available to local seed companies, it will speed up the process of the development of new varieties with these three genes incorporated. It will initiate a new era of fast development of improved varieties with a wider scope of obtaining better cotton yields in the future.

The biggest threat to the cotton crop in Pakistan is CLCV disease. This menace badly damaged the overall production of cotton crop in the country and divested the poor farmers and ripped the rural economy. The Bt genes do not offer any resistance to this disease. Therefore, a separate program for developing resistant cotton material against CLCV would be necessary to nip this disease from the country. A program titled "Cotton Productivity Enhancement Program" funded by US grant money was started in 2011 to address the problem of CLCV. Under this program, the US and

Pakistani scientists are working jointly on this issue and trying to find out the resistant seed material or gene source against this disease. Pakistan has made a generous investment in cotton research and development. At present, three dedicated research institutes are working full time for cotton researchable productivity enhancement and quality improvement issues. Some provincial and federal research institutes also have dedicated sections working on the cotton crop. Improved cotton varieties have been released by these institutes with high yield potential and improved quality attributes. Recently all these institutes have also developed and released the Bt cotton varieties. Cotton varieties with yield potential of 5-6 tons per ha, fiber length of 32 mm, fiber strength of 97,000 lbs per square inch and fiber fineness of 4.0 micronaires are available. Because of the large potential for seed business, the private sector has also made investment for establishing cotton research and development infrastructure, and now aggressively developing the Bt cotton varieties.

The cotton and textile industry are prime sectors for sustaining and boosting Pakistan's national economy, especially for the development of the rural sector and the uplift of the poor farming community. Therefore, the government has identified textile as a key priority sector and has announced a new 5-year policy (2014-19) for enhancing its growth by attracting private sector investment for modernizing the textile infrastructure and machinery and also increasing the IT use by the industry. So that it can stay competitive in the world market and also face the challenges of contemporary technologies and scientific development in this sector. The government envisages future growth in the cotton and textile industry by doubling the cotton and textile exports from US $ 13 billion to US $ 26 billion within the next 5 years. The main focus for enhancing cotton production includes measures such as increasing cotton productivity, more use of the certified and improved seed, controlling CLCV disease, and improving integrated pest control.

9.2.2. Wheat

Wheat is the main food security crop of Pakistan. It provides staple grain food for more than 192 million people in the country. The wheat crop has a significantly large contribution to the economy of Pakistan. It contributes 10.3% to the value added in agriculture and 2.2% to National GDP. About 28% of crop sector income is generated by wheat alone. It is also supplying 72% of the calories and 64% of the proteins in the average diet. It is the largest crop in the country grown on >40% of the total cropped area and occupies about 80% of cropped area in Rabi season. During 2014-15, it was grown to 9.2 million ha, while the province of Punjab contributed 6.9 million ha which is 75% of the total wheat area. Sindh contributed 1.1 million ha (12% of the total wheat area), Khyber Pakhtunkhwa (KPK) 0.8 million ha and Balochistan 0.4 million ha both together contributing 13% of the total wheat area.

The bumper wheat crop of Pakistan was produced in 2013-14 with 25.98 million tons of grain harvest. Earlier from 1999-2000 to 2012-13 its production fluctuated between 21 and 24 million tons. The next crop (2014-15) was also substantially big with 25.49 million tons of wheat production (Table 9.6). The forecast for the 2015-16 crop by the Ministry of National Food Security and Research is 26.0 million tons with the size of the Punjab crop expected to be 19.0 million tons. However, the forecast by USAID Foreign Agricultural Service for the next crop is 25.5 million tons. The three big wheat crops in three consecutive years were due to the availability of sufficient irrigation water, more use of improved seed and other inputs, timely planting and favorable weather conditions. The nitrogenous fertilizer off-take between October 2014 and February 2015 was 20% more than the previous year, whereas phosphate fertilizer off-take was 45% more during the same period. The availability of irrigation water during the last two wheat seasons remained satisfactory. However, this situation may not persist in coming years, and it may adversely affect future wheat production in the country.

Table 9.6 Area, production and average yield of wheat during 1990-00 to 2015-16

Year	**Area (000 ha)**	**Production (000 tons)**	**Productivity (kg ha^{-1})**
1999-00	8463.0	21078.6	2491
2004-05	8358.0	21612.3	2586
2009-10	9131.6	23310.8	2553
2013-14	9199.4	25979.4	2824
2014-15	9200.0	25478.0	2769
2015-16 (E)	9250.0	26000.0	2811
Annual growth rate (%)	0.6	1.4	0.8

Source: Govt. of Pakistan (various issues), E: Estimates of Ministry of National Food Security and Research.

Pakistan is among the top eight wheat-producing countries based on the area and production of this crop. But it is way behind when wheat productivity is compared across the countries. It stood at 60th place in the ranking list of world wheat productivity in 2010. The yield potential of most local wheat varieties is 6.0 tons per ha, whereas the national average yield is only 2.8 tons per ha. The annual growth rate of wheat area (0.6%), total production (1.4%), and productivity per unit area (0.8%) are very low as obvious (Table 10.6). These growth rates are much lower than the population growth (2.0% per year) and also lower than the simultaneous increase in food demand. This situation will lead the country towards a greater wheat deficit in the future. The situation warrants the policymakers, planners and politicians to readjust the priorities and give due weight to research and development of wheat and other food crops, especially with the emphasis on enhancing their productivity per unit area. It would help to ensure food security on a sustainable basis in the backdrop of diminishing land and water resources. According to official figures, the per capita wheat consumption stands at 120 kg per year which is among the highest in the world. The Household Income Expenditure Survey (HIES) 2011-12, however, indicates 92 kg per capita consumption in the country. According to the official per capita consumption of 120 kg per year (API 2012) with a population of 191.71 million

(Economic Survey of Pakistan, 2014-15), an allowance to cater to the needs of Afghanistan (0.6 million), and use for seed (1.0 million tons) and feed (0.6 million tons), the country would need at least 25.2 million tons of wheat each year. If food security reserves of 1.0 million tons are also maintained, the need would then exceed 26.2 million tons. According to conservative estimates, the future demand for wheat would grow at least 3.0% per year, which would cover only an increase in demand due to population growth. At this rate, Pakistan would need 29.2 million tons of wheat after five years (by the year 2020) and 33.8 million tons after 10 years (by the year 2025). The possibility of increasing the area under crop and further augmentation of water resources are limited; the major emphasis of future production strategy will be on increasing the crop productivity per unit area.

Food security has been a prime focus of all governments; therefore, they intensively intervened in wheat marketing and pricing to ensure its availability around the year at a reasonable price. In 2016, the government decided to procure 6.6 million tons of wheat at a support price from the farmers. The ending stock of wheat will be 3.5 million tons at the end of this year. The procurement of additional 6.6 million tons this year will make total stocks more than 10 million tons. The government has increased the wheat support price from Rs 1200 per 40 kg to Rs 1300 per 40 kg for the years 2014-15. This has been done to increase the farmers' income and also to promote wheat production in the country. The Provincial Food Departments (PFDs) and federal agency Pakistan Agricultural Storage and Services Corporation (PASSCO) procures wheat at harvest time. These departments/organizations procure wheat at support price from the surplus wheat producing areas directly from the farmers from May to July each year. This wheat is stored for release to flour mills during a short supply period. The release price is decided by the provincial governments based on procurement price, actual wastage, transportation charges and storage cost. The release prices vary from province to province. Support price mechanism gives protection to farmers at the time of harvest from low prices that prevail in the market due to the glut of wheat supply. Usually, the support price remains more than the average market price for 3 to 4 months after harvest. According to a study (API 2012), farmers and common household owners retain about 50-60% of the wheat produced for home consumption and market the rest. Government procures 25 to 30% of the farmers' produce and about 15 to 18% is purchased by private sector stockers and flour mill owners. The government provides 4 to 6 million tons of wheat to milling units which are about 10% of their milling capacity. About 12.0 million tons of wheat is milled by the organized sector and the rest is grounded by the unorganized sector consisting of chakkies and small grinding machines in rural and urban areas. The organized sector has about 1200 milling units of various capacities with a total installed milling capacity of 206,000 tons per day. This industry is running at 20% capacity and mills about 40,000 tons of wheat every day. Pakistan has been a wheat importer up to the year 1999-2000 and used to import 1.0 to 4.0 million tons of wheat every year to meet domestic food needs. Starting from the year 2000-01 the imports reduced drastically to 0.052 million tons due to bumper crop of 21.07 million tons harvested in 1999-00. The import scenario changed since then. Now some private traders import wheat in small quantities to sell in Karachi and surrounding areas as an event of a trade. Since 2000-01 Pakistan has started exporting reasonable quantities of wheat (Table 9.7). The maximum quantity of wheat export was done in 2007-08 (2.2 million tons) and 2008-09 (2.1 million tons). In normal years it ranges between 0.5 and 0.8 million tons. Afghanistan is the major export market of Pakistan, where wheat flour of 600,000 tons is sold every year. The rest of the wheat is exported to other neighboring countries such as Sri Lanka. The wheat export forecast for 2015-16 is 1.0 million tons. Pakistan has allowed an export subsidy of US $ 50 per ton to encourage exports from government-held stocks to offload the stocks before the harvest of the coming crop. The government has also imposed a 20% regulatory duty on wheat imports to discourage further imports during 2016 and to protect the farming community from the low market price. The international wheat prices are down due to good wheat crops across the world and large end stocks. This would make wheat exports from Pakistan to other countries difficult at the domestic stock price of wheat.

Table 9.7. Wheat import and export of Pakistan

Year	Import (000 tons)	Export (000 tons)
2000-01	52.0	253.0
2005-06	815.0	600.0
2010-11	112.0	1781.0
2011-12	52.0	414.0
2012-13	52.0	850.0
2013-14	400.0	750.0
2014-15	749.0	700.0
2015-16 (E)	0.1	1000.0

Source: (i) Govt. of Pakistan (several issues). (ii) USDA Foreign Agricultural Services (February 2016), E: Estimated

Wheat's present stock position in the country is better today than ever before. At the end of the wheat year in 2016, it is expected that a wheat stock of 3.890 million tons will be available in the country. With the projection of the next wheat crop production at 26.0 million tons the stock will exceed 4.0 million tons (Table 10.8).

9.2.3. Rice

Pakistan is the 11th largest rice producer in the world, the 4th largest rice exporter based on the quantum of exports, and the 3rd largest exporter based on export value (Table 9.9). Rice is the second staple grain of the country and plays a pivotal role in the national economy. It contributes 2.7% to agriculture value added and 0.6% to national GDP. Rice is consistently contributing more than 2.0 billion US $ to the overall country's export earnings since 2013-14. Rice is a small farmers' crop. During 2015-16 rice was planted on 2.85 million ha, which is 12.5% of the total cultivated area and 31% of the Kharif cropped area. Punjab contributes about 65% of the area, Sindh 26%, KPK 2% and Balochistan contributed 7% to the rice crop.

The increase in rice area during the last 15 years was very little. During 1999-2000, rice was cultivated on 2.52 million ha which increased to 2.85 million ha in 2015-16 (Table 9.10). Two major types of rice are grown in the country, i.e., Basmati and IRRI. About 92% of the Basmati area is located in Punjab province, and other provinces mostly grow IRRI-type rice.

Table 9.8 Wheat production, consumption and stocks from 2013-14 to 2015-16

Particular	Quantity (million tons)		
	2013-14	2014-15	2015-16
Beginning stocks	02.62	02.22	03.89
Production	24.21	25.98	26.00
Import	00.40	00.75	00.10
Total supply	27.23	28.95	29.99
Export	00.75	00.70	01.00
Feed	00.60	00.80	00.80
Seed	01.00	01.00	01.00
Human consumption	22.66	22.56	23.01
Total supply	25.01	25.06	25.81
Ending stocks	02.22	03.89	04.18

Source: (i) Govt. of Pakistan (several issues), (ii) USDA Foreign Agricultural Services (February 2016)

Table 9.9 World ranking for rice production and exports 2015-16

Country	World production (million tons)	Rank	Export by quantity (million tons)	Rank	Export by value (US $ billion)	Rank
China	145.8	1	-	-	-	-
India	100.0	2	8.5	2	7.9	1
Indonesia	36.3	3	-	-	-	-
Bangladesh	34.6	4	-	-	-	-
Vietnam	28.2	5	7.3	3	1.8	5
Thailand	16.4	6	10.3	1	5.4	2
Philippines	11.5	7	-	-	-	-
Myanmar/ Burma	12.2	8	1.8	6	0.9	6
Brazil	8.0	9	0.8	8	0.39	9
Japan	7.9	10	-	-	-	-
Pakistan	6.9	11	4.6	4	2.2	3
USA	6.1	12	3.3	5	2.0	4

Cambodia	4.4	13	0.8	9	0.4	8
Uruguay	0.93	-	0.95	7	0.5	7
World	469.5	-	42.1	-	24.8	-

Source: USDA Foreign Agricultural Services (February 2016)

Table 9.10 Area, production, average yield and export of rice

Year	Area (million ha)	Production (million tons)	Average yield (kg ha^{-1})	Exports	
				Qty (million tons)	Value (US$ billion)
1999-00	2.52	5.16	2.05	2.10	0.63
2004-05	2.52	5.02	1.99	2.80	1.03
2008-09	2.96	6.95	2.35	3.19	1.17
2009-10	2.88	6.88	2.39	4.18	2.18
2013-14	2.79	6.80	2.44	3.72	2.27
2014-15	2.85	7.01	2.46	4.10	2.04
2015-16 (E)	2.85	6.90	2.42	4.60	2.25
Annual growth rate (%)	0.80	1.96	1.11		

Source: (i) Govt. of Pakistan (several issues), (ii) USDA Foreign Agricultural Services (February 2016), E: Estimated

Basmati rice is famous for its long grain, superior quality, and aroma. Basmati varieties when grown on *Kallar* soils under the climatic conditions of *Kallar* tract develop maximum aroma and other characteristics which are specific for Basmati rice. The *Kallar* tract lies between river Ravi and river Chenab in Punjab and is spread over 6 districts, *viz*. Sheikhupura, Narowal, Sialkot, Gujranwala, Lahore, and Hafizabad. This region has a sub-humid and sub-tropical climate and receives 500 to 1000 mm of rainfall, which is best suited for Basmati varieties, therefore, their cultivation is concentrated in these districts. However, these varieties are also grown in neighboring districts of Jhelum, Kasur, Okra, Faisalabad, and Sahiwal. Basmati has a high demand in the domestic as well as international markets and is sold at a premium price. The production of rice is forecasted at 6.9 million tons in 2016. The Punjab and Sindh provinces both together accounted for about 90% of the total rice production. Basmati production is about 33% of the total rice production. Basmati varieties are usually low yielding than the IRRI type varieties. The national average yield of Basmati rice ranges between 1700 and 1800 kg per ha, whereas the national average of IRRI varieties ranges from 2900 to 3200 kg ha^{-1}. However, the progressive farmers, at their farms, take 5000 kg and 8000 kg per ha yields of Basmati and IRRI varieties, respectively. The annual growth in the area, production and average yields has been nominal (Table 9.10). Therefore, large-scale promotional efforts for increasing rice productivity will be essential for enhancing the average yield per unit area and achieving sustainable long-term growth in rice production. Domestic consumption of rice ranges from 2.6 to 2.7 million tons. It includes about 200,000 tons of broken rice for poultry and animal feeds and about 400,000 tons are used for sowing of the next crop. The rest of about 2.0 million tons are used for human consumption. The consumption of 2014-15 was registered at 2.8 million tons and for 2015-16 it is forecasted at 2.9 million tons (Table 9.11). The closing stocks of rice at the end of each market year vary greatly based on the quantum of exports and the size of domestic production. During 2013-14 and 2014-15, the end stocks were 1.2 and 1.3 million tons. The end stocks for 2015-16 are forecasted at 0.8 million tons (Table 9.11). Rice is an exportable commodity. Pakistan is exporting rice since 1960 when a quantity of 124,000 tons of rice was exported. These exports remained less than half a million tons up to 1971 and started rising and crossed the mark of one million tons in 1978. The rice export quantum exceeded 2.0 million tons in 1999, enhanced to 3.0 million tons in 2007 and finally touched 4.0 million tons in 2009-10 (Table 9.10). The rice exports for 2015-16 are projected at 4.6 million tons because of the increase in domestic production and the availability of more exportable stocks. However, rice export is threatened because of the recent increase in duty by Kenya and Iran on the import of rice from Pakistan and the imposition of import quota by China. On the positive side, an MOU has been signed between Pakistan and Indonesia for the import of 1.0 million tons of rice from Pakistan between 2016 and 2019. This deal, if materialized, can help further increase rice exports.

The majority of rice is exported to Saudi Arabia, UAE, Kenya, Iran and Afghanistan. Pakistan also exports some quantity of rice to the USA. All rice exports are done by the private sector without any interference from the government. Nevertheless, the exporters have not focused on value addition by creating their quality brands and they continued the traditional practice of bulk exports. Now some large companies have made reasonably large investments in improving their processing machinery and developing their brands and presenting their products in attractive packaging. The future focus on this line will help to expand their exports at a premium price.

Table 9.11 Rice production, export, domestic consumption and end stock

Particular	2013-14	2014-15	2015-16 (E)
Beginning stock	0.50	1.20	1.40
Production	6.70	7.00	6.90
Imports	0.03	0.00	0.00
Total supply	7.23	8.20	8.30
Exports	3.40	4.00	4.60
Domestic consumption	2.63	2.80	2.90
Total use	6.03	6.80	7.50
End stock	1.20	1.40	0.80

Source: (i) Govt. of Pakistan (several issues), (ii) USDA Foreign Agricultural Services (February 2016), E: Estimated

Rice production has been stagnant in Pakistan for the last 8 years. The rice production was 6.95 million tons in 2008-09 and that remained stuck at 6.90 million tons after 8 years in 2015-16. The average yield per unit area of both Basmati and IRRI type rice has also been quite low in Pakistan. The annual expansion in area and improvement in rice productivity also remained static during this period (Table 9.10). This is an alarming situation and thus needs proper analysis. If rice production constraints are examined, we can see that major constraints include: (i) use of low-quality seed; (ii) low plant density per acre; (iii) insufficient availability and inefficient use of irrigation water; (iv) low and uneven use of fertilizers; (v) old and low yielding rice varieties; and (vi) decreasing market prices for paddy in domestic and international markets. Due to low market prices, farmers do not get due returns for their produce. Therefore, they are not interested in increasing the area under this crop nor do they use the appropriate level of inputs. Pakistan lacks rigorous breeding programs in public sector research organizations for the development of new rice varieties. The private sector is not participating in the variety development efforts because of the non-existence of plant breeders' rights legislation. Provincial governments should revisit their rice breeding programs and reset time-bound targets for developing new high-yielding rice varieties and hybrids. Governments should also provide the necessary funding to support these targets. Agricultural extension departments should closely work with farmers at the time of transplanting to achieve an appropriate plant population in rice fields. In short, a dedicated promotional approach would be required for increasing the pace of sustainable growth in the rice crop.

9.2.4. Sugar Crops

Pakistan grows two sugar crops, i.e., sugarcane and sugar beet. Sugarcane is the major crop of the country and is cultivated on more than 1.0 million ha, whereas sugar beet is a very minor crop and is grown on about 2,700 ha only. During 2014-15, sugarcane was cultivated on 1.13 million ha and the forecast for 2015-16 is 1.17 million ha (Table 9.12). Punjab contributes 65% in total sugarcane planted area (0.76 million ha), Sindh 25% (0.29 million ha) and KPK 10.0% (0.12 million ha). Sugarcane is a full-year and high delta of water crop and requires 60-90 acres inches of irrigation water for its growth. It does best in tropical climatic conditions, therefore, Sindh offers more favorable climatic conditions for its growth than Punjab and KPK provinces. The national average yield in Sindh province is 10 to 12% more than Punjab and 35 to 40% better than the yields obtained in KPK province. This crop is more remunerative for farmers in Sindh as they obtain more yields and also take two crops from the same land by planting onions as intercrop, which mature when sugarcane resumes growth in the spring season.

The production of sugarcane ranges from 47.8 to 63.2 million tons during the last 16 years, i.e., from 1998-99 to 2014-15. The forecast for sugarcane production for 2015-16 is 65.47 million tons (Table 9.12). With this quantum, Pakistan stands 6th in the world for its production. Productivity per unit area, however, is quite low compared to other countries. The national average yield was 47.8 tons per ha in 1998-99 which increased to 57.5 tons ha^{-1} in 2013-14. This 20% increase in average yield over a period of 16 years refers to an annual growth of 1.0% per year which is a slow growth rate. Other sugarcane-growing countries have quite high average yields. For example, the average yield of sugarcane in China is 77 tons ha^{-1}, in India 70 tons, Philippines 92 tons, in Thailand 92 tons, and Egypt 105 tons per ha. Pakistan stands at 60th position in the world for sugarcane productivity ranking.

Table 9.12 Sugarcane area, production, average yield and sugar production and consumption

Year	Area (million ha)	Production (million tons)	Avg. yield (kg ha^{-1})	Sugar production (million tons)	Domestic consumption (million tons)	Per capita consumption (kg/year)
1998-99	1.15	55.19	47.8	3.54	3.04	22.85
2004-05	0.97	47.24	48.9	3.12	3.94	25.83
2009-10	0.94	49.37	52.4	3.14	4.19	24.12
2013-14	1.17	67.46	57.5	5.61	4.51	24.00
2014-15	1.13	63.20	55.9	5.23	4.70	25.00
2015-16 (E)	1.17	65.47	56.1	5.43	4.95	25.82
Annual growth rate (%)	0.07	1.00	1.0	2.70	3.10	0.77

Source: (i) Govt. of Pakistan (several issues), (ii) USDA Foreign Agricultural Services (February 2016), (iii) PSMA (2014), E: Estimated

It is a very important cash crop of the country as it contributes 2.1% in agriculture value added and 0.5% to National GDP. Exports of sugar, molasses, and ethanol earned US $ 656.0 million during 2013-14. The sugar industry is the second largest agro-based industry after the textile industry in the country. It has 88 mills located in the provinces of Punjab (44), Sindh (37), and KPK (7) with a total installed capacity of more than 100 million tons of crushing sugarcane. This industry produces sugar, molasses, and ethanol which are used for local consumption as well as for export to other countries. Pakistan produced 5.61 million tons of sugar in 2013-14 and 5.23 million tons of sugar during 2014-15. The forecast for its production during 2015-16 is 5.43 million tons (Table 9.12). Pakistan is the 7th largest sugar producer of sugarcane in the world after Brazil, India, China, EU, Thailand, and Mexico. A small quantity of sugar is also produced from sugar beet which ranges from 17,276 tons in 2000-01 to 33,000 tons in 2012-13. The sugar recovery in Sindh is better than in Punjab. The average recovery in Punjab is 9.92%, whereas it is 10.49% in Sindh. The sugar recovery from sugar beet is more than from sugarcane and it ranges from 10.78 to 10.89%. About 80 to 85% of the sugarcane is crushed in the mills for sugar production. Rest is used for sowing, juice production and Gur making. The Gur recovery from sugarcane is 13.5 to 14.5% and a substantial quantity of Gur is also produced in the country, which ranged from 285,000 tons in 2003-4 to 639,000 tons in 2013-14. Provincial governments decide the indicative prices every year before the start of sugarcane crushing. The indicative prices for 1990-91 were Rs 15.25 per 40 kg for Punjab and KPK, while Rs 15.75 per 40 kg for Sindh (Table 9.13). These prices are revised every year to ensure a reasonable return to the framers of their investment and labor. The indicative prices for 2014-15 were fixed at Rs 180 per 40 kg for Punjab and KPK and Rs 182 per 40 kg for Sindh. Over 25 years, the indicative prices increased at an average rate of 11.3% per year. The second bumper sugarcane crop during 2013-14 caused surplus sugar stocks in the country which depressed the domestic market prices. The government permitted sugar export and allowed a US $100 per ton export subsidy to deplete the surplus sugar stocks. The sugar industry has also been protected through the imposition of a 40% import tariff to protect domestic sugar prices by avoiding the import of cheap sugar from the international market.

Table 9.13 Indicative price of sugarcane since 1990-91

Year	**Rs per 40 kg**		
	Punjab	**Sindh**	**KP**
1990-91	15.3	15.8	15.3
2000-01	35.0	36.0	35.0
2005-06	45.0	60.0	45.0
2010-11	125.0	127.0	125.0
2011-12	150.0	154.0	150.0
2012-13	170.0	172.0	170.0
2013-14	170.0	172.0	170.0
2014-15	180.0	182.0	180.0
Annual growth rate (%)	11.3	11.2	11.3

Source: (i) Govt. of Pakistan (2013-14) (ii) PSMA (2014)

Historically, Pakistan is a sugar deficit country. The gap between production and consumption is bridged through the import of refined and raw sugars. The export of sugar started in 1993-94 when 121,565 tons were exported. During the next 22 years up to 2015-16, Pakistan exported sugar for 16 years except for 7 years when sugar was imported because of low sugarcane production. For the last three consecutive years since 2013-14, sugar is exported in quite large quantities. With this quantum, Pakistan has become the 7th largest net exporter of sugar after Brazil, Thailand, Mexico, India, Guatemala, and Belarus. The country exported 729,000 tons of sugar during 2013-14 and 600,000 tons during 2014-15. The forecast for the export of sugar during 2015-16 is 700,000 tons. There are 19 distilleries in the country that can produce over 500,000 tons of ethanol every year. Therefore, Pakistan also exports large quantities of sugarcane byproducts every year including ethanol and molasses to earn foreign exchange (Table 9.14).

Table 9.14 Import and export of sugar and export of molasses and ethanol since 1990-91

Year	Quantity in million tons			Ethanol export (million litres)
	Sugar import	Sugar export	Molasses export	
1990-91	0.43	0.00	0.77	8.23
1995-96	N/A	0.32	0.81	1.17
2000-01	0.93	0.00	1.19	10.06
2005-06	1.53	0.06	0.50	33.79
2009-10	0.37	0.00	0.96	101.26
2013-14	0.01	0.73	0.20	492.48
2014-15	0.01	0.60	N/A	N/A
2015-16 (E)	0.01	0.70	N/A	N/A

Source: (i) PSMA (2014)

The domestic consumption of sugar has been 3.039 million tons during 1998-99 which increased to 4.950 million tons after 17 years in 2015-16 registering a growth rate of 3.1% per year which is high growth by all domestic and international standards (Table 9.12). The national per capita consumption is 25.82 kg/year, which is also very high compared to other countries such as India (14 kg/person/year), Bangladesh (10 kg), and China (11 kg). The high sugar consumption is because of increased diversification of the food business market and the proliferation of the food processing industry in the country. Since 2010-11, global sugar production is more than world consumption. This situation has added to the world stocks and depressed the international sugar prices. The global end stocks were 78.01 million tons in 2013-14 and 77.23 million tons during 2014-15. The domestic sugar end stocks were 1.27 million tons in 2013-14 and 1.21 million tons during 2014-15. The end stocks for 2015-16 are forecasted at 1.00 million tons (Table 9.15).

9.2.5. Oilseed Crops

Pakistan grows several oil crops such as rapeseed-mustard, canola, sesame, groundnut, castor, sunflower, soybeans, and safflower. In addition, three oil-bearing tree crops, olives, coconut, and oil palm also maintain their presence in some agro-ecological zones. At present, all of these crops, except rapeseed, canola, and sunflower, are minor crops and do not produce much oil which goes into the edible oil or ghee manufacturing industry. In this scenario, cotton seed is the major source of edible oil in the country though it is a by-product of the cotton crop which is primarily grown for its fiber. The local production of edible oil from rapeseed, canola, sunflower, and cotton seed is less than 20% of the domestic consumption requirement. The gap is bridged by the import of this commodity from abroad.

Table 9.15 Sugar production, export, domestic consumption and end stock

Particular	Quantity (million tons)		
	2013-14	**2014-15**	**2015-16 (E)**
Beginning stock	0.86	1.27	1.21
Cane sugar production	5.60	5.20	5.40
Beet sugar production	0.03	0.03	0.03
Refined sugar import	0.01	0.01	0.01
Total supply	6.49	6.51	6.65
Exports	0.73	0.60	0.70
Domestic consumption	4.50	4.70	4.95
Total use	5.23	5.30	5.65
End stock	1.27	1.21	1.00

Source: (i) Govt. of Pakistan (several issues), (ii) USDA Foreign Agricultural Services (February 2016); E: Estimated

The area and production for rapeseed, canola, and sunflower fluctuate considerably from year to year because these crops compete with the wheat crop for land. Wheat market prices are guaranteed by the government through a support price mechanism because of its importance as the prime staple food of the country. Whereas rapeseed, canola and sunflower market prices are influenced by international prices which may not always remain remunerative and viable against wheat. Therefore, both of these oil crops lose their area to wheat. Sunflower is also grown in the summer season but it gives low yields in this season and cannot compete with other summer crops like rice, cotton and maize. It is projected that during 2015-16 due to low global prices of rapeseed, canola and sunflower area under these crops will reduce further. The area of the canola crop could not increase more than 17,000 ha and production by more than 18,000 tons despite a lot of promotional efforts made by the Pakistan Oilseed Development Board (PODB) for its expansion in the country. The production of sunflower seed increased from 149,000 tons in 1999-00 to 603,894 tons in 2007-08 then it started decreasing and reduced to 193,000 tons in 2013-14 (Table 9.16). During the same period, cotton seed production increased steadily with the increase in area and productivity of the cotton crop. A considerable quantity of canola and sunflower seeds are also imported every year to keep the local solvent extraction industry operational. During 2014-15, soybeans have also been imported from the USA because of the favorable tariff structure. Import of these seeds was 0.5 million tons in 1999-00 which increased to 1.26 million tons in 2014-15. The country’s import tariff structure is designed to encourage the import of seed rather than the import of meal or oil facilitating better utilization of the huge installed capacity of the local oilseed extraction industry. Cotton seed is the major source of edible oil production in the country. During the last 16 years (since 1999-00), its oil accounts for about 73 to 79% of indigenous vegetable oil production. The edible oil produced from rapeseed, canola, and sunflower seed together accounted for 27% in 1990-00 to 21% in 2014-15. The edible oil produced from the imported oilseed contributes about 34 to 43% share of the total local oil production in the country. The oil produced locally from all these sources was 0.619 million tons in 1999-00, which exceeded more than 1.2 million tons in 2014-15 (Table 9.16). The forecast for edible oil production for 2015-16 is 0.890 million tons. It is also projected that the cotton crop, due to its economic importance, will most likely grow at a steady rate in the future and will continue to play a major role in total domestic edible oil production in the country. Similarly, significant quantities of oilseeds will also continue to be imported for keeping the local oil extraction industry operational.

Table 9.16 Production of various oilseeds, seed crushed for oil extraction and oil produced from 1999-00 to 2015-16

	Production of oilseeds (000 tons)											
Year	Rape-seed + canola	Cottonseed	Sunf-lower seed	Imported rape and sunflower seed	Beginn-ing stock	Total supply	Waste/ other uses	Seed crushed	Oil from rape, cotton & sunflower seed	Oil from imported seed	Domestic edible oil produc-tion	End stock of seed
1999-00	297	3824	149	500	150	4920	480	4290	444	175	619	150
2004-05	216	4852	328	720	170	6286	620	5476	551	252	803	190
2009-10	174	4392	325	750	210	5851	574	5092	514	262	776	185
2013-14	248	4344	193	787	120	5692	570	4930	524	275	799	192
2014-15	220	5103	200	1260	192	6975	687	6116	581	441	1022	172
2015-16	160	5034	190	1100	172	6656	652	5839	505	385	890	165
Annual growth rate (%)	- 4.0	1.8	1.6	5.4	-	2.0	-	2.0	0.8	5.4	2.5	-

Source: (i) APSEA (several issues), (ii) Govt. of Pakistan (several issues), (iii) USDA Foreign Agricultural Services (February 2016)

Pakistan is a chronic deficit in edible oil production; therefore, a large quantity of edible oil is imported every year to cater the domestic needs. During 1999-00, a total of 1.05 million tons of edible oil was imported, which increased to 2.5 million tons in 2014-15 costing about US $ 2.0 billion of foreign exchange. The quantum of imports during 2015-16 is forecasted at 2.8 million tons (Table 9.17). Since 1999-00, edible oil imports have been increasing at an annual growth rate of 5.7%. The RBD palm oil constitutes more than 90% of the total imported oil. The second major oil is soybean oil which has a 5 to 6% share in imported oil. Other oils such as sunflower, rapeseed, linseed, coconut, maize, olive and palm kernel are also imported in small quantities. During the last 16 years (since 1999-00), the domestic demand for consumption has grown by 2.4-fold from 1.46 million tons in 1999-00 to 3.52 million tons in 2014-15 (Table 9.17). The forecast for consumption during 2015-16 is 3.6 million tons. The high consumption growth is because of rapid growth in population, improvement in income, increase in growth in the poultry subsector, modernizing the dairy industry, and expansion in the food processing industry. The ending stock of edible oil will remain in the range of 200,000 tons during 2015-16.

Table 9.17 Edible oil production, import, consumption and end stock from 2013-14 to 2015-16

Particular	**Quantity (000 tons)**		
	2013-14	**2014-15**	**2015-16 (E)**
Seed crushed	4825	5815	5230
Beginning stock of edible oil	186	186	215
Edible oil production	1005	1250	1035
Edible oil Import	2347	2510	2820
Total supply	3538	3946	4070
Exports	40	40	50
Industrial use	115	115	115
Food	3135	3515	3644
Feed/waste	66	61	61
Total consumption	3312	3515	3644
End stock	186	215	200

Source: (i) APSEA (several issues), (ii) Govt. of Pakistan (several issues), (iii) USDA Foreign Agricultural Services (February 2016), E: Estimated

The government has put a lot of effort to promote and expand the cultivation of oilseed crops in Pakistan. In this regard, a World Bank-funded project, the National Oilseeds Development Project (NODP) was launched country-wide in 1989-90 and then it was supported by the establishment of PODB in 1995. But the efforts did not bear fruit and the area under these crops did not increase because of the lack of demand by the oilseed extraction industry which was contempt with using cheap imported oilseeds for running their industry and minting lucrative profits from this business. The government's decision of withdrawing support prices from all crops except wheat also proved counter-productive for oilseed crops. Lack of funding for research, and improving seed quality and technology also worked as barriers to promotion of these crops.

9.2.6. Pulses

Pulses are a rich source of vegetable proteins for people living in developing countries. Pulses are also rich in fiber, amino acids, iron, zinc, and some bioactive compounds that help to prevent and manage anemia, obesity, chronic diabetes, coronary vascular disorders and cancer (CGIAR 2015; Marinangeli and Jones 2012).

In addition, pulses cultivation enriches soil fertility by fixing atmospheric nitrogen into soil that can be utilized by plants for growth (Frame 2005). India is the largest producer (18.5 million tons), importer (3.8 million tons) and consumer (22.5 million tons) of pulses. Other large producers of pulses during 2013-14 were Myanmar (6.02 million tons), Canada (4.96 million tons), China (4.34 million tons), and Australia (3.89 million tons). Pulses are low-yielding crops; therefore, their averages yields are also low, e.g., according to 2014 figures, the world average stands at 910 kg ha^{-1}, India 730 kg ha^{-1}, Canada and USA 1900 kg ha^{-1}, Australia 1100 kg ha^{-1} and Myanmar 980 kg ha^{-1}. Pulses production in Pakistan touched a high mark of 1.089 million tons in 2006-07 and then it declined sharply in the following years. During 2013-14, the area came down to 1.17 million ha from 1.532 million ha in 2007-08 registering a decrease of 24% in pulses area within six years. Similarly, the production of pulses reduced to 0.544 million tons in 2013-14 from a high level of 1.089 million tons in 2006-07, depicting a decline of 50% in pulses production (Table 9.18). The chickpea and mungbean are two major pulses of Pakistan, whereas peas, lentil and mash are minor crops. The decline of 50% in production occurred across all these pulses, however, a decline in the area of these crops was variable. The reduction in the area of minor pulses (pea, lentil and mash) was 48%, the decrease in the area of two major pulses (chickpea and mungbean) was 18% and the decline in area under other pulses (pigeon pea, cowpea, moth bean and common beans) was 40%. The reduction in pulses production from 2006-07 to 2013-14 was due to a reduction in the area as well as a decline in productivity of chickpea crop from 793 kg ha^{-1} to 420 kg ha^{-1}, i.e., 47% reduction. No decline in productivity has been noted for other pulse crops during the same period. The main reasons for low productivity are: i) low input farming of pulses on marginal lands, ii) government and farmers give priority to major crops such as cotton, wheat, rice and sugarcane, iii) R & D and funding support is insufficient, iv) no planning and program for creating life-saving irrigation system for pulse crops and v) losses due to drought and disease.

Table 9.18 Area, production and average yield of all pulses during 1990-00 to 2015-16

Year	Area (000' ha)	Production (000 tons)	Productivity (kg ha^{-1})
1999-00	1419	802	569
2004-05	1492	1094	733
2009-10	1395	763	547
2014-15	1170	544	465
Annual growth rate (%)	-1.4	-2.9	-1.5

Source: Govt. of Pakistan (various issues)

Chickpea is the major pulse of Pakistan. It occupies >70% of the land under all pulses crops grown in the country and contributes 65 to 70% to the total production of all pulses. Its major area of production is the Thal desert and Pothowar plateau in Punjab and grown under water-stressed conditions with minimal inputs and management. The major disease is gram blight which often causes failure of the crop. Therefore, drought and blight disease are the two major constraints of this crop. New varieties with drought tolerance and disease resistance can help to sustain the crop in the country. Mungbean is the second largest pulse crop in the country. It occupies about 11 to 15% of the area under all pulses and contributes 15 to 17% to the total production of all pulses. It is grown as *Kharif* crop in rotation with wheat. Major production areas are Rawalpindi, Bhakkar, Mianwali, and Layyah in Punjab province. Research programs focus on developing high-yielding varieties having wider adaptability, resistance to diseases, short duration and uniform maturing traits. Emphasis is also given to seed multiplication for the promotion of these crops. Improving pulses production in the country would require more input in research and development and farmers' education and technical backstopping.

Pakistan consumes >1.0 million tons of pulses every year. During most of the years, the quantum of pulses production in the country remains below this level. Therefore, a significant quantity of pulses is imported every year (Table 9.19) for meeting local consumption needs. During 2004-05, a total of 367,000 tons of pulses worth Rs 10.4 billion were imported, which sharply increased to 607,000 tons valued at Rs 38.4 billion in 2014-15 at a growth rate of 5.1% per year. Global trade analysis reveals that exports and imports of pulses have increased appreciably since 1990. Global exports quantum during 1990 was 6.6 million tons which increased at a growth rate of 3.3% per year and reached 13.4 million tons in 2012. During the same period, the value of global exports increased by four-fold from US $ 2.5 billion to US $ 9.5 billion. Constraints of pulses production and low productivity faced by developing countries may result in a production deficit against their increasing demand. However, per capita consumption analysis reveals that per capita consumption has dropped across the developing and developed countries by about 20% that is from 7.6 kg per person per year in 1990 to 6.1 kg per person per year in 2012. This trend reflects the change in dietary patterns and also shows the failure to produce enough pulses against their growing demand (FAO 2016).

Table 9.19. Import of pulses 2004-05 to 2014-15

Years	Quantity (000 tons)	Value (Rs billion)
2004-05	367	10.45
2009-10	445	21.97
2010-11	628	34.39
2011-12	672	38.81
2012-13	472	31.50
2013-14	499	31.53
2014-15	607	38.40
Annual growth rate (%)	5.1	13.8

Source: Govt. of Pakistan (various issues)

9.3. Horticultural Crops

Pakistan is producing a large number of fruits, vegetables, and flowers almost around the year. The country is self-sufficient in the production of fruits and vegetables and also exports the surplus production. Floriculture has been developed as innovative farming and as a non-conventional business. Off-season vegetable production in tunnels and special agro-climatic zones is also expanding rapidly which has enhanced farmers' profitability and ensured the availability of vegetables around the year. Main fruits in the country are citrus, mango, banana, apple, grapes, pomegranates, apricots, peaches, pear, plum, guava, persimmon, lemon, litchi, papaya, strawberry, walnuts, figs, dates and many more. These fruits are grown on about 776,000 ha every year and their aggregate production is more than 6.4 million tons (Table 9.20). During the last 14 years (1999-00 to 2013-14), the area and production of mangoes and apples increased appreciably (60 to 101%), whereas the area and production of other fruits either increased little or reduced somewhat. The overall annual growth rate of fruit production during this period remained nominal at 0.7%. Kinnow (a type of mandarin) is a very special type of citrus variety produced in the country. According to an estimate, about 95% of world kinnow is produced in Pakistan. Similarly, Pakistan is famous for its mango taste and varieties. There are about 150 varieties of mango grown in the country. According to FAO estimates of 2001, Pakistan is the 5th largest producer of mangoes in the world. Several vegetables are also grown in Pakistan that including onion, potatoes, tomatoes, spinach, cauliflower, cabbage, radish, turnip, eggplant, okra, gourds, papers, cucumber, squashes, chilies, garlic, coriander, etc. The area under all vegetables is around 424,000 ha and production is more than 6.0 million tons (Table 9.21). The area and production of onions, potatoes and tomatoes increased significantly during the last 14 years (1999-00 to 2013-14). The present vegetable production caters to the consumption needs very well of a rapidly growing population. The overall annual growth rate of all vegetable production during this period registered at 1.8% which is a fair growth rate. However, to remain in the business in the future and to become competitive in global trade we need to increase the annual growth rate to the tune of 3 to 4% and deploy state-of-the-art and knowledge-based technologies for their production, postharvest handling, and manufacturing value-added products.

The quantum and value of fruits, vegetables, and cut flowers exports are very small and Pakistan does not stand anywhere on the world trade ladder of these commodities. The export quantum of fruit and vegetables was 1.3 million tons in 2013-14 and the value was Rs 70 billion (about US $ 700 million) (Table 9.22). Whereas the value of world exports of fresh fruits was US $ 68 billion and of fresh vegetables was US $ 35 billion and their combined value was about US $ 103 billion during the year 2013. The quantum of these exports grew at an annual rate of 4.5% and the value of exports grew at a rate of 10.2% during the last 12 years, i.e., from 2001 to 2013 (Anonymous 2014b). The main products that were traded during this period were banana, apple, and orange among fruits; and tomatoes, onion, pepper, cucumber, and carrot among vegetables. The good news for Pakistan in this comparison is that the growth rate for the quantum of fruits and vegetable exports during the last 5 years (2008-09 to 2013-14) was 8.9% and the rate of increase in value was 29.3% (Table 10.22), which were 98% and 187% better, respectively, than the growth rate observed in world exports of these commodities. It shows that Pakistan has huge potential for significantly increasing its fruits and vegetable exports in the future if the private sector is properly supported by the government through compatible policies and the required infrastructure facilities.

Table 9.20 Area and production of fruits: 1999-00 and 2013-14

Fruit	1999-00		2013-14		Change (%)	
	Area (000 ha)	Production (000 tons)	Area (000 ha)	Production (000 tons)	Area	Production
Citrus	198	1943	194	2168	-2.0	11.6
Mango	094	938	171	1659	81.9	76.9
Banana	028	125	028	0120	0	-4.0
Apple	052	377	105	606	101.9	60.7
Guava	060	495	064	547	6.7	10.5
Dates	077	580	090	522	16.9	10.0
Others[A]	149	1388	124	802	-16.8	-42.2
Total	658	5846	776	6424	17.9	9.9
Annual growth rate (%)	-	-	1.2	0.7	-	-

A: Apricot, peaches, grapes, pear, plums, pomegranate, and almonds. Source: Govt. of Pakistan (several issues)

Table 9.21. Area and production of vegetables: 1999-00 and 2013-14

Vegetable	1999-00		2013-14		Change (%)	
	Area (000 ha)	Production (000 tons)	Area (000 ha)	Production (000 tons)	Area	Production
Onion	110	1648	144	1740	30.9	5.5
Potatoes	111	1868	158	2883	42.3	54.3
Tomatoes	29	283	63	599	117.2	116.6
Others[A]	81	932	59	794	-27.1	-14.8
Total	331	4731	424	6016	28.1	27.2
Annual growth rate (%)	-	-	1.9	1.8	-	-

A: Spinach, cauliflower, cabbage, radish, turnip, eggplant, okra, guards, papers, cucumber, squashes, etc. Source: Govt. of Pakistan (several issues)

Table 9.22 Export and export of fruits, vegetables and their products and import of dry fruits

Year	Export of fruit, vegetable and products		Import of dry fruits	
	Quantity (000 tons)	Value (Rs billion)	Quantity (000 tons)	Value (Rs billion)
2008-09	909	19.6	118	6.6
2009-10	1167	31.8	116	7.3
2010-11	1563	50.7	107	7.5
2011-12	1312	51.9	111	8.1
2012-13	1512	66.0	106	7.9
2013-14	1394	70.8	130	10.5
Annual growth rate (%)	8.9	29.3	1.9	9.7

Source: Govt. of Pakistan (2013-14)

The agricultural production system in Pakistan is mostly supply based. Most of the commodities are being grown because they have been there over a long period of time. The futuristic approach in the competitive world economy requires linking up the production system with consumer demand in the country and overseas. There is a need to identify the time windows when various fruits are in short supply in the international market and various countries. During these lean supply periods, our fruits and vegetables should be available for export. Pakistani citrus (orange and kinnow) contains seeds which is a barrier to their promotion for overseas trade. The research institutes, especially in Punjab, should, therefore, enhance their efforts to develop seedless kinnow varieties. In addition, Pakistan has not much focused, in the past, on the development of non-conventional commodities such as cut flowers, mushrooms, spices, and medicinal plants which need to be boosted further.

The postharvest handling losses of fruits and vegetables, being perishable, are very high and range from 25 to 35%. The country still lacks badly the needed infrastructural arrangements for postharvest handling, preservation and quick transport of fresh vegetables, fruits and flowers in refrigerated vehicles to the consumer markets in the country and around the globe. Realizing this setback, the Government has taken measures to encourage the import of necessary machinery for this purpose at zero-rated GST.

Pakistan exports had also badly suffered due to being substandard and of heterogeneous quality. This has generally remained a neglected area in the past. Although the government has made some investments in the improvement of the quality of its agricultural products through the establishment of a network of laboratories and the introduction of quality standards for various agricultural commodities/products, the system has not yet started delivering as expected.

Pakistan has a large potential for further increasing the production and export of fruits, vegetables and other non-conventional horticultural commodities. There are several important areas where the attention of government and private sectors is needed on a priority basis for strengthening the fruits, vegetables, and floriculture production-consumption system. That includes: (i) frequently organizing educational programs for growers and exporters on fruit plucking technologies, removal of field heat, proper and safe transportation, addressing the threat of pests and diseases particularly the fruit fly, grading and processing of the produce and using appropriate packaging; (ii) develop cold chain infrastructure in the main production areas and at airports for the state of the art handling, and efficient and safe delivery of the horticultural produce; (iii) attract private sector investment for building cold chain facilities for efficient transportation of horticultural produce and products; (iv) focuses on the implementation of quality standards for export of horticultural commodities; and (v) to expand the industry for waxing, grading and packing of fruits/vegetables through providing incentives.

9.4. Future Prospects

Expansion of the agriculture sector with a growth rate of about 3.5% per annum during the last six decades has been successful in producing enough food for catering to the needs of the growing population along with the production of some surpluses for enhancing exports and contributing to the developing economy. The population of Pakistan has increased by 4.75-fold since 1950, that is, from 40.38 million in 1950 to 191.72 million in 2015. At this growth rate, the population of Pakistan in 2025 has been projected at 227 million (Anonymous 2014a) indicating that about 36 million additional people would be requiring food during the next 10 years. At the present per capita consumption rates, it would require the production of additional 4.32 million tons of wheat, about 0.90 million tons of rice, 0.2 million tons of pulses, 0.86 million tons of sugar, 0.16 million tons of vegetables, and 0.45 million tons of edible oil to feed the projected additional population. The future population scenario envisages a tall order and aggressive challenge of producing substantial additional food for humans, non-food commodities for industry, and feeds for livestock from the same land and water resources during the next 10 years and beyond. Various elements have contributed to the previous growth in the crop sector such as bringing additional area under cultivation, augmentation of water resources especially the groundwater, use of the improved seed, intensive application of fertilizer and improvement in crop management practices. Major crops like cotton, wheat, rice, sugarcane and maize have been the key sources of agricultural growth. The basic agriculture production factors like land and water though had increased appreciably during the last 60 years, but the possibility of their further expansion is low. Therefore, future increases in food production would mostly depend on vertical growth in this sector that can be realized through achieving enhanced crop productivity, higher cropping intensity and efficient water use rather than an increase in net cultivated area and total water availability. The agriculture sector has the potential to feed the growing population and produce enough surpluses for enhancing exports, however, that would require minimizing the impediments of production which are restraining the efficient use of inputs, adoption of advanced production technologies by farmers, marketing imperfections and policy distortions. These constraints have repeatedly been identified in various studies and reports but not much was done to address these issues categorically for their translation into action and implementation. As a first step, in view of meeting the future food demand in the changing international and geo-political scenarios, the agriculture sector must be recognized as the priority and leading sector of the country and duly supported with a favorable policy package, sufficient funding and knowledge-based technology interventions necessary for achieving sustainable agriculture growth and overall economic development.

9.5. Recommendations

Following recommendations are made for the way forward:

i. Replacing subsistence farming with the commercialization of agriculture and enhancing value-added agriculture. Commercialization can be achieved by increasing crop and water productivity through management practices and technology interventions. Introducing income generation activities on the farm by providing financial assistance and training to farmers and improving their skills and capacity to run small entrepreneurial ventures are the essential components of this package. This approach will generate employment, ensure food security and reduce poverty. Small and medium farmers (93% of total) owning 61% of cultivated land are the target for this intervention.

ii. Water management on supply and demand sides by using water conservation techniques, efficient irrigation methods, building new water reservoirs, canals and drainage system and expediting institutional reforms.

iii. Provision of an appropriate regulatory environment (e.g., intellectual property rights) is necessary for increasing the role of the private sector in technology advancement and ensuring their participation in the process of productivity enhancement.

iv. High-value horticulture crops such as fruits, vegetables, cut-flower, spices and medicinal plants have high production potential and export potential which can be enhanced by technology interventions and the developing of the required infrastructure for improving quality, grading, transportation, cool chain facility, reefers and commodity handling at airports and other export terminals. Government should also focus on value-addition of horticultural commodities by establishing a processing industry and marketing of value-added products.

v. Agricultural exports should be enhanced by improving the quality of agricultural produce through fixing quality standards and improving the quality of commodities through grading, polishing and waxing methodologies and improving handling and packaging skills and materials. Upgrading plant quarantine facilities and services, and controlling the indiscriminate use of pesticides are also needed for the promotion of agricultural exports.

vi. Trade and markets are necessary to accrue the maximum benefits and ensure reasonable returns to farmers. For this purpose, the government should develop improved markets, and easy access to working capital, establish modern market information systems and encourage private investment and participation in developing other critical infrastructure.

vii. Public Investment should be enhanced to create essential public goods. The main areas are agricultural research, farm-to-market roads and maintenance and development of upstream irrigation and drainage infrastructure. The priority among alternative investments also requires critical review.

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Chapter 10

Livestock Sector

Muhammad Abdullah and Umair Younas♦

Abstract

Pakistan is an agriculture-based country. The agriculture sector share is 19.5% of the Gross Domestic Product (GDP) during 2016-17. This sector is a source of livelihood for 42.3% of the rural population. Whereas livestock a sub-sector of agriculture has a major contribution to agricultural value added (58.33%) as well as to national GDP (11.8%). Pakistan got high potential for animal production all over the world and is blessed with renowned buffalo, cattle, goat and sheep breeds that are famous for rich fat milk production, high growth rate, and resistance to harsh climatic conditions. However, despite high production potential, per animal productivity is less compared to other countries. This might be attributed to the horizontal progress as animal numbers increase each year rather than improving livestock genetic pool by simple selection and culling methods. There is a huge gap between demand and supply of animal products in the livestock sector that is needed to fill as per capita availability of milk and meat is reported to be 170.2 L and 14.5 kg per annum which is far less than that of developed countries.

Keywords: Livestock, agriculture, dairy, buffalo, cattle, small ruminants, milk production, meat production, Pakistan.

10.1. Introduction

The term ‘livestock’ in a broad sense, includes all animals, birds, and other living creatures used for producing items for the use of human beings. In a narrow sense,

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the term livestock is loosely used to include the mammal farm animals like cattle, buffalo, sheep, goats, donkeys, camels, and horses, etc.

In Pakistan, livestock is an important sub-sector of agriculture and occupies a unique position in the agro-based economic development of the country. The sector meets the domestic demands of milk, meat, and eggs. It also provides a net source of foreign earnings. The livestock sector is blessed with world-renowned breeds of buffalo, cattle and small ruminants. It is central to the livelihood of the rural poor in the country and millions of families in rural areas are engaged in raising livestock as their main source of livelihood and food products. Livestock can play an important role in poverty alleviation and can uplift the socioeconomic conditions of our rural masses.

10.1.1. Livestock Role in National Economy

Pakistan is essentially an agriculture-based country with the world's largest canal-based irrigation system. Livestock works as a sub-sector of agriculture and possesses a key position in the economic stability of this country. Domesticated animals assume a vital part of the country's economy as providing family wages and producing profitable business in the rustic populace, especially among the landless laborers, small-scale farmers and rural women. Around 30-35 million country populaces are engaged with raising livestock, having family possessions of 2-3 buffaloes/cattle and 5-6 sheep/goats per family which help them to drive 30-40% of their income from domesticated animals.

Rural families that are involved in livestock operations are more than 80 million. It gives important sources of necessary items of human food like milk, meat, and eggs. It likewise gives fleece, hair, hide, skin, blood, bones, and farmstead excrement and is the main source of traction for cultivation and rural transport. It is observed that livestock animals play an imperative part in the lives of around 35 million individuals or around 25% of the total population. Animals and their products give a noteworthy source of nutrition and regular cash income to this concerned part of the population. The livestock sector provides employment for more than half of the country’s population while associated with the marketing and processing chain (Govt. of Pakistan 2017).

The contribution of livestock to the agriculture value added is 58.3% during 2016-17 (Figure 10.1) as compared to 55.6% during last year (2013-14). Similarly, the contribution to the national GDP is 11.8% (Figure 10.2) during 2014-15 although the contribution was the same during the same period last year. Gross value addition of livestock has increased from Rs. 778.3 billion (2013-14) to Rs. 801.3 billion (2014-15), recording an increase of 3.0% as compared to the previous year (Govt. of Pakistan 2017).

Various stages of management of buffaloes, cattle, goats, sheep and other draft animals in rural areas must be enveloped by livestock production in a systematic and required pattern while keeping concerns with up-to-date husbandry techniques. The need for most recent developments is that their management ought to be seen effectively and ought to be given due significance if the production from livestock is fancied up to their hereditary possibilities. It likewise grasps the opportunities covering their appropriate natural breeding or artificial insemination, proper hygienic housing, proper disease surveillance, balanced feeding, suitable vaccination programs as well as handling of manure and pollution control.

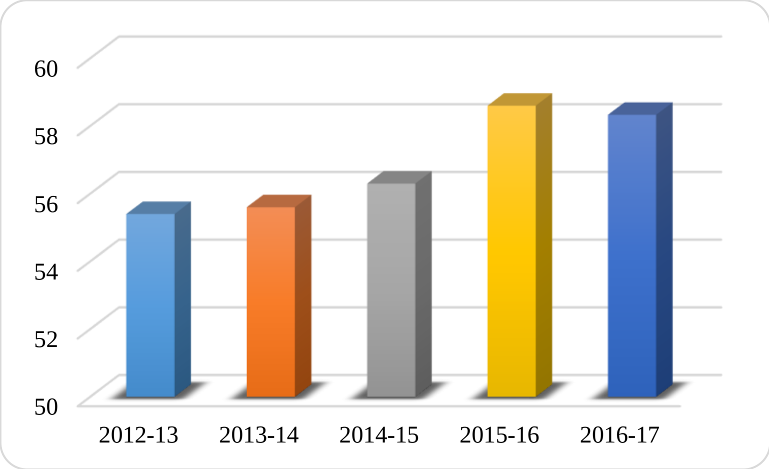

Figure 10.1 Contribution (%) of livestock sector in agriculture value added over past 5 years

Source: Govt. of Pakistan (2017)

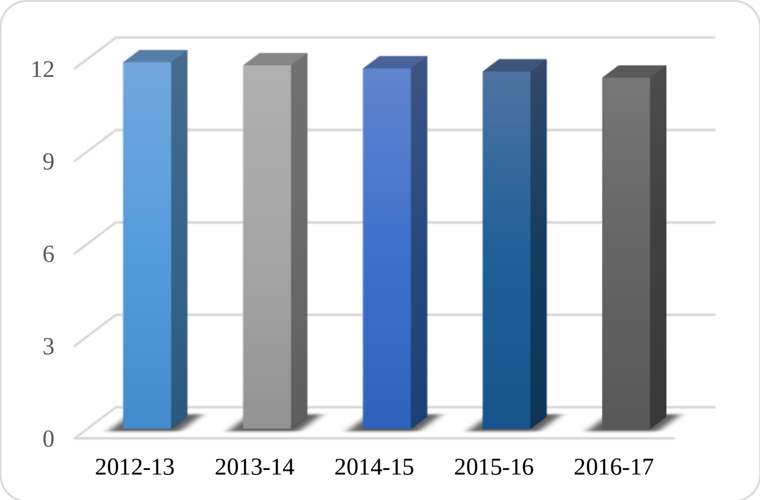

Figure 10.2 Share (%) of livestock sector in national GDP over past 5 years

Source: Govt. of Pakistan (2017)

The second biggest economic activity after crop husbandry is livestock production for the rural population of Pakistan. Unless we deal with rural livestock, the production capability of such a colossal number of animals can't be upgraded. Previously, numerous endeavors have been propelled in such a manner however those couldn't maintain and perished without having fruitful or productive results. Of the numerous enormous reasons, the most critical was that those advancements were not according to the needs of small-scale farmers, landless livestock proprietors and tenants. The farmers ought to get the answer to their issues from the researchers and extension workers that must be practicable, economical, cost-effective, efficient, adjustable as well as solution oriented. Modern efficient technologies should also be coupled with economic incentives and services in the public and private sectors.

10.1.2. Functions of Livestock Sector

Livestock is a source of high-quality food. Large and small ruminants are capable to converts inedible to edible products like milk, meat and eggs (Figure 10.3). Buffalo is known as the best specie to convert poor quality roughages into valuable food items. Livestock helps in improving the family nutrition status, especially in a country like Pakistan where there is a desperate need for supply of animal protein to common people against the huge demand needed to fill. Pakistan is one of those countries where children are dying due to poor nutrition and illness, especially those under five years of age. This sector allows some domestic consumption of essential nutrients.

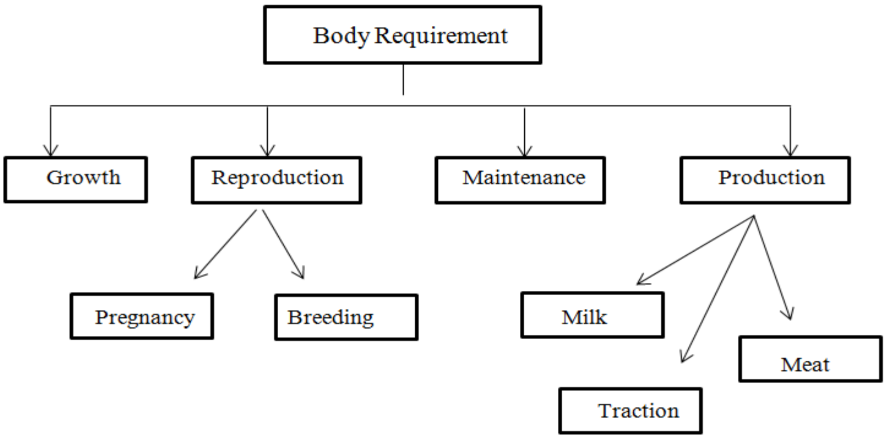

Figure 10.3 Classification of nutrients requirement for large ruminants (milch type)

Livestock is the principal source of draft power for rural transport and agricultural base activities like cultivation. Especially male animals are used for traction purpose. A major benefit of livestock products is a form of regular cash income like milk and meat. It also buffers the risks due to crop failure as well as unemployment. Biogas plants are one of the recent trends in Pakistan that have already been adopted by various countries to take an advantage of animal dung rather than discarding it. The dung and feces from livestock are used as a fuel source in rural households. Livestock helps in soil fertility by supplying the farmyard manure with regard to agriculture operations. Various other products like wool from sheep, hair, and mohair from goats are acquired. Hormones like insulin can be extracted from bovines for pharmaceutical use. Similarly, rennet is an enzyme used in the cheese industry and can be extracted from the abomasum of young un-weaned calves. Livestock is also a source of foreign exchange earnings (12 % of total export). Livestock animals are used for recreational purposes and are a symbol of Pakistan culture. In this regard, Horse and Cattle shows are regular events for livestock. It offers a platform for healthy competition and recreation. Last but not least, livestock help in improving the socio-economic status of millions of rural families. By working in a cooperative manner, people of a village or a specific region can be more benefitted.

10.2. Livestock Population and Recent Trends

10.2.1. Current Status of Livestock Population

In Pakistan, livestock includes cattle, buffalo, sheep, goats, camels, horses, asses, and mules. Goats are highly populated in Pakistan followed by cattle, buffalo and sheep (Figure 10.4). Despite a large number of cattle, the major share in total milk production comes from buffalo whereas, the least share comes from sheep.

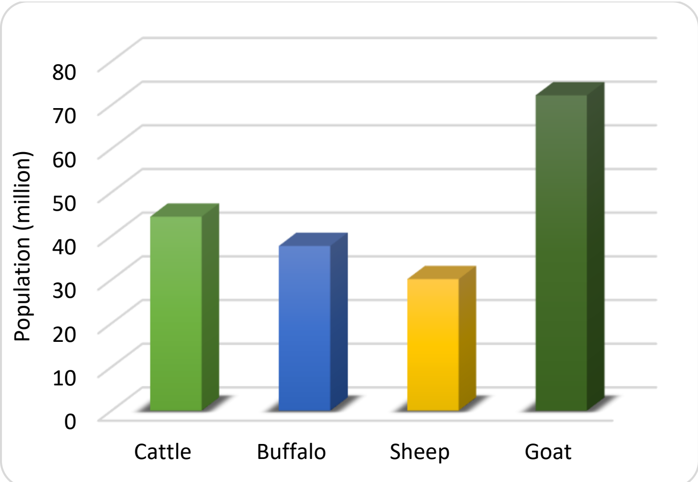

Figure 10.4 Livestock population in Pakistan

Source: Govt. of Pakistan (2017)

10.2.2. Current Status of Livestock Products

Buffalo's share in total milk production of Pakistan is 61% (Figure 10.5) followed by cattle and small ruminants. The major contribution to total meat consumption is from beef as compared to lower from mutton (Figure 10.6). This might be attributed to the high prices of mutton that shifted people's trend toward beef and poultry. Other livestock products like hides, skins, wool and hairs are increasing at slow but steady growth (Table 10.1).

10.2.3. Recent trends for livestock population and products

According to the Economic Survey of Pakistan (Govt. of Pakistan 2016-17) the livestock population is increasing each year (Figure 10.7), and therefore not only animal products (Figures 10.8 and 10.9) and by-products are increasing but also per capita availability for milk and meat (beef, mutton and poultry) is improving yet lot of gaps is needed to fill.

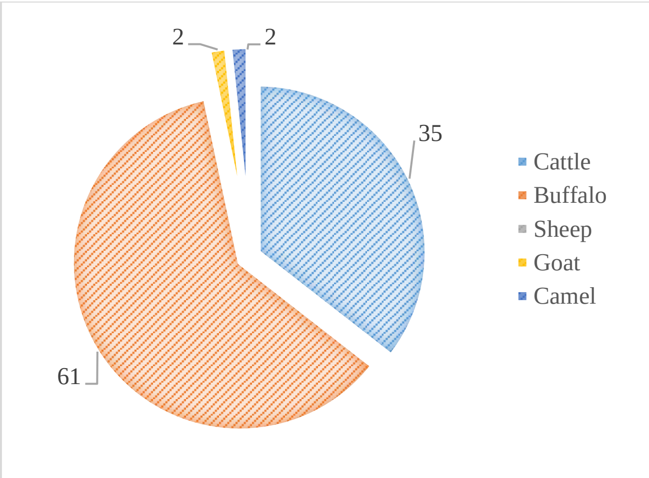

Figure 10.5 Contribution (%) in milk production by various livestock species

Source: Govt. of Pakistan (2017)

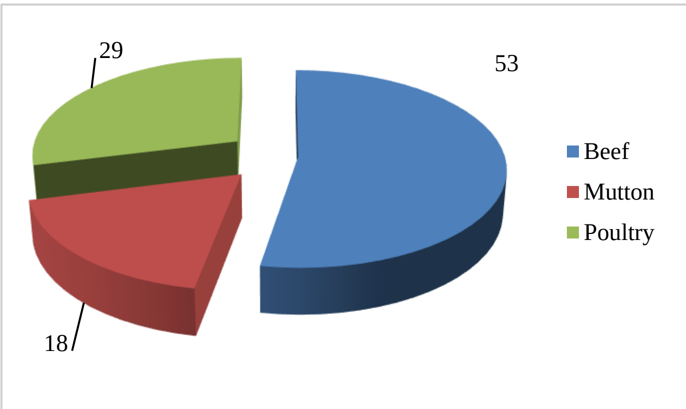

Figure 10.6 Contribution (%) in total meat production

Source: Govt. of Pakistan (2017)

Table 10.1 Estimated Livestock Products Production

	Units	2014-15	2015-16	2016-17
Hides	000' Nos.	15368	15,886	16,421
Skins	000' Nos.	53,060	54,278	55,526
Wool	000' Tons	44.6	45.1	45.7
Hair	000' Tons	44.6	26.5	27.2
Eggs (Poultry)	Million No.	15,346	16,188	17,083

Source: Govt. of Pakistan (2017)

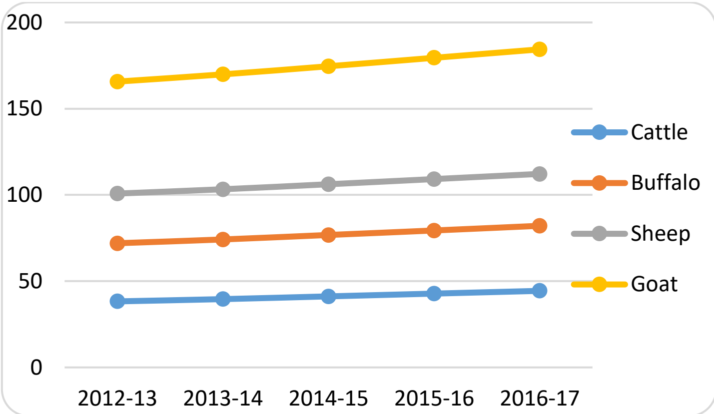

Figure 10.7 Trend of livestock population (million) over past 5 years

Source: Govt. of Pakistan (2017

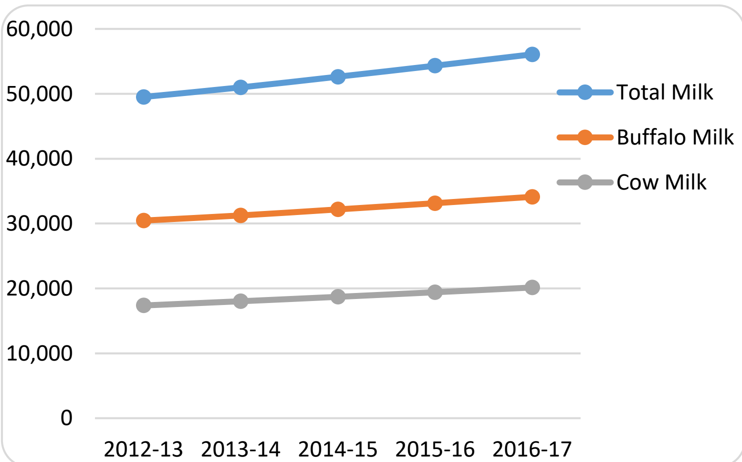

Figure 10.8 Trend of milk production (million tons) over past 5 years

Source: Govt. of Pakistan (2017)

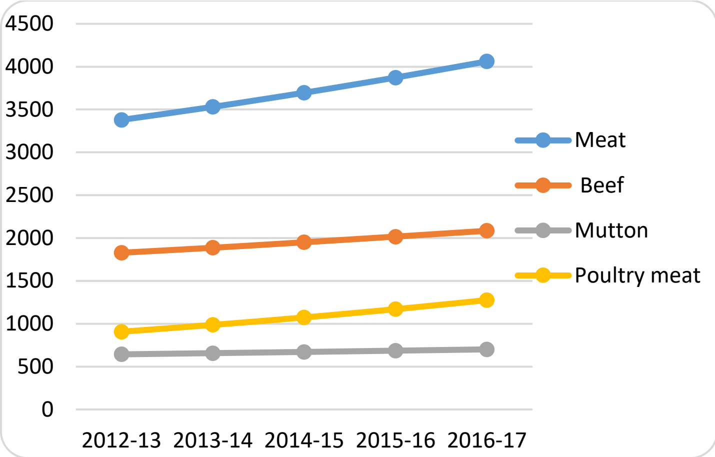

Figure 10.9 Trend of meat production ('000 tons) over past 5 years

Source: Govt. of Pakistan (2017)

10.2.4. Growth Drivers in Livestock Sector

The various segments of livestock improvement plans that can play a pivotal role as described by Govt. of Pakistan are 1) Support to livestock subsistence farmers and women for poverty alleviation by organizing, empowering and facilitating them for their capacity building. 2) Increasing per animal productivity through balanced nutrition, use of superior genetics and better animal husbandry. 3) Improving the livestock market operations, value addition and regulatory regime. 4) Realizing the potential of livestock assets by developing private enterprise. 5) Provision of high quality food products (milk and meat) to domestic consumers and use of research and technology to strengthen the export market.

10.2.5. Women Role in Livestock

In Pakistan, the rural women that deal with agriculture operations do not hesitate to participate in activities related to livestock management. Women in a large portion of various parts of the world are reported to work with livestock animals better than men. The small-scale and little landholder women in rural areas earn revenue by keeping and raising livestock. In little, landholder family unit ladies win salary by raising domesticated animals and they probably spend it for the sustenance of the families. Some livestock-related responsibilities taken by women include milking animals (Figure10.10), caring and management of young stock as well as looking after sick or diseased animals. The same situation prevails in Pakistan consisting of more than 200 million people and a large part of it resides in rural areas. The greater part of our populace living in country ranges, whose employment depends straightforwardly or in a roundabout way on agribusiness division. According to the report of UNDP (1997) rural women's participation rate in crop and livestock production activities is about 79.4%, which is higher than that of men (60.8%). Like other parts of the world, rural women in Pakistan are among millions of landless male laborers and small farmers, who are fighting back against rural poverty and toil hard to meet basic needs of food, clothing and shelter through their reliance on crop production. A survey conducted in five districts of KPK revealed that 82% of women participated in agri-based activities.

Figure 10.10 Rural women engaged in livestock related activities

10.3. Buffalo and Cattle Production Systems in Pakistan

The classification of production system is based on three raising system i.e.

1) Extensive **2)** Semi intensive **3)** Intensive

10.3.1. Extensive System

The extensive system is further divided into following categories:

1) Pastoralism
2) Crop agriculture with extensive cattle production
3) Commercial ranching

10.3.2. Pastoralism

No settled agriculture and sedentary cultivation rather lead a life of nomadism. People are essentially opportunists. These are prevalent in desert areas of Punjab, Sindh and Baluchistan. Animals are grazed in tight groups moving quickly over ranges (browsing as well as grazing). Milk production is a function of the season rather than lactation. Men, women and children may conduct milking. Infestation of diseases and parasites is the most prevalent along with mineral and protein deficiency.

10.3.2.1. Crop agriculture with extensive cattle production

This system is between pastoral nomadism and settled agriculture. They are termed agro-pastoral. This system occurs where land resources are limited, the population is increasing rapidly and there is a possibility of growing cash crops. This is observed in almost all parts of the country where the above-mentioned conditions are present. Cattle and buffalo used in this system are usually indigenous ones but with some crossbred cattle. Animals are kept in native. When there is a scarcity of feed the livestock is shifted to other areas of grazing. Milk production is a function of the season rather than lactation. Diseases and parasitic infestation are the most prevalent along with mineral and protein deficiency.

10.3.2.2. Commercial ranching

No commercial ranching system exists in Pakistan. However, there is a wide scope in the country as almost 70% of arid and semi-arid land of the country is consisted of ranges.

10.3.3. Semi Intensive System

10.3.3.1. Sedentary crop agriculture with livestock production

Semi-intensive system is the most important livestock production system. This system includes more than the half population of livestock reared in the country. Cattle owned by landless people were also included. The system is characterized by a small size of holdings, a mixture of subsistence, semi-subsistence and cash economies.

Cattle are kept for work and milk production. Old animals are used for meat. Agriculture wastes and industrial by-products are used as feed sources. In general, the cattle used in this system are indigenous in origin, but crossbred animals are also kept to have high milk yield. Feeding is often haphazard and management poor. Farmers don’t cultivate the sufficient area. Cattle are grazed and fed together with industrial by-products and available fodder. Farmers are responsive to the advice and have the potential for improvement.

Health services are relatively available and occasionally farmers get benefit from them. Milk surplus to that of family needs is sold. The major problem of the farmers is the size of land holdings. One thing, which farmers need to be realized, is that milk is the best cash crop.

10.3.4. Intensive Systems

This system is also known as a landless system since the animals are kept in the house and fed. Zero grazing dairy production and feedlot for small ruminants and cattle are examples of this. These are essentially indoor or semi-indoor animal production systems. However, an extensive and intensive component of the production system may be combined according to the production stage of animals. Therefore, dairy cattle may be kept on pastures, but calves will be raised in an indoor system.

There are two components of modern sector cattle production:

1. Dairying **2.** Beef production

The former has been developing in Pakistan but yet is in its infancy stage while there is a huge gap present in the latter component. There are small numbers of large-scale private or government-owned dairy farms. In this system, cattle are kept on very good concentrated feeds and provided with veterinary cover and modern techniques of A.I. (artificial insemination) although most of the farmers keep their bulls. Animals of high production potential are maintained. Milk production from buffaloes and cattle under various production systems is quite different (Table 10.2). The majority (80%>) of households are keeping less than 6 animals and flock size of 1-30 (Table 10.3).

Table 10.2 Milk production of cows and buffaloes under various production systems

Pakistan Production System	Average Milk Production (liters)	
	Buffaloes	Cattle
Rural subsistence smallholdings	1350	450
Rural, market-oriented smallholdings	3050	1500
Rural commercial farms	3450	1800
Peri-urban commercial dairy farms	3450	1800

Source: Pasha (2007)

Table 10.3 Number of Households Reporting Livestock (million household)

Herd size	Cattle	Buffalo	Flock size	Sheep	Goat
1-6	5.20 (84.1%)	5.00 (83.4%)	1-30	1.39 (88.9%)	6.57 (96.7%)
7-15	0.82 (13.3%)	0.84 (14.1%)	31-75	0.11 (7.6%)	0.17 (2.5%)
16-50	0.14 (2.3%)	0.14 (2.3%)	76-350	0.05 (3.2%)	0.05 (0.7%)
> 50	0.02 (0.3%)	0.01 (0.2%)	> 350	0.005 (0.3%)	0.004 (0.1%)
Total	6.18 (100%)	5.99 (100%)	Total	1.56 (100%)	6.80 (100%)

Source: Govt. of Pakistan (2006)

10.4. Constraints in Livestock Sector

Pakistan is a developing country and like other developing nations, there are various bottlenecks in the livestock sector of this country.

10.4.1. Constraints in Dairy Sector

Below given are the key constraints in the dairy sector:

1) Allocation of insufficient amount of funds despite densely livestock populated Punjab province.
2) Imposition of GST on milk products, including packaged milk.
3) A large number of livestock animals is a reflection of animal breeding on a horizontal basis thus the number is increasing only rather than per animal productivity.
4) Prolong calving interval, dry period and late puberty age in livestock lactating animals.
5) Enormous milk losses (15-20%) due to poor handling and storage as a consequence of improper chilling facilities.
6) The grazing ground for small and large ruminants is disappearing due to human population pressure.
7) Marketing system is weak and marketing channels are poorly organized. Large numbers of owners are dependent on the middleman. The remote area is scattered, the market is inaccessible directly to the small-scale farmers.
8) People got less interest in large animal farming due to increasing price of animal and their feed despite of poor genetic potential of livestock.
9) Lack of extension services.
10) Traditional approach of farmers towards health and management of farm animals due to lack of technical knowledge.
11) Relatively large investment is required in the dairy business.
12) Per capita milk and meat consumption are very less compared to developed countries.

10.4.2. Constraints in Meat Sector

Some important constraints of meat sector are as under:

1) Slaughter of baby calves (60-80 kg) and calves are raised on a poor diet.
2) End of career or old animals are slaughtered.
3) Slaughter of sick and diseased animals.
4) Limited commercial fattening farm activity.
5) Unhygienic meat transportation thus playing with people’s health.
6) Lack of specific meat breed in Pakistan despite good potential.
7) Absence of meat processing & packing at the government level.

10.4.3. Nutritional Constraint in Livestock Sector

1) Competition of land for fodder vs cereal crops.
2) Periods of fodder shortage.
3) Uncommon use of fodder storage techniques in rural areas (silage, hay).
4) Poor nutritional status of some fodder is hampering the the livestock productivity in general and milk production in particular.

10.4.4. Breeding and Genetic constraint in Livestock

1) Lack of an established registration system for animals.
2) Lack of pedigree records and improper handling of production records.
3) Problems in AI techniques and poor-quality semen for AI.
4) Semen of proven sires of domestic breeds is often not available. People are dependent on exotic semen.
5) Poor use of population genetic principles for the selection of superior animals.

10.5. Strengths and Opportunities in Livestock Sector

Following are the key strengths and opportunities in the livestock sector of Pakistan:

1) Livestock is the backbone and mainstay of the economy. This sector provides the raw materials for the food and leather industry.
2) Pakistan is the 4th largest milk-producing country and largest goat and mutton producing country after China and India.
3) Pakistan is the 2nd largest buffalo milk-producing country after India.
4) Pakistani cattle and buffalo breeds are much tolerable and adaptive to hot humid climates with resistance against ticks.
5) There is a gap between demand and supply of animal-based protein in Pakistan that can be overcome using high population density on vertical lines.
6) A 55% of the total small ruminant population is mainly found in Asia, particularly in India and Pakistan.
7) Pakistan stands as 4th largest country for goat milk and 2nd for goat meat production.
8) Third largest country for the goat population and the second largest number of buffaloes are Pakistan.
9) Pakistan grabed position in the top ten countries for cattle population and sheep population is also quite high (11th position).
10) Livestock is a major source of food items, i.e., milk, meat and eggs. Huge gap needed to be filled to increase per capita availability.

11) Source of farmyard manure that can be used for biogas plants.
12) Sizeable foreign exchanges earning through exports.
13) Wide scope of Milk Production, ranking 5^{th} in the world.
14) Livestock is an ample human resource employment sector. More than 8.0 million families in rural areas are engaged in this sector. Livestock is the 2^{nd} biggest source of livelihood in rural areas.
15) Huge demand and supply gap in the dairy sector and meat sector.
16) Increase in demand for animal origin food due to population growth, urbanization, income growth, changing consumer preferences and export potential.
17) Rising trend for keeping and raising cross-bred lactating animals with an aim to get more milk production. Rural people are getting aware of animal health and comfort. Improving the control of external parasites may enhance the value of hide or skin.
18) Livestock sector is a priority area for the Punjab government and SBP. A massive migration of labor to cities can be checked/stopped by generating employment.
19) Dairy products needs are 30% higher than supply. Value added by dairy products is rising in demand. Customers are ready to pay prices for good quality meat.
20) Commercially viable sector with great credit potential and absorption capacity.
21) Vast range of areas of operation, more needs and scope of development

10.6. Meat Sector and Halal Market in Pakistan

Mutton has been the food of choice for consumers for the last few decades due to its specific flavor and tenderness in Pakistan. Pakistan has successfully placed its position for high sheep (30.1 M) and goat (72.2 M) population as well as mutton and goat milk production in the top ten countries, worldwide (Govt. of Pakistan 2017). About 66% of all goat breeds and 57% of all sheep breeds resides in China, Pakistan and India. In Pakistan, there are few numbers of registered slaughtered houses and <1% of total meat production is being exported.

Meat production in Pakistan is 100% halal base with direct access to more than 450 million consumers in the Middle East, Central Asia and Europe. Halal meat is a rapidly developing market ($ 300 billion) in the world, helping around 16% of the aggregate world exchange, however being ranked 18^{th}, Pakistan's experience, this is not to the extent that it ought to be, viz. 2.9% of global halal meat production. In fact, no Muslim country features among the top 10 halal meat exporters. These facts suggest the great opportunity and tremendous potential to maximize and enhance productivity as well as quality. Compared to large animals, small ruminant farming requires a little investment with a quick return.

Raising Raising sheep and goats is not labor-intensive job and requires capacity building on the improvement of small ruminant productivity that will help in employment creation, enhancing soil fertility, improving livelihood, rural growth, and coping with a deficiency in animal protein in developing countries. Various breeds of small ruminants in Pakistan have the ability for multiple (twin) births like in goats Beetal (56%), Teddi (47%; triplet 15%) and in sheep Lohi (22%), Thalli (11%) and this ability can be improved through selecting process.

10.7. Livestock Breeds in Pakistan

10.7.1. Buffalo Breeds

The domestic or water buffalo (*Bubalus bubalis*) belongs to the family Bovidae. The river type is the one found throughout India, Pakistan, Bangladesh, Nepal and Sri-Lanka. These are primarily milch animals. The river buffalo, as a rule, shows a preference for clean running water, whereas the swamp buffalo likes to wallow in mud holes, swamps and stagnant pools.

There are two best buffalo breeds in Pakistan namely Nili-Ravi and Kundi that are normally inherited in the irrigated areas and alongside rivers with a potential of more than 5000 liters of milk production per lactation (Bilal et al. 2006). About 76.7% buffaloes in Pakistan belong to the Nili-Ravi breed, which is the most popular of buffaloes in Pakistan (Khaliq and Rahman 2010).

10.7.1.1. Nili-Ravi Buffalo

The home tract of the Nili-Ravi buffaloes includes Lahore, Sheikhupura, Faisalabad, Okara and Sahiwal districts of central Punjab and Multan and parts of Bahawalpur and Bahawalnagar districts of southern Punjab.

These buffaloes are massive and wedged shape animals (Figure 10.11). These are mostly blacks with a white muzzle, lower parts of 4 legs, forehead and switch of the tail due to which it is also named as “*Punjkalian*”. They have small curly horns and wall eyes.

Males attain maturity at the age of 30 months while females grain that at 36 months. Milk yield is 1800-2500 liters with a 6.5% butter fat. Age at 1st calving is 47 months, lactation length 312 days, dry period 198 days, service period 211 days, calving interval (520 days) and gestation period 306±10 days. It is the best buffalo breed in Pakistan and called the Black Gold of Pakistan. Adult males weigh 550-650 kg while female’s 350-450 kg. The growth rate of the animals when kept on fattening rations is about 800-1000 g/day.

Figure 10.11 Nili-Ravi Buffalo (Punj-Kaliyan/Black gold of Pakistan)

10.7.2. Cattle Breeds

Cattle also belong to the family Bovidae. European cattle are non-humped called *Bos taraus* while Pakistani cattle is having hump called *Bos indicus*. Sahiwal and Red Sindhi are the two best milch cattle breeds of Pakistan. Pakistani cattle are classified into the following three categories on the basis of the purpose for which it is mainly kept.

1. Milch breeds:

i. Sahiwal ii. Red Sindhi

2. Draught breeds

i. Heavy draught breeds

a. Dajal b. Bhagnari

ii. Medium draught breeds

a. Dhanni b. Rojhan

iii. Light draught breeds

a. Lohani

iv. Dual purpose breeds

a. Tharparker b. Kankrej

10.7.2.1. Sahiwal cattle

The home tract of the Sahiwal cattle includes Faisalabad, Okara and Sahiwal districts of central Punjab, and Multan district of southern Punjab. The breed is medium in size and has a fleshy body (Figure 10.12). Females have reddish dun color while males have darker color around orbit, neck and hindquarter. Males have stumpy horns while females are generally polled. Ears are medium-sized and dropping. Hump in males is massive but nominal in females. The switch of the tail is black. Milk yield is 1500-2200 liters with a 4.5% butter fat. Age at maturity is 850 days, age at 1st calving 2 ½ to 3 years, lactation length 275 days, dry period 172 days, service period 142 days, calving interval 412 days and the gestation period is 280±10 days. The average growth rate is 0.4-0.5 kg in males and 0.3 to 0.35 kg in females. Adult males weigh 400-500 kg while females 300-350 kg.

10.7.2.2. Red Sindhi cattle

The home tract of the Red Sindhi cattle includes Karachi, Thatta, Dadu, and Hyderabad districts of Sindh, and the Lasbella district of Baluchistan. The breed is medium in size with a compact body and red color. Males have darker color around the shoulders (Figure 10.13). Hindquarters are round and dropping in males and the switch of the tail is black. Ears are medium-sized and dropping. Hump in males is well developed and ears are fine a small. The sheath is developed in males but is nominal in females. The switch of the tail is black. Milk yield is 1500-2000 liters with a 4.0% butter fat. Age at 1st calving 1180 days, lactation length 275 days, dry period 180 days, calving interval 430 days, and gestation period 280±10 days. The average growth rate is 0.3 kg in males and 0.23 kg in females. Adult males weigh 425-525 kg while females 300-350 kg.

Figure 10.12 Sahiwal cattle (Milch breed)

Figure 10.13: Red Sindhi Cattle (Milch breed)

10.7.3. Sheep Breeds

Sheep belong to the family Bovidae. Out of the total of 29 sheep breeds, 14 are thin tail and 15 are thick/fat tail. Most of the breeds are coarse wool. Mostly sheep are raised for mutton purpose and wool production is the secondary objective. In the following tables, sheep breeds of Pakistan are mentioned with their home tracts.

10.7.3.1. Kajli Sheep

The home tract of this breed is Sargodha, Gujrat, Mandi Bahauddin and Mianwali. Its body is white with brown or black lower one-third of ear and a black circle around eyes and that iss why it is called Kajli. The nose is typical roman (Figure 11.14). The body weight of adult males is 55 kg and that of females is 45 kg. Annual wool production per animal is about 3 kg with 37 µ fiber diameter. These are extensively preferred as sacrifice animals during Eid ul Edha.

10.7.3.2. Lohi/Parkani Sheep

The home tract of this breed is Lahore, Gujranwala, Sheikhpura, Faisalabad, Jhang, Sahiwal, Okara, Sialkot, Sargodha, Gujrat and Mandi Bahauddin. Its body is white with brown ears and head (Figure 10.15). The nose is typical roman. It bears the name *Parkani* because there is a small ear-like structure on the main ear. The body weight of adult males is 65 kg and that of females is 50 kg. Annual wool production per animal is about 3 kg with 39 µ fiber diameter. These are extensively preferred as sacrifice animals during Eid ul Edha.

Table 10.4 Thin Tailed Sheep Breeds of Pakistan

Province/region	Breed name	Home tract
*NA and AJK	Baltistani	Baltistan (NA)
	Kail	Neelam and Leepa valley (AJK)
	Kali	Kotli
	Poonchi	Abbaspur, Aliabad, Kelar, Kahuta and Kotli
**KPK	Damani	DI Khan and Banu
	Kaghani	Kaghan valley (Abbotabad, Mansehra, Peshawar and Murdan)
	Rambouillet	French imported (Mansehra)
Sindh	Kachhi	Tharparer, Mirpurkhas, Sanghar and Rann of Kachh
	Kooka	Nawab Shah, Naushero Feroz, Dadu, Larkana, Khairpur and Sukhur
Punjab	Buchi	Bahawalpur, Bahwal Nagar and Thal desert
	Cholistani	Rahimyar Khan, Bahawalpur and Bahwal Nagar
	Kajli	Sargohda, Gujrat, Mandi Bahauddin and Mianwali
	Lohi	Lahore, Gujranwala, Sheikhpura, Faisalabad, Jhang, Sahiwal, Okara, Okara, Sialkot, Sargohda, Gujrat and Mandi Bahauddin
	Sipli	Bahawalpur and Bahwal Nagar
	Thalli	Thal desert and Sargohda, Multan, Muzaffarghar, Jhang and Mianwali

Northern Areas and Azad Jamu & Kashmir; Khyber Pakhtunkhwa*
Source: Shah (1994)

Figure 10.14 Kajli Sheep

Table 10.5 Fat Tailed Sheep Breeds of Pakistan

Province/region	Breed name	Home tract
*NA and AJK	Gojal	Hunza valley and NA
	Kohai Ghiza	Kohai Ghiza mountain
	Pahari	Mirpur and Muzzafarabad
**KPK	Balkhi	Peshawar, DI Kan and Banu
	Hashtnagri	Peshawar, Murdan, Haripur, Banu and Kohat
	Michni	Peshawar and Kohat
	Tirahi	Banu, Kohat and Peshawar
	Waziri	Northern Waziristan, Banu, Kohat and Peshawar
Baluchistan	Baluchi	Kalat and Quetta
	Bibrik	Sibi, Quetta, Loralai and Zhob
	Harnai	Sibi, Quetta, Loralai & Zhob
	Rakhshani	Kharan, Mekran, Chaghi and Kalat
Punjab	Salt Range	Attock, Rawalpindi, Jhelum, Sargohda and Mianwali
Sindh	Dumbi	Dadu, Thata and Karachi

Northern Areas and Azad Jamu & Kashmir; Khyber Pakhtunkhwa*
Source: Shah (1994)

Figure 10.15: Lohi Sheep (Perkanni)

10.7.4. Goat Breeds

Goat also belongs to family Bovidae. Salient features of Pakistani goat breeds are most of them are of medium size; kept mainly for meat and hair production although some produce considerable amount of milk but non breed has been developed as dairy breed. In the following tables goat breeds of Pakistan are mentioned with their home tract.

10.7.4.1. Beetal goat

The home tract of this breed is Jhelum, Gujrat, Mandi Bahaudin, Sialkot, Gujranwala, Lahore, Faisalabad, Sheikhpura, Jhang, Sargohda, Multan, Sahiwal and Okara. Its body color is golden brown, red spotted with white or black patches with pendulous ears (Figure 11.16). Nose is roman. Body weight of adult males is 46 kg and that of females are 37 kg. Udder is well developed & milk yield is 290 liter during a 130 days lactation period. Twinning and triplet rate is about 50%.

10.7.4.2. Teddi Goat

The home tract of this breed is Sargohda, Gujrat, Jhelum and Rawalpindi. Its body color is creamy white, black and brown (Figure 11.17). Body weight of adult males is 30 kg and that of females are 23 kg. Milk yield is 65 liter during a 130 days lactation period. Twinning rate is 50% while triplet rate is 15%.

Table 11.6 Goat Breeds of Pakistan

Province/region	Breed name	Home tract
*NA and AJK	Baltistani	Baltistan (NA)
	Beiari	Kotli and Muzzafarabad
	Buchi	Kotli, Muzzaffarabad and Poonch
	Desi/Jattal	Mirpur and Kotli
	Jarakheil	Chilas, Diamer and Hazara
	Kohai Ghizar	Gilgit, Yasin and Imit

	Kooti	Almut and Kail
	Labri	Jhellum, Leepa and Neelam valleys
	Piamiri	Hunza & Khunjrab
	Shurri	Muzzafarabad and Poonch
**KPK	Damani	Banu, DI Khan and Peshawar
	Gaddi	Kaghan valley
	Kaghani	Kaghan valley
Punjab	Beetal	Central Punjab including Jhelum, Gujrat, Mandi Bahaudin, Sialkot, Multan, Sahiwal and Okara, etc.
	Dera Din Panah	Muzzafargarh and Multan
	Hairy Goat	DG Khan
	Kajli/Pahari	DG Khan and Loralai (Baluchistan)
	Nachi	Bahawalpur, Multan, Muzzafagarh and Layyah
	Pothwari	Pothwar area
	Teddy	Sargohda, Gujrat, Jhelum and Rawalpindi
Balochistan	Khurasani	Chagzi, Loralai, Quetta and Zhob
	Lehri	Kachhi
Sindh	Bari	Hyderabad, Dadu, Khairpur, Nawabshah and Khairpur
	Bugri	Hyderabad, Badin and Mirpur Khas
	Chappar	Karachi, Thata, Dadu and Larkana
	Jattan	Mirpur Khas
	Kamori	Nawabshah
	Pateri	Hyderabad, Nawabshah, Khairpur and Sanghar
	Sindh Desi	Dadu, Nawabshah and Larkana
	Tapri	Hyderabad, Sanghar, Mirpur Khas and Sanghar
	Tharki	Thar

Northern Areas and Azad Jamu & Kashmir; Khyber Pakhtunkhwa*
Source: Shah (1994)

Figure 10.16 Beetal Goat

Figure 10.17 Tedi goat

Table 10.7 Global Statistics for Sheep

Sheep Population	Top Exporters	Top Importers
China	N Zealand	France
Australia	Australia	UK
India	UK	China
Iran	India	US
Sudan	Ireland	S Arabia
Nigeria	Uruguay	Belgium
N. Zealand	Belgium	Germany
UK	Spain	UAE
Pakistan	Netherlands	Italy
S Africa	Germany	Papua New Guinea

Source: *FAOSTAT (2014)*

Table 10.8 Global Statistics for Goat

Goat Population	Top meat producers	Top Exporters	Top Importers
China	China	Australia	United States
India	India	Ethiopia	UAE
Pakistan	Pakistan	China	China
Bangladesh	Bangladesh	Pakistan	Qatar
Sudan	Sudan	France	Hong Kong
Nigeria	Nigeria	Saudi Arabia	Saudi Arabia
Iran	Iran	New Zealand	Italy
Ethiopia	Indonesia	United States	France
Mongolia	Greece	Spain	Canada
Indonesia	Mali	Argentina	Trinidad and Tobago

Source: FAOSTAT (2014)

10.8. Punjab Government Initiatives for Livestock

Various mega projects were undertaken and successfully completed by livestock and dairy development board (Punjab) to strengthen this sector. Some of these projects are:

1) Support Services for Livestock Farmers Phase-III (964.15 million; 2005-06 to 2009-10)
2) Establishment of Milk processing plants at Layyah and Sialkot (1152.8 million; 2006-07 to 2010-11)
3) Free Vaccination under Chief Minister Program 2005 in Punjab (116.2 million; 2007-08 to 2009-10)
4) Development of Cholistan Breeds of Livestock through Provision of Better Animal Services (210.9 million; 2007-08 to 2009-10)
5) Camel Breeding & Research Station at Rakh Mahni, Bhakkar (169.7 million; 2007-08 to 2008-09)
6) Up-gradation of Research Facilities at Livestock Production Research Institute, Bahadurnagar, Okara (250.0 million; 2008-09 to 2009-10)
7) Barani Livestock Development through Women Empowerment (120.1 million; 2008-09 to 2010-11)
8) Cholistan Livestock Development Project (277.0 million; (2008-09 to 2010-11)
9) Establishment of New Disease Diagnostic Laboratories in Punjab Phase-II (160.0 million; 2008-09 to 2010-11)
10) Research Centre for Conservation of Sahiwal Cattle Jhang (Phase-II; 120.8 million; 2008-09 to 2010-11)
11) Shadbad Co-operative Livestock Farms (431.0 million; 2009-10 to 2010-11)
12) Strengthening of Communication and Extension Network of Livestock Department (85.0 million; 2009-10 to 2010-11)
13) Establishment of Animal Disease Surveillance and Reporting System in Punjab (57.0 million; 2009-10 to 2011-12)
14) Enhancing Beef Production in Punjab (317.7 million; 2009-10 to 2012-13)

Whereas some of the new mega projects are:

1) Establishment of University of Veterinary and Animal Sciences at Bahawalpur (1686.0 million; 2014-15 to 2016-17)
2) Poverty Alleviation of Poor Women through provision of Heifer and Sheep / goats in Punjab (2160.0 million; 2014-15 to 2017-18)
3) Enhancing Dairy Production through Exotic Semen (98.0 million; 2014-15 to 2016-17)

4) Productivity Enhancement through Genetic Improvement in Small Ruminants/ upgradation of facilities at LES Khairewala & Alladad Farm (180.0 million; 2014-15 to 2016-17)
5) Up-Scaling RCCSC Genetic Improvement Programme (450.0 million; 2014-15 to 2016-17)

10.9. Future Prospects of Livestock Sector in Pakistan

Demand-supply gap: There is a huge gap that is needed to be filled between demand (7%) and supply (3-4%) of animal products. The population of Pakistan is rising each year and thereby this difference urges us to work on new horizons for livestock progress.

Motivational environment: The livestock environment, at present, is not much friendly. People are afraid to spend due to fear of loss and hesitation due to huge investments in the dairy sector. Peoples need a motivational environment with a basic understanding of this sector and its importance. A large portion of Pakistan's population comprises youth who can play a pivotal role in the livestock industry.

Per capita availability of milk and meat: According to the planning and development division (nutrition section, Islamabad; 2010-11) the per-capita availability of milk and meat is 118.60 and 16.76 kg/annum, respectively is far less than that of developed countries and shows massive space between demand and supply.

Modernization of dairy plants: Upgrading and innovative measures are required to be taken for existing dairy sheds. There has to be the establishment of new hygienic modern dairy plants at the national level. The milk procurement channel must be upgraded in order to ensure that dairy plants work at their full capacity.

Government intervention: Government needs to intervene and replace the old infra-structure of livestock and replace it with modern and according to international standards. The livestock and dairy development department is doing some serious efforts to control illegal practices by quack doctors in the field and farmers are encouraged to contact in case of any query for livestock improvement (Figure 11.18).

Vertical improvement: Livestock animals with high genetic potential for milk production are the keystone for a successful production strategy. People already gaining interest in their animal health and enhancing productivity however they need to discourage random mating. Animals with proper pedigree records and good production records should be used to get the next generation. A dire need for national progeny testing schemes carried out by animal breeding and genetics expert.

Implementation of strategies: There is a need for a comprehensive understanding along with an insight into the present and past dairy sector plans and implement the dairy farming strategies.

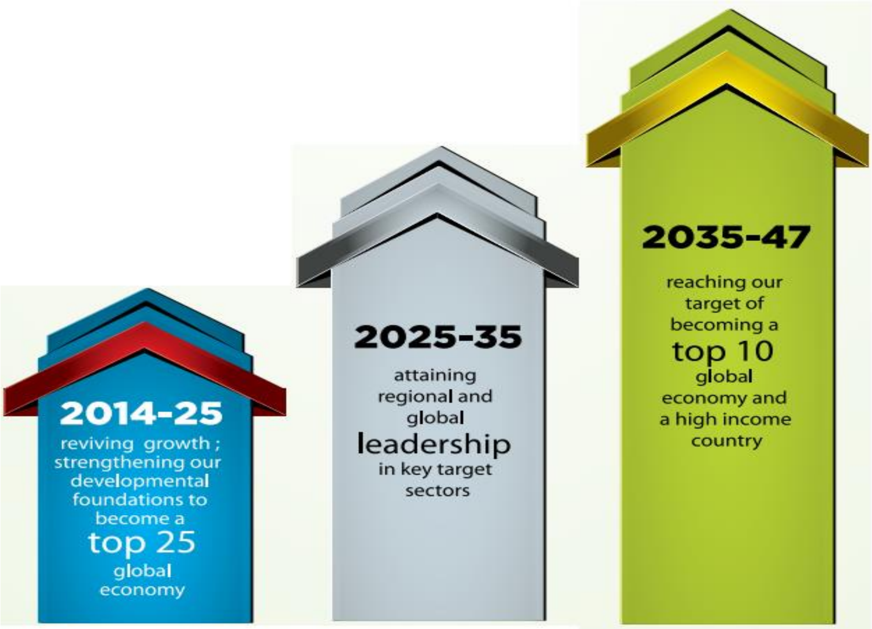

Figure 10.18 Pakistan targets for economic growth

Source: Govt. of Pakistan (2015)

Improved feeding regimes: Superior fodder qualities needed to be identified and propagate to lessen the problem during fodder deficient months. Through extension services, awareness must be created among farmers and peoples of rural area about the importance of forage conversation through silage and hay making as well as use of minerals supplement. Urea molasses block, ration formulation and use of high yielding fodder varieties gaining popularity.

Disaster management program: During last decade, Pakistan suffers from various disasters including earth quacks and floods that substantially affected the livestock and thus economy was affected. An estimated loss of 5.1 m US$ was noted during 2010 flood and fertile land of Punjab was affected. In future, livestock disaster management programs are required to initiate and work on regular basis to lessen the negative impacts on economy.

Punjab government growth strategy for Livestock-2018: The future strategy for livestock sector aim to achieve the 25% increase in the average productivity of livestock animals. Similarly, 25% increase in contribution of livestock to national GDP is planned. Share in livestock products and by-products in exports is aimed for 25% increase and 10% increase in household income of small livestock farmers. The future road map would exceptionally help and promote the value addition in livestock.

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Chapter 11

Forest Sector

Muhammad Tahir Siddiqui and Muhammad Farooq Azhar♦

Abstract

Forests are an important part of the world biome and have always been admired by man through children's tales and folklores of many nations. One-fourth area of any landscape should be forests for ecological balance and sustainability. Pakistan is in the arid and semi-arid belt, therefore, receives less rainfall and results in low forests naturally. Ever increasing population is another threat to these meager natural resources. It put extra pressure to clear more and more land for agriculture as the pre-existing agricultural land is being turned into housing towns and industrial zones. Almost all major forest types of the world are present in Pakistan. Although they are less in the area yet are critical in different ways. They have the oldest junipers in the world and world second in area wise. Forests and trees help protect watersheds of major rivers. They also provide so many essential products for rural and urban dwellers. Some wavering efforts from the government and less enthusiasm by the common people in protecting forests outcomes the world's higher deforestation rate in the country. Involving the common man, particularly the farmers, with the best possible integration of forestry and agricultural practices is the best strategy for protecting existing forests and promoting forestry.

Keywords: Forest, Forest Resources, Growing Stock, Deforestation, Afforestation

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11.1. Introduction

All shades of major world vegetation are present in Pakistan due to the variable physio-climatic and edaphic conditions of the country. Topographically, the country is cheered with the splendor of many contrasts. It started with sandy beaches, and mangroves in the south, abruptly changes into wild sandy deserts in the south-west and a large fertile productive plain, the Indus basin to the northern tree-clad mountain system, comprising the Karakoram (Mount Godwin-Austen or Chhogori is the world 2nd highest mountain in this range with 8611 m height), the great Himalayas, and the Hindu-Kush, with permanent snow and glaciers and over 100 peaks of over 5,400 m. This mountain system is one-third of all mountain ranges in the country. The western mountain ranges are dwarf and dry, comprising the Sufed Koh and the Suleiman stretching towards the south-western ranges forming a moderately high and cold Baluchistan plateau with less rainfall. The mountains of the northern region are important watersheds and are continuously eroded due to natural and anthropogenic activities. The majestic Indus plain consists of alluvial plain and sand-dune deserts. Five rivers; namely, Indus, Jhelum, Chenab, Ravi, and Sutlej irrigate this Indus plain. Much of the silt of the alluvial plain is from natural geological erosion of mountains in the north brought down by rivers. Thal desert lies between the rivers Indus and Jhelum, while Cholistan and Thar deserts occur in the south-east of the country (Siddiqui 1997).

The total forest area under the control of the Forest Departments (including Azad Kashmir and the Northern Areas) is 4.26 million ha (FSMP 1993). The per capita forest area is only 0.037 ha compared to the world average of 1.0 ha (NIPS 2009). A study conducted in 2012 disclosed the actual covered forest area of Pakistan as 5.1% (Bukhari et al. 2012). However, according to a study conducted by Food and Agriculture Organization (FAO) in 2015, Pakistan has only 2.2% (1.67 million ha) forest area, of which just 20.2% (340,000 ha) is primary forest. Further, the country has witnessed deforestation at an alarming rate of 2.1% on average between 1990 and 2015. At the national level, the deforestation rate is estimated at 27,000 ha per year in private and community-owned natural forests (Govt. of Pakistan 2015). Plantations in farmland, along roadsides, canal, and railway sides covering an estimated area of 466,000 ha and16, 000 ha, respectively do not constitute forests within the context of legal, ecological, or silvicultural/management definition of forests (Quraishi 2005). Import of wood and wood products costs the resource-poor country more than 5000 million rupees annually. Domestic wood requirements touch 48.52 million m3 whereas wood production is 14.4 million m3 only. This demand for wood is 3 times higher than the annual increment of forests or potential sustainable supply (Govt. of Pakistan 2015). This demand is fulfilled by importing wood and wood products.

About 75% area falls under the arid and semi-arid zone and the availability of moisture for the growth and perpetuation of vegetation is a big constraint. Whatever little is available has been exploited indiscriminately to meet the ever-increasing demand of a fast-growing population. Heavy incessant grazing and lopping do not give any respite to natural regeneration or young saplings planted in afforestation/reforestation campaigns. Forest sites have deteriorated to the point of almost no return due to misuse and mismanagement. The people living in the watersheds and deserts are forced to cut trees for their survival as no substitutes are available for heating, cooking, construction of hutments, and the rearing of their livestock. To cap it, forestry projects are given low priority by the people who matter and there is a sub-optimal investment in development programs. Trees are a living entity and in the absence of backup and maintenance funds, all the labor and money invested in development projects goes waste. There is a total lack of awareness of the problem and there are weak and ill-equipped extension services to motivate the people to plant and protect trees.

11.2. Forest types

Variation in forest resources is mainly due to climate and altitude. The area under various forest types in the country was derived from forest working plans and is summarized in Tables 11.1 A and 11.1 B. The province-wise area under forest cover is summarized in Table 11.2. The following forest types are found in Pakistan (Champion et al. 1965; Sheikh and Hafeez 1997).

11.2.1. Littoral and swamp forests (Mangroves)

These are low heightened, often only 3-6 m tall, more or less dense forests found in the tidal zone of the Arabian sea (Indus delta), around the coast of Karachi (Keti Bandar) and Pasni, and Gawadar in Baluchistan. Species are a few and markedly gregarious, all evergreen with entire leathery leaves. Vivipary habit and development of pneumatophore is common. The mean annual rainfall is 152 to 229 mm. The main species are *Avicenniea officinalis* (95%), *Ceriopstagal* and *Rhizophora mucronata* (5%). *Rhizophora mucronata*is was re-introduced successfully in recent years by the regional forest department and *Aegicera scorniculatum* is under trial. According to the latest estimates, world Littoral and Swamp forests cover at least 14 million ha and in Pakistan, these forests cover an area of 207,000 ha and claim the 7th largest in the World. These forests come in world headings when Sindh Forest Department sets a new world record by planting 8, 47, 275 mangrove saplings at Kharo Chaan near Keti Bandar district Thatta on 22nd of June 2013 by 300 volunteers in 11 hrs. These forests are natural habitat and breeding place for marine life and fish and are also potential sources of firewood.

11.2.2. Tropical dry deciduous forests

These are forests of low or moderate height consisting almost entirely of deciduous species. Their canopy is typically light though it may appear fairly dense and complete during the short rainy season. This type does not occur extensively in Pakistan but there are limited areas in the Rawalpindi foothills carrying this vegetation type, all much adversely affected by close proximity to habitation or cultivation. These forests occur at an elevation of 1200-2000 feet. The chief tree species are *Lannea* (Kamlai, Kembal) *Bombax ceiba* (Semal), *Sterculia*, *Flacourtia* (Kakoh, Kangu), *Mallotus* (Kamila, Raiuni) and *Acacia catechu* (Kath). Common shrubs are *Adhatoda* (Bankar, Basuti, Bansha), *Gymnosporia* (Putaki) and *Indigofera* (Kathi, Kainthi).

Table 11.1A. Forest types (Compact forests)

Forest Type	Area (Acre)
Irrigated Plantation	424775.73
Riverine Forest	175702.03
Scrub Forest	676335.75
Range Land	203321.00
Desert	38226.50
Coniferous	113416.00
Coniferous/Scrub Forest	30704.00
Miscellaneous*	1709969.24
Total	3372450.25

**unclassified*

Table 11.1B. Forest types (Linear strip plantations)

Forest types	Area (km)
Road Side	10665.15
Rail Side	2580.50
Canal Side	33795.37
Total	47041.02

11.2.3. Tropical thorn forests

These are pronouncedly xerophytic forests with short height and open canopy in which thorny hardwood leguminous species predominate. This type occupies most of the Indus plains (elevation 1200 feet) except for the driest parts. In upper Indus plains, these forests are known as Rakh while in lower Indus plains as Scrub forests. They are most widely spread from the Arabian Sea including southern Sindh and western Balochistan to the major part of the Punjab plains. The mean annual temperature varies from 24 to 27°C with a maximum of 50°C in summer while the mean annual rainfall is 762 mm but varies from year to year and sometimes less than 127 mm.

The major tree species are *Prosopis cineraria* (Jhand), *Capparis decidua* (Karir, Karil), *Zizyphus mauritiana* (Ber), *Tamarix aphylla* (Farash) and *Salvadora oleoides* (Pilu, Wan) which can grow on a wide range of soil textures, from flat deep alluvial soils to heavy clays, loams and sandy loams. Vegetation also includes a large number of shrubs of all sizes. The forest climax is very frequently degraded to a very open, low thorny scrub of *Euphorbia* (Thor), *Zizyphus* (Ber), etc. owing to the universally heavy incidence of grazing and other biotic factors. Edaphic variants, especially associated with a degree of salinity, shallowness over rock, etc., often occur. Characteristic pioneer vegetation is developed on inland sand dunes and semi-deserts of the areas of least rainfall.

These forests are merged with riparian forests along riverbanks and called as *Riverain* forests in Sindh province where *Acacia nilotica* species is grown for its economic importance and in Punjab known as *Bela* forests where artificially grown *Dalbergia sissoo* is a major tree species. Together with scrub forests, these forests provided an ideal habitat to the wildlife of the area which seasonally migrated according to their needs, during cold winter from the lower hills towards the plains in search of food and shelter, from the flood plains towards the dry areas during floods and towards the rivers during the summer drought. *Riverain* forests now grow in the forms of disjoint patches over an area of 173,000 ha. With the development of the canal irrigation system in Pakistan, this forest type is transferred into irrigated agriculture which is carried over 18.67 million ha and irrigated tree plantations (manmade forests) over an area of 103,000 ha to fulfill the timber requirements.

11.2.4. Sub-tropical broad-leaved evergreen forests

These are also called as *Kau phulai* forests and consist of xerophytic, thorny and small-leaved evergreen species. This type occurs at a height of 1500-5000 feet on the foothills and lower slopes of the Himalayas, Margalla hills, Malakand, the Salt Range, Kala Chitta and the Suleiman Range. The typical species are: *Olea cuspidata* (Kau) and *Acacia modesta* (Phulai), the two species occurring mixed or pure, and the shrub *Dodonaea* (Sanatta) which is particularly abundant in the most degraded areas. The total area of these forests is estimated to be 1,191,000 ha.

11.2.5. Sub-tropical pine forests

These are open inflammable pine forests having a high canopy which may be up to 120 feet with no or very little under vegetation which mostly consists of a dry evergreen shrub layer. This type consists of Chir pine *(Pinus roxburghii)* forests found between 2953-5577 feet elevations in the Western Himalayas. It is within the range of the south-west summer monsoon and receives mean annual rainfall of about 762 mm to 1270 mm. It is the only pine (*Pinus roxburghii*) found in these forests with a little overlap with *Pinus wallichiana* (Kail) at the upper limit.

11.2.6. Himalayan moist temperate forests

The evergreen forests of conifers, locally with some admixture of oak and deciduous broad-leaved trees fall in this category. Their undergrowth is rarely dense and consists of both evergreen and deciduous species. These forests occur between 4500 to 10,000 feet elevations in the Western Himalayas (Murree, Kaghan, Azad Jammu and Kashmir, Nathiagali and Shogran) except where the rainfall falls below 1000 mm in the inner ranges, especially in the extreme north-west.

These forests are divided into a lower and an upper zone, in each of which definite species of conifers and/or oaks dominate. In the lower zone, *Cedrus deodara* (Deodar, Diar), *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* (Partal) are the main conifer species in order of increasing altitude, with *Quercus incana* (Rin, Rinj) at lower altitudes and Q. *dilatata* above 2130 m. In the upper zone, *Abies pindrow* and *Q. semecarpifolia* are the dominant tree species. There may be pockets of deciduous broad-leaved trees, mainly edaphically conditioned, in both zones. Alder *(Alnus* pecies) colonizes new gravels and sometimes Kail does the same. Degradation forms take the shape of scrub growth and in the higher reaches; parklands and pastures are subjected to heavy grazing.

11.2.7. Himalayan dry temperate forests

Generally, these forests occur at an elevation of 5000-11000 feet extending to 12000 feet on southern aspects which receives less annual rainfall (the south-west monsoon). These are open evergreen forests with open scrub under growth. Both coniferous and broad-leaved species are present. This type occurs on the inner ranges in the north-west areas which include northern areas like Chitral, Neelam, Kaghan valley, higher parts of Suleiman Range, Ziarat and Shingarh. Dry zone deodar, *Pinus gerardiana* (Chalghoza) and/or *Quercus ilex* are the main species. Higher up, blue pine communities occur and in the driest inner tracts, the oldest forests (over 4500 years) of blue pine, *Juniperus macropoda* (Abhal, Shupa, Shur) are found in Ziarat (2nd largest in the world after California, USA) and some *Picea smithiana*is found in Gilgit.

11.2.8. Sub-alpine forests

Sub-alpine forests are the topmost tree formation in Himalaya below timberline at 11000 to 12000 feet elevation on northern aspects. It is found in Kashmir, Upper Dir, Swat, Chitral and Hazara. Evergreen conifers and mainly evergreen broad-leaved trees occur in the relatively low open canopy, usually with a deciduous shrub by under growth of *Viburnum* (Guch), *Salix* (Willow), etc. *Abies spectabilis* and *Betula utilis* (Birch) are the typical tree species. High-level blue pine may occur on landslips and as a secondary sere on burnt areas or abandoned clearings. Rhododendrons (Bras) occur in the under-storey but do not form extensive communities as they do in the central and eastern Himalayas. Dwarf junipers are often abundant.

11.2.9. Alpine scrub

This zone exists above the timber line (about 1100 feet altitude and above) where only a limited number of herbaceous species exists. These species have flexible stems to bear snow pressure. Most of the time this zone remains covered with snow. Under this type, there are shrub formations 1 m to 2 m high extending 150 m or more above the sub-alpine forests. Alpines are present in Kashmir, Hazara and Upper Dir. The characteristic genera are Salix, Lonicera (Phut), Berberis (Sumbul, Sumblue), Cotton easter with Juniperus and occasionally Rhododendron or Ephedra (Asmania).

11.3. Present Scenario

The forest resources have been eroded gradually but surely over a period of time. Starting with the invasion of this Sub-continent by the Central Asians, a chain of battles and wars pushed the people of the plains to the distant areas for refuge here and they made heavy in roads in the forests for their dwellings, agriculture, grazing, etc. The scientific management of the forests in the Himalayas started more than a century ago. During the first and second world wars, the accessible forests were over-exploited to feed the war machine. At the time of land settlement, certain rights of the local population were admitted for timber, fuelwood, grass cutting and grazing. Since these rights have multiplied with the growth in population, they are no more compatible with the resource potential. Thus, when Pakistan came into being, the forest in this part of the Sub-continent had already been depleted to a very large extent. The situation was further aggravated by the mass migration of people from across the border in 1947. The meager resources had to bear the pressure of unsettled emigrants.

The forestry sector plays an important role in soil conservation, regulates the flow of water for irrigation and power generation, reduction of sedimentation in water conveyances and reservoirs, and employment and maintenance of ecological balance. There is a dire need to increase the area under tree cover not only to meet the material needs of the growing population but also to enhance the environmental and ecological services being provided by the forests. Some good efforts in increasing and restoring the forest area in Pakistan are made. In 2016, the Government of Pakistan announced the Green Pakistan Program, with a goal to plant over 100 million trees in the country. Earlier, The Billion Tree Tsunami Afforestation Project in Pakistan's northern Khyber Pakhtunkhwa (KPK) province was launched which has surpassed its target by restoring and planting trees in 350,000 ha of degraded forest landscapes (IUCN 2017).

Table 11.2 Forest cover for each province (area in million ha)

Province	Geographic area	Forest area
Total	79.61	4.55
Punjab	20.63	0.49
Sindh	14.09	1.03
Khyber Pakhtunkhwa	10.17	1.31
Balochistan	34.72	1.72

Source: Govt. of Pakistan (2014)

A reliable and complete inventory of forest growing stock is not available nationally. Forest department working plans cover approximately 50% of coniferous forest area and contain estimates of volume, but many of these are based on outdated inventories. Coniferous forests of KPK, Punjab and AJK have more complete inventories than other forests. The Forest Sector Master Plan (FSMP) compiled data for a 1.3 million ha area of 29 working plans in KPK, 3 in Punjab and 4 in AJK, and 3 working schemes in Northern areas ((Table 11.2). The growing stock of coniferous forests covered by these plans/schemes was 185 million cubic meter feet (m^3f) or an average of 145 m^3f per ha. Applying the average standing volume per ha for each province gives the total coniferous growing stock (Table 11.3).

Table 11.3 Total coniferous growing stock (000 m^3f)

Province/Territory	Coniferous growing stock
AJK	40,729
Northern Areas	59,400
KPK	124,080
Punjab	7,380
Total	231,589

The species composition of the growing stock of coniferous forests was also determined from 29 working plans of KPK (Table 11.4). The percentages are derived from forest types dominated by one or two of these species.

Table 11.4 Species composition of the growing stock of coniferous forests

Forest Types	Growing stock (%)
Spruce/Fir	39
Kail (*Pinus wallichiana*)	23
Deodar (Cedrus deodara)	18
Fir *(Abies pindrow)*	8
Spruce *(Picea smithiana)*	6
Chir (Pinus roxburghii)	4
Broad leaved	1
Scrub	1

11.4. Conclusion

German forester Gattlob Konig 140 years ago said rightly “civilization began when the first trees were felled, and it will end when the last tree is cut” (Baquar 2017). Civilization indeed starts with the transformation of forest lands into cultivated lands and this phenomenon is continued with the increase of population. In agricultural-based economies, forests are always shrunk and conversion into agricultural land is considered the cheapest means of increasing production. Already meager forest resources in Pakistan have been under constant stress due to several climatic, edaphic, and biotic constraints. Furthermore, there are socio-political and administrative pressures for land allotment to army officers and local influential people which have aggravated the half-hearted forest rehabilitation efforts. The latest development of infrastructure in and around major cities have destroyed urban plantation drastically and increased the smog and other forms of air pollution frequently. Forest policy and legislation are only on papers that require the execution in true letter and spirit. National development policies should be conceived and planned by public servants rather than public representatives. Apart from vested interests and corruption, the policies are aimed at protecting the institutional interests of the department or the organization, with the welfare of the people and the sustainability of the resource kept at lower or zero priority. Pakistan's forest policy has suffered from a lack of proper reforms, and maintenance of the status quo has been the main theme of the country's forest policies. In addition, any change would mean challenging the existing status quo, which is guarded by beneficiary groups from within the same institutions. In Punjab, tree-raising efforts with private as well as public investments to reduce deforestation and enhance forest conservation with sustainable economic development has been launched in 2017 by assigning a blank area of 99,077 acres to South Punjab Forest Company (SPFC). But real implication with true spirit is still far behind the required afforestation.

Following are the possible ways for improving the forest sector in the country:

1) Forest and forest product statistics should be updated and published on regular basis.
2) Consider forests and trees as important ecological assets and carbon sinks. Their cutting should be prohibited unless a similar number of plants has been grown in suitable places.
3) Execute ways of managing each forest as a commercial tree farm under working plans for maximizing the yield of timber and fuel wood, and protect them effectively from illegal cutting, browsing and threats such as fire.
4) Forest lands not to be de-notified as well as transferred to the government-owned wastelands for afforestation and government-owned lands along canals, roads, and railway tracks for planting trees to the concerned forestry departments unless already planted.
5) Start pilot projects in low rainfall zones to develop techniques for their afforestation.
6) Enact legislation to provide incentives, and credit support to rural communities for micro-enterprises.
7) Launch a national action plan for tree growing by emphasing on each landowner to grow a specified number of trees per unit area of landholding (both farmlands and large residential towns). Constitute a working party to prepare programs for accelerating the pace of timber harvesting, transportation, and regeneration.
8) Promote the best possible integration of forestry and agricultural practices, as most farmers consider trees as the hindrance in arable lands due to their competition for water and nutrients, shade and allelopathic effects.

9) The feasibility of afforesting riverain lands/belts in consultation with the Flood Commission should be designed.
10) Pilot projects to determine grazing capacities of forestlands in various ecological zones and to expand pure forest systems into silvopastoral and/or may be agri-silvopastoral systems are direly needed, wherever possible to make trees more acceptable to the community.

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Chapter 12

Farm Machinery in Pakistan

Muhammad Iqbal, Muhammad Azam Khan and Khawaja Altaf Hussain♦

Abstract

Pakistan's agriculture has reached a stage, leading toward industrial agriculture, the man-machine relationship is strengthening and the output rate improving year-wise. Indigenous manufacturing and skill training are increasing to attain standardized production. The trend toward export to earn foreign exchange has led to competitive market behavior. The farm machinery manufacturing industries are becoming pivotal for the industrial farming system. Multiple effects of industries are spreading fast and rural unemployment/disguised employment is reducing. Non-traditional crop farming is on the rise and cropping intensity has improved. High-efficiency irrigation system, and no-till/zero-till machine use is on the rise, and improved crop varieties and better animal breeds have been introduced, resulting in higher average yields. The farming systems are transforming into industrialized agriculture. Time is near when agriculture as an industry will become a dream of every young Pakistani to become a part.

Keywords: Machinery, Zero-tillage, Zone, Mechanization, Commercialization, Indigenization

12.1. Historical Background

The historical background of agricultural machinery used in Pakistan was traced back to the report of the Royal Commission on Agriculture in which the Commission recognized the need to replace the oxen with the tractor but stressed the need for a proper search of different aspects of farm mechanization (Commission on

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Agriculture in India 1928). On Commission's recommendations, the Agricultural Engineering Workshop of the Department of Agriculture in Faisalabad was founded in 1914 and strengthened to undertake research and development of agricultural implements. In 1945, the Famine Commission of Inquiry stressed the need to minimize the pressure of animals on the land by using farm tractors for farm operations (Woodhead 1945). In 1951, the Pakistan Agricultural Enquiry Committee recognized the opportunity to use machinery for the rapid development of new lands and the cultivation of riverine tracts (PAEC 1953). The Food and Agriculture Commission also realized the need to introduce farm mechanization in Pakistan (PFAC 1960). In Revelle's report, it was commented that suitable agricultural machinery and tools should be designed and manufactured for small landholders (Anonymous 1964). It was also suggested to develop small horsepower tractors. The five-year development plans have subsequently provided funding for the expansion of the developmental work of the area with heavy machinery and the creation of a network of agricultural laboratories in the province (Chancellor 1970). Agriculture Machinery Organization (AMO) has been established at the Agriculture Department, Government of West Pakistan to continue the work already underway with the "Power Farming", Research Station Agriculture Faisalabad with a mandate to develop the land and to increase water supply with the help of machines. Bulldozers and power plant drilling have been added to the system to complement the efforts that are undertaken by the Thal Development Authority which later merged into the Agricultural Engineering in 1970.

12.2. Tractor Manufacturing/Assembling in Pakistan

Millat Tractors Limited (MTL) was established in 1964 and started marketing Massey Ferguson (MF) Tractors in Pakistan. An assembly plant was established in 1967 to assemble tractors in imported semi-knocked down (SKD) conditions. Al-Ghazi Tractors Limited (AGTL), established in 1983, installed its plant in Dera Ghazi Khan, Punjab, Pakistan, and started to produce New Holland tractors and generators in collaboration with Fiat New Holland. In 1991, Al-Futtaim Group of Dubai, took over management of Al-Ghazi Tractors, with the acquisition of 50% of its shares. Production of tractors under the government program approved disposal started in 1981 and five companies were licensed to produce tractors. The producers of Belarus, Ford, and IMT tractors left the business and now only two manufacturers are actively involved in the local production of tractors. M/s Millat Tractors Ltd. Lahore and M/s Al-Ghazi Tractors Ltd. Dera Ghazi Khan are producing 10 models of tractors in the range from 50 to 85 hp (Table 12.1). Both companies have production/assembly plants and distribution networks and after-sales services around Punjab and Pakistan. M/s Millat Tractors Ltd. is producing around 45,000 units per year, while M/s Al-Ghazi Tractors Ltd., has an installed capacity of over 30,000 tractors on a single-shift basis. In addition to these two main manufacturers of tractors, a few other manufacturers are also involved in the manufacturing and marketing of locally assembled and imported tractors on a limited scale. Two models of tractors have been presented in Figure 12.1.

Table 12.1 Makes and models of tractors in Pakistan

S. No	Tractor Company	Model	Rated speed (RPM)	Max Power (hp)	Lower link lift capacity (kg)
1	Millat Tractors Limited (MTL)	MF-240	2250	50	1415
2		MF-260	2250	60	1415
3		MF-350	2250	50	2145
4		MF-360	2250	60	2145
5		MF-375	2000	75	2145
6		MF-385	2200	85	2145
7		MF-385 (4WD)	2200	85	2145
8	Al-Ghazi Tractors Limited (AGTL)	FIAT-480	2160	55	1540
9		FIAT-480 (S)	2160	55	1450
10		FIAT-640	2160	65	1650

Source: Millat Tractors Limited, Millat Group. www.millattractor.millatgroup.net
Al-Ghazi Trectors Limited, www.alghazitractors.com/

12.1. Farm mechanization in Pakistan

Agricultural mechanization, an important input in modern agriculture, improves the productivity of both land and labor, in addition, to an increase in cropping intensity and helps to support timely sowing of crops, cultural practices, reduction of post-harvest losses, etc. It considerably saves fodder and feeds through a reduction in the number of draft animals. Thus, a transition from subsistence to commercial agriculture can be achieved through the dissemination of modern, efficient, cost-effective mechanization technologies to farming systems. Therefore, the efficient use of scarce agricultural resources coupled with accelerated agricultural mechanization is of utmost importance. Agricultural mechanization has been selective in Pakistan and only those operations have been mechanized for which there had been a shortage of labor or power at peak farming operation timings. The effects of mechanization had always been overall positive. Farm mechanization not only increased the income and labor productivity at the farm but also generated off-farm employment in manufacturing, supply/maintenance of agricultural machinery, provision of other inputs and post-harvest operations of agriculture produce. The most popular forms of mechanization in Pakistan have been bulldozers, drilling rigs, tube-wells, grain threshers, sprayers, tractors, cultivators, and trailers, etc. Out of all the tractor owners, 95% have cultivators, 20% have MB plows, 15% have disc plows, 5% have chisel plows, 5% have rotary tillers, 10% have disc harrows, 10% have ridgers, and 22% have seed drills/planters (Figure 12.2).

The horsepower for availability per acre in Punjab is 0.74, which is much lower than India (1.01), China (1.57) and Japan (2.83). This low farm power input led to crop losses of 15-20% in cereals and 40 to 45% in fruits and vegetables, which can be reduced to a minimum by increasing the availability of power for the timely execution of farm operations. The organizations dealing with the issues related to agricultural mechanization in Pakistan are: the Ministry of Food Security and Research, Research and Development Institutions, especially Agricultural and Biological Engineering Institute (ABEI), NARC, Islamabad under the Pakistan Agricultural Research Council (PARC) at the federal level; Agricultural Mechanization Research Institute (AMRI), Multan under the Punjab government, Agricultural Mechanization Research (AMRC), Tandojam under Government of Sindh, Center for Agricultural Industries, Mian Channun under Punjab government and the Agricultural Light Engineering Program (ALEP), Mardan under the Khyber Pakhtunkhwa Government; agricultural machinery manufacturers; financial institutions; autonomous bodies at the federal and provincial level; Provincial Directorates of Agricultural Engineering; and agro-services providers (Anonymous 2006).

Al Ghazi Tractor FIAT 640 Millat Tractor MF 375

Figure 12.1 Two models of tractor in Pakistan

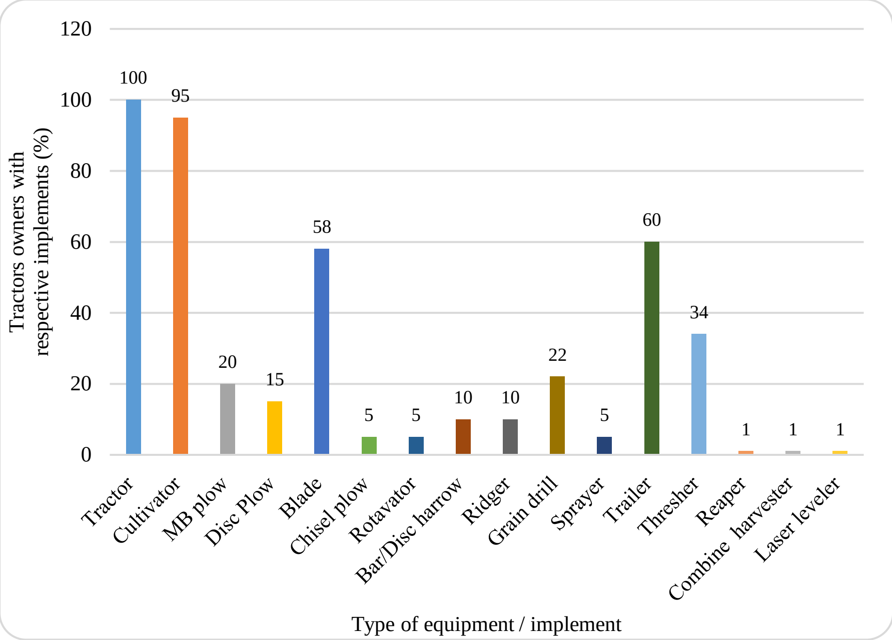


Figure 12.2 Tractor owners (%) having various agricultural machinery
Source: Govt. of Pakistan (2004)

12.2. Farm Machinery and Implements Manufacturing in Pakistan

There were 15 manufacturers of agricultural machinery in the late 60s. As a result of government policies such as liberal discounts on import duty on raw materials, exemption from sales and income taxes, their number went to about 500. Farm machinery and equipment available at farms have been presented in Table 12.1. The agricultural machinery and tools manufacturing industry of Pakistan produces a large number of agricultural tools and machinery, including tractors. The industry, however, is dominated by micro and macro businesses, many of which manufacture agricultural machines in their backyard in small laboratories/workshops mostly with conventional machines locally. These units, ubiquitous throughout Pakistan, outsource components to other small-scale operators. The towns of Daska, Faisalabad, Okara and Mian Channu house large clusters of farm implements manufacturers. The segment of agricultural and manufacturing tools is large, fragmented and mostly unorganized. The industry is producing agricultural, horticultural and forestry tools for soil preparation and cultivation, harvesting and threshing, etc. This sector caters to the local market and is facing problems of lack of standardization and quality, Design and Engineering capacity, management structures and enough financial resources for the manufacturer. Despite these problems, the industry produces and meets the needs of the national agricultural sector in a big way. Some large manufacturers have also begun to export agri machinery to Africa and Afghanistan. Little efforts have been seen in manufacturing standardized agricultural machinery and equipment for the supply to the end users. Farming communities in Pakistan could not be attracted to buy better, but expensive equipment because of accessibility problems. The NARC of Pakistan has developed standardized design and quality-based equipment. But for some reason, there is no coordination between NARC and manufacturers of the private sector. The Agricultural Engineering Departments of the Provincial Governments and their performances were well below the mark. A "Center of Agricultural Machinery Industries" was established with the financial support of the Dutch government in Mian Channu to serve as a common facility center and training institute for the cluster there. Overall, the current state of things is a mixture of shows and opportunities (SIB 2012).

Table 12.1 Status of Farm Machinery and Equipment in Pakistan

Machinery	1968	1975	1984	1994	2004
Tractor	18909	35714	157310	252861	401663
Cultivator	14338	31619	146863	236272	369866
MB plow	2335	2734	7319	28413	40050
Disc Plow	2513	2938	6355	20372	29218
Blade	3925	4200	69004	164489	233126
Chisel plow	-	-	712	6535	8514
Rotavator	-	-	2101	5594	47919
Bar/Disc harrow	2007	2373	8140	13233	23764
Ridger	-	120	4711	10984	71338
Grain drill	563	1174	11251	64126	70810
Sprayer	-	473	-	20778	21756
Trailer	-	18074	98787	176412	242655
Thresher	-	5635	78377	112707	137270
Reaper	-	-	-	7972	8073
Combine harvester	-	-	-	1524	6000
Laser leveler	-	-	-	-	2785

Source: Govt. of Pakistan (2004). Pakistan Agricultural Machinery Census, Gulberg III, Lahore, Punjab, Pakistan.

12.3. Land Development and Leveling Machinery

About 3.88 million acres are laying desert as culturable excluding rainfed cultivated areas of Thal and Potohar areas (Govt. of Pakistan 2012). For land development waste culturable, tractor-mounted front blades and bulldozers are commonly used. Tractor-mounted front blades are available through the private sector, while bulldozers for land development are available from the public sector. This land-culturable waste can be economically developed for growing through the use of crawler tractors/bulldozers only. The existing fleet of 338 bulldozers with the Department of Agriculture of Punjab is not sufficient to convert 3.88 million acres of culturable land into cultivated land. It is estimated that with the current strength of bulldozers, it will take about 100 years to develop the entire desert culturable into cultivated.

Poor land leveling not only results in wastage of water for irrigation (up to 50%) but also adversely affects the germination of seeds, as in the lowest points, the seed is damaged due to submersion while at peaks did not germinate because of lack of proper soil moisture conditions. For the precision leveling of cultivated fields, periodic laser leveling is required as the seedbed preparation and sowing operations disturb the ground level to a certain extent. Land development machine pictures have been presented in Figure 12.3.

Bulldozer Tractor front blade Laser land leveler

Figure 12.3 Pictures of land development machines

12.4. Soil Tillage Implements

Tillage is the physical or mechanical manipulation of the soil with tools and implements that results in good tilth (a descriptor of soil that combines the properties of particle size, moisture content, degree of aeration, rate of water infiltration, and drainage) for better germination and subsequent growth of crops. Tillage needs to be done at the right time with the right implements to get good tilth. The tillage process is generally accomplished in two stages, namely, primary and secondary tillage.

Primary tillage, normally known as ploughing, is the opening of the compacted soil with the help of different plows. In addition, primary tillage also aims for inversion (whenever necessary) of soil and uprooting of weeds and stubbles. Chisel plow, M.B. plow and disc plow are the main types of primary tillage implements (Figure 12.4).

MB plow Disc plow Chisel plow

Figure 12.4 Primary tillage implements

Secondary tillage, on the other hand, is performed after primary tillage for lighter or finer operations; after primary tillage, the fields are left with large clods with some weeds and partially uprooted stubbles. Harrowing is done to a shallow depth to crush and break the clods and uproot the remaining weeds and stubbles. Disc harrows, cultivators, rotary tillers (rotavator), etc., are commonly used for this purpose (Figure 12.5). Planking is done to crush the hard clods and smoothen the surface soil and compact the soil lightly.

Disc harrow Cultivator Rotavator

Figure 12.5 Secondary tillage implements

In Punjab, the cultivator is the most widely used implement for primary as well as secondary tillage of the soil. Repeated use of cultivator not only creates hardpan which adversely affects root development/penetration, but it does not fulfill the purpose of tillage. Most of the progressive farmers do use MB plow and disc plow for primary tillage and disc harrow and rotary tiller (rotavator) for secondary tillage especially for sowing of wheat after paddy and cotton in Punjab. Sometimes 3, 5 and 7 tine chisel plow is also used for deep tillage to break hardpan, rupture compacted soils and improvement of sub-surface drainage before the use of primary tillage implements. Conventional methods of tillage and seedbed preparation require repeated use of tractor passes which causes soil compaction. On the other hand, repeated use of tillage and seedbed preparation implements not only leads to the wastage of organic matter (due to high temperature) but also adds CO_2 to the atmosphere which is a greenhouse gas.

Soil preparation for wheat sowing by conventional techniques after harvesting rice requires high energy consumption and time. For this reason, the wheat sowing is usually delayed, especially in the paddy growing areas resulting in low yield. Therefore, two resource conservation technologies named zero till machine and zone disk tiller machines were developed by PARC and the University of Agriculture, Faisalabad (UAF), respectively, to minimize the intercrop gap, increase crop yield and mitigate greenhouse gases (Figure 12.6).

Zero tillage machine developed at FMI, PARC, Islamabad (Source: Raza et al. 2006)

Technical Specifications

Power requirement: 50 hp tractor; Field capacity: 1 acre/hr; Operating cost: Rs. 350/ac; Savings: Rs. 1700/acre

Zone disk tillage machine (GOP Patent 139296) developed at UAF

Technical Specifications

Power requirement: 50 hp tractor; Field capacity: 1 acre/h; Diesel saving: 75% ; Irrigation saving: 30%; Labor saving: 75%; Yield increase: 14%

Figure 12.6 Resource conservation technologies

12.5. Seedbed Preparation

The seedbed must be loosened and smoothened without big lumps or clods of soil so that the seeds can be planted easily, and at a specific depth for best germination. The presence of large lumps/plates and uneven surface would tend to make the depth of seeding random. The preparation of a seedbed can include the removal of debris, insect eggs and spores of diseases that are often found in plant residues. Preparation also involves leveling the ground to a certain extent. Sometimes, the use of tools for plowing does not provide favorable conditions for the germination of seeds and growth; therefore, soil preparation implements are used to provide soil aggregates of appropriate size. Some of the soil preparation concretization commonly used in Punjab include cultivating land followed by land leveling and compacting with dashboard/leveler (Figure 12.7). The use of rotary tiller and disc harrow for the preparation of the land is expanding.

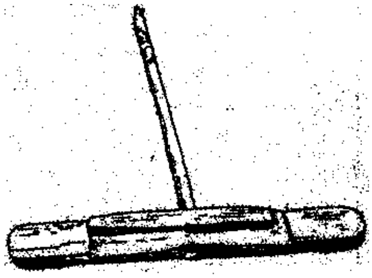


Figure 12.7 leveler (*Sohaga*)

12.6. Crop Seeding and Planting Machinery

After proper seedbed preparation, plant stand depends mainly on proper seed depth as too superficial seed is subject to attacks of the birds while the seed too deep cannot germinate due to heavy loads of earth on the seeds.

12.6.1. Crop Seeding/Sowing/Drilling Machinery

For a correct rendition of any crop, the plant population and row to row distance plays an important role, which can be achieved only when using proper sowing machines. One of the main reasons for low yield of crops is inadequate plant population. Due to limitation of time or high costs of tillage and seedbed preparation, some farmers spread seed manually by hand, which does not provide desired plant population. For sowing of wheat, Rabi drill (with or without fertilizer placement unit) is commonly used in Barani as well as in irrigated areas (Figure 12.8a). These tips are generally not equipped with system for preventing entrance ground on the back of each pore due to which the pores are closed and choked frequently. For sowing wheat after harvesting rice crop, wheat seed drills are usually used after the conventional methods of soil preparation which delays sowing from 3 to 4 weeks and results in lower yields. For timely sowing of wheat in rice fields harvested by hand, zero tillage drill and zone disk tillage drill were introduced. Another problem for sowing wheat in combine harvested rice crop is burning of rice straw as zero tiller/zone disk tiller machine fail to manage/manipulate heavy residues for sowing wheat seed. Burning of rice straw (Figure 12.8b), not only affects soil microbes, but also results in economic loss. For sowing of wheat in combine harvested rice fields, happy seeders and rockets were developed, which are able to sow wheat, in the presence of residues of paddy. Bed and furrow system of sowing of grain crops on raised beds not only helps to save water but is particularly suitable for saline soils.

Figure 12.8a Rabi drill

Figure 12.8b Rice residue burning image

12.6.2. Row Crop Planting Machinery

For planting row crops such as cotton, maize, sunflower, peanut and others, planters are commonly used, which does not put the seeds in one place rather seed is dropped more or less in a continuous manner which needs thinning the plants to keep the required plant population. To overcome the problem of planting more than the recommended seed rate, fluted roll and seed plate planters are used but on a limited scale. These planters are able to put seeds in soil with respect to desired rate and plant to plant distance (Figure 12.9). Hill Plantation is a technique by which a group of 4-5 seeds is placed in one place. This technique is useful in soils that tend to crust after rainfall or light irrigation. The collective strength of the birth of several seeds placed in a point guarantees the germination of seeds in these soils.

Maize planter

4-Row Multi-crop bed planter

Source: www.uaf.edu.pk

Wheat crop sown by multi-crop bed planter

Source: www.uaf.edu.pk

Figure 12.9 Row crop planters

Sugarcane set planters are also employed on a limited scale in which the whole cane is fed vertically, and sets are cut automatically by the reciprocating blades (Figure 12.10a). This planter has been designed and developed at the Agricultural Mechanization Research Institute, Multan (AMRI). Vertical cup planters for planting potatoes are used on a limited scale in the Okara district of Punjab (Figure 12.10b).

Figure 12.10a Sugarcane planter, AMRI, Multan

Figure 12.10b Potato planter, Trade Key

12.7. Fertilizer Application Machinery

According to field tests conducted by Adaptive Research Farms (ARF), Sheikhupura and Ayub Agricultural Research Institute (AARI), Faisalabad, the efficiency of used fertilizers is about 50% which is attributed to an inappropriate application of machinery and equipment. Inefficient application of fertilizers not only results in pollution of groundwater but also results in an increase in production costs. In Punjab, basic fertilizers are generally applied by manual broadcasting or by tractor-mounted fertilizer broadcaster. Fertilizers delievred at the time of sowing are applied mainly through drills and planters while the next dose is applied by broadcasting and in row crops is applied with the aid of attachment fertilizer provided with the intercultural equipment. Some planters are available for the placement of fertilizer i.e., DAP in bands (Figure 12.11). The use of fertigation (fertilizer application through drip irrigation) in irrigated crops is also used but on small scale (Figure 12.11). Some progressive farmers apply fertilizers through foliar application. The performance of a sprinkler depends on the quality and operation of the pump pressure, the type of nozzle and the droplet spectrum produced from the nozzle.

Manual broadcasting fertilizer

Fertilizer band placement drill for wheat

Source: Ahmad et al, 2004

Fertilization through the water drip irrigation

Source: www.jaffar.com

Figure 12.11 Fertilizer application machinery

12.8. Irrigation Machinery

According to the Directorate of Water Management, Lahore, water use efficiency in Pakistan is the lowest in the world. The water use efficiency in the case of wheat is 10% of the efficiency of water use in China and in the case of rice is almost 5% of the efficiency of water use in the Philippines. For irrigation, tube wells are used to pump groundwater where irrigation canal water is lacking. In river areas where groundwater is within 30 feet, for the lifting of water, centrifugal pumps are used, for lifting water from a depth of 30 to 100 feet, turbine pumps and for lifting water from a depth of 100 to 200 feet, submersible pumps are commonly used. In the hills, some farmers are using jack pumps that have the ability to lift water from more than 500 feet in depth. The efficiency of centrifugal pumps is lower, while the same for the jack pumps is higher. For the application of water for irrigating crops in sandy soils, drip systems are used on a limited scale. Irrigation machinery in Pakistan has been presented in Figure 12.12.

Conventional method of irrigation

Tubewell water for irrigation

Maize under drip irrigation
Source: www.edu.pk

Furrow irrigation through perforated pipe
Source: www.uaf.edu

Figure 12.12 Irrigation machinery

12.9. Crop Protection Machinery and Equipment

According to a field study conducted by AFR and AARI, weeds can reduce crop yield by up to 40%. Weed control in Punjab is done either through mechanical means or chemicals. For mechanical weed control in flatbed sown wheat, bar harrows are used. For mechanical weed control in row crops such as cotton and maize sowed flat or on beds, the rigid tine intercultural equipment is used. Most intercultural instruments are equipped with systems for the application of fertilizer. Sometimes, rotary machines are also used in place of rigid teeth for the weeding. For weed control in crops of sugar cane, disc ratooners and rotary hoe are employed on a limited scale. Some of the interculture equipments have been presented in Figure 12.13.

Disc ratooner for sugarcane interculture

Bed furrow interculture equipment for cotton

Interculture ridger

Figure 12.13 Interculture equipment developed by AMRI, Multan

In Pakistan, the cotton crop is attacked by about 150 types of insects and mites (Attique and Rashid 1983). These insects and parasitic mites act as a significant limiting factor in achieving potential cotton yield. According to field trials conducted by the Central Cotton Research Institute (CCRI), Multan, insecticide/pesticide application efficiency is a maximum of 50% which has been attributed to the use of inappropriate and poor-quality of spray machinery and faulty application methods. Sprayers including knapsack sprayers, tractor-operated sprayers, and handheld sprayers are generally used in Pakistan. The drop pipe sprayer, having a density of up to 200 droplets/cm^2, results in leaf coverage of over 80% on lower leaves while up to 100% on upper leaves of the plants (Gan-Mor et al. 1996). The UAF has designed a tractor-mounted drop-pipe boom sprayer to spray the crop leaves both on the upper and lower surface leaves. The locally produced knapsack sprayers are manually operated. Tractor-operated sprayers used in Punjab are mostly of boom type for field crops (Figure 12.14).

Boom sprayer, AMRI, Multan

Drop pipe boom sprayer
Source: ww.uaf.edu.pk
GOP Patent No. 139290

Knapsack sprayer

Figure 12.14 Crop sprayers

12.10. Crop Harvesting and Threshing Machinery

Harvest losses of wheat, rice and other oil crops were estimated at 10-15%, which are attributed to delayed harvesting and the use of appropriate harvesting machines as well.

12.10.1. Harvesting and Threshing Machinery for Cereal Crops

The harvest of wheat and rice is conventionally done using hand scythes/sickles. Tractor-mounted reapers and combine harvesters are also used to a greater extent (Figures 12.15, 12.16). The rice harvest is mostly done with the combine harvester that is causing excessive losses of grain and grain internal injury, therefore, reducing the rice recovery and increasing kernel breakage during milling. This is because of the use of rasp bars threshing drums instead of spike teeth peak threshing drums.

Manual harvesting with scythe/sickle | Bundle making of manually harvested crop | Animal threshing crop

Figure 12.15 Manual harvesting, bundle making and animal threshing wheat in Pakistan

Indigenized Self-propelled multi-crop reaper, Source; www.uaf.edu.pk | Harvesting with tractor mounted reaper | Combining wheat

Figure 12.16 Mechanical harvesting and threshing of wheat in Pakistan

Wheat threshing is largely done with the help of stationary threshers, which are powered through the tractor rear mounted Power Take Off (PTO) shaft. Locally developed wheat threshers are heavy in weight and therefore costly; energy inefficient, with less security measures and pollute the rural atmosphere with the dust during wheat threshing. Pakistan agricultural machinery manufacturers have a long smithy shop experience with little professional education in that field. This situation has given rise to many problems for the production of quality standards by comparing the international market. The engineers of the Department of Farm Machinery and Power, UAF, Faisalabad, look technically the real problem and rebuilt a beater wheat thresher employing a reverse engineering approach and reduced its weight from 1600 kg to 1300 kg. The beaters and flywheels were technically improved. The damage in grain was reduced four times, as well as the average efficiency of threshing, increased by 98-99%. The replacement of three flywheels with only one flywheel of the required dimensions saved 24.38 kN-m energy. The fluctuation in the speed reduced to 2.055 times with twice less coefficient of energy than a conventional thresher. By redesigning and changing the direction of the exhaust fan, the average grain cleaning efficiency improved from 97.44 to 98.18%. Further, the crop feeding system was improved with a better designed, developed and manufactured feeder conveyor while conventional thresher lacked this conveyer. This increased the speed of advance up to 2,770 kg/h intake of the crop. The economic return of a newly developed thresher has been found to be 26% greater and saving in diesel fuel 1.3 L/h than that of the original conventionally developed thresher (Figure 12.17).

Wheat threshing with conventional thresher

Wheat threshing with conventional redeveloped thresher. Source: www.uaf.edu.pk

Figure 12.17 Beater wheat threshers

After harvesting, the rice is threshed manually/with tractor crushing followed by manual cleaning. With this traditional system, the threshing of rice continues for 3 or 4 months in Sindh and Balochistan provinces. This system is highly laborious, and time-consuming, deteriorates the quality of the rice and the rice crop is exposed to the weather. To overcome these problems a high-capacity rice thresher has been introduced in the rice-growing areas of Sindh and Balochistan provinces (Figure 12.18a). The rice thresher was imported from Thailand and tested on local varieties at Rice Research Institutes Kala Shah Kaku and Dokri. After incorporating minor and needful changes, the machine was extensively tested on IRRI varieties and found encouraging results. Six manufacturers are now producing this machine in various localities viz; Nawab Shah, Larkana Faisalabad, Lahore and Rahim Yar Khan.

For threshing chickpeas, a wheat threshing machine is used after incorporating sieves of adequate size and adjusting the speed of the beater and fan, but the threshed product quality is poor as compared with threshing standards (Figure 12.18b).

Figure 12.18a Improved rice thresher

Figure 12.18b Chickpea thresher

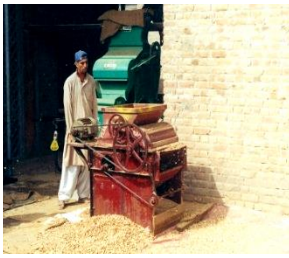
Source: Zafar (2005)

12.10.2. Harvesting and Threshing/Shelling Machinery for Non-cereal Crops

Harvesting non-cereal crops such as cotton, maize, sunflower, rapeseed/mustard, peanuts, and sugarcane are mostly done manually, but sometimes machines are also employed for the purpose. Cotton harvesting mechanization is perhaps the most expensive operation of collecting any crop, such as cost of cotton pickers commercially available is in the range of Rs. 15-20 Million for a 2-row machine and above Rs. 25-30 Million for a machine of 4 rows. Some efforts have been made in the past to introduce the USA make cotton pickers, but due to the exorbitant cost of crop collection, these machines have not been able to meet success.

The maize and sunflower are harvested with combines equipped with sunflower and maize headers. Similarly, crops of rapeseed/mustard are also harvested with wheat grain harvesters. In the absence of headers, the combine harvester is used as stationary combines for threshing sunflower heads after 1-2 days of sun drying in the field. For harvesting groundnut crops, groundnut diggers are also used. For threshing oilseed crops like canola, rapeseed, and wheat thresher has been used after incorporating the required size sieves and adjusting the threshing drum and blower speed. For the shelling of groundnut and maize, locally developed stationary shellers are used (Figure 12.19).


Maize sheller


Groundnut sheller


Sunflower thresher

Figure 12.19 Harvesting and threshing/shelling machinery for non-cereal

Source: Govt. of Pakistan (2014-15)

12.10.3. Harvesting Machinery for Fruits and Vegetables

Harvest losses of fruits and vegetables were estimated to be 15-20%, which is attributed to the collection at a too early mature stage and use of the inadequate collection and management methods. Due to the perishable nature of fruits and vegetables, special skills are required for the collection and management to maintain the quality of products. To minimize crop losses, maintain quality and increase shelf life, preparing pre-collection should be timely, which includes an arrangement of the required number of laborers, sufficient containers and packages, and ensuring that all the harvesting and handling equipment/tools are in operation.

The collection of fruits and vegetables is mostly done manually using some kind of help for the harvest as clippers, scales, scissors, knives, and snipers. Locally developed fruit orchard and potato machinery have been presented in Figures 12.20 and 12.21.


Pole pruner


Fruit clipper


Post hole digger

Figure 12.20a Fruit Orchards Machinery

Source: Govt. of Pakistan (2014-15)

Figure 12.20a Fruit tree and sugarcane pit planting machine

Source www.uaf.edu.pk

Potato planter | Rotary potato digger | Vegetable ridger

Figure 12.21 Potato production machinery

Source: Govt. of Pakistan (2014-15)

12.10.4. Farm Gate Post-harvest Processing and Storage Machinery

Farm gate processing is limited to washing, cleaning, and bagging/wooden box packaging of fruits and vegetables, and the cleaning and classification of cereals. Treatment after the harvest of cereals is mostly done at processing plants. It was estimated that the post-harvest losses, in the case of cereals are 10-15% while the same for fruits and vegetables is 20-25%. These losses have been attributed to inadequate handling, transport at the farm and use of inadequate post-harvest operations *viz*. pre-cooling washing and drying, sorting, grading, disease/insect treatment, protective coating, packaging, and storage.

12.11. Farm Machines Developed/Adapted and Commercialized by Public Sector

Farm machines developed, commercialized by the public sector and registered by the Registration and Patent Department, Karachi, Government of Pakistan have been presented in Tables 12.2, 12.3, and 12.4.

Table 12.2 Farm machines developed by public sector and patented by the Registration and Patent Department, Karachi, Government of Pakistan

S. No	Title of machine	Patent No.	Sealing Date
1	A Zone Disk Tiller Drill System	139296	June 30, 2008
2	An improved Boom Sprayer for crops	139290	June 30, 2008
3	A boom sprayer test bench	139291	June 30, 2008

Source: www.ipo.gov.pk/patent/gazette

Table 12.3 Farm machines developed and commercialized by PUBLIC SECTOR of Pakistan

Faculty of Agri. Engg. & Technology, UAF *Source: www.uaf.edu.pk*	**ABEI, NARC, Islamabad** *Source: PARC (2015)*	**AMRI, Multan** *Source: Govt. of Pakistan (2014-15)*
1. Improved beater wheat thresher	1. Zero till drill	1. Modified Bed & Furrow shaper planter
2. Improved boom sprayer for crops	2. Wheat straw chopper-cum-blower	2. Tree pruner
3. Multi-crop bed planter	3. High capacity rice thresher	3. Fruit picker
4. Multi-crop self-propelled reaper	4. Reaper–windrower	4. Power winch
5. Zone disk tiller drill	5. Groundnut stationary thresher	5. Orchard sprayer
	6. Groundnut digger	6. Fodder cutter
	7. Wheat-cum-canola thresher	7. Coulter type furrow opener seed drill
	8. Mobile flat-bed dryer for sunflower	8. Mobile bhoosa baler
	9. Fertilizer band placement drill for wheat	9. Orchard sprinkler mobile rain gun
	10. Solar-cum gas fired fruit dryer	10. Stubble shaver
	11. Seeder for wheat and rice	11. Rota drill
	12. Mobile seed processing unit	12. Sugarcane ridger
	13. Pneumatic row crop planter	13. Wheat straw copper collector
	14. Modified maize sheller	14. Cotton ridger with fertilizer attachment
		15. Mealy bug lance
		16. Small rotary beater coulter

Table 12.4 Farm machines developed by public sector of Pakistan

Faculty of Agri. Engg. & Technology, UAF *Source: www.uaf.edu.pk*	**ABEI, NARC, Islamabad** *Source: PARC, 2015*	**AMRI, Multan** *Source: Govt. of Pakistan (2014-15)*
1. Aquifer storage and recovery technology to	1. Fertilizer band placement drill for wheat	1. Axial flow pump
	2. Groundnut digger	

recharge saline ground water 2. Boom Sprayer Test Bench 3. Gasifier for small farmers 4. Green-house solar dryer 5. Improved Boom Sprayer for spraying crops 6. Improved wheat straw chopper 7. Low and medium pressure sprayer 8. Modified in Korean Rice Transplanted 9. Multi-crop bed planter 10. Multi-crop self-propelled reaper 11. Multi-operational machine 12. Orchard Spraying Machine 13. Rainwater harvesting technology 14. Ring automatic irrigation system 15. Rotary pit digger for sugarcane planting 16. Skimming well technology 17. Solar Energy for extraction of essential oils from medicinal plants 18. Solar Saline Water Evaporator 19. Zone Disk Tiller Drill	3. Groundnut stationary thresher 4. High capacity rice thresher 5. Mobile flat-bed dryer for sunflower 6. Mobile seed processing unit 7. Modified maize sheller 8. Pneumatic row crop planter 9. Reaper –windrower 10. Seeder for wheat and rice 11. Solar-cum-gas fired fruit dryer 12. Wheat straw chopper-cum-blower 13. Wheat-cum-canola thresher 14. Zero till drill	2. Bed and furrow equipment for row crops 3. Chain trencher 4. Dry sowing drill 5. Fodder mower and crop dryers 6. Fruit picker 7. Gravity separator 8. Groundnut digger 9. Groundnut sheller 10. Indent cylinder 11. Multi-crop sheller 12. Oil seed thresher 13. Paddy thresher 14. Potato digger 15. Power winch 16. Precision planter 17. Rice thresher 18. Rice transplanter 19. Rotary ditcher 20. Rotary slasher, mulcher/shredder 21. Seed cleaner grader 22. Seed drill 23. Self-leveling boom sprayer 24. Stubble drill 25. Sugarcane planter 26. Tree pruner 27. Wheat thresher 28. Zero tillage drill

12.12. Farm machinery exports and potential

The world trade market of more than US $ 4.0 trillion exists. Most of this market is for standardized products of high-end. But because of accessibility problems in poor agricultural countries, there is a low-end product market. Some estimates are that the world trade market of low-end products is about US $ 500 million. Pakistan has already entered the international market and low-end agricultural tools are currently exported to Nigeria, Kenya, Tanzania, Morocco, Ghana, Afghanistan, etc. All this is done through Export Company's export trading working as consolidators and exporters operating in these countries. The export performance in numbers is, however, negligible. Improving the current state of affairs can be managed by capitalizing on existing strengths and by overcoming weaknesses. Pakistan exports agricultural machinery and tools to quite a large number of African countries, including Nigeria, Kenya, Tanzania, South Africa, Morocco, Ghana and regional countries including Bangladesh, Afghanistan and the United Arab Emirates, etc. Most of these exports are made by consolidators, engineering, or trading companies securing export orders and getting parts developed by various vendors. It is possible to export to African countries and standardize parts development for European companies. The graph (Figure 12.22) for exports of agricultural machinery over the five years from 2005 to 2009 indicated a tremendous increase after a slump during the year 2006.

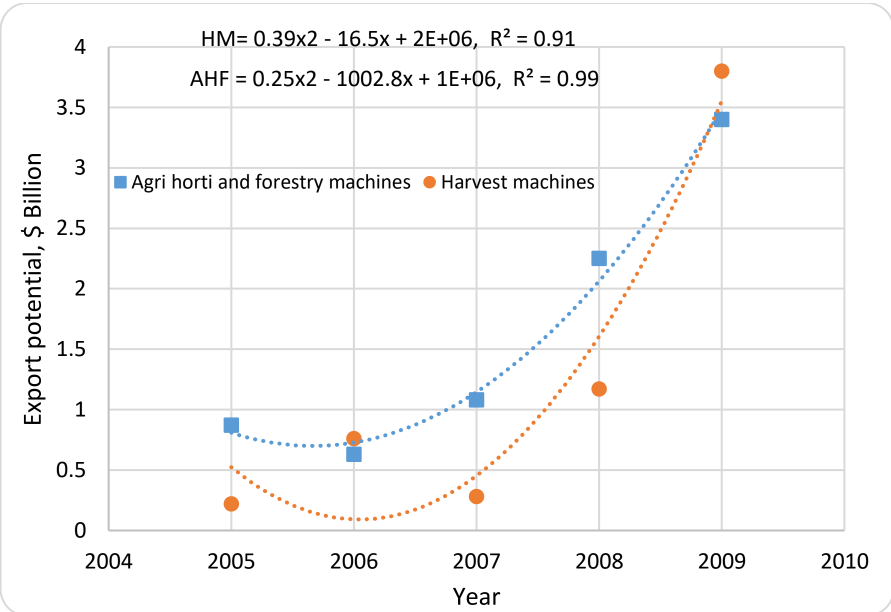


Figure 12.22 Farm machinery exports and potential

Source: SIB (2012)

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Chapter 13

Seed Sector in Pakistan

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Abstract

Availability of good quality seed of improved varieties at affordable prices to the farmers is highly important for increasing agricultural production. Historically, the seed production and distribution system in Pakistan has passed through many developmental phases. With the implementation of the Seed Act 1976, seed production and distribution were improved in the public sector, and later on, the private sector was allowed in 1981. By 2015, seed legislation was improved and the private sector was highly encouraged which has the capacity to employ more than 50,000 people. Unluckily, the institutional capacity of the public sector eroded over time and was thus limited to less than 10%, whereas the private sector showed tremendous horizontal growth in the present scenario. The seed supply amounted to about 27% of the country's total estimated seed requirement. The seed production had not only remained much below than seed requirement but it could not reach the resource-poor farmers. The local accessibility of certified seed for wheat, cotton, maize, and rice is satisfactory and seed demand for vegetables, oil seed crops, and fodders is met by imports. The seed certification and inspection system is not properly functional due to the lack of staff and outreach in the seed certifying agency. There is a dire need to develop National Seed Policy to establish a road map for Public Private Partnership.

Keywords: Seed legislation, Seed system, Seed certification, Seed production, Pakistan seed industry

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13.1. Introduction

Agriculture plays a significant role in the economy of Pakistan with a share of 19.5% in GDP and 42.3% in employment which shows a decline as compared to the previous year GDP i.e., 21.5% (Govt. of Pakistan 2016). Seed is the defense line for agricultural production and key input among all other agricultural inputs. It acts as a catalyst and contains all genetic material that gives the capacity to stand in harsh environments (Louwaars and de Boef 2012). As quality seed has surety to enhanced agriculture production, profit and food security, it should be available on time to all the farming community. In Pakistan, the supply of quality seed is restricted to some crops i.e., wheat, rice and cotton, completely not available to minor crops i.e. fodder, vegetables and pulses, so they are mainly imported (MNFSR 2017). Certified seed fulfills only 27% of total demand while the remaining is met through the informal sector, which is comprised of farmers' self-saved seed. Therefore, there is a dire need for professionally skilled manpower equipped with updated knowledge and skills related to seed production and procurement.

Seed is a crucial element in any seed industry and marketing so it should be of higher quality and vigor that ensures high agricultural production. High-quality seeds with improved vigor contribute nearly 30% of the total production (Ellis 2004). In Pakistan, the informal sector is the dominant sector over the formal sector. About 90% of cereals, 23% of vegetables, and 45% of cottonseed are obtained from local sources (PES 2016). The registered seed companies mainly went for local commercial seed production of crops like wheat, cotton and rice. Hybrid seeds of maize, vegetables, oilseeds and fodders remained on the import list where millions of dollars are being spent every year on their imports.

Since the Seed act 1976, the public sector had been eminent for years but now the trend is moving towards the private sector with the approval of the Truth-In-Labeling Rule. By 2016, rules are also developed for breeders, multi-national seed companies' products, import and export of seed, hybrid, and GMOs certification to promote the farming community to meet the total certified seed requirement in the country (Hussain 2011). Under the improved seed amendment bill, enabling environment was developed for the private sector to participate in all areas of variety development, seed production, multiplication and distribution. The private sector was encouraged to produce basic seeds and establish accredited seed testing laboratories. In spite of all these efforts, the law was not implemented properly due to an acute shortage of human resources in the concerned department.

Farmers always demand high-quality seed at low price, however, low-value seed with high price is dominant in the local market. Private companies are selling seed of high value and high price, which is not affordable to resource-poor farmers. So Pakistan faces many issues to promote the public seed industry in the country. The scarcity of seed processing units, storage facilities, market efficiency, and less developed seed sector demote the public sector. Inadequate research in vegetable farming promotes seed import and ultimately its price remains high. A large number of seed companies only focus on a few crops except seed quality. Farmers have less knowledge about new technology and agronomic practices, they use poor quality seed and for uniformity increase the seed rate which is not a good practice. The lack of availability of good quality seed to farmers is due to inefficient marketing, lack of implementation of rules and regulations, financial limitations, political pressure, and less awareness (Hussain 2011). There are enough trained and skilled inspectors that may hold integrity in the highest regard. Therefore, concerted efforts of concerned stakeholders are needed across the seed production and distribution value chain for providing quality seeds to farmers. This chapter provides an overview of the current status of the Pakistan seed industry.

13.2. Developmental Phases of Pakistan Seed Industry

When Pakistan came into being, a seed distribution system was not existing. The rules and regulations were developed and policies, as the seed act 1976, were formulated for the movement of quality seed in the country. However, according to technology and the current situation, changes are made in the seed system. The seed system passed through four different phases as detailed below (Rana 2014).

13.2.1. First phase (1947-1961)

After the independence, there was only one inherited institute for seed production i.e., Punjab Agriculture College and Research Institute, Lyallpur. There was no independent seed production unit and distribution system in country. Many crop-based stations were present like cereal stations, rice station at Kala Shah Kaku, vegetable and sugarcane research stations.

13.2.2. Second phase (1961-1972)

In this economic era when there was a need of quality seed and research of new varieties, the government took two major steps; one to diverge the Punjab Agriculture college into University of Agriculture (UAF) and Ayub Agriculture Research Institute (AARI) and second the development of West Agriculture Pakistan Development Corporation (WAPDC) to establish a systematic way of seed production and distribution in the country. But this system was dissolved as it failed due to excessive procurement. It also created awareness to quality seed production as many testing laboratories were established under its function.

13.2.3. Third phase (1973-1980)

This was started in 1973 when Pakistan Government intended help from World Bank for the development of seed system. That was a big project, which started the basics for the first Pakistan Seed Act 1976. This ordinance provides a sound basis for running the seed system in the country along with institutions as approved in Seed Act. The institutional infrastructures which were established under Seed Act 1976 were: National Seed Council on Federal Level, Provincial Seed Council on Provincial Level, Federal Seed Certification Department (FSCD), and National Seed Registration Department (NSRD). The FSCD and NSRD were merged in 1997 and produced a new organization named as Federal Seed Certification and Registration Agency, which control quality assurance section of crop varieties. Several projects were completed in this phase like establishment of testing laboratories: strengthening the public sector and also processing the plants and trainees.

13.2.4. Phase 4 (1980- till now)

In this duration, FSC and RD led private companies towards agriculture business, which resulted in the registration of private companies; first private company registered in 1981 and then eight other companies registered themselves. This is the initiation of seed industry in Pakistan. In 2000, 291 companies were registered with FSC and RD, and till now 850 are registered. In startup, these companies used basic seed from public sector for multiplication, but from last decades they began to develop their own varieties of crops and some companies also started import and export with foreign local industries. They replaced the public sector and became domineer for several crop i.e., maize hybrids, vegetables, fodders and oilseed etc.

13.3. Seed Systems in Pakistan

About 70% of the country's population lives in rural areas. Now a days, agriculture field are moving towards the technology and developments to face competition. Besides these, informal sector has been dominant for decades over formal sector. Strong partnership between public and private sector will boost up the facilitation of high quality seed. Both public and private sectors produce seed in Pakistan, but are not able to produce enough quantity of seed to meet farmers' requirements.

13.3.1. Informal Sector

Informal system is a system in which small farmers manage their seed from different ways. This system is also called traditional or farmer's system. More than 90% seed comes from farmers and other local shopkeepers, trailers and traders for sowing (Seboka and Deressa 1999; Thiele 1999); this is uncertified seed with less quality standards. This usually exists outside the legislation, laws and rules; and seed in this method is stored and again used on farm. Certification process and quality control mechanism is fully absent (Kiambi et al. 2016). This system is mostly organized and managed by farmers, undocumented, flexible and dynamics in nature and native to community (Sperling 2008).

About 70-90% seed sources are utilized from informal system in South Asia (Sperling and McGuire 2010). In Pakistan, farmers received about 90-93% seed of cereals, 21-24% vegetables seeds, 44-47% cotton and almost 98% seed of legumes from this sector (Govt. of Pakistan 2016). The main purpose is to get only production not the commercialization of the products as in formal system. Despite all of these, the varieties have some special attributes like taste and nutrition and receive their importance in community. A diverse gene pool is also established and conserve in this system. This is the only source of neglected and underutilized species. This sector can't be differentiated through formal sector in local seed market, where public and private companies also sale uncertified/unregistered seed.

This segment needs more intentions by Government for achieving betterment as in past neglected when policies are made. With financial incentive, effective marketing strategies, basic infrastructure, regulatory controls and provisions Government can prominently enhance quality of agricultural products. Farmers of day don't believe in approved variety; they demand for breeding lines through breeders. Although both systems are important in a country but even then not supported by Government especially informal system. This brings negative effect on production as well as farmer's income. Farmer's system should be reliable with support and association with any founder of approved varieties (Almekinder 2000). In order to strengthen the informal sector, Government should trade, conserve and distribute the local germplasm to maintain the diversity and vital gene.

13.3.2. Formal Sector

Formal seed system is distinguished through sequences of activities, which are performed to get high standard seed after maintaining the genetic purity and identity containing high physical, physiological and quality attributes. In this, firstly variety is developed through breeding, and then approved according to National rules. It contains both public and private sectors. It comprises all the regional, national, international and private companies and association, with the function of production, processing, marketing and distribution. This sector is supported by plant breeding institutions and research stations. As it is involved in variety approval, distribution and marketing of seed so they highly followed rules and regulation for managing variety, genes, certification standards, labeling and pricing. This system also called *ex-situ* conservation of seeds and underpins by breeding program and research purpose for crop improvement. This system can be derived by technology, knowledge and research; comprises of innovation, distinctness, uniformity and stability. Hybrids are example of this class. They originate through a proper certification challenge, have less chance of diseases and have high germination with maximum longevity (Kiambi et al. 2016). National Government also helps by making policies, rules and regulation, through both formal sector and breeders receive the benefits. Only 20-25% certified seed is produced by formal system to meet the whole country's requirements (Wekundah 2012).

Public and private sectors both are partners of formal seed system. Formal sector is expected to supply all crops certified seed to farming community of Pakistan to meet the current demand of seeds. The seed processing capacity of formal system was only focused in Punjab and Sindh. In national policy, private sector is free to import and export of any kind of seed. Today, they are dealing with low volume high profit seed while public sectors are bound to produce high volume low cost seed especially for cereals and pulses. Multinationals mostly deal with hybrids and get high profit in country mainly through maize, fodders, and oilseed. There is dire need to aware the farming community towards local hybrid as they are available at suitable price.

Table 13.1 Seed sector and seed and planting material

Seed Sector	Categories	Crops/Seeds
Formal Sector	Public Sector	Wheat, Cotton, Maize, Rice, Gram, Vegetables, Fruit and Nursery Plants
	Private Sector	
a.	National Companies	Wheat, Cotton, Maize, Rice, Gram, Vegetables, Fruits and Nursery Plants
b.	Multi Nationals	Hybrid Maize, Sunflower, Fodder and Forages
c.	Seed Importers	Maize, Sunflower, Fodder and Forages, Potato and Vegetables
Informal Sector	Farmers Own Source	Wheat, Cotton, Rice etc.

Source: FSC & RD (2013)

13.3.2.1. Public Sector

The Public sector not only obliged to produce the progeny of pre-basic seed of various crops received from research institutes but also provides policy to run seed industry and regulatory framework. In Punjab, PSC (Punjab Seed Corporation) is the functional unit and can produce its own pre-basic, basic, certified seed with collaboration of breeders as well as FSC and RD. Sindh Seed Corporation in Hyderabad is also involved in production and supply of seeds while Agricultural Development Authority (ADA) in KPK and Balochistan Department of Agriculture (BDA) in Quetta is only responsible for managing seed. On federal level, research is conducted by Pakistan Agriculture Research Council (PARC), Agriculture Research Institute of Pakistan Atomic Energy Commission (PEAC), and Pakistan Central Cotton Committee (PCCC) while on Provincial level, AARI, Faisalabad facilitates with 39.5% of total varieties to seed sector (Rana et al. 2015).

Universities

Five major agricultural universities in Pakistan play a key role in breeding programs and research development in public sector. Among them, main involvement in R&D is carried out by University of Agriculture, Faisalabad with research in range of disciplines and trainees to lead the industry with innovative technology. Five major universities are: University of Agriculture, Faisalabad, Arid Agriculture University, Rawalpindi, Agriculture University, Peshawar, Sindh Agriculture University, Tando Jam and Lasbella Agriculture University, Water and Marine Sciences, Lasbella (Rana 2014).

Punjab Seed Corporation

Punjab Seed Corporation is pioneer in seed industry; it is semi governed institute of Punjab Government, developed after seed act 1976, for production, processing, marketing, and storage of major and minor crops seed throughout the province. The main purpose of this is to facilitate the farmers with quality seed having reasonable price. They also aid the private seed sector through basic seeds for the production of certified seed. Punjab Seed Corporation has more than 1200 registered growers, 7303 acres farms, 72,000 metric tons processing capacity, and 6,700 metric tons storage capacity, 19 sales points in Punjab and more than 200 dealers in other provinces (PSC 2015). It usually processes the seed of rice, cotton, maize, wheat, fodders, vegetables, pulses, potatoes and oilseed crops. PSC is unable to sell its seed stock every year due to poor demand of their product and poor marketing strategy (Rana 2014). At present, PSC is striving hard to develop public-private partnership in vegetable hybrid seed production but it is very unfortunate that lack of human resources in the department is the main hindrance of its performance.

13.3.2.2. Private seed sector:

A vast number of private companies are present in Pakistan as compared to other developing countries. This shows that Pakistan seed industry still is in developing phase. After the approval of “truth in labeling rule” 1991, many companies have gained a great opportunity to produce their own seed of any crop and then market. Till now, more than 972 private companies are registered and 5 “Multinational” companies (MNCs) are working in state. Of which 213 private companies are deregistered due to their inefficiency and irregular activities; now total are 759 with 5 MNCs (Salam 2012). Due to lack of regular survey, it is difficult to update the company’s data. These are the main providers of certified seed and change their role by developing own varieties and hybrid in maize and sorghum. National seed companies only multiply public varieties and obtain seed from public sector.

Table 13.2 Total number of varieties registered by formal sector

Crop	**Public sector**					**Private sector**	**Total**
	Punjab	Sindh	Balochistan	KPK	Islamabad		
Wheat	59	24	8	40	3		134
Rice	16	13		6	-		35
Barley	3		4	3	-		10
Maize	11			12	-	2	25
Cotton	74	21		1	-	13	109
Sugarcane	14	8		16	-	1	39
Pulses	43	4	1	19	5		72
Fodder	27		1	7	-	2	37
Oil seed	20	5		22	8	5	60
Fruit	2			33	-		35
Vegetables	36	1	8	12	-		57
Total	305		22	171	16	23	613

Source: FSC and RD (2013)

Table 13.3 Total number of companies registered

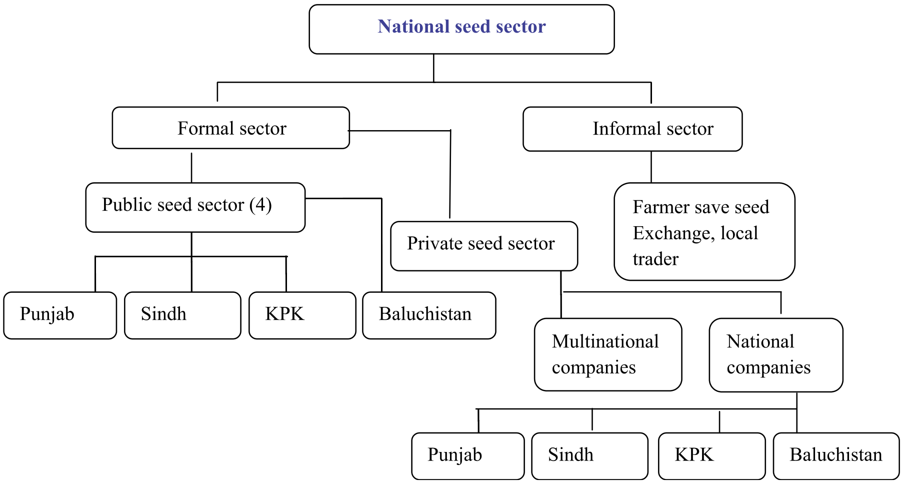
Type of company	Punjab	Sindh	KPK	GB and Ibd	Balochis-tan	Total
Public	1	1	1	-	1	4
Private (national)	621	98	23	3	5	750
Private multination al)	4	1	-	-	-	5
Total registered	626	100	24	3	6	759
Deregistered	182	23	5	-	3	213
Total	808	123	29	3	9	972

Source: FSC and RD (2013)

Five MNCs working in Pakistan seed market are Monsanto Pakistan Agritech, Pioneer Pakistan Seed Ltd, Bayer Crop Sciences, Syngenta Pakistan Ltd and ICI Pakistan Ltd. From these, Monsanto and pioneer have great role in introducing hybrids in Pakistan seed business. They bring hybrids of sorghum, sunflower and maize while canola hybrids came through ICI (Husain and Hussain 2007). Syngenta and Bayer introduced the GM crops and sooner or later will commercialize it. Private seed companies have their own associations. Both private and MNCs are the source of new seed germplasm in Pakistan of many crops, now they are producing their own varieties. Now they are ruling on certified seed market and are reducing the public sector role in market.

In seed market, several agrochemical based companies are now producing seed with brand name and have started their seed business i.e. Four Brothers, Fauji Foundation, Neelum seed Ltd and Auriga chemicals etc. They get financial aid from many sources like public and private banks i.e. Zarai Traqiati Bank. There are many restrictions while operating a company; scarce availability of breeder seed, absence of Intellectual property rights, which ultimately reduce the R&D, and legislative and institutional frame work which has become old.

Seed Production and Supply in Pakistan



13.3.3. Public-private partnership

For emerging economies, such as the needs of the population of Pakistan, they have to meet the existing high-level tax sources for seed industries. Public and private partnerships (PPP) in developing nations have a way of procurement and a significant part of the structure of infrastructure concerns with these gaps. PPP can be effective as a tool by credit and equality of core and non-core profits mobilization in industry likewise in developing countries.

PPP also includes the risk of tax. It should be limited and administered. With these challenges, Governments usually try to identify the proportional majority of PPP party proposals, implement legal and institutional reforms of the PPP, and then to see the value for money. These integrity assessment processes and operations ensure that PPP transfers are suitable for developing financial policy and financial obligations. These systems have equality issues for developmental consequences if they have technical challenges. This is a PPP development framework that Pakistan should have done so far in different ways in a current process.

The incentives for investing in the private sector in research and food development in the world continue to depend on the perception of an effective and weak market and market for information agencies. These improvements include strengthening system testing and verification, protecting farmer's consumption education and breaking the monopoly of the relevant countries and strategies. This can be done through the involvement of public and private stakeholders. The signal generated by more and more enterprises and private manufacturers are able to identify and use the technologies and new ones to increase the yield and productivity in agriculture (Spielman 2003).

There are many examples of PPP model in the world which include Monsanto and Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) on genetically modified soybean in Brazil, Mayco Foundation from ICAR and the biotechnology network Rockefeller Fellow in India and unique approach public-private partnerships in China. Thus, China has rapidly expanded its capacity for producing plant biotechnology, and Libya has rapidly provided and tested a wide range of GM crops, including rice, maize and potatoes etc. with successes. China can develop as a model for neighboring countries, including Pakistan (Pray and Fugile 2001).

13.4. Seed Rules and Regulations

Organization of Economic Corporations and Development (OECD) and Association of Officials Seed Certification Agency (AOSCA) are the main seed schemes in the world. Among these schemes, Pakistan is following OECD rules in variety approval and seed certification system. The headquarter of OECD is present in Paris. It was developed after World War II, on Dec 14, 1960 by United States with 18 European nations and Canadian union. Now 59 countries expand it, while bureau contains three main countries i.e. USA, South Africa and Italy. Mostly, developing countries are its members. It mainly focuses on raising the economy by reducing the poverty and ensures environmental effect of growth and social development. It is mainly concern with the seed certification mechanism.

AOSCA established in 1919 by USA also called International Crop Involvement Association, mainly focuses on production, identification, distribution and promotion of certified seed. Its certifying agencies are present in member countries including Canada, Australia, South Africa, New Zealand, Brazil, Chile and Argentina. The main goal of this association is to provide any type of propagating material, which meets the minimum certification standard and movement among local, national and international markets. They also offer Identity Preserved (IP) and Quality Assurance (QA) programs to member countries.

13.4.1. Seed Act, 1976

A framework was developed under the Seed Act 1976, conducting by rules and regulation to derive seed industry in the country smoothly. Further rules for Biosafety and plant breeders’ rights are also included in this Act. This act provides “setup for controlling and regulating the quality of seeds” of different crops. For this purpose, three main institutions are established along with protocol for variety approval, seed certification and production of particular class of seed on economic level (FSC & RD 2016). Institutions established under the Act are: National Seed Council (NSC), Provincial Seed Council (PSC), Federal Seed Certification and Registration Department (FSC & RD). Main functions of these are under:

National Seed Council: Works under the Chairmanship of Federal Minister-In-Charge of agriculture and act as an advisory committee. It performs a range of regulatory mechanisms i.e. inter Provincial movement of seed, initiation of Provincial projects, ensure and protect investment, guide the quality control department, develops approved seed production farms, regulate inter Provincial seed movement, co-ordination for the maintenance of genetic potential and advising on import of seed.

Provincial Seed Council: Provincial seed council is established by concerned Provincial Government as already written in Act. It performs all the function same as National Seed Council but on Provincial level and approve the variety but on the recommendation of FSC & RD**.**

FSC & RD: It works under National Seed Council and keep record of registration and approval of different crop varieties. It also control quality of seed, field inspection, sampling, testing, issuing certificates, carry post control trails, seed lots delivered for processing, arranging training courses and provide technical staff and specialist advisors.

This act gives power to FSC & RD to notify the varieties and regulation of seed for sale. It also appoints registered grower, seed analyst, seed officers and seed inspector by registering them in official gazette. It also mention the penalties in case of any violation of provision of this Act. There is no role for private companies as they were not present at that time when Act was formed.

13.4.1.1. Salient features of Seed Act, 1976

National Seed Council was established for policy regulation, inter provincial seed movement and investment in seed industry. Federal Seed Certification Agency was established to control the seed quality, filed inspection, testing of seeds, arrangements of training courses and providing of technical staff. Provincial Seed Council was developed to streamline seed production and business at province level. Federal Government has power to notify varieties along with their labels and minimum standard of germination and purity by notification in official gazette. Federal Seed Certification Agency may appoint or register any farmer or grower as a registered grower to produce seed as described in Seed Act. It prescribes the method used for certifying a seed lot by Federal Certification Agency. It authorizes Federal seed certification agency to appoint Seed Analyst, Seed Certification officer and Seed Inspector by notification in official gazette for testing purity of seed lots. It gives authority to Seed Inspector to inspect the seed lot and take sample from any type of seed from any person who is either producing, selling, delivering or distributing that lot, and also send to the nearest laboratory for testing.

This Seed Act did not mention the role of private companies as well as MNCs, and did not provide any method for their registration and certification. It only assigns the role of seed multiplication to the private company. There weren't present any minimum standard for import of seed as well as fruit plant nursery for their registration and certification also. There did not exist any type of method to ban a variety and its cultivation. It also didn't confer any plant breeder's rights. Different amendments are given to National Assembly of Pakistan, which was approved in 2016 (The Gazette of Pakistan 2015). These amendments are:

- **Seed registration rules 1987**; Registration of varieties (procedure, requirement, assessment)
- **Fruit plants certification rules 1988**; Registration of fruits plant nurseries, certification and tagging.

- **Truth in labeling rule 1991**; Seed standards, sampling, testing, marking and labeling, seed treatments, import of seed and flowers seed minimum standards for import.
- **National bio-safety rules 2005**; This rule was framed under PEPA (Pakistan Environmental Protection Act 1997), which control import, export, trails and sales of seed after obtaining a issued license from Federal Government. This rule is mainly for the GMOs crop and other imported crops.

13.4.2. Seed (Amendment) Act 2015

It is an update form of seed act 1976 to cover all modern seed industry and seed certification. It was given to national assembly in August 2014 with all new features according to current seed industry situation and modern technology used for seed development. It defines the clear role of registered seed companies, growers and dealers in the private sector. It also gives permission to private sector to produce basic seed and establish their accredited laboratory. This act also allows the registration of GMOs crops after getting a certificate from NBC (National Biosafety Committee). It implies heavy penalties than it was in previous Seed Act 1976.

13.4.2.1. Salient features of Seed (Amendment) Act 2015

This act clearly describes the classes of seed, varieties, genetically modified varieties, horticultural nursery, hybrid seed, misbranded seed, terminator technology and truth full labeled seed (The Gazette of Pakistan 2015). With the establishment of National Seed Council, FSC & RD and Provincial Seed Council, it prescribes the method to notify the variety, regulate the sale of seed and varieties and appointment of registered growers. The Ministry may grant registration to any person to do seed business in Pakistan, and it will remain valid for five years from the date of issue. It may be cancelled earlier if may found any issue or contravenes to any provision of this Act. The dealers and processing plants are registered under this Act. Private sector was encouraged to establish accredited seed testing laboratories as prescribed manner by Federal Government. Genetically modified variety can be registered after getting a certificate from National Biosafety Committee along with an affidavit, which declares that variety doesn't contain any gene or gene sequence involving terminator technology. Horticultural nurseries are registered before carrying any type of business from FSC & RD, after consulting from Federal Government. This Act contains heavier offences and penalties of two hundreds thousands rupees or three month of imprisonment, or may be both (The Gazette of Pakistan 2015).

13.4.3. Plant Breeder Rights 2016

WTO known as "World Trade Organization" deals with the rules and regulation of trade between nations. It's headquarter is present in Geneva, and was established on 1 January 1995. It contains 164 members' countries till July 2016. Pakistan being a member of WTO is bound to give rights to Plants breeder (Chaudhry 2001).

These rights are based on international Union for the Protection of New Varieties of Plants UPOV 1991 system, with the objective of IPR for new plant varieties. This Act is enforced in more than 74 countries. According to this, plant breeder will provide protection by patent or sui-generis system. Breeder can be authorized its right to any one for production and selling his variety or may give license to others for distribution of variety. This right allows the breeder to recover his investment, which has been used in variety development process by importing or exporting the material or may offer for sale in market. National Assembly passed 2016 PBR Bill in its 5th session in September, 2016.

PBR bill protects the rights of breeders and encourage them to develop new varieties. It supports in the establishment of viable seed industry to ensure availability of high quality seed in Pakistan. Plant Breeder "Rights Registry" shall be developed by Federal Government under the Ministry of NFSR. For facilitating the applicants, NFSR may set Registry Office at Provincial Government when needed. This registry will perform several functions i.e. protection of new varieties, certification, ensuring the movement of approve varietal seed to farmers, contains characterization and documentation of approved variety, and perform all action for smooth running of the registry.

It creates discipline in seed industry through securing the variety approval rights in local market as well as in international trade market. A plant variety shall be considered for protection if it meets the DUS (Distinctness, uniformity and strength) characteristics. It should be novel, distinct, stable to an environment and uniform in nature. It should have complete breeding history, DNA profile, through which novelty will be evaluated and applicant must have affidavit as a proof that it doesn't contains any terminator technology gene or group of genes. Applicant must have certification from NBC for GMO variety. Plant breeder will get benefit from these rights till 25 years in case of trees and vines, while 20 years in case of any other crop. This rule increases the number of new varieties, helps to introduce new material in country and promote investment by breeders or industry (Iqbal 2016).

13.5. Quality Control and Certification

Seed is the basic input of agriculture and ultimate output of every crop, so it should be vigorous. Quality seed are of great importance both for production and for export as well. International agriculture market demands healthy and vigorous seed product (Bishaw et al. 2012). Quality seed should be true to type, physiologically pure and free from diseases (Wimalasekera 2015). Production of quality seed is a big challenge to meet the food demand of increasing population.

13.5.1. Classes of Seed

According to **OECD** generally four seed types are defined: breeder seed / nucleus seed, foundation seed, registered seed and certified seed.

13.5.1.1. Breeder/ nucleus seed

Seed or any vegetative propagating material generated by the plant breeders/ institutions under controlled condition with great supervision. It is rare to develop a variety; only skillful and knowledgeable breeder can produce with minimum amount of seed. It contains highest purity, about 100% and require more attention. Label is not issue to this seed class.

13.5.1.2. Pre-Basic Seed/ foundation seed

Progeny of breeder/ nucleus seed is called foundation seed, which are produced and maintained by any research officer on agricultural station. According to national system of multiplication, its genetic purity and identity is kept maximum. Directly or indirectly, it is source of all the other certified seeds. Its purity should be 99.9% and is labelled with white color along diagonal violet lines by FSC & RD.

13.5.1.3. Basic Seed/ registered seed

It is progeny of pre-basic seed and is handled by registered grower on the behalf of Government. Its genetic purity and identity are maintained and ensured all the standards of certification, and it must contain 99.5% purity, with white color labeling.

13.5.1.4. Certified seed

Progeny of basic seed and either certified seed is known as certified seed. It is handled to maintain sufficient genetic purity and identity to meet the specified standards for the crop being certified. It must have maximum genetic purity of 99%, doesn’t exceed two generation of foundation seed. Progressive farmers grow progeny according to prescribed manner followed by inspection for approval by certifying agency. Its label color is blue issued by FSC & RD.

13.5.2. Plant Variety Registration

According to Seed Act 1976, variety should be approved as given protocol. To ensure health and other requirements, a variety should met with given information (by breeder) to prevent it from misleading. For variety approval, FSC & RD is responsible for the evaluation. It creates report on DUS and VCU characteristics and recommends the NSC for registration after confirmatory process.

13.5.2.1. Variety testing parameters

It contains crop botanical name, proposed name by the grower, justification of innovation, area covers, kinds of cultivar, origin and method for development, cropping system, yield, duration of season, performance in biotic or abiotic stresses, impact of fertilizer, and crop description etc.

13.5.2.2. Development and testing of variety

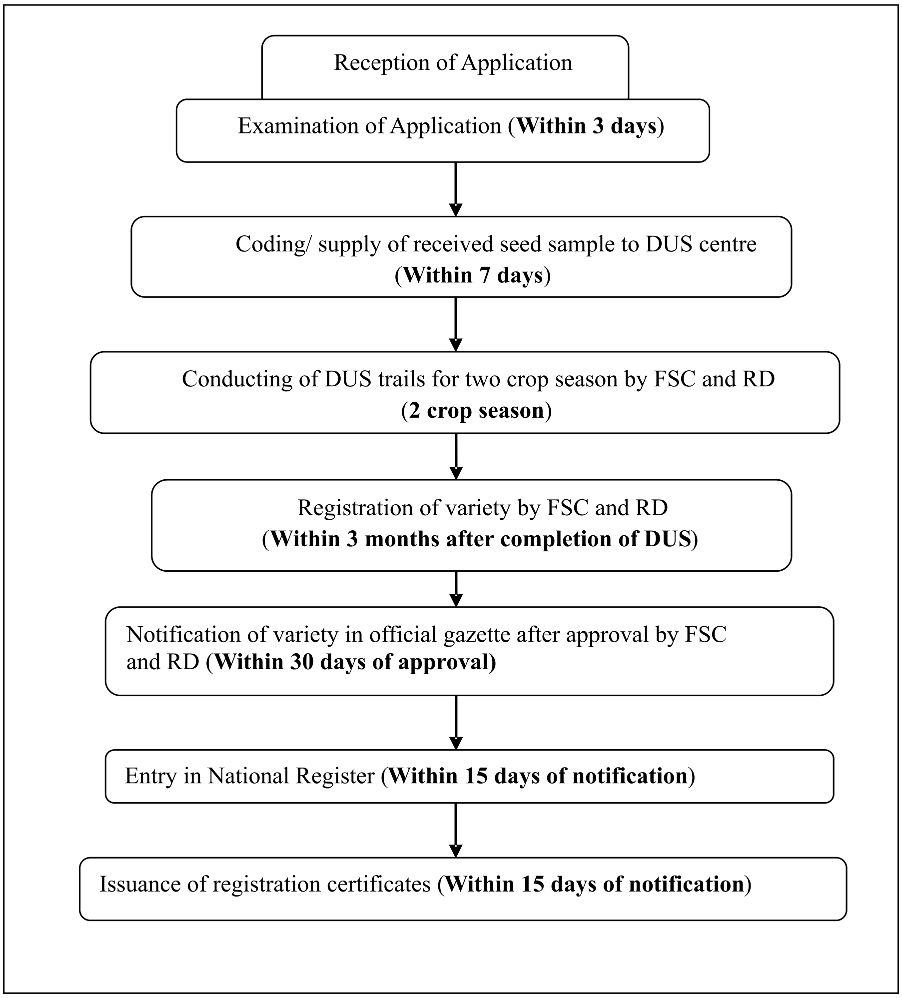
PARC is coordinated for all research pertaining to variety evaluation and also provide funding for innovative research not carried earlier. PCCC only carry cotton varieties for approval. Micro varietal trials are organized on breeding stations and sub-stations. Zonal trials are designed out for sufficient numbers or years. Multinational company after local trials gets benefits under truth-in-labeling rules.

Breeder handovers the seed of new variety to PARC, after evaluation it gives the results of VCU (value for cultivation and used) to FSC & RD. Simultaneously, he also submits seed sample to FSC & RD for DUS (distinctness, uniformity, stability) test.

13.5.2.3. Registration and release

After testing, if variety meets the requirements for VCU and DUS, it is ready for registration by FSC & RD. The resulted reports are given to FSC & RD, where Federal Seed Registration Committee evaluates it and recommends to NSC for approval and release the variety. Notification is given by FSC & RD, although a number of agencies are involved in this procedure. FSC & RD keeps the record of variety with descriptive list and may multiply through seed certification system.

Steps involved in registration of a variety (FSC & RD)



13.6. Seed Certification System

It is a legal strategy to ensure quality of seed. This mechanism is controlled by FSC & RD. It maintains genetic and physical purity and quality attributes of superior crop and secure availability to farmer.

13.6.1.1. Process of certification:

In Pakistan, adapted procedure for certification contains these two basic steps: Crop inspection (in the field) for genetic purity and seed testing (in the accredited laboratory) for physical purity.

Crop inspection

i. **Registration**: Any person /grower, who want to certify his seed lot, must get registered himself and must provide all information regarding to particular seed class to certification agency.

ii. **Crop inspection**: Before crop inspection in field, the inspector notified by FSC & RD verifies all information. It includes the verification of seed by label attached to bag, seals, and receipt of purchasing seed. Area, location of field, cropping pattern of that area, isolation distance from other crop, health and condition of the crop in respected field, are also verified with application for inspection by applicant. After confirmation, a detailed assessment of crop in field is carried out by the inspector based on mixing with other cultivars, species and weedy plants. Diseased plants are also monitored. After evaluating these factors, if it meets the criteria of inspection, company is informed about decisions and the department issues a certificate.

Seed testing

Only that person can submit application for sampling whose crop is approved by seed inspector after field inspection. FSC and RD recommended an officer for seed sampling; he draws three samples from a seed lot through prescribed manner as given in ISTA rule 1990. First sample is given to the central seed testing laboratory for post control, second to the grower and third to the respective seed testing laboratory where it is tested.

i. Seed analysis

Sample submitted to the lab is further tested for quality attributes i.e. seed purity percentage, admixture with others varietal or weedy seeds, inert matter, seed borne diseases, moisture test, 1000-seed weight, germination percentage and health attributes. Individual seed go through examination process and a report is generated.

ii. Temporary label

After testing, certification of fitness and temporary labels are issued by the departments. Labels carry: Monogram of FSC and RD, Reference number, Species, Cultivars, Total number of bags and approximate weight of seed lots.

iii. Final label

Final labeling is given after processing of seed lot by seed agency and is further analyzed by laboratory. Finally owner gets permission for marketing and any type of business.

iv. Post checking

Post checking of certified seed can be monitored at any stage after seed lot is finally labeled. If the seed lot doesn't match with the information, whole consignment will be restricted for further usage.

13.6.2. Seed import

Pakistan utilized billions of rupees on importing of seed especially for hybrids, oil seed, vegetables seed, potatoes, forages and flowers. FSC & RD is empowered by Federal Government to manage the quality of import and export of seed. After the approval of Truth-in-Labeling Rules 1991, anyone can export or import seed. Karachi, Lahore and Islamabad are the main port of entries. Packet or container having imported seed must bear a label of identity i.e. Name of crop species, lot number, quantity, purity percentage, germination percentage, moisture percentage, percentage of other seeds, date of production and expiry. Seed should be only of those varieties as mentioned in official gazette. Seed lot should be less than 10 kg. Importer must inform the FSC & RD about his shipment and sample information. FSC & RD has successfully monitored the quality of seed since 1991. This allows a check against the entry of any material containing pathogen or virus and secures the local variety from its effect.

Table 13.4 Imported seed in certified seed market by private sector (2013)

Crop	**Certified seed total seed requirement (%)**	**Private sector Total certified seed (%)**		
		Local production	Import	Total
Wheat	25	72	0	72
Rice	117	82	8	90
Maize	49	25	74	99
Cotton	52	83	0	83
Potato	1	0	99	99
Pulses	0.2	97	0	97
Oil seed	50	24	69	93
Vegetables	92	4	96	100
Fodder	52	0	100	100

Source: Abacus Market Research (2015)

13.6.3. Fruit plant certification & nursery registration system

Pakistan receives millions of rupees from export of various fruits like mango and citrus. This ratio can be increased by exporting high quality fruit and can only be done after registration of nurseries. Fruit nursery certification is an essential consideration for improving the quality, maintenance of uniformity and purity concerns. A healthy and disease free nursery can enhance the production. Recently rules for nursery registration and certification of fruit plant has approved by NSC. Now 120 nurseries have been registered by FSC & RD. Of these, 94 nurseries are registered in KPK, 12 in Balochistan and 14 in Punjab, which provides more than 65000 certified plants. FSC & RD provides Technical Assistance for the establishment of Germplasm unit (GPUs) (FSC & RD 2015).

In KPK, 3 Germplasm units were setup for fruit plant certification of tropical, sub-tropical and temperate fruits i.e., stone and pome fruits which were shift to D.I. Khan, Dargai and Haripur respectively (Husain 2011).

13.7. Issues and Challenges of Pakistan Seed Industry

13.7.1. Demand and supply of seeds

Pakistan seed industry has showed a remarkable change in seed production from 1976-2010. However, still yield and quality is lower than that of global standard. Seed requirement percentage is low in country, and the remaining demand is met by uncertified seed or through informal sources. The availability of certified seed for wheat, cotton, maize and rice is satisfactory and seed demand for vegetables, oil seed crops and fodders are met by imports (FAO 2014). Estimation of required seed is based on area under cultivation, seed application and also replacement rate for various crops. The country's gross seed requirement in 2016 was 1680 thousand MT while total seed availability was 410 thousand MT and the remaining demand of seeds was met through local or informal sector (FSC & RD 2015-16). Among formal sector, private sector is the major contributor (18.85%) in provision of seed as compared to public sector (4.8%). Out of 4% imported seed, vegetable and fodder seeds are mainly exported. The seed supply amounts to about 27% of the country's total estimated seed requirement. Thus, there is huge demand of certified seed in the country and there is great opportunity for private investment in the seed sector (Hussain and Bhutta 2002).

Table 13.5 Area, Seed Requirement and Seed Availability for the Year 2015-16

Crop	**Area**	**Total seed**	**Targeted**	**Seed Availability (M.T)**			
	000 Ha	requirement (MT)	Seed Requi. (MT)	Public	Private	Imported	Total (Loc+Imp)
Wheat	9,045	1,085,400	217,080	75,455	239,566	0	315,020
Cotton	3,200	40,000	40,000	687	28,677	0	29,364

Paddy	2,847	46,660	12,744	4,269	43,962	8,470	56,701
Maize	1,064	31,914	9,574	70	3,105	13,919	17,094
Pulses	1,337	47,496	9,499	230	1,259	0	1,489
Oilseeds	830	10,582	2,116	2	95	494	591
Vegetables	254	5,570	5,070	21	106	7,301	7,427
Fodders	1,942	40,138	40,138	-	27	37,307	37,335
Potato	149	372,725	74,545	-	-	3,051	3,051
Total	20,668	1,680,485	410,766	80,734	316,796	70,542	468,072
							27.86%

Source: Govt. of Pakistan (2015)

13.7.2. Seed production

At present, hybrid seed production and early generation seed production is a challenge for formal seed sector. There is a lack of capacity building of public and private sectors in seed production technology and have no appropriate processing plants for vegetable seeds (Hussain and Bhutta 2002; FAO 2014). There is inadequate supply of pre-basic and basic seeds including parent seeds for hybrids in public sectors for multiplication. MNCs have stopped local seed production because they want surety about germplasm protection and availability of seed production farms to them for promotion of local seed production in the country. There is no relaxation on taxation and levies on local seed production. Thus, companies preferred to import seed from India, Thailand, Holland, China, Turkey and other European countries. In spite of formal sector involvement in production of many varieties, there is no enough seed production for farming community except cotton (Hussain and Bhutta 2002). However, poor germination of cotton seed is a big problem faced by farmers in the country, thus, farmers are receiving seed with 45% germination and they have to use more seed rate @ 6-8 kg per acre; but if germination is more than 80% then less than 2 kg seed is required (Abdullah 2010). Almost 100% cotton seed, 33% maize seed and 20% other cereal seeds are being supplied by formal sector, however, seed sector failed to produce enough seed for vegetables and fodders which is alarming in the seed industry (Hussain and Bhutta 2002). It is evident from Table 14.6 that public sector contributed significantly in the release of varieties whereas private sector has started developing new varieties for commercial release now. It is expected that varieties released by private sector will be larger than public sector in future due to approval of new seed legislations. Punjab based institutions from public sector has remarkably contributed in the release of varieties for the farming community.

Table 13.6 Number of registered and released varieties

Crop	**Public sector**					**Private sector**	**Total**
	Punjab	Sindh	Balochistan	KPK	Islamabad		
Wheat	59	24	8	40	3		134

Rice	16	13		6	-		35
Barley	3		4	3	-		10
Maize	11			12	-	2	25
Cotton	74	21		1	-	13	109
Sugarcane	14	8		16	-	1	39
Pulses	43	4	1	19	5		72
Fodder	27		1	7	-	2	37
Oil seed	20	5		22	8	5	60
Fruit	2			33	-		35
Vegetables	36	1	8	12	-		57
Total	305		22	171	16	23	613

Source: Govt. of Pakistan (2013)

13.7.3. Seed Processing

Seed processing refers to all those post-harvesting steps through which we obtain pure and high quality seed. These are drying, pre-cleaning, cleaning, grading and seed treatment. Normally, there are two main methods of drying i.e. sundry and forced air dry. In summer season, crops are mostly dried in the field, while in rainy season, they are brought inside the shade and they take time for drying. In forced air drying, moisture contents reduce through artificial dry method by using hot air. Sack drying, bin drying and column drying are some of the artificial dry methods.

Punjab Seed Corporation has four efficient processing plants in Punjab, which process quality seed of major and minor crops for the farmers. The seed processing capacity of cereal plant and cotton ginning and processing plant is 20 tons per hour and 15 bales per hour respectively. Multinational and few national seed companies have installed seed processing plants for cereals and cotton (Hussain and Butta 2002). Moreover, small seed companies are getting processing facility from other established processing plants in Punjab and Sindh. In comparison to public sector, private sector primarily focuses on quality seed processing while ignoring seed losses whereas public sector seed losses are up to 12% during seed processing. At present, there is no proper infrastructure for vegetable seed processing expect few national seed companies in Punjab who are involved in processing and production of peas, okra and radish seeds. Government should provide subsidy to the seed sector for the installation of seed processing units that will encourage local seed production of vegetables.

13.7.4. Seed Marketing

Seed prices in the market varies based upon production and procurement by the seed companies and the government is not paying attention on that. The prices of private companies are comparatively higher than public sector. Private companies have strong dealer system for marketing and distribution of seed to farmers than public sector based companies. Normally, imported seed is expensive than locally produced seed. The government has no solid policy to control the prices of seed of various crops in the market (Hussain and Butta 2002). Few national seed companies are also involved in the marketing of hybrid maize seed by using inbred lines of multinational seed companies and therefore multinational seed companies are marketing only imported seeds. They are waiting for the strong implementation of seed laws to stop illegal seed supply in the market for discouragement of approved local varieties.

Out of international seed trade, worth over US$43 billion per annum, Pakistan has no share in world seed export but 3035 metric tons vegetable seed having worth US$ 66 million was imported in 2015 (International Seed Federation 2015). An estimated data of seed market industry in Pakistan was PKR 72.25 billion in 2011 (Hussain 2011). This data was collected from both formal and informal sectors. The market size in 2014 was PKR 105 billion according to FSC & RD, which was increased by 13% from 2011.

Table 13.7 Estimated value of seed market according to FSC & RD (2012 and 2014)

Crops	2012		2014	
	Reqt. (000 Tons)	Value (PKR M)	Reqt. (000 Tons)	Value (PKR M)
Rice	42.5	5,525	42.5	6,906
Wheat	1,085.4	39,074	1,085.4	51,557
Maize	31.9	5,478	31.9	10,408
Cotton	40.0	8,400	40.0	6,000
Potato	378.0	7,875	378.5	15,750
Vegetables	5.1	1,543	5.1	1,721
Fodder	40.1	10,625	40.1	12,030
Pulses	50.9	-	50.9	-
Total	1,673.90	78,520	1674.4	104,372

Source: Govt. of Pakistan (2012, 2014)

13.8. Conclusion

Pakistan seed sector is undergoing a major transformation in recent years. Seed laws are updated and are at various levels of implementation, which creates enabling environment for stakeholders to invest in seed business. It is impossible to establish sustainable and viable seed industry in the country without the joint efforts of academia, seed industry, research and public sector institutions. There is need to improve research and development in public sector. Enhancement in the seed production, processing and distribution system can play a great role in the development of public industry. By implementation of current rules and regulation, seed market will improve and promote trading. Formal and informal linkage should be strengthened so that farmers with small land holding receive full advantage and thus encourage the farming community.

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Chapter 14

Fertilizers in Pakistan

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Abstract

Fertilizers are an integral part of modern crop production and presently farming without fertilizers is not feasible. Fertilizer use in Pakistan is consistent with food demands and also with the global developments that have increased several folds since its introduction. The imbalance and inefficient fertilizer use have remained a major concern over the period of time. The nitrogen to phosphorus ratio has also improved in recent years while the use of potash is still negligible. Integrated use of chemical and organic fertilizers is the need of time to maintain the soil health and fertility and to keep the crop production system more sustainable in order to meet the growing needs of the population. Pakistani soils have a low organic matter which is also responsible for low fertilizer use efficiency, so the use of green and organic manure should also be endorsed. Integrated plant nutrition is the best management system that envisages the use of both chemical and organic fertilizers to keep the agriculture system more productive, economical, sustainable, and environmentally friendly.

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Keywords: Fertilizer; Organic fertilizer; Manure; Inorganic Fertilizer; Nutrients; Fertilizer use Efficiency

14.1. Introduction

According to the United Nations (UN), the global population of 6.7 billion is expected to reach 9.2 billion by 2050 (UN DESA 2015). The report Millennium Project and its State of the Future (2015) projected that another 2.3 billion people are expected to be added to the planet in the next 35 years and to keep up with population and economic growth; food production should increase by 70% by 2050. By 2050 new systems for food, water, energy and economics will be needed to prevent massive and complex human and environmental disasters. According to Food and Agriculture Organization (FAO), food production must be increased by 70 percent by 2050 in order to feed the growing world population (FAO 2016). However, each year about 100,000 km^2 of croplands are lost through soil erosion; a soil degradation that refers to absolute productive soil losses in terms of topsoil and nutrients. If we continue on the same trajectory we are on, we will produce about 30% less food over the next 20 to 50 years. Soil degradation is primarily happening due to various activities such as overgrazing, tillage practices, deforestation, urbanization, overexploitation of land and industrialization.

The total area of Pakistan is 79.61 million ha and out of which only 28% i.e. 22.67 million ha is only available for cultivation. About 19.28 million ha (85 %) of the cultivated land is irrigated, while the rest of the land is under rainfed cultivation. Rangeland, which covers over 50% of the total area of Pakistan, can be used as a potential source of livestock development. Pakistan is amongst the countries having the highest growth rate of 2% per annum and its population is expected to be 260 million by 2030 and correspondingly the arable cultivated land is estimated to increase from 22.5 million ha to 26.3 million ha by 2030 i.e. growth of 0.5%. It means that per capita land availability would further decrease from 0.15 ha to 0.09 ha by 2030. Therefore, to feed the 260 million population by 2030; Pakistan has to produce 37 million tons of wheat. So, wheat productivity must increase to 4.0 tons per ha from the current producing level of about 2.9-3.0 tons per ha. Therefore, a 40% increase in per ha wheat production is not possible without enhancing fertilizer utilization both in terms of quantity and quality. Fertilizer use also coupled with imbalanced nutrient consumption is the main reason for low fertilizer use efficiency and productivity in Pakistani soils and agriculture production systems.

For a sustainable and productive agriculture system, the use of organic additives should also be emphasized to complement the chemical fertilizers while conserving the soil and environment; the approach is known as Integrated Plant Nutrient Management (IPNM). Over the years, FAO has been actively supporting encouraging, and developing an Integrated Plant Nutrition System (IPNS), through which the management of plant nutrition and soil fertility in cropping and farming systems is adapted to site-specific characteristics and to locally available resources. Though the efficient use of chemical fertilizers is recognized to be a quick source of boosting crop production aspects, about a 50% increase in cereal production in developing countries during the 1970s was attributed to only the use of fertilizers

(FAO 1984). After soil and water, chemical fertilizer is considered the most important element in providing quantity and quality food for growing the world's population. To meet the world's continuously increasing food demands, the role of optimum and balanced fertilizer use will increase in the future. If the use of major nutrient supply is abruptly discontinued, the world food output would probably plummet by about 40 percent or more (World Watch Institute 1990).

The fertilizer is any material; natural or synthetic which is applied to soil or plant tissues to supply one or more nutrients that are essential to plant growth or a substance used to make soil more fertile. The term fertilizer is derived from the Latin word *fertilis*, meaning "fruit bearing". Fertilizer can be defined as a mined, refined, or manufactured product containing one or more essential plant nutrients in available or potentially available forms and in commercially valuable amounts without carrying any harmful substance above permissible limits. The first "artificial fertilizer" namely single super phosphate (SSP) was developed in 1842 in the United Kingdom. Production of potash fertilizers started in 1865 in Germany and of coal-derived ammonia fertilizers in 1890. The dominant fertilizer products are those that contain nitrogen (N), phosphorus (P) and potassium (K) in many chemical and physical forms, and their combinations in order to meet the need for their application under different conditions (FAO 2005). In 1940, the world used about 4 million tons of fertilizer, the figure reached 137 million tons in 2000, and 187 million tons in 2016 (FAO 2015).

The geographical and climatic conditions of Pakistan have large variability. Pakistan has the benefits of both irrigated plains and range areas extending from the coastal ranges in the south to the alpine pastures in the north. While overall soils of Pakistan are poor in organic matter (OM) resulting in low crop production. To address this problem, a combination of N, P and K fertilizers are being applied most commonly. The current use of the three major fertilizers (NPK) is about 163 kg ha^{-1}. This rate is very low as compared to the 300-600 kg of NPK ha^{-1} in Europe and other agricultural developed countries. Similarly, yields obtained per ha are much lower in Pakistan 2500 kg ha^{-1} compared to the 4000-5000 kg ha^{-1} in Europe (Govt. of Pakistan 2015).

The application of compost materials and farmyard manure (FYM) has been supposed simple practices to restore the contents of OM in soil. Growing leguminous crops in rotation with high nutrient demanding crops and fallowing have been very popular practices in the past (Muhammad et al. 2007; Maltsogluo et al. 2015). However, now to feed the ever-increasing population, supplementing the soil with artificial nutrients has become imperative. In Pakistan, the most widely applied fertilizers are available in different NPK ratios.

Depletion of soil fertility is a major constraint for higher crop production in Pakistan. Most of the cultivated soils have OM below 1%; on the other hand, the addition of OM is also very low and negligible (Nisar and Arshad 2003). Almost all farmer community is relying on chemical fertilizers to recover the existing nutrient deficiency for profitable crop yields. Consequently, a suitable combination of organic and inorganic sources of nutrients is necessary for sustainable crop yields (Shah et al. 2007).

The fertilizer sector of Pakistan is working smoothly and also enhancing its production capacities on a need basis. In the past, about 50% of the country's fertilizer demand was fulfilled by imports. Currently, Pakistan is meeting 75-80% of its fertilizers demand domestically, while approximately 20-25% is fulfilled through imports.

14.2. Sources of Fertilizers

A large number of diverse materials can serve as sources of plant nutrients. These can be natural, synthetic, recycled wastes and biological products including microbial inoculants. However, based on their sources, fertilizers are primarily of two types i.e. natural or organic fertilizers and synthetic or inorganic fertilizers (FAO 2005). Both of these sources have been in use by the human being and both have their benefits and drawbacks as discussed below.

14.2.1. Organic fertilizers

Proper maintenance of soil OM is an important part of nutrient management. Addition of OM improves both chemical and biological properties of soil, as well as is a source of supplying macro and micronutrients (Gulshan et al. 2013). The most stable form of OM is humus. It plays an important role in improving the soil structure, nutrient retention, and water holding capacity of the soil. It has been shown that addition of compost, animal and green manures to the soil improves the microbial diversity and populations (Fawole et al. 2010). In many areas, the most common practice is fallow periods during which the natural regenerative process restores the organic content of the soil. Hence, the ever increasing demands of food and to meet their requirements by growing population, fallowing is not being adopted and with passage of time the trend is diminishing.

Organic fertilizers traditionally have provided the nutrients in shifting the agriculture systems where fallow periods are alternating with periods of cultivations to engage the lands throughout the year. While the crop production in such systems has been reduced to half (Senjobi et al. 2010). Organic fertilizers are usually low in nutrients contents and also release nutrients at much slower rates comparatively to mineral fertilizers. Due to low nutrient contents and slower nutrient release rate, organic manures cannot meet nutrient requirements of high yielding crops. Moreover, organic manures are not sufficiently available in such a huge quantity that can meet entire nutritional requirements of high yielding crops. Nutrients availability and release rate from OM depends mainly on carbon to nitrogen ratio (C:N) in a substance (Table 14.1). The C:N ratio of a material can have a significant effect on crop residue decomposition, particularly residue cover on the soil and the crop nutrient cycling (Muhammad et al. 2007).

The decomposition of the organic materials is brought about by soil microorganism. A soil microorganism needs a diet with a C:N ratio near 24:1, with 16 parts of carbon used for energy and eight parts for maintenance. This 24:1 of C:N ratio is considered optimum, and the soil microorganisms will consume it relatively quickly with essentially no excess C or N left over. The materials added to the soil with a C:N ratio greater than 24:1 will result in a temporary N deficit condition, known as immobilization. Those materials with a C:N ratio less than 24:1 will result in a temporary N surplus condition known as mineralization. This is why composting operations strive to achieve a blend of materials with a C:N ratio of about 30:1. Therefore, the resident microbes can readily decompose the compost pile leaving a little food and structure left over to feed and shelter the microbes after the compost is applied to the soil (Brady and Weil. 2002).

Table 13.1 Carbon to nitrogen (C:N) ratios of crop residues and other organic materials

Material	C:N ratio
Rye straw	82:1
Wheat straw	80:1
Oat straw	70:1
Corn stover	57:1
Rye cover crop (anthesis)	37:1
Pea straw	29:1
Rye cover crop (vegetative)	26:1
Mature alfalfa hay	25:1
Ideal microbial diet	24:1
Rotted barnyard manure	20:1
Legume hay	17:1
Beef manure	17:1
Young alfalfa hay	13:1
Soil microbes (average)	8:1

Source: *USDA (2011)*

Production of agricultural commodities with use of organic manures is called organic farming. Organic farming is low input and low output agriculture system and even in developed countries like USA, Canada, and Japan its extent is not more than 2% because of low production. The developing countries like Pakistan, where population pressure is high and per capita income is low, cannot afford it. Further in future, there is a limited scope of organic farming due to its low productivity and shrinking land and water resources.

14.2.1.1. Types of organic fertilizers

Soil organic matter is regarded as a key parameter of soil fertility and productivity. It has number of important roles to play in soil, both in their physical and chemical structure, sink for plant nutrients and medium for biological activities (Sarwar et al. 2008a). The introduction of improved varieties into a traditional farming system tends to create a situation where the nutrient demands of the crop outstrip the natural ability of the ecosystem to replenish its organic resources. Although, progressive farmers can exploit the natural regenerative properties of organic waste products by incorporating the organic material back into the soil to maintain soil fertility (Sarwar et al. 2008b). Thus, the farmer either opts for a balanced farming system, which will be able to sustain the medium yields over a long period with minimal chemical inputs. The high cost of fertilizers and their impacts on environment have great motivations to study the recycling of the large quantities of organic residues produced as byproducts of the agro-industries in agriculture (Renato et al. 2013).

Although, the organic fertilizers are also being prepared on large scale but these are not referred as commercial fertilizers, due to their much lower nutrient content compared to inorganic fertilizers. Organic fertilizers are based on their origin and can be divided into five main categories as plant substances, animal processed byproducts, mineral based fertilizers, composts and manures. Their further details are discussed below.

14.2.1.2. Bio-fertilizers

Bio-fertilizers are low cost and environment friendly plant nutrients source. Bio-fertilizers provide nutrients by gradual degradation of the OM. Biological preparations include live or latent cells of microorganisms or their metabolites. When these are inoculated to seed, soil or roots of seedlings, they promote plant growth and enhance the harvestable yield (Malusa et al. 2012). These microorganisms colonize the rhizosphere of plants and promote the plant growth by promoting the availability of primary plant nutrients. These rhizosphere bacteria are collectively called as plant growth promoting rhizobacteria (PGPR) (Naveed et al. 2015). The main sources of bio-fertilizers are N fixing bacteria, P solubilizing, K mobilizing bacteria and mycorrhizae (Afzal et al. 2008). The source of microbes, their habit and mode of action of bio-fertilizer are summed up in the Table 2 given below (Motghare and Gauraha 2012; Ahmad et al. 2013).

Table 14.2 Grouping of Bio-fertilizers based on their nature and function

S. No.	Groups	Examples
	Nitrogen (N_2) Fixing Bio-fertilizers	
1	Free-living	Azotobacter, Clostridium, Anabaena, Nostoc
2	Symbiotic	Rhizobium, Frankia, Anabaena azollae
3	Associative Symbiotic	Azospirillum
	P Solubilizing Bio-fertilizers	
1	Bacteria	*Bacillus megaterium* var. *phosphaticum* *Bacillus circulans, Pseudomonas striata*
2	Fungi	*Penicilliumsp, Aspergillus awamori*
	K Mobilizing Bio-fertilizers	
1	Vesicular Arbuscular mycorrhiza	Glomussp, Gigasporasp, Acaulospora sp.

2	Ectomycorrhiza	Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.
3	Orchid mycorrhiza	*Rhizoctonia solani*
	Bio-fertilizers for Micro nutrients	
1	Silicate and Zinc solubilizers	Bacillus sp.
	Plant Growth Promoting Rhizobacteria	
1	Pseudomonas	*Pseudomonas fluorescens*

Bio-fertilizers are applied either directly to the seeds prior to sowing or are applied in the main field by mixing it to the farm manure in dried form or broadcasted. Another popular form of bio-fertilizer application is by dipping roots of the seedlings prior to sowing. These are available in both powder as well as liquid form, but later are often preferred over former due to longer shelf life, better survival rates, and minimum chance of contamination and ease of application. These liquid bio-fertilizers along with their methods of application and required amount are discussed in Table 3 (Motghare and Gauraha 2012).

In recent years, the use of bio-fertilizers has gained popularity because of sustainability of their use as it improves soil health, conserves soil and environment and is cost effective. In some cases, these bio-fertilizers are also used in combination with the chemical fertilizers. Although, bio-fertilizers are low in costs, high yielding and eco-friendly but there are some constraints that limits their application such as the use of less efficient strains, and lack of qualified technicians in production units. The main limitations include short shelf life of inoculants, their dependency on season and sensitivity to soil characteristics like salinity, acidity, drought, and water logging, etc. (Mondal et al. 2015). However, application of bio-fertilizers is becoming popular in organic farming cultures.

Bio-fertilizers in Pakistan

Bio-fertilizers are now commercially available from National Agricultural Research Centre (NARC) Islamabad, Soil Bacteriology section, Ayub Agriculture Research Institute (AARI) Faisalabad, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad and National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad for a range of crops (Zahir et al. 2013).

However, various research groups and organizations are engaged in research and development on bio-fertilizers and have made their efforts to increase the application of bio-fertilizers in agriculture in Pakistan (Ahmed et al. 2013) as shown in Table 3. Inconsistent field performance, lack of regulation and standards, quality issues of the product, awareness and lack of publicity are the major constraints in the widespread use of bio-fertilizers in Pakistan. If these problems are resolved, better results and responses can be expected through bio-fertilizer use in Pakistani agriculture sector. Assuring quality of products with extensive field-based testing, capacity building of resource persons and stakeholders on standard production processes, storage and application will help a wider adoption and popularization of the bio-fertilizer technologies (Naveed et al. 2015).

Table 14.3 Recommendations of bio-fertilizers applications for various crops

Crop Type	Recommended Biofertilizer	Application method	Quantity to be used
Cereals	Azotobacter	Seed treatment	200 ml/acre
Wheat, oat, barley	Azospirillum	Seed treatment	200 ml/acre
Rice	Azospirillum	Seed treatment	200 ml/acre
Oil seeds; mustard, sesame, linseeds, sunflower, castor	Azotobacter	Seed treatment	200 ml/acre
Millets; pearl millets, finger millets, kodo millet	Azotobacter	Seed treatment	200 ml/acre
Maize and sorghum	Azospirillum	Seed treatment	200 ml/acre
Bacco	Azotobacter	Seedling treatment	500 ml/acre
Leguminous plants/ trees	Rhizobium	Soil treatment	1-2 ml/plant
Agro-forestry/fruit plants	Azotobacter	Soil treatment	2-3 ml/plant at nursery
All fruit/agro-forestry	Azotobacter	Soil treatment	2-3 ml/plant at nursery

14.2.1.3. Manures and composts

Tropical soils are adversely affected by sub-optimal soil fertility and erosion, causing deterioration of the nutrient status and changes in soil organism populations (Akande et al. 2010). Manure and compost not only supply many nutrients for crop production, including micronutrients, but they are also a valuable source of OM. Increasing soil OM improves the structure or tilth of soils. Most vegetable and agronomic crops returns only small amounts of crop residues to the soil, so that manure, compost and other organic amendments may help to maintain soil OM content (Rosen and Bierman 2005).

Composts and animal manure both are good organic sources of nutrients to the soil. Compost is rich source of nutrients with high OM content and use of compost can be beneficial in improving the soil OM status. Composting of organic wastes is a cost effective and environment friendly way of waste recycling (Mahfooz at al. 2006). The OM in various forms and at various stages of decomposition can be used in soil for improvement of crop productivity. Organic wastes are available in huge amount at farms and industrial wastes scale such as sugar, cotton, rice and food processing based industries. The organic manure and compost are important in sustainable farming by providing plant N–supply, improvement in soil physical, chemical and biological properties and reduced mineralization rate etc. Compared to composts, manures release nutrients at a slower rate, thus compost is preferred over control. Compost has the greatest potential as a marketable product and quality compost has a value in international market. Especially, in the scenario of globalization and WTO, its demand is increasing day by day.

Depletion of nutrients and poor OM contents of Pakistani soils can only be replenished or recovered by applying compost to these poor soils. On the basis of experimental results, a recommendation for the farmers is formulated that they should compost the crop residues to apply in their soils for the increased sustainable crop production. In this way, the soil fertility can be improved with a net improvement in land productivity (Sarwar et al. 2008a).

14.2.1.4. Animal wastes and farmyard manure

Pakistan annually produces about 50 million metric tons (mmt) of crops, animal and poultry wastes. The use of organic wastes has emerged as a non-hazardous and cost effective source of fertilizers around the world. Only in the Karachi city of Pakistan, waste amounts to 6600 tons per day. Other than environmental pollutions, there is the loss of 1.5 million tons of nutrients, which are available in farmyard manures (FYM) and 101 million tons of N from poultry manure.

The term FYM refers to the decomposed mixture of dung and urine of farm animals along with the litter (bedding material and leftover material from roughages or fodder fed to cattle).

There are about 28 million animals (cows, buffaloes, goats, and horses, etc.) in Pakistan, besides about 50 million tons per year of crop residues and 6 million birds in poultry. The animals and birds produce about 443 million tons of dung per year. Based on different assumptions, it is estimated that about 1.5 million tons of nutrients are available from FYM. Of this quantity, N accounts for 726 thousand tons, P_2O_5 for 191 thousand tones and K_2O for about 617 thousand tones. FYM (cow manure) contained 1.87 % N, 2.47% P_2O_5 and 2.11% K_2O. On an average, well decomposed FYM contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. A long-term research revealed that the application of dung manure at 5 t ha^{-1} per year can save the soil resources from degradation. Senjobi et al. (2010) reported a remarkable improvement in all the growth parameters of the leafy vegetables due to addition of sheep and goat manures. Therefore efficient utilization of animal waste will not only clean our environment but money spends on fertilizer could also be saved.

14.2.1.5. Poultry manure

Poultry manure has long been recognized as the most desirable organic fertilizer. It improves soil fertility by adding both major and essential nutrients as well as soil OM which can improve moisture and nutrient retention. With the expansion of poultry industry, generation of poultry litter has also increased tremendously. Owing to its high content of plant nutrients, poultry litter is considered the most valuable organic resource for fertilizing purpose due to good supplement of micro and macro nutrients. It contains approximately 1.1 to 1.5% of N, 0.8 to 1.3% P, and 0.5 to 2.7% of K (Gachene and Kimaru 2003). Poultry manure application registered over 53% increases of soil N, and 0.09% to 0.14% exchangeable cations in the soil (Boateng et al. 2006).

Chicken manure is rich in essential nutrients and contains about 3.23% N, 4.27% P_2O_5, 2.54% K_2O, and 35.4% organic carbon (OC). Various experiments have explored that crop yields per hectares were increased and maximum values were obtained with 12 t ha^{-1} applications of poultry manure (Shah et al. 2007). In Pakistan, approximately 1.2 million tons poultry manure is produced that can be used as potential source of OM to the crops (Qureshi et al. 2014).

14.2.1.6. Crop residues

Post-harvest crop residue is a critical source of soil OM. Addition of crop residues to soil not only meets the nutritional requirement, but also helps to protect the soil against water and wind erosion with substantial improvement in soil health. Leaving the crop residue in the field improves nutrients cycling and soil health, and sustains the soil productivity. About 98% of the soil N is stabilized in the OM, which is slowly released and in combination with other nutrients contributes to efficient crop production.

The use of crop residues as a source of plant nutrients supplements is increasing in many parts of the world where inorganic fertilizers have not proved to be economically and environmentally viable. At a time, when there is increasing concern about decline in OM content of soils, the use of crop residues may play an important role as a source of nutrients, OM and as mulching materials. In such system, incorporation of plant residue into soil provides a better physical condition for soil health and plant growth. After decomposition, the residue releases plant nutrients and builds up soil OM.

Another common practice is postharvest burning of crop residues. Despite of some advantages like killing of deleterious pests and clearing the piles before wheat planting, burning results in huge losses of N (up to 80%), P (25%), K (21%) and S (4-60%), and air pollution depriving of soil organic matter (SOM). This loss of SOM is one of the documented threats to sustainability of advanced agriculture. Incorporation of residues leads to build up of SOM, soil N, P and K by improving soil health (Arshadullah et al. 2012).

The major disadvantage of their incorporation is the immobilization of inorganic N. However, N at 15-20 kg ha^{-1} as starter dose with straw incorporation increases yield of wheat and rice compared to burning. Major proportion of wheat straw is being consumed by livestock. *Kallar* grass is known as a salt tolerant grass capable of producing a good amount of biomass on degraded soils in summer which may be utilized. Crop residues are used for mulching to protect soils from desiccation during the period of fallowing. Mulching of seed beds is also found to be positive for better germination, getting good crop yield and improves the soil quality in terms of organic C and biotic activity (FAO 2005). An increase in infiltration of water into the soil has also been reported with addition of crop residues.

In most rain fed areas of Pakistan, due to poor soil fertility, the farmers usually grow winter crop and then leave the soil fallow. They conserve moisture from the summer rains in the soil until the time of sowing of a winter crop by combination of tillage practices. As the population of Pakistan is increasing rapidly, the demand for food, fiber etc. is consistently increasing. To meet the increasing demand of food, it will not be feasible to leave the land fallow. Under such situations, appropriate cropping system must be adopted to sustain the soil fertility, and improving the crop productivity (Mohammad et al. 2010).

Filter cake and still effluent

Filter cake, a residue obtained from the treatment of sugar cane juice by filtration during white and black sugar processing, can be used to provide significant P, OM and moisture to soil. It has been used as a complete or partial substitute for mineral fertilizers in sugarcane and in other crops cultivation, and is commonly used as substrate in compost production (Fravet et al. 2010). The mechanized harvest of sugarcane, which is used widely in countries producing this crop, leaves about 6 – 24 t ha^{-1} of residues on the soil surface annually (Viator et al. 2008).

Filter cake is utilized as fertilizer in several countries, including Pakistan. The main effect of filter cake on soil chemical properties are increased N, P, calcium and sulpher concentrations by increasing cation exchange capacity (CEC) of soil, and reduced concentrations of exchangeable aluminum (Al^{3+}) which is toxic to plants as shown in Table 4. Thus, due to its specific characteristics, filter cake can play a fundamental role in agricultural production, in the maintenance of soil fertility, and as a soil conditioner (Rossetto et al. 2008).

The Pakistan sugar industry produces over 1.2 million tons of filter cake every year, which is a rich source of OM, micro and macronutrients (Table 4). Some factors, such as lack of solubility and unbalanced concentrations of nutrients, limit the application of filter cake to soil. In Pakistan, most of the filter cake is sold to the brick industry and the still effluent is drained out as waste, with a consequent loss of plant nutrients and causing environmental pollution (FAO 2005).

Table 14.4 Estimates of the potential contribution of byproducts produced by sugar-alcohol agro-industry to annual recycling of mineral elements in agriculture

Residues	Nutrients N	Nutrients P_2O_5	Nutrients K_2O	Volume of residues	Returning nutrients N	Returning nutrients P_2O_5	Returning nutrients K_2O
	(% in dry residue)				($t\ yr^{-1}$)		
Filter cake[1]	1.40	1.94	0.39	2.34 million t dry cake yr^{-1} (Mt dwt)	32800	45400	9130
Straw[2]	0.46	0.11	0.57	34.5 million t dry straw yr^{-1}	158700	37950	196650
	($g\ m^{-3}$ vinasse)						
Vinasse[3]	375	60	2.035	270 billion L yr^{-1}	101250	16200	549450
Total	—	—	—	—	292750	99550	755230

14.2.1.7. Biogas slurry

Biogas plant is basically designed to allow the anaerobic digestion of organic materials which produces mainly from methane gas along with traces of H_2S, CO_2, NH_3, CO and biogas slurry (BGS). The slurry produced by a biogas plant is considered to be an effective fertilizer and soil conditioner. This contains many nutritive elements including N, P, K, iron (Fe) and other trace elements (Gupta 2007).

Comparatively, FYM is not as richer in micro-nutrients as BGS. The processing of manure in an anaerobic digester is only a partial manure degradation process. In addition, BGS is free of weed seeds because anaerobic digestion kills more seeds than any manure processing system. The N in animal manure is normally available in an organic form but after passing through the fermentation process in a biogas digester, it change (by bacteria) to inorganic form [mostly ammonium N (NH^{4+})] which is easily soluble and utilized by the crop plants (Nasir et al. 2010).

14.2.1.8. Other solid and liquid based materials

Other solid and liquid based materials are available including sewage sludge, waste water, fish pond effluent, city refuse and some wastes from food processing industries. These materials cannot be used directly as a source of plant nutrients. However, after proper processing and removal of heavy metals, contaminants and other undesirable materials, these sources have the potential of being a good source of plant nutrients.

14.2.1.9. Fish pond effluent

The efficiencies of N fertilizer use are very low, approximately 32-35%. A large proportion is lost to the atmosphere by ammonia volatilization and denitrification. The nutrients losses in the soil from chemical fertilizers and unprecedented prices hike and the unavailability of fertilizers at proper time has also becoming the matter of serious concern in farming (Zhang et al. 2009). About 30 to 70% of N applied through nitrogenous fertilizers to agricultural crops is lost due to NH_3 volatilization, denitrification, and NO_3 leaching losses (Maqsood et al. 2016).

Phosphate also becomes immobile and less available to plants, especially under high pH conditions encountered in most of the agricultural soils of Pakistan. Formulated feeds and large amount of green and animal manures are applied to fish ponds, leading to OM accumulating in pond bottoms with time. OM accumulation rates of 0.87 g m^2 dl have been reported (Zarina et al. 2010).

The poorer soil fertility is attributed to continuous cropping which makes the soil highly vulnerable to soil degradation. NPK application results in reduction of soil pH while the fish pond effluent increases the soil pH. Thus, the fish pond effluent has considerable amounts of relative exchangeable Ca, Mg and K that can help in improving soil pH (Sarwar et al. 2008b).

14.2.1.10. Municipal wastewater

In general, municipal wastewater is made up of domestic waste water, industrial waste water, storm water, and ground water seepage entering the municipal sewage network (Hussain et al. 2002). As a by-product of conventional waste water treatment, sewage sludge is introduced as a potential agricultural resource in combination with waste water irrigation.

Sewage sludge is by-products of municipal and industrial waste water treatment and a rich source of nutrients. Sewage sludge having high content of OM, macro and micro nutrients, can be used as fertilizer for food, vegetable, horticultural plants and pasture, which in most cases can be beneficially recycled. Waste water and its nutrient contents can be used extensively for irrigation and other ecosystem services (Jamil et al. 2006). Both treated and untreated municipal waste water in the vicinity of large cities is used for vegetable production. Due to high cost of mineral fertilizers and escalating trends in their prices, there is an increasing trend of using sewage sludge in agriculture, especially under intensive cropping in arid and semiarid regions of the country (Usman et al. 2012).

14.2.1.11. Composition of wastewater

Though the actual composition of waste water may differ from community to community, usually all municipal waste water contains the following broad groupings of constituents (Table 5).

Table 14.5 Organic matter content and major nutrients in sewage sludge (Pakistan)

Fertility parameters	Pakistan
Organic matter (mg kg^{-1})	19,400
Total nitrogen (mg kg^{-1})	16,000
Available N (mg kg^{-1})	5200
Available P (mg kg^{-1})	70
Available K (mg kg^{-1})	288

Soil OM, soil nutrients (N, P and K), inorganic matter (dissolved minerals), toxic chemicals and pathogens are considered essential for enhancing soil fertility, quality and sustaining the soil productivity. Application of sewage sludge at a rate of 200 t ha^{-1} increased the total N of soil aggregates by 57% and available P by 64.2%. Phosphorus and N release very slowly through degradation of OM as compared to inorganic fertilizers and therefore, the organic compounds are available for longer period (Hussain et al. 2002).

Soil OM in sludge mainly consists of soluble matter with a small amount of lignin and cellulose that contribute to its composition. That is why the OM within the sludge has the potential to mineralize relatively in a quick manner. This potential results in rapid degradation that could lead to enhance the nitrate and P levels in the soil. However, WHO has developed outline to mark the criteria that would prevent the transmission of communicable diseases while optimizing resource utilization and recycling (Usman et al. 2012).

Restricted irrigation refers to the irrigation of crops not intended for direct human consumption, and thus covers the irrigation of industrial crops (e.g., cotton, sisal, and sunflower); crops processed prior to consumption (e.g., wheat, barley, oats), also known as Category A; and fruits trees, fodder crops and pastures, known as Category B. Unrestricted irrigation, on the other hand, refers to all crops grown for direct human consumption, including those eaten as raw (e.g., lettuce, salads, cucumber etc.) and irrigation of sports fields and public parks, known as Category C (Hussain et al. 2001).

The application of sewage water in agricultural applications is very common since long time. However, studies revealed that the OM content in sludge can improve the soil physical, chemical, and biological properties with ensuring better cultivation and aqua-ferrous capacity of soil, especially when applied in the form of dewatered sludge cake. Biosolids reduces runoff and increase the surface retention of rain water (Csattho 1994). The addition of sewage sludge to agricultural lands is the better option of recycling nutrients present in it. Therefore, sewage sludge may be considered as an important biological resource for sustainable agriculture.

14.2.2. Inorganic or Mineral fertilizers

Fertilizer is a substance applied to soils to enhance the crop growth and yield. Fertilizer products are in largely variations of three primary soil nutrients, namely N, P and K. However, usage of a particular fertilizer is primarily determined by the suitability of a nutrient for a specific crop. Nitrogen and its compounds are the most commonly used fertilizers, contributing more than 60% of global demand followed by phosphate and potash (IFA 2013). During the past four decades, we have witnessed the doubling of the human population and a concurrent doubling of food production. Plant nutrition has played a key role in this dramatic increase in demands and also for supply of foods. Increments in crop production have been made it possible through the use of commercial man-made fertilizers. The use of N fertilizer has increased almost nine folds and P more than four folds.

Inorganic/synthetic fertilizers can be subcategorized into different subgroups depending upon their nutrient contents as given below:

14.2.2.1. Single Element or Straight Fertilizers

Single element fertilizers contain only one of the primary nutrient elements (N, P, and K), below are the important single element fertilizers (Table 14.6).

Table 14.16 Composition of various synthetic fertilizers

Fertilizer	Composition
Urea	46% N
Calcium Ammoinum Nitrate	26% N
Ammonium Sulfate	21% N
Single superphosphate	18% P_2O_5
Triple superphosphate	46% P_2O_5
Muriate of Potash	60% K_2O
Sulfate of Potash	50% K_2O

14.2.2.2. Multi-Nutrient or Complex Fertilizers

These are fertilizers which contains two or more primary nutrient elements in combination. These fertilizers can be subdivided into two types; compound and mixed fertilizers.

14.2.2.3. Compound fertilizers

These are fertilizers which are produced through a chemical process in which different components of fertilizers reacts chemically and homogeneous product of uniform composition is produced which represents certain chemical compound. Important compound fertilizers are Nitrophos, Diammonium Phosphate, Monoammonium Phosphate, Potassium Nitrate and Urea Phosphate as given in below table (Table 7)

Table 14.7 Composition of various compound fertilizers

Fertilizer	Composition
Nitrophos	22% N, 20% P_2O_5
Diammonium Phosphate	18% N, 46% P_2O_5
Monoammonium Phosphate	11% N, 52% P_2O_5
Potassium Nitrate	13% N, 44% K_2O
Urea Phosphate	18% N, 44% P_2O_5

14.2.2.4. Mixed Fertilizers

Mixed fertilizers are also called as blended fertilizers and are produced by dry mixing of several fertilizers with no chemical reaction. In Pakistan, only available multi-nutrient blended fertilizer is NPK (Table 8).

Table 14.8 Composition of various mixed fertilizers

Fertilizer	Composition
NPK	8% N, 23% P_2O_5, 18% K_2O
NPK	17% N, 17% P_2O_5, 17% K_2O
NPK	15% N, 15% P_2O_5, 15% K_2O

Inorganic fertilizers always consist of the nutrient element(s) bonded to an inert carrier. Consequently, the total weight of the fertilizer does not correspond exactly to the weight of the nutrient it contains. The weight of the nutrient comprises only a part of the total fertilizer weight and varies according to the chemical composition of the fertilizer. For example a 50 kg bag of urea fertilizer (46% N) contains 23 kg N and 27 kg of inert material.

Fertilizers can be of different colors depending upon their nutrient contents and raw material being used. Fertilizers can be formed in all three forms *i.e.* solid, liquid and gas, depending upon their use and application. While, in Pakistan mostly fertilizers are available in large or small granular form; however some fertilizers are also available in crystalline powdered and liquids or in suspensions forms. In Pakistan fertilizers are sold in 50 kg bag.

Fertilizers Available in Pakistan

In Pakistan, fertilizer supply is fulfilled through local production and imports. Pakistan's fertilizer industry is mainly concerned with primary nutrients namely NPK as they are deficient in majority of soils. In Pakistan, N is deficient in 100% whereas, P is deficient in more than 90% of soils and K is deficient in 40% of soils. Deficiency of micronutrients like zinc (Zn) and boron (B) is also widespread in the country. Locally manufactures fertilizers are urea, calcium ammonium nitrate (CAN), single superphosphate (SSP), nitrophos (NP) and diammonium phosphate (DAP) whereas, imported fertilizers are diammonium phosphate (DAP), triple superphosphate (TSP), mono-ammonium phosphate (MAP), murate of potash (MOP), sulfate of potash (SOP) and ammonium sulphate as shown in Table 9. On small scale, micronutrients like zinc sulphate and borax are also imported.

Table 14.9 Fertilizers available in Pakistan

Fertilizer name	Chemical Analysis %		
	N	P_2O5	K_2O
Nitrogenous fertilizers			
Urea	46	0	0
Calcium Ammonium Nitrate	26	0	0
Ammonium Sulphate	21	0	0
Phosphate Fertilizers			
Diammonium Phosphate (DAP)	18	46	0
Single Superphosphate (SSP)	0	18	0
Triple Superphosphate (TSP)	0	46	0
Monoammonium Phosphate (MAP)	11	52	0
Nitrophosphate (NP)	22	20	0
NPK	8	23	18
	17	17	17
Potash Fertilizers			
Sulphate of Potash	0	0	50
Muriate of Potash	0	0	60
Micronutrients			
Zinc Sulphate	Zn – 33%		
	Zn – 21%		
Borax	B – 10.5%		

Urea

Urea is a concentrated straight nitrogen fertilizer which contains 46% N. Its entire N is present in amide form (NH_2) which converts to ammonium (NH_4^+) in the soil. Urea also contains small quantity of biuret, a toxic chemical produced during its production and its concentration is ensured to be below than standard (nontoxic) level *i.e.* < 2%. Urea is white in color and is available in prilled or granular form varied in size from 1 mm to 3 mm. It is suitable for all kind of soils, can be applied through broadcast and side dressing, because of its high water solubility it can also be applied through fertigation and foliar sprays.

Calcium Ammonium Nitrate (CAN)

It is straight nitrogenous fertilizer which contains 26% N. Half of N is in ammonical form and half in nitrate form. It also contains calcium as this fertilizer is produced by mixing ammonium nitrate with lime. Calcium part of CAN is not soluble but nitrogen is readily soluble.

Ammonium Sulfate (AS)

It is low nutrient contents straight nitrogenous fertilizer but its production had been stopped in 1997-98 due to high production cost and its plant was converted to urea manufacturing plant. It contains 21% N and it also has 24% sulphur (S) content. It is white crystalline salt and might have yellow, brown and grey tint. Presently, very limited quantity is being produced in the country as byproduct of Pakistan steel while few private companies are importing and marketing it with different brand names.

Di-ammonium Phosphate (DAP)

It is a concentrated compound fertilizer which contains 46% P_2O_5 and 18% N. It is granular and free flowing fertilizer. It is suitable for all types of soils and is recommended for all crops. Its application can be done through broadcast, band placement and fertigation as its water solubility is more than 95%. Sometimes, questions have raised about its suitability for heavy textures and salt affected soils, but data available through experimentation have shown that it is equally effective in all types of soils because its net reaction is acidic as its ammonical nitrogen when undergoes nitrification process produces certain amount of acid in soil. In Pakistan, only Fauji Fertilizer Company (FFC) is producing DAP domestically with annual installed capacity of 675 thousand tons; all other companies are only importing and selling it.

Single Superphosphate (SSP)

It is single nutrient straight fertilizer which has 14-20% of P; but in Pakistan, only 18% grade is available. It is available both in powder and granular form and its color could be grey or brown. In addition to mono-calcium phosphate, it also has 46% calcium sulfate (gypsum).

Triple Superphosphate (TSP)

This is concentrated phosphate fertilizer which has 46% P_2O_5 and is mostly available in granular and free flowing form. TSP is not produced in Pakistan and some quantity of it is being imported by some private companies, but in these days it is not available in our market.

Nitrophosphate (NP)

It is produced by treating the rock phosphate with nitric acid. It can also be called ammonium nitrate phosphate as half of its nitrogen is in ammonical form and half is in nitrate form. In Pakistan, 22-20-0 grade is manufactured and sold. Its solubility is about 80-85%.

Sulphate of Potash (SOP)

It is straight potash fertilizer which contains 50% K_2O. It is available in white crystalline salt and also in granular from. It is suitable and recommended for all types of soils and crops; even in salt affected soils. It is water soluble and can also be applied through fertigation. It is imported fertilizer but its consumption has not increased much due to its high cost.

Muriate of Potash (MOP)

It contains 60% K_2O and is available in granular from. It is imported fertilizer and is not produced in Pakistan. It can be applied in all types of soils except soils with high chlorides accumulation. Its application is not suitable for chloride sensitive crops like tobacco, potato, fruits and vegetables.

NPK Fertilizers

This is multi nutrients mixed fertilizer which is produced in Pakistan through dry physical blending of compounds fertilizers like urea, DAP and MOP or SOP. Only Engro Fertilizers Company has installed a plant of 100 thousand tons capacity at Karachi. It produces three types of fertilizer grades having composition of 8-23-18, 15-15-15 and 17-17-17 NPK respectively.

Fertilizer Use in Pakistan

Commercial use of fertilizer has started after green revolution in Pakistan with introduction of high yielding cereal varieties as these have higher nutritional requirements and it has produced thrust in the country for nutrient use. Prior to green revolution, national nutrient demand was near 71 thousand tons or 5 kg ha^{-1} which got momentum after green revolution and increased to 3.7 million tons nutrients or 163 kg ha^{-1} in 2015-16. This shows an increase of more than fifty folds over the period of 50 years. But our current fertilizer requirement is still less than many high yielding countries like New Zealand, China, Egypt, Netherland, Belgium, Japan, United Kingdom and Germany where nutrient requirement is about 1486, 644, 575, 310, 294, 259, 234 and 199 kg per ha, respectively (FAO 2015). Despite of impressive increase in fertilizer use, it remained imbalanced as largest growth was in consumption of N nutrient as compared to P and K fertilizer. P fertilizer use is improved and has reached to 44 kg ha^{-1} but still there is a gap to increase further its usage.

Consumption of potassic fertilizer has always remained insignificant due to lack of awareness and high cost. Lot of efforts are yet required to enhance their use by putting more concentration in its promotion and allocation of more funds for extending subsidy to K fertilizers in Pakistan. Furthermore, the use of micronutrients is also negligible, and this has created serious imbalance in fertilizers usage, thus imparting negative impact on crop productivity. Main reason for increasing this imbalance use was mainly price differential as prices of P and K fertilizers remained two to three times higher than nitrogenous fertilizers. If we further look down to province wise average NPK consumption, during 2015-16, Sindh province has highest NPK consumption of 294 kg ha^{-1} followed by Punjab, KPK and Balochistan provinces having off take of 152, 92 and 71 kg ha^{-1}, respectively (Table 10).

Table 14.10 Hectare basis fertilizer use in Pakistan in selected years (kg ha^{-1})

Year	Nitrogen	Phosphate	Potash	Total
1965-66	4.5	0.1	-	4.6
1985-86	56	17	1.6	75
1995-96	88	22	1.0	111
2001-02	103	28	2.0	133
2005-06	122	38	1.4	161
2010-11	132	32	1.4	166
2015-16	118	44	0.9	163

Pakistan Nutrients use Balance ratio

Fertilizer nutrients consumption has increased manifold during the past 40 years. It reached one million nutrient tons in 1980-81, 2.5 million tons in 1995-96, crossed figure of 4.0 million tons in 2009-10 but later on settled down to 3.7 million tons in 2015-16 (Table 11). Soils of Pakistan are deficient in N and P; an optimal combination of these nutrients is necessary to achieve the higher yield levels (Akram et al. 2007). Moreover, lack of awareness among farmers community also plays a role in determining the use of fertilizers. Not realizing the benefits of an optimal NP ratio, farmers tend to favor the products available in the market at cheaper rates. Demand of the fertilizers industry is directly aligned with growth in agricultural sector. The sector accounts for 21% of the GDP and absorbs around 44% of the country’s workforce.

Nitrogen accounts for 72% of the total nutrients, whereas, P is 27% and K is less than 1%. The average N, P_2O_5, K_2O nutrient ratio during 2015/16 was 2.65:1:0.02 whereas, it was 3.46:1.0:0.03 in 2005-06 and 4.02:1.0:0.06 in 1995-96 as shown in Table 11. Imbalance usage of NPK nutrient is one of the major factor which affects fertilizer use efficiency which resultantly affects the crop yields. Desirable NPK ratio is 1.5-2:1:0.5 and present NPK ratio of 2.65:1:0.02 can be brought to desired level by promoting the use of Phosphate and Potassic fertilizers and by providing these at affordable prices. There is a need to extend the subsidy on both of these fertilizers especially K fertilizers. Government has recently given subsidy on nitrogenous and

P fertilizers but there is a need to allocate more funds for P and K fertilizers to promote their use especially K fertilizers.

Table 14.11 Nutrients off take in Pakistan (000 nutrient tons)

Nutrient	**1995-96**	**2000-01**	**2005-06**	**2010-11**	**2015-16**
Nitrogen	1991	2264	2927	3134	2672
Phosphate	494	677	851	767	1007
Potash	30	23	27	32	20
Total	2515	2964	3804	3933	3699
% Change	-	3.5	5.6	0.7	-1.1
NPK ratio	4.0:1:0.06	3.4:1:0.02	3.5:1:0.03	4.1:1:0.04	2.61:1:0.01

Fertilizer Production and Imports

Fertilizer requirements in the country are met from both domestic production and imports (Tables 12-15). Currently, a combined production capacity of different fertilizer plants in Pakistan is 8983 thousand tons. The annual production capacities of different fertilizers are as follows: urea 6.3 million tons, DAP 675 thousand tons, CAN 680 thousand tons, NP compounds 740 thousand tons, SSP 405 thousand tons and for NPK compounds 100 thousand tons (NFDC 2015-16).

Prior to 1980-81, the country imported well over 50% of its annual fertilizer requirements. However, the situation changed following the expansion of the local industry during the 1980s and 1990s. The prevalent demand and supply gap in the market has triggered setting up of new plants in the country and during the period of 2000-2010 fertilizer industry has undergone major expansion by installing new plants and expanding the existing capacities. Notable additions in this period were urea and DAP plant by Fauji Fertilizer Company Bin Qasim, urea, CAN, NP plant by Fatima Fertilizer Limited, urea, NPK plants by Engro Fertilizer Limited and SSP plant by Suraj Fertilizer Limited. There are nine fertilizer industries working now, and among those Fauji Fertilizer Company Limited is largest company having market share above 50% followed by Engro Fertilizer Limited and Fatima Fertilizer Company.

Table 14.12 Fertilizers production in Pakistan in terms of nutrients

Years	(000 nutrient tons)			
	N	P	K	Total
1991-92	1043.8	105.5	0.0	1149.3
1992-93	1227.3	104.8	0.0	1332.1
1993-94	1565.9	92.9	0.0	1658.9

1994-95	1544.1	92.1	0.0	1636.2
1995-96	1693.4	96.1	0.0	1789.5
1996-97	1681.5	80.7	0.0	1762.2
1997-98	1660.5	67.5	0.0	1728.0
1998-99	1795.2	90.7	0.0	1885.9
1999-00	2039.6	223.5	0.0	2263.2
2000-01	2053.8	243.8	0.4	2298.1
2001-02	2134.0	142.7	8.9	2285.6
2002-03	2192.4	111.1	11.5	2315.0
2003-04	2272.5	255.3	12.9	2540.7
2004-05	2373.0	325.0	20.0	2718.0
2005-06	2476.0	341.0	15.0	2832.0
2006-07	3476.7	307.9	11.9	2746.0
2007-08	2513.0	294.0	16.0	2822.0
2008-09	2532.0	364.0	10.0	2907.1
2009-10	2669.0	403.0	10.0	3082.0
2010-11	2642.0	423.0	12.0	3076.0
2011-12	2541.0	431.0	10.0	2983.0
2012-13	2257.5	438.6	7.5	2703.6
2013-14	2643.6	454.5	11.4	3109.6
2014-15	2754.5	504.7	12.1	3271.3
2015-16	3120.8	541.3	12.3	3674.5

Source: *NFDC (2016-17)*

Table 14.13 Domestic production of fertilizers in Pakistan in terms of fertilizer source

Year	Urea		Ammonium Nitrate		Ammonium Sulphate		SSP		Nitrophos		DAP		
	Tones	46% N	Tones	26% N	Tones	21% N	Tones	18% P	Tones	23% N	Tones	18% N	46% P
1991-2	1898	875	300	78	93	21	194	34	310	71	-	-	-
1992-3	2306	1061	302	79	93	20	205	36	297	68	-	-	-
1993-4	3104	1428	243	63	82	17	195	35	251	58	-	-	-
1994-5	3000	1380	314	82	80	17	147	26	285	66	-	-	-

1995-6	3258	1499	383	100	84	18	104	19	337	78	-	-	-
1996-7	3258	1499	330	86	78	16	1	*	350	81	-	-	-
1997-8	3284	1511	316	82	0.5	0.1	-	-	293	67	-	-	-
1998-9	3550	1633	339	88	0.0	0.0	22	4	285	66	46	8	21
1999-00	3995	1838	386	100	0.0	0.0	146	26	371	85	1062	191	489
2000-01	3983	1832	374	97	0.0	0.0	160	29	285	66	325	59	150
2001-02	4260	1960	329	86	0.0	0.0	162	29	306	70	67	12	31
2002-03	4407	2027	335	87	0.0	0.0	147	26	305	70	0	0	0
2003-04	4435	2040	350	91	0.0	0.0	168	30	363	84	268	48	123
2004-05	4611	2121	330	86	0.0	0.0	164	30	339	78	408	73	188

Source: *NFDC (2006-07)*

Table 14.14 Fertilizers imports in terms of nutrients in Pakistan

Years	(000 nutrient tons)			
	N	P	K	Total
1991-92	360.0	257.0	15.0	632.0
1992-93	393.0	357.2	8.9	759.1
1993-94	313.0	547.0	43.0	903.0
1994-95	73.0	186.0	2.0	261.0
1995-96	248.8	280.6	51.6	581.0
1996-97	472.8	381.0	24.3	878.1
1997-98	286.9	415.7	11.1	713.7
1998-99	421.8	425.0	37.2	884.8
1999-00	233.0	416.0	13.8	662.8
2000-01	194.0	369.1	16.5	579.6
2001-02	178.5	429.5	17.7	625.7
2002-03	215.7	542.4	7.9	766.0
2003-04	204.2	553.5	6.4	764.1
2004-05	309.7	458.1	16.9	784.7
2005-06	603.0	640.0	25.0	1268.3
2006-07	307.6	476.2	12.1	796.0
2007-08	286.7	565.7	23.9	876.3
2008-09	457.0	112.0	0.04	568.0

2009-10	901.0	522.0	21.0	1444.0
2010-11	383.1	243.5	17.9	644.6
2011-12	871.0	291.0	15.0	1177.0
2012-13	456.4	271.2	6.8	734.5
2013-14	702.6	431.7	14.1	1148.4
2014-15	486.2	474.6	23.4	984.3
2015-16	336.8	556.5	8.0	901.2

Source: *NFDC (2016-17)*

Fertilizers consumption of the nation has increased several times since the time of separation with an enormous increase in the population from 30 million to 201.99 million. This increase in fertilizer is in line with the increased domestic productivity of crops. This increased production not only provides farmers with relatively cheap source of fertilizers but also has reduced the pressure on imports. Imports of fertilizers of year 2010-11 to 2015-16 are shown in the Table 15.

Imports are exhibiting 35% decline from 2312 thousand tons in year 2010-11 to 1508 thousand tons in 2015-16. This mainly happened due to increase in domestic production.

Table 14.15 Pakistan fertilizers imports in terms of fertilizer source (000, tons)

Type of fertilizer	2011-12	2012-13	2013-14	2014-15	2015-16
Urea	1647	761	1155	650	253
DAP	595	589	933	1031	1201
SSP	28	-	-	-	17
SOP	22	10	3	6	12
NP	13	1	12	2	5
MOP	7	3	21	34	3
AS	-	1	3	7	15
Total	2312	1365	2127	1729	1506

Source: *NFDC (2016-17)*

Development of domestic production and consumption of N and P fertilizers during the period from 1994 to 2016 are illustrated in Figures 15.1 and 15.2. Nitrogenous fertilizer production is surplus in the country and Government of Pakistan has allowed fertilizer industry to export 600 thousand tons urea fertilizer. While, 58% of the P fertilizers is being imported as 42% DAP fertilizer is produced domestically. Presently, Pakistan is importing 20-25% of its total fertilizers demand and mostly these are P and K fertilizers (DAP, MOP, and SOP). Imports are mainly handled by private sector except urea which is being handled by Trading Corporation of Pakistan (TCP), a public sector organization,

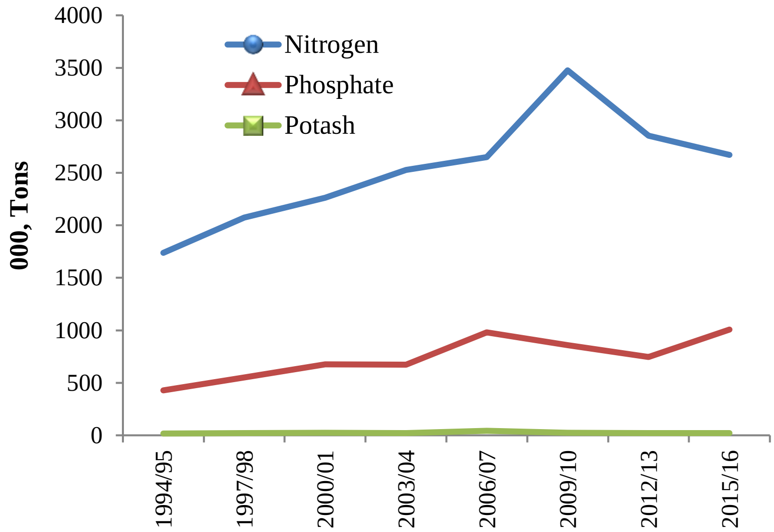

Figure 14.1 Fertilizer nutrient consumption in Pakistan

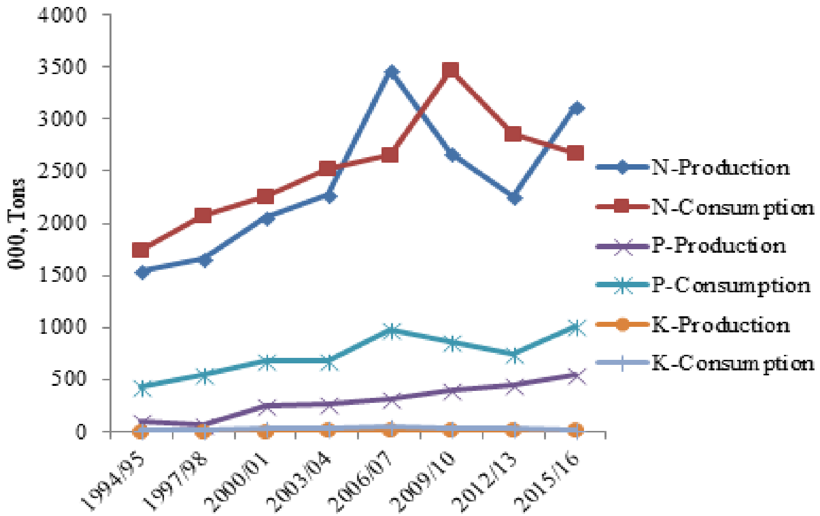

Figure 14.2 NPK domestic production vs consumption

Fertilizer off take product wise

In Pakistan six fertilizers namely urea, DAP, CAN, NP, SSP and various blends of NPKs are manufactured while others fertilizers like ammonium sulphate, SOP and MOP are being imported. During the year 2016-17 Pakistan's agriculture sector has consumed total fertilizers of 10435 thousand tons, out of which 8796 thousand tons were domestically produced fertilizers while 1638 thousand tons were imported fertilizers. Among the different fertilizers, share of urea is 61% followed by DAP, NP and CAN etc. as shown in Figure 15.3. Data of total fertilizers off take, production and imports of Pakistan are given in Table 16 while province wise fertilizer off take is shown in Figure 15.4.

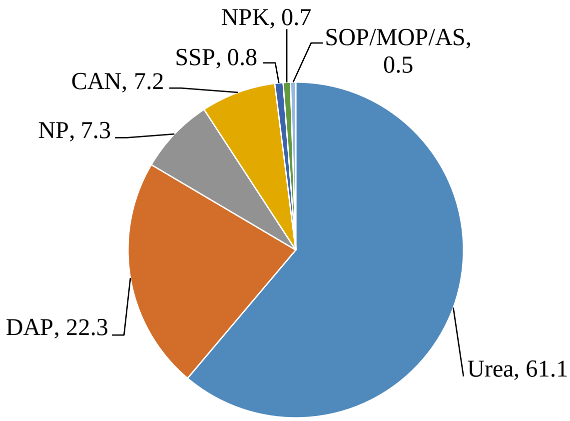

Figure 14.3 Products share (%) in total fertilizers off take

Table 14.16 Total fertilizers off take, production and imports in Pakistan

Years	(000 Nutrient Tons)			
	Total off take	Production	Import	Import to offtake %
1991-92	1883.9	1149.3	632.0	34
1992-93	2147.6	1332.1	759.1	35
1993-94	2146.8	1658.9	903.0	42
1994-95	2183.1	1636.2	261.0	12
1995-96	2514.9	1789.5	581.0	23
1996-97	2412.9	1762.2	878.1	36
1997-98	2646.1	1728.0	713.7	27
1998-99	2583.3	1885.9	884.8	34
1999-00	2833.4	2263.2	662.8	23
2000-01	2963.9	2298.1	579.6	20
2001-02	2928.6	2285.6	625.7	21
2002-03	3019.7	2315.0	766.0	25

2003-04	3222.0	2540.7	764.1	24
2004-05	3694.0	2718.0	784.7	21
2005-06	3804.0	2832.0	1268.3	33
2006-07	3671.6	2746.0	796.0	22
2007-08	3581.0	2822.0	876.3	24
2008-09	3711.0	2907.1	568.0	15
2009-10	4360.0	3082.0	1444.0	33
2010-11	3933.0	3076.0	644.6	16
2011-12	3861.0	2983.0	1177.0	30
2012-13	3621.2	2703.6	734.5	20
2013-14	4089.1	3109.6	1148.4	28
2014-15	4316.5	3271.3	984.3	23
2015-16	3699.3	3674.5	901.2	24

Source: *NFDC (2016-17)*

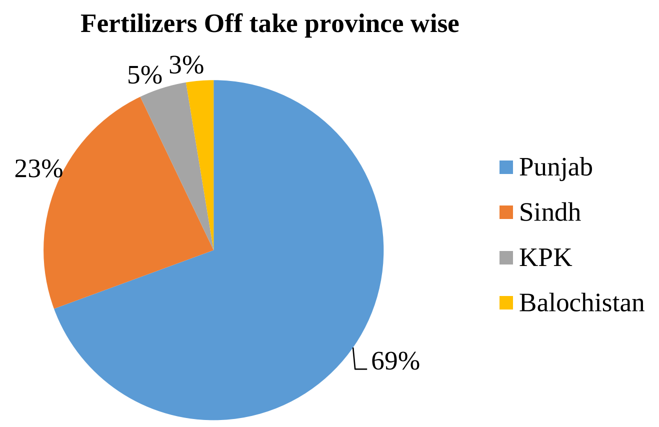

Figure 14.4 Province wise fertilizers off take in Pakistan

Contribution of Fertilizer to Crop Production

Several researches have estimated that about 50% increase in grains production is attributed to fertilizers use during 1970s in developing countries (FAO 1984). In countries with advanced agriculture systems, about 60% increase in yields was due to fertilizers use in last 100 years. In Pakistan, PARC and provincial soil fertility institutes through their various studies established that optimum fertilizer use contributes 30-75% towards final crop yields in different crop production zones. However, majority of studies have established that among different crop production factors about 50% increase in crop yield can be attributed to balanced fertilizer use.

Geographical Distribution and Consumption of Fertilizers

The consumption of fertilizers is mainly determined by size of agricultural land, cropping pattern, seasonality, irrigation water availability and prices of fertilizers. Punjab has the largest agricultural area and therefore consumes the greatest share of fertilizers i.e 69% of total fertilizers, followed by Sindh, KPK, and Balochistan provinces i.e 23%, 5% & 3%, respectively. However, fertilizer use per unit cropped area is variable in different provinces of Pakistan. During 2016-17 average fertilizer use in Sindh was 368 kg ha^{-1} in comparison to 212 kg ha^{-1} in Punjab. Similarly, consumption in KPK and Balochistan is 120 kg ha^{-1} and 124 kg ha^{-1} whereas; at Pakistan level use is 222 kg ha^{-1}. This indicates that great variation exists in fertilizer use within provinces.

Seasonal distribution is split between kharif and rabi seasons. About 40% fertilizers are used in Kharif season while, about 60% are consumed in rabi seasons. Proportion of N fertilizers almost remains the same but of P fertilizer is different as about 70% P fertilizers are used in rabi season while, 30% are used in kharif season. In kharif 2016, quantity of 1926 thousand tons of nutrients were consumed while 2678 thousand tons of nutrients were used in rabi 2016-17. Province wise and total consumption of fertilizers is shown in Tables 14.17 and 14.18.

Table 14.17 Province wise consumptions of fertilizers (000, nutrient tons)

Year	Year/Province	Nitrogen	Phosphate	Potassium	Total
2011-12	Total	3206	633	21	3861
	Punjab	2181	451	16	2649
	Sindh	657	126	3	786
	KPK	222	35	2	259
	Balochistan	146	21	1	167
2012-13	Total	2853	747	21	3621
	Punjab	1988	537	15	2540
	Sindh	523	123	3	649
	KPK	213	51	2	265
	Balochistan	130	36	1	167
2013-14	Total	3185	881	24	4089
	Punjab	2164	623	17	2804
	Sindh	731	187	4	923
	KPK	177	48	1	227
	Balochistan	112	23	1	136
2014-15	Total	3309	975	33	4317
	Punjab	2252	714	23	2989
	Sindh	788	182	6	975

	KPK	168	54	2	224
	Balochistan	101	26	1	128
2015-16	Total	2672	1007	20	3699
	Punjab	1772	718	13	2503
	Sindh	715	227	5	947
	KPK	133	39	1	174
	Balochistan	52	23	1	76
2016-17	Total	3730	1269	41	5040
	Punjab	2537	930	31	3498
	Sindh	924	255	7	1186
	KPK	173	50	2	225
	Balochistan	96	34	1	131

Source: *NFDC (2017-18)*

Table 14.18 Consumption of fertilizers in Pakistan (000, tons)

Domestic consumption (000s) tons	2014-15	2015-16	2016-17
Urea	5937	4558	6372
CAN	487	382	750
DAP	1801	1823	2329
NP	515	605	759
SSP	100	112	83
SOP	6	8	25
MOP	30	8	28
AS	8	10	18
NPK	69	69	70
All Fertilizers	8953	7575	10435

14.2.2.5. Fertilizer grade and cost comparison

Fertilizer grade is the amount of nutrients found in a bag of fertilizer and these are expressed in weight percentages of N, P_2O_5 and K_2O. For example, a grade of "46-0-0" (urea) indicates a fertilizer containing 46% N, while, a grade containing "10-15-18" indicates a fertilizer containing 10% N, 15% P_2O_5 and 18% K_2O (IFA 2013). In Pakistan fertilizer bags have 50 kg weight and percentage of nutrients is printed on the bags. To calculate the amount of nutrients in a bag, divide the nutrient percentage given on bag by 2. For instance urea bag has 46% N, if we divide this by 2, result come to 23, therefore urea bag contains 23 kg of N. Fertilizer recommendations are normally given in nutrients, for application of correct amount of fertilizers, it is important to have good knowledge of fertilizer calculation. Requirement of plant nutrients can be fulfilled from different fertilizer products available in the market. The prices of different fertilizers should be compared on the basis of per unit nutrient rather than on basis of weight of fertilizers. Prices of fertilizers in Pakistan are given in Table 19.

Table 14.19 Prices of fertilizers in Pakistan

Fertilizer	Price Rs./50 kg bag	Per bag Nutrient contents	Per unit nutrient price Rs./kg
Urea	1379	23 kg N	60
CAN	1198	13 kg N	92
DAP	2596	23 kg P_2O_5	89
SSP	886	18 kg P_2O_5	98
NP	1869	20 kg P_2O_5	121
SOP	4100	25 kg K_2O	164

Source: *NFDC (2016-17)*

For multi-nutrient fertilizers like DAP (18-46-0, NPK) and NP (22-20-0, NPK), price of each nutrient is calculated separately and is subtracted from price of fertilizer bag. For example market price of DAP is Rs. 2596/bag, the price of N on the basis of urea is Rs. 540 (9 × 60). By deducting price of N from Rs. 2596, remaining amount would be price of P.

14.2.2.6. Crop production regions of Pakistan and fertilizer recommendations

Basically, the country has been divided into ten agro-ecological zones based on physiography, climate, land use, and availability of water. Fertilizer recommendations for different crops produced in different regions are prepared by provincial research institutes and are released for information to the agriculture extension services for dissemination to the farming communities. Federal institutes (PARC, NFDC) and the fertilizers industries also compile the information of this kind and publish it for the farmers. The NFDC, under an FAO project, developed a methodology for interpreting crop responses to fertilizers, economic analysis and calibration with soil analysis. The general recommendations issued by government departments are given in Table 20.

Table 14.20 Fertilizer recommendations for crops

Crop	CPR	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Wheat irrigated	Punjab I, II, III	75–160	60–110	60
	Sindh I, II, III	130-170	60-90	50
	NWFP II	120–150	60-90	50
	Balochistan III	90-120	60	50
Wheat rainfed	Punjab V	100	75	60
	Punjab IV	60–75	60	-

	NWFP I	60-100	30-60	-
	Balochistan II	60	30	-
Paddy	Punjab II	75–160	67	60
	Sindh II	134-180	67-100	50
	NWFP I	120–150	90	60
	Balochistan III	120	60	50
Cotton	Punjab I	120–170	60	60
	Sindh I	90-140	60	50
Sugar cane	Punjab III	170–270	60-110	60–120
	Sindh III	200-300	100–125	100-170
	NWFP II	120–175	100	100
Pulses	Punjab IV	20–30	60–90	-
	Sindh III	90-120	60	-
	NWFP III	25-50	80	-
Maize	Punjab IV	90–120	60–90	30-60
	NWFP I	60-90	60	-

Source: *FAO Nations (2004)*

14.2.2.7. Chemical fertilizers and environment

Chemical fertilizers are used extensively in modern agriculture, in order to improve crops yield and use of inorganic fertilizers is also inevitable in future due to ever increasing food demand owing to continuously increasing population. However, nutrient leaching from agricultural soils into ground water and surface water causes various environmental and human health concerns. Fertilizer industry is considered to be source of natural radionuclides and heavy metals as a potential source. It also contains heavy metals like Hg, Cd, As, Pb, Cu, Ni, and Cu; natural radionuclide like ^{238}U, ^{232}Th, and ^{210}Po (FAO 2009). However, in recent years, fertilizers consumption increased exponentially throughout the world, causes serious environmental problems.

Fertilizers application may affect the accumulation of heavy metals in soil and plant systems. Plants absorb the fertilizers through the soil and thus heavy metals can enter the food chain. Thus, fertilization leads to water, soil and air pollution (Savci 2012). One popular fertilizer, urea produces ammonia emanation, contributes to acid rain, groundwater contamination and ozone depletion due to release of nitrous oxide by denitrification process. With its increased use and projections of future use, this problem may increase several folds in the coming decades.

But in Pakistan, fertilizer use level is low as compared to many advanced and high yielding agriculture countries. Presently, in Pakistan per ha nutrient use is 163 kg ha^{-1} whereas, in New Zealand, China, Egypt, Netherland, Belgium, Japan, United Kingdom and Germany, nutrient use is 1486, 644, 575, 310, 294, 259, 234 and 199 kg ha^{-1}, respectively (FAO 2015). Present fertilizer use level, the climatic conditions, the soil parameters and the topography in Pakistan do not warrant any environmental hazards from proper fertilizer use which have been faced by other countries. In developed countries, intensive use of fertilizers and pesticides and concentrated livestock production is posing severe environmental pollution. On contrary, developing and underdeveloped countries are facing problems of land degradation due to mining of agricultural land, deforestation and cultivation of unsuitable lands. Potential impact of excessive fertilizers use on environment is given below.

14.2.2.8. Effects of chemical fertilizers on water pollution

Nitrogen emissions from agriculture causes a number of significant and growing environmental problems, including the pollution of drinking water, eutrophication of surface waters (inland and coastal), and acidification of natural landscapes (Ilker et al. 2007). Continuous use of nitrate contaminated water has been linked to gastric problems, goiter, birth malformations, and hypertension etc. Perhaps one of the deadly effects of chemical fertilizers is methemoglobinemia of infant's also known as blue baby syndrome. The risk is most often occurs when infants are given formula reconstituted with nitrate contaminated water. The condition causes a decrease in oxygen in the blood and results in a blue-grey skin color, causes lethargy and or irritability and can lead to coma or death.

According to the conditions, nitrate accumulates and leaches in varying amounts and reaches the depth of soil. In soil, ammonical fertilizers are converted to nitrate through nitrification by microorganisms (Savic 2012). Nitrate leaching is particularly linked to agricultural practices such as fertilizing and cultivation. In irrigated agricultural lands in some of the arid and semiarid regions, nitrogenous fertilizers causes increased amounts of nitrate accumulation in the soil along with the evaporation of water. Problem of nitrate pollution in drinking water is associated with those countries where soils are high in organic matter along with high usage of nitrogenous fertilizers. Nitrogen present in nitrogenous fertilizers, organic matter and crop residues after decomposition converts into nitrates and is subject to leaching into ground water but our country don't have nitrate toxicity level as its level in ground water is well below the standard of 50 mg/l.

Organic matter is very low in soils of Pakistan which is even less than 1% and fertilizer use is also less than their recommended rate. Furthermore, Pakistan is located in arid to semi-arid region having low to medium rainfall. So, under present circumstances problem of nitrate polluted water in Pakistan is not expected even in future too. However, precautionary safety measures and best farm management practices should be adopted at farm level to increase fertilizer use efficiency and farm productivity. Nitrogenous fertilizers should be incorporated in the top of soil or top dressed followed by irrigation to avoid the leaching losses.

In the event of urea top dressing to standing crop, it is usually followed by irrigation. Urea undergoes hydrolysis and oxidation and is finally converted to nitrates. The movement of nitrates along with water is downward for the first few days and then the movement is reversed. There is hardly any chance of nitrates moving to ground water. Thus it is evident that use of urea scarcely causes contamination of our ground water in most of the agricultural soil of Pakistan (Maqsood et al. 2016)

Nutrients contamination through surface runoff also leads to eutrophication of water bodies as N and P nutrients enrichment of lakes and rivers that promotes excessive algae growth and other aquatic plant species. Eutrophication of water bodies may leads to oxygen deficiency in surface water which might starves out fish and other crustaceans. This has bad impact not only on the aquatic ecosystem, but also on local communities who depends on food sourced from those areas. There is no serious problem of eutrophication that has reported in yet country.

14.2.2.9. Effects of chemical fertilizers on soil pollution

Over the time, toxic heavy metals like cadmium (Cd) and arsenic (As) can accumulate in soil by continuous and excessive usage of Cd containing phosphate fertilizers. Concentration of these heavy metals depends upon source of raw material of phosphate fertilizers. The use of P fertilizers is 44 kg ha^{-1} which is still low than recommended dose as compared with other countries like New Zealand, Egypt, China and Japan where average phosphate nutrient use is 983, 133, 156 and 96 kgs ha^{-1}, respectively (FAO 2015).

Possibility of Cd accumulation in our soils is beyond reality even in future due to its low use but regular national research should be done to assess the nutrient contamination in our soils. However, continuous consumption of city sewerage wastes and industrial byproducts should be used after proper analysis to avoid soil contamination with harmful substances.

Generally, in Pakistan, the use of fertilizers is inadequate and imbalanced and this situation is also harmful and leads towards soil quality deterioration and soil degradation. Imbalanced use of fertilizer causes nutrient mining due to inadequate replenishment of removed nutrients and soil organic matter resulting in reduced soil fertility and farm productivity by negatively affecting the soil nutrient balance.

14.2.2.10. Effects of chemical fertilizers on air pollution

Nitrogen is one of the most important fertilizers in agricultural production. When it is applied in inadequate amounts, significant losses occur both in food productivity and quality. In fact, when N fertilizer applied in excessive amount, it causes air pollution by N oxides (NO, N_2O, and NO_2) and elemental N emissions. Nitrogen loss to atmosphere occurs by ammonia volatilization and denitrification. Ammonia volatilization occurs in anaerobic conditions or in flooded rice. Now a day, there are some gases in the atmosphere such as water vapor, carbon dioxide, methane, hydrogen sulfide (H_2S) and chlorofluoro carbon (CFC), which are associated with these compounds. Also there are some gases on lower layers of tropospheric ozone. These gases contribute to the greenhouses effect. Global atmospheric N_2O is increasing at rate of 0.1% each year (Pidwirny and Hanson 2006).

Emissions of ammonia from fertilized lands results in decomposition of ecosystems and vegetation damage. Ammonia may be oxidized and turns into nitric acid, sulfuric acid from industrial sources, and creates acid rain after the chemical transformations (Savci 2012). Acid rain can damage vegetation. Moreover, it could be deleterious for organisms that live in lakes and reservoirs.

Urea is applied to soil at the time of planting when soil moisture level is low and can also use as top dressing after irrigation. When urea is applied to soil at the time of planting, it is mixed well into the soil. Urea is hydrolyzed into ammonium carbonate by enzymatic reactions. The ammonium carbonate undergoes ionization and ammonium ions are adsorbed on to the soil particles. The ammonium ions are then oxidized to nitrates by microbe's actions. The nitrate ions thus formed are either taken up by the plants and microorganisms, or move downward. But due to low moisture and arid environment there is little downward water movement and hence no significant downward movement of nitrate takes place.

Positive Effects of Fertilizers on Environment

Fertilizers when applied in balanced amount results in increases crop production and improve soil health. Adequate plant nutrients and high fertilizer use efficiency develops extensive root system, promotes vigorous plant growth, quicker ground cover, more water use efficiency and high resistance against weather stress and pest attack. More vegetation due to vigorous growth and greater root system not only improves atmospheric oxygen balance but also reduces surface runoff, nutrient leaching and soil erosion losses.

Adequate plant nutrition increases quantity and quality of foods, feeds and fibers. High quality food not only feeds animal and human populations while also improves quality of life. Better supply of N increases protein contents and also supplies vitamins contents. Similarly, P fertilizers improve phosphate minerals, vitamins and strengthen the bones. While K increases carbohydrates contents and different vitamins especially vitamin C. Balanced plant nutrients can also help to correct the nutrient deficiency associated with diseases. Presently, FAO is working in Pakistan on zinc bio-fortification of wheat to correct the Zn associated diseases.

14.2.2.11. Fertilizers and Crop Production

The losses of soil fertility in many developing countries possess an immediate threat to quality and safe food production. Agricultural soils are losing their fertility by continuous plant nutrients exhaustion that is a real and immediate threat to food security and to the livelihood of millions of peoples. The loss of soil fertility reduces yields and affects water holding capacity leading to greater vulnerability to drought, fertile and productive resource for the farmer and the entire ecosystem.

It is essential to encourage the use of NPK fertilizers, so as to achieve the desirable consumption ratio of 4:2:1 to maintain the soil health and to sustain the crop yield and productivity.

An IFA world fertilizer manual has revealed that for producing 5 tons of rice grain/ha, 304 kg nutrients (111 kg N, 35.5 kg P_2O_5 and 148 kg K_2O ha^{-1}) are required. For producing 5 t ha^{-1} of wheat grain, 367.7 kg nutrients (139.6 kg N, 41.2 kg P_2O_5 and 188 kg K_2O) are needed. For producing 8.8 tons of grains yield per ha of wheat and rice in rice-wheat system, 663 kg nutrients (235 kg N, 92 kg P_2O_5 and 336 kg K_2O) are required (Alam 2001). With the use of commercial fertilizers, world populations would probably soon exceed the food supply than with fertilizers and other modern necessities such as improved seed, better insecticides and more effective fungicides, the critical population pressures can be delayed perhaps indefinitely.

Relatively, low cost of fertilizers as compared with the cost of other farm inputs, such as land, wages and farm machinery have also contributed towards increasing fertilizer consumption.

The proper use of fertilizers on soils of low natural fertility makes it possible to grow a wider variety of crops. Widening the selection of crops can results in the use of more vigorous, efficient and valuable cropping systems. The net result of the liberal use of fertilizers is greater efficiency in the utilization of land, labor and water. The main objective of fertilizer use is to improve the efficiency of lands and to increase the crop productivity (Mujeri et al. 2012).

The overall aim is the sustainability and growth in agricultural sector that should meet the growing population for food security and the promotion of economic growth. The average farm size in Pakistan is quite small. Farmers are mostly dependent on fertilizers for their crop production that they have been left with no other choice without the balance use of fertilizer (Fertilizer Sector 2016).

14.2.2.12. Fertilizer Use Economics

According FAO survey, contribution of fertilizers in improving crop production is estimated to be more than 50%. Pakistan is facing challenge of feeding an ever increasing human population with shrinking agricultural lands. For increasing crop production, balanced use of fertilizers is imperative. Approximately, about 30% of the population lives below the poverty line. The average farm size in Pakistan is quite small. Due to low soil fertility and population pressure, balanced and judicious fertilizer use is the only option for increasing the crop production. Farmer's decision regarding fertilizer use is affected by many economic and social constraints like cash flow situation of farmer, expected return on fertilizer investment, expected economic return, support price of crop, timely availability and price competitiveness of fertilizers. Farmer's asses selling price of their crops and relates with cost of fertilizers. High fertilizers prices coupled with low crop prices induces farmers for low fertilizer use. Due to deregulation, withdrawn of partial subsidy, imposition of 17% general sales tax and other taxes regarding international prices, the market of fertilizers was gone high and was affecting nutrient balance negatively. Recently, government of Pakistan has provided relief to the farmers by announcing a "kissan package" and reduced GST rate on fertilizer and other agricultural inputs. Government also engaged fertilizer in this relief package, resultantly prices of urea and DAP fertilizers are reduced by Rs. 400 & 500 per bags. It is anticipated that fertilizer use will improve in future due to affordability and suitability moreover average food quality and production will also increase.

14.2.3. Fertilizer Policy

The government has privatized and deregulated fertilizer imports and prices. In 1986, all subsidies on N fertilizers were abolished followed by P in 1993 and K in 1997. Provincial quotas were abolished, provincial supply organizations in the public sector abandoned and import controls were lifted. All imports are controlled by the private sector. In 2001, the government imposed a 15% GST on all fertilizer products. Government of Pakistan in recent its budgets 2015-16 and 2016-17 has announced historic subsidies and allocated billions of ruppes to reduce the prices of fertilizers by lowering GST to 5% and providing per bag subsidy. Consequently, due to such action, price of urea reduced by Rs. 400 per bag and prices of DAP by Rs. 500 per bag. Presently, there is no government intervention in fertilizer business. However, under 'Fertilizer Acts· promulgated by provinces' fertilizers quality is monitored by the provincial governments.

14.2.4. Future prospects of new technology fertilizers

Currently, fertilizer industry, research institutes, and extension workers are facing great challenge to increase fertilizer use and improve fertilizer use efficiency (FUE). One approach of increasing FUE is the properly usage of available fertilizer and other is to develop efficient fertilizers. It has been argued that along with conventional fertilizers, special or enhanced efficiency of fertilizers should also be developed to improve the FUE and to maximize the agriculture production. These fertilizers can be termed as foliar fertilizers, slow and controlled release fertilizers and nitrification or urease inhibitors. Application of foliar fertilizer is already underway in Pakistan to vegetables and orchards, but backing of proper research, technical knowledge is missing and quality of the products is also under question. Pakistan fertilizer industry is already working on development of neem's coated and microbial coated fertilizers to enhance the FUE by controlling the release of nutrients. Development of controlled or slow release fertilizers is important as it will not only improve the efficiency of fertilizers but will also conserve the environment by minimizing their losses. The main obstacle for acceptance of these next generation fertilizers among the farming community is their high cost of production. However, if researchers succeed in production of slow or controlled release fertilizers at economical cost, there is a huge potential ahead. Fertilizer industry should invest in this new research to meet future challenges.

14.2.5. Future vision

Pakistan comes under arid and semi-arid climatic region where soils are usually poor in OM content, droughts prevail most part of the year and salinity is another additional problem. Pakistan is also at a risk of high population rate that is expected to keep on increasing in future as well. All these factors along with shortage of cultivable lands are imposing serious threats to the condition of food security of the country. Application of chemical fertilizers for optimization of soil nutrients contents and to improve yields has become imperative. Pakistan has been importing tons of chemical fertilizers and spending billions of rupees on fertilizers imports. But fertilizer sector of the country is also developing and enhancing its fertilizers producing capacities. Recently, some export of urea fertilizer to other countries is also reported. Our soil topography is also in favor of chemical fertilizers applications as no severe cases of pollution are feared and reported. Despite of all, there is lack of balanced application of NPK fertilizers. Therefore, attention is needed in this regard soon. All over the world, organic farming is trending to avoid environmental and health risks associated with the applications of chemical fertilizers. However, in developing countries such leisure is not affordable due to comparatively low yields of organic applications. In Pakistan, integrated plant nutrient management is the most suitable approach that envisages the use of both chemical and organic fertilizers to increase the crop yields while conserving soil fertility and environment. There shall be 30 to 50% increase in average yield. In addition to this, development of efficient is also necessary to meet the future challenges. There is a need to formulate and execute national level program to provide the linkage, coordination, sharing of information among agricultural education, research, extension, fertilizer industry and other private sector engaged in agri-business for addressing the crucial issues of Pakistan's agriculture and benefit of the farming community and agricultural development. However, to bring sustainable growth in crop sector, promotion of balanced fertilizer use, farmer's easy access to quality fertilizers and seeds, awareness to safe and selective pesticides and technological support are the need of the time.

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Chapter 15

Pesticide Use in Pakistan

Ahmad Nawaz♦

Abstract

Pesticides have improved our way of life for several decades. They are essential for today's system of sustainable and productive agriculture. In the beginning of late 1930s from the discovery of the DDT (dichlorodiphenyl trichloroethane) to the present day pyrethroids and new chemistry pesticides, tremendous activity has occurred related to the development of synthetic and biological based pesticides. Now, the total worth of global pesticide market is about more than $45 billion. In Pakistan, the history of synthetic pesticides for plant protection started in 1947 with only 508 hand sprayers and 16 vehicles available for use. Currently, there have been 389 pesticides (single) chemical and 1392 (mixture) registered in Pakistan which are developed by more than 400 pesticide companies. The total business worth of pesticide market is about Rs. 32.75 billion with total import of 43590 metric tons of formulated products. In addition to crop, stored products protection, public health and urban pest control, the pesticides can also impose serious threat to environment and cause health hazards effects to non-target organisms including man and animals. Moreover, many insect pests of agricultural importance have gained resistance against a number of old and fewer new chemistry insecticides available in the market. In Pakistan, pesticides are contaminating the water, soil, food products, animals as well as humans by causing direct or indirect (residues) toxicity. It is unlikely that there will be pesticides-free agriculture over the next several decades but promoting integrated pest management (IPM) would be one way to reduce reliance on chemical insecticides. IPM encourages greater dependence on biological approaches, use of biotechnology and judicious use of chemical insecticides. Most importantly, the government should commit themselves to promote IMP and launch the substantial

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educational efforts to persuade millions of producers to modify their approaches to manage pests.

15.1. Introduction

Any substance or mixture of different substances intended to protect crops by preventing, destroying, repelling or mitigating a pest in known as a pesticide. The term pesticide has been around for centuries and its use in agriculture has increased crop yield and quality, lessened the workload of pest management and improved sustainable food production for food security. The cost-efficient food production is necessary due to inevitability of a growing world population. The productivity and efficiency in agriculture will depend on the development and the use of improved practices, such as resistant varieties (insects and diseases), precision agriculture, application of proper kinds and amounts of fertilizers, efficient use of water, and labor-saving machinery and equipment. But these developments will not be effective until integrated with crop protection chemicals because the amount of crop yield lost yearly to pests and diseases can run upwards of 30% (CAST 2014).

Pesticides can be divided into different categories depending upon their chemical nature (Figure 16.1). In addition, they may also be divided into two main types i.e., (i) contact or non-systemic pesticides and (ii) systemic pesticides. The non-systemic pesticides (contact) or surface coating pesticides do not appreciably penetrate plant tissues and not transported, or translocated, within the plant vascular system. The disadvantages of such type of pesticides were that they are susceptible to the effects of the weather and new plant growth was not protected and hence open to attack by insect and fungal pathogens. In contrast, the systemic pesticides penetrate the plant cuticle and move through the plant vascular system. The advantages include the protection of plants from attack as well as inhibit or cure established infections/infestation of pests and pathogens; they are not affected by weather effects. Furthermore, the pesticides can also be categorized on the basis of their target organisms, mode of entry and mode of action (Table 16.1).

Pesticides are designed to kill or otherwise adversely affect living organisms. Pesticides are inherently toxic and most of them create risk of harm to humans, animals, beneficial insects, such as bees or the environment. Many people, when considering chemicals including pesticides, fail to distinguish between the toxicity and hazard. Toxicity on the one hand, refers to the ability of a chemical to cause poisoning when administered in adequate quantity through specified routes. Hazard on the other hand, means the probability that a substance will cause harm in the circumstances of usage. Two distinct types of toxic effects (acute and chronic) can be observed from many poisons. But at the same time, pesticides are important and useful to society because they can preserve crops by killing potential disease-causing organisms and control insects, rodents, weeds, and other pests (EPA 2014).

15.2. Pesticide Use

15.2.1. Global History of Pesticide use

Pesticides have been used in different forms (sulfur, copper, organic mercury, soap, herbs and oils) to control insects and diseases as early as 2500-1500 BC by Sumerians and Chinese (Schumann 1991). Similarly, Pliny in 79 A.D. advocated the use of arsenic as an insecticide and by 900 A.D., the Chinese were using arsenic and other inorganic chemicals in their gardens to kill insect pests. By 1101 Chinese had also discovered the use of soap to control pests and the naturally occurring pesticide Nicotine was extracted from tobacco leaves in the 17^{th} century and used against the *Plum curculio* (true weevil) and the lace bug. In 1705, Hamberg suggested mercuric chloride as a wood preservative and approximately one hundred years later Prevost described the use of copper sulfate for the inhibition of smut spores (Waxman 1998).

In 1850, two important pesticides such as rotenone and pyrethrum were developed from the roots of derris plants and from the flower heads of chrysanthemum species respectively which are still widely used against different pests. During the same time new inorganic materials were introduced for controlling insect pests of different crops. For example, investigations lead to the introduction of an impure copper arsenite (Paris green) in 1867 for controling Colorado beetle in USA. Similarly, lead arsenate was used for control of gypsy moth in 1892. The control of potato blight and vine mildew was accidently discovered by Millardet in 1882 when they treated roadside vines with a mixture of copper sulfate and lime in order to discourage pilfering of the crop. Further experimentation established effectiveness of copper sulfate, lime, and water mixture against vine mildew and the mixture named as Bordeaux mixture, a mixture of copper sulphate ($CuSO_4$) and slaked lime ($Ca(OH)_2$) used as a fungicide.

The formaldehyde was introduced for the first time in 1897 for fumigation and copper arsenite was replaced by calcium arsenate in 1912 which soon became important for controlling the cotton boll weevil in USA. The organomercurials used for the first time for seed dressings against cereal smut and bunt diseases in 1913. The health hazard problems of arsenical insecticides in fruits and vegetables stimulated the search for less toxic pesticides which led to the introduction of organic compounds (tar, petroleum oils and dinitro-o-cresol). The modern era of synthetic pesticides really starts in 1930s and important examples include alkyl thiocyanate insecticides and the first organic fungicides (dithiocarbamate fungicides). A Swiss chemist, Paul Hermann Müller (12 January, 1899 - 13 October, 1965) discovered the powerful insecticidal properties of dichlorodiphenyltrichloroethane (DDT) in 1939 which became the most widely used single insecticide in the world around 1943. Müller was awarded noble prize in 1948 for his discovery of the high efficiency of DDT as a contact poison against arthropod pests. Many chlorinated hydrocarbon insecticides were developed in 1940s such as aldrin, dieldrin, heptochlor and endrin. During World War II, organophosphate insecticides were developed as chemical warfare agents. But unfortunately, organochlorine and organophosphate pesticides were highly poisonous to non-target organisms which force the development of more selective and less poisonous pesticides.

In the beginning of late 1930s from the discovery of the DDT to the present day pyrethroids and new chemistry insecticides, tremendous activity has occurred related to the development of synthetic and biological based pesticides (Lamberth et al. 2013). Similar development in many other potent, selective and safe pesticides had shown not only increased production and consumption but awareness and sense of judgment about hazards and risks as well. Currently, there is no alternate control measure to combat insect pests except chemical insecticides, and pesticides are the first and foremost choice of the applied biologist unless and until more acceptable techniques can be developed. In 1962, Rachel Carson an American marine biologist wrote a book “Silent Spring” and highlighted the risks associated with the use of toxic compounds for crop production. The Silent Spring and other books served to illustrated negative effects of pesticides on non-target organisms and illuminated that great efforts must be taken to prevent the misuse of pesticides and other toxic chemicals. In recent decades, man has made great advances in the genetic manipulation of genes. It is now possible to create in the laboratory seeds and thus crops which possess the genetic ability to kill or inhibit economically important insect pests and diseases.

15.2.2. Global Market of Pesticides

The conventional pesticide sales at user level estimates revealed that the world market of pesticide was ~ \$25,280 million in 1993 in which the herbicide share was 46% followed by insecticides (31%), fungicides (16%) and other miscellaneous pesticides (6%). The volume of active ingredient (AI) used was about 4500 million lbs. The United States market of pesticides was the largest market by sharing 34% of total world market of worth ~ \$8,484 million and 24% of total AI (Waxman, 1998). In 2001, worldwide expenditures totaled > \$32 billion on pesticides. Similarly, the statistics of 2006 and 2007 showed that approximately 5.2 billion pounds of pesticides were used worldwide and the total worth of pesticide was > \$35.8 billion in 2006 and > \$39.4 billion in 2007. The observation again showed that herbicides accounted for the largest portion of total use, followed by other pesticides, insecticides and fungicides. The U.S. pesticide market accounted for 22% of total world pesticide amount used and sales amounted to approximately \$12.5 billion which represents almost 1/3rd of the world’s overall expenditures on pesticides. The herbicides such as glyphosate, atrazine, metolachlor-S, acetochlor, 2,4-D and pendimethalin, and the fumigants metam-sodium, dichloropropene, methyl bromide, and chloropicrin were among the top 10 pesticides used in agriculture in terms of pounds applied (EPA 2014).

15.2.3. Pesticide history and market in Pakistan

In Pakistan, the history of synthetic pesticides for plant protection started in 1947. At that time, only 508 hand sprayers and 16 vehicles were available for use. In 1951, the locust problem became severe and chemical pesticides were used for the first time to combat locust attacks. The aircrafts for aerial sprays were obtained and utilized for spraying to control locust attack. Later on, aircrafts were used to combat sugarcane pyrilia, the *Pyrilla perpusilla* infestations on sugarcane in KPK (Khyber Pakhtunkhwa). After initial success, the pesticide use was extended to cotton, rice and orchards in the whole country.

The era of pesticides in Pakistan can be divided into six distinct periods depending upon the mode of distribution, pricing and time period i.e., (i) 1947-1965: the pesticides were used free of cost by the government, (ii) 1966-1974: government provided the pesticides from a flate rate of Rs. 0.25/ltr to 75% subsidized price, (iii) 1975-1979: 25% pesticide distribution was through public sector while 75% through private sector and government announced 50% subsidy on ECs/WPs and 75% subsidy on granules, (iv) 1980-1985: complete withdrawal of pesticide subsidy in Punjab, Sindh and KPK except in Baluchistan, Federally Administered Tribal Areas (FATA) and Azad Kashmir (AK), (v) 1986-1991: complete withdrawal of subsidy in all provinces except Baluchistan and 100% distribution through private sector, and (vi) 1992-1993: duty and surcharge exempted on imports of weedicides and only duty exemption on pesticides (Jabbar and Mallick 1994). In 1954, the pesticide business started with the import of 254 metric tons of formulated products and increased to a maximum of 20,648 metric tons in 1986-87. Until 1980, the government controlled the import, and subsidized the distribution of pesticides (Jabbar and Mallick 1994). The active ingredient consumption of pesticides increased at a rate of 25% per annum from 906 metric tons in 1980 to 5519 metric tons in 1992. In 1991, sprayed area has increased from 1.8 million hectare to about 3.8 million hectare (18% of total cropped area). During 1980 to 2000, there had been a substantial increase in the use of pesticides in terms of value and volume. In 2002, it was reported that pesticide use increased by ~ 70 times while cotton yield increased only two-folds. The 80% of pesticides were used on the cotton crop. The pesticide value exceeded Rs. 12-14 billions, which added to the cost of production. The share of pesticide market on provincial basis was 90% for the Punjab, 8% for Sindh and 2% for KPK and Balochistan (Khooharo et al. 2008).

In 1991-92, herbicide used in USA was 85% of the total pesticides used (USDA 1987). On the other hand in Pakistan insecticides share was 85% of the total pesticides used, and almost 65% of insecticides were practiced against cotton insect pests (Jabbar and Mallick 1994). Most pesticides used in Pakistan were insecticides (74%), followed by herbicides (14%), fungicides (9%), acaricides (2%), and fumigants (1%) (Khan 1998). The synthetic pyrethroids were introduced in Pakistan in 1980 and within five years (1980-1985), more than a dozen brands of pyrethroids were made available to farmers. The estimates showed that more than 70% of the total pesticides market was of synthetic pyrethroids (Malik 1986) and constituted about 45% in terms of value, followed by phoshphatic group (39%), chlorinated hydrocarbon (9%) and carbonate pesticide (4%) during 1984 (Memon 1986).

Free aerial spraying was previously provided to control pest attacks on major crops. The Plant protection department had now a fleet of 22 aircraft which sprayed about 351,000 hectares of cropped area in the year 1995-96. Currently, the department has a fleet of 20 aircrafts and most of them require maintenance (DPP 2015). According to the Prime Minister’s task force on agriculture, mostly insecticides are used on cotton crop, which means 6.62 million acres under cotton crop are the target of pesticide use. Influenced by international campaigns, 26 pesticides have been de-registered (DPP 2015) and the import of either technical grade material or formulations are banned in the country: including four of the "dirty dozen" pesticides.

The sale of pesticides in 1995 was of worth Rs. 9 billion (US$ 222 million). This does not include the relatively large quantities of pesticides smuggled from across the border. About 145 pesticide formulations have been registered. The pyrethroids have the greatest share, with 45% of the market by value, followed by organophosphates with 39%, chlorinated hydrocarbons 9% and carbamates 4%. According to the Agriculture Census, in 1980, 4% of total farms used chemical plant protection measures, but this rose to around 25% in the 1990s, that is 1.28 million farms or up to 16% of total cropped area.

Currently, there have been ~1392 registered pesticides in Pakistan. The total business of worth of pesticide market is Rs. 32.75 billion with total import of 43590 metric tons of formulated products. The insecticides are of about 52% of total pesticides imported in Pakistan with a business of worth about Rs. 17.03 billion. The weedicides business is now increasing in Pakistan with a share of about 31% (Rs. 10.15 billion) and fungicides share is about 16% (Rs. 5.24 billion) while the others are sharing 1% of total pesticides with a worth of about Rs. 0.33 billion. The 46% (Rs. 7.83 billion) of total insecticides are being used to control the sucking insect pests. The rest of pesticides are mostly used to control the bollworms and other insects (DPP 2015).

15.3. Types of Pesticide Formulations

A mixture of active and inert ingredients is called pesticide formulation which effectively controls a pest. The components of pesticide formulation having pesticidal activity are called active ingredient (AI) and are rarely used in pure form to control the pests. Therefore, they are mixed with inert (inactive) ingredients to make them safer, more effective, easier to measure, mix and apply them more easily and efficiently. The final pesticide formulation is used either as packaged or diluted with solvents (e.g., water, a petroleum-based solvent) or other carriers (e.g., silica or silicates). Pesticide then formulated into different usable forms for effective storage, efficient application, safety for applicator and environment and economical and easy application with available equipment. But these goals are not always easy to achieve due to chemical and physical characteristics of the technical grade pesticide. Because some materials in their raw or technical condition are not stable to air and sunlight, some are liquids, other solids, some are volatile, other not, some are soluble in water or oil while other may be insoluble. Therefore, different types of pesticide formulation are available in the market because of two main reasons i.e., (i) the chemistry of AI and (ii) various formulations offer different advantages. Pesticides are mostly used as liquids than solids; even some dry formulations (wettable powders) are diluted or suspended in liquids before being applied.

Adjuvants (additives) are chemicals added to a pesticide to increase its effectiveness or to reduce its phytotoxicity or drift. Several different types of adjuvants are wetting agents and emulsifiers, spreaders, stickers, penetrants, dispersing agents, foaming aids and suppressants etc. Most of the formulations as manufactured often contain all necessary adjuvants in appropriate amounts but sometimes, however, the applicator add specific adjuvants prior to application of the pesticides.

15.3.1. Emulsifiable Concentrates (EC or E)

These are most commonly used formulations in which the AIs are insoluble in water. So, they are dissolved in petroleum-based solvent having emulsifiers which have properties similar to detergents and soaps, and allow the pesticide to be mixed with water effectively. When dissolved in water, ECs form “milky” suspensions called emulsions and only slight agitation is required to maintain suspension. The AI in ECs is given as a percentage or as pounds per gallon. Each gallon of EC usually contains 25 to 75% or 2 to 8 pounds per gallon active ingredient. ECs leave little visible residues on plants but some time damage may occur due to the sensitivity of plants to the solvents and additives. These types of formulations are especially suitable for low-pressure, low-volume sprayers and for mist blowers. They can also be used with dilute hydraulic sprayers, low-volume aerial sprayers and low-volume ground sprayers. The solvents used may cause rubber hoses, gaskets and pump parts to deteriorate rapidly unless they are made of some resistant materials like neoprene rubber.

15.3.2. Wettable Powder (WP or P)

In this formulation, the AIs are combined with dry diluents (inert carrier) such as clay, talc or silica and with wetting agents (surfactants) and/or dispersing agents. These are finely divided and relatively insoluble powders. The formulated product usually contains 25% AI or even more (15 to 95%) depending upon the condition. In the spray tank, a constant and vigorous agitation is needed to maintain the suspension because WPs form a suspension rather than a true solution when added to water. The formulated products are easy to store, transport and handle. The concentrated dust may be inhaled by the applicators during mixing which can cause hazardous effects but WPs usually not absorb through skin as readily as ECs. In contrast to ECs, there is very little chance of WPs to burn foliage, even at high concentrations. But, they are abrasive and may cause both pumps and nozzles to wear more quickly.

15.3.3. Water-Soluble Powders or Soluble Powders (WSP or SP)

These formulations are not commonly found due to the insolubility of many solid AIs in water. The technical grade material is a finely ground, water-soluble solid which may contain a small amount of wetting agent to assist its solution in water. These formulations do not require constant agitation as required by wettable powders and flowables because WSP form true solutions and no precipitation. Due to their dusty quality, they may be packaged in convenient, water-soluble bags which are simply dropped into the spray tank and little agitation is required to make the final suspension. They are also nonabrasive to application equipment but can present an inhalation hazard to applicators during mixing. The amount of AI in soluble powders ranges from 15 to 95%.

15.3.4. Water-Soluble Bags/ Water-Soluble Packs (WSB/WSP)

Some formulations of wettable or soluble powders are sold in water soluble bags or water soluble packs in such a way that the inner bag is placed directly in the spray tank and subsequently dissolve. The main advantage of such formulations is the elimination of measuring and minimizes the risk of exposure to applicators during mixing. These bags have unique physical property and biodegradability. Therefore, they are used more frequently in the packaging of fertilizers and pesticides in recent decade.

15.3.5. Water-Soluble Concentrates, Liquids or Solutions (S, WS, WSC or WSL)

The AIs in water-soluble liquids or concentrates are soluble in water. Therefore, it is formulated either with water or with a solvent which mixes readily with water such as alcohol. WSCs or WSLs form a true solution and require no further agitation when added and mixed to water in spray tank. Water-soluble concentrates are often liquid, salt or amine solutions.

15.3.6. Oil Solutions (OS)

The oil solutions formulation may be highly concentrated because the AIs are formulated either with oil or with some other organic solvent. It may be sold in a dilute form ready for application or further dilute before application. The oil solutions are the ready-to-use household and garden insecticide sprays. They are sold in a variety of bottles, cans and plastic containers, and intended to be used directly on pests. The oil solutions may be used as roadside weed sprays, for standing pools or fogging machines to control mosquito larva and household insect pests. They are sold as oil concentrates of the pesticide to be diluted with kerosene or diesel oil before application. The compound is dissolved in oil and is applied as an oil spray. In addition, it contains no emulsifier or wetting agent. The oil solution may cause damage to vegetation and also may cause significant deterioration of rubber sprayer components of the spraying equipment.

15.3.7. Flowables or Sprayable Suspensions (F, FL)

Those AIs are formulated as flowables which are not soluble in either water or the more commonly available organic solvents and sometimes called water-dispersible suspensions. The AI is impregnated on a diluent such as clay then milled to an extremely fine powder and suspended in a small amount of liquid. The resulting formulation becomes thick and appears like a paste or cream and can be measured by volume like WPs. Flowables are mixed with water for application and combined the benefits of both WPs and ECs. They require moderate agitation in spray tank and are becoming increasingly popular. They are used in the same types of pest control operations as ECs but there are fewer phytotoxicity problems with flowables than with ECs.

15.3.8. Water-dispersible granules or Dry Flowables (WDG or DF)

Water-dispersible granules are finely divided powders that are formulated into concentrated, dustless granules and resemble with wettable powder formulations. To maintain a uniform spray mixture, DFs form a suspension in water and require little agitation as well. Once in water, the granules break apart into fine powder. These formulations contain a high percentage (75 to 90%) of AIs. Although, DFs are sold in dry form but they are not like dust and can be handled easily but they are not meant to be applied directly until granules designed for application in the dry form.

15.3.9. Ultralow-Volume Concentrates (ULV)

The formulation may contain only the AI or the AI in a small amount of solvent and can be defined as a spray application of undiluted formulation at a rate less than or equal to 1/2 of a gallon per acre. These formulations often require specialized application equipment and a large area can be sprayed with a small volume of liquid. Although, evidence is not conclusive but there is some concern about significant drift with ultralow volume sprays than with dilute solutions. These formulations are applied now on few sites and prohibited unless it is specifically designated on the label or is based on an official written or published recommendation.

15.3.10. Encapsulated or Microencapsulated Formulations

In this type of formulations, small and permeable polymer or plastic (15 to 50 μm in diameter) spheres are used and the AI (liquid or dry) is incorporated in them through a special process. The spheres are then mixed with wetting agents, thickeners and water to give desired concentration of pesticide in a flowable form. These formulations usually contain 2 pounds per gallon of AI. The pesticide spray mixture can be applied with conventional sprayers after preparing the required dilution. They are effective for longer period of time than other formulations containing the same AI. In contrast, they may pose serious threat to honey bees which may take capsules with pollen back to their hives.

15.3.11. Dusts (D)

Dusts are finely ground, dry mixture consisting of a low concentration of AI (1 to 10% by weight), combined with an inert carrier (talc, chalk, clay, nut hulls or volcanic ash). Dusts are formulated for application in the dry form and are simplest formulations of pesticides to manufacture, ready to use and easy to apply. Dust particles may drift long distances from target site even when wind velocities are low and due to drift potential, herbicides are not formulated as dusts. Dusts leave a visible residue on plants and applicator may also be exposed to dust through inhalation. Despite the fact that dusts are easy to handle and apply, they are least effective and ultimately the least economical pesticide formulations due to poor rate of deposit on foliage unless it wets from dew or rain. Most parts of dust formulations drift (upward and downward), and only 10 to 40% of the material reaches the target site.

15.3.12. Granules (G)

Granular formulations are similar to dust formulations except the inert particles are much larger and because of the size of granular particles, this formulation is much safer. Granules are normally made by applying a liquid formulation of AI (ranging from 2 to 40% by weight) to particles of absorptive material such as clay, corn cobs or walnut shells. The AI is either coated outside of the granules or is absorbed into them and then released gradually from the inert material. They are generally less susceptible to degradation and leaching than other soil-applied formulations of pesticides. In addition, they drift less but pose little inhalation hazards but often difficult to accurately calibrate granular spreader for uniform distribution in the target field. The granular formulations used for soil treatment either directly or applied over plants and used to control soil pests (weeds, nematodes and insects) living at or below ground level. Granule formulations are mostly used for insecticides or herbicides with AI range from 2 to 25% and are used almost exclusively in agriculture. These formulations can be applied at any time of day without the risk of drift in winds up to 20 mph. They can also be applied at planting time to protect roots from pests (cutworms) or to introduce a systemic effect for above-ground parts of plants. The disadvantage with granules is that proper coverage of plants may be a problem with this formulation.

15.3.13. Poisonous Baits (PB)

Poisonous baits can be defined as a pesticide mixed with an edible material (attractive to a particular pest) and pests are killed by consuming poison in a single feeding or over a period of time. Baits do not to be applied to whole area and are mostly used to control rodents and fruit flies. They must be placed where it is likely to be consumed. The percentage of AI in bait formulations is quite low (<5%) and only small amounts of pesticide are used to treat relatively large area. However, baits may be attractive to non-target organisms so extra precautionary measure should be taken to prevent non-target organisms or use baits which are adequately selective for the target pests.

15.3.14. Fumigants

Fumigants are a rather loosely defined group of formulation and can be defined as a substance or mixture of substances which produce gas, vapors, fumes or smoke intended to destroy different pests (insects, bacteria or rodents) particularly insect pests of stored commodities in storage and quarantine treatments in sealed containers. They may be volatile liquids, solids or gases and used to disinfest the interiors of buildings, objects and many type of materials. The materials should be enclosed so as to retain the fumigant. Fumigants are also used for soil treatment in horticultural nurseries, greenhouses and on high-value crops to control nematodes, insects (larvae and adults), diseases and weeds. The treated soil may require covering with plastic sheets for several days to retain the volatile chemical, allowing it to exert its maximum effect on the target pests.

15.4. Regulatory Mechanism of Pesticides in Pakistan

The Department of Plant Protection with its head office at Karachi is responsible for registration and other regulatory aspects of pesticides. The regulation of import, manufacturing, formulation, refilling/repacking, sale, use and advertisement of pesticides are controlled under the Agricultural Pesticides Ordinance, 1971, through the Agricultural Pesticides Rules, 1973 (Annex III). In addition, Pakistan is also signatory of different international conventions such as, Rotterdam Convention (1992), Stockholm Convention (2001) and Basel Convention (1994) for the regulation of POPs (Persistent Organic Pollutant), Hazardous waste and other Hazardous chemicals. Generally once a pesticide is registered, its registration is renewed periodically. Currently, almost 26 pesticides have been de-registered and their import is banned in Pakistan (Table 16.2).

The provision of Pesticide Ordinance included appointment of inspectors and procedure for taking samples for quality analysis but it was unsatisfactory due to different constraints (Jabbar and Mallick 1994). There are three types of pesticide registration practices performed by using form-1 (registration under trade name), form-16 (Registration of pesticide not having a trade name) and form-17 (import permission of pesticides registered in the manufacturing country). There are almost 5 per-shipment inspection agencies which inspect the pesticides before shipping to Pakistan which are, (i) M/s. Baltic Control Pakistan, (ii) M/s. NMCI Pakistan (Pvt.) Limited, (iii) M/s. Inspectorates Corporation International (Pvt.) Limited, (iv) M/s. Control Union Pakistan (Pvt.) Limited and (v) M/s. Inspectorates Pakistan (Pvt.) Limited (DPP 2015).

The main focus of pesticide business in Pakistan is by import and the local manufacturing is only a small proportion of total pesticides. The members of APTAC (Agricultural Pesticide Technical Advisory Committee) advise the government on technical matters. There is not a single independent institute capable of conducting pesticide research. However, the overall situation regarding over-use and strict enforcement of regulations seems bleak. Policy concerns focus on “quality standards” rather than pesticide use. Recent legislation reflects a concern with adulterated pesticides, rather than with the quantities of pesticides used. List of pesticides importer companies registered in Pakistan is given in table 16.3 (DPP 2015).

15.5. Pesticide Problems

Among all the chemical substances, pesticides are ubiquitous in nature and have particular importance. These are unique chemical stressors, designed to have biological activity and intentionally placed in large quantities in the environment. Most of pesticides are used in our homes and gardens or we buy goods that have been sprayed during production. Pesticides may be washed off surfaces around homes during rain; these pesticides enter drains and ultimately discharge into rivers. Thus each food product may contain several residues of pesticides. Then daily ingested meals may contain a large number of pesticides. Their widespread introduction into the environment, often without adequate safeguards, creates problems such as (i) Human poisonings and health risks, (ii) Environmental hazards, (iii) Loss of biodiversity, (iv) Wildlife deaths, (v) Animal and livestock deaths, (vi) Interference with natural pest control, (vii) Resistance among pests, (viii) Unwanted imports, (ix) Obsolete and unusable stocks, (x) Residues in food, (xi) Water pollution and (xii) High input costs etc.

It is estimated that only 0.1% of pesticides applied reach the target organisms while the remaining 99.9% disperse in the environment through air, soil and water. Thus, pesticides are causing pollution in natural ecosystems, affecting human health and other biota. Pesticides are also introduced to the environment during manufacturing, handling and transportation in developing countries like Pakistan (Pimentel 1995; Zia et al. 2008). This happens mainly due to lack of awareness of the harmful effects of pesticides. As a result, pesticide residues contribute to pollution and can cause serious environmental and human health problems as they are also reported to be carcinogenic to humans (George and Shukla 2011). About 12.7 million cancer cases and 7.6 million deaths have been reported in 2008, accounting for 56% of the cases and 64% of the deaths in the economically developing world. It is also predicted that there will be 16 million new cases every year by 2020. Deaths from cancer worldwide are projected to continue rising, with an estimated 13.1 million deaths expected in 2030 (Ferlay et al. 2010; Jemal et al. 2011). Many pesticides are highly toxic to aquatic life, they can have devastating effects on rivers if used carelessly or not disposed off properly. Pesticide pollution can be driven by rainfall, with contamination of rivers and groundwater occurring from water draining off land or infiltrating to the water table. Safe water supplies are vital for life and good health (Damalas and Eleftherohorinos 2011). In addition, it is clear that at the same time humans are exposed to a number of different chemicals via food, air and water. Among these chemicals, pesticides are very important because they are widely used against animals, insects & plants and are released into the environment. Exposure to pesticide mixtures may cause unexpected adverse effects like synergistic, antagonistic or additive.

Pesticides are also contaminating our surface and groundwater (Lamers et al. 2011). Groundwater quality is important as groundwater supplies nearly a one third of our drinking water. Groundwater also supplies the base-flow to rivers and lakes and sustains many wetlands. It is of vital importance that the quality of this resource is protected. The increased use of pesticides is one aspect of a general intensification of agriculture over the past fifty years. For example, partly as a consequence of the increased use of pesticides, the number of farmland birds has declined. Evidence suggests that certain pesticides that find their way into water can interfere with endocrine (hormone) systems which affect fertility and reproduction in fish and leading to developmental changes. Similarly, persistence of pesticides in soils is another major concern and different studies showed the presence of pesticides in soil but most of the time pesticide residues in the soil and environment have always lagged behind due to financial constraints and the lack of proper facilities.

Since 1962, when Rachel Carson's Silent Spring first revealed the hazards of DDT, scientists have exposed more and more information about the health hazard effects of pesticides posed to humans and animals. Fresh water comprises 3% of the total water on earth (Azizullah et al. 2011). There are almost 6634 registered industries in Pakistan and around 1228 are considered to be highly polluting which includes textile, pharmaceuticals, ceramics, petrochemicals, food industries, steel, oil mills, sugar industries, fertilizer factories and leather tanning (Sial et al. 2006; WWF 2007). Pakistan Council of Research in Water Resources (PCRWR) conducted a detailed study which reveals that an average of 84 to 89% of water sources throughout the country have a water quality below recommended standards for human consumption (PCRWR 2008). The contamination of drinking water in Pakistan is linked with industrial wastes and municipal sewage due to lack of water disinfection practices and quality monitoring at treatment plants. Therefore, the contaminated water is the main source for waterborne diseases and 20 to 40% of patients in hospitals of Pakistan are suffering from water-linked diseases like hepatitis, cholera, dysentery, cryptosporidiosis, giardiasis and typhoid. These diseases account for one third of all deaths in the country (WB-SCEA 2006). Diarrhea is also a water-linked disease. In Pakistan, it accounts for 14% of illnesses in children (0-5 years) and for 7% of all diseases in people of all ages (Azizullah et al. 2011). An estimated number of 0.2 to 0.25 million children in Pakistan die every year due to diarrhea and other water related diseases (WWF 2007).

In spite of the fact that pesticide poisoning information is limited in Pakistan, several outbreaks of acute and chronic poisoning have been reported. The first was on mercury poisoning in which 34 people affected and 4 died in 1963 after eating mercury treated grains (Inayatullah 1996). In 1972, poisoning accident occurred in Multan during unloading a consignment of phorate and 7 of them died (Baloch 1985). Similarly, 37% of field workers were affected (2800 cases) in 1976 due to poor work practices during malaria control program (Baker et al. 1978). Another outbreak occurred in 1984 in Talagang (Attock district) and 194 persons from 18 villages were affected. The reported cause was the shipment of contaminated sugar in that area. Among the affected persons, 70% were children. Almost 10% of the patients were died (Rowley et al. 1987). Recently more than ~20 peoples were died in Fatehpur (Layyah) due to eating of poisonous sweet.

The pesticide poisoning cases were also reported from different hospitals in Pakistan. A survey on acute poisoning was conducted by the causality department of Mayo Hospital Lahore. They reported that among 407 poisoning cases, 12 cases were due to pesticide poisoning (Sarwar 1973). In another study, a review of about 755 acute poisoning cases from 1976-1985 was carried out at the Jinnah Postgraduate Medical Centre Karachi. Among all the cases, 39% were due to organophosphorus poisoning and the mortality rate was significantly higher than other cases of poisoning (Jamil 1989). Similarly, Nishtar Hospital Multan reported about 112 patients with acute poisoning was admitted and 75% were affected by insecticides (Chaudhary et al. 1992). Acetylcholinestrase (AChE) levels in blood can be used to measure chronic poisoning of pesticides. In 1991, Masud reported that out of 88 cotton picker females only 1% had normal AChE level in their blood and 74% females had an inhibition of 12-50% of the enzyme (Masud 1991). Similarly, only 12% had normal AChE levels out of 33 cotton picker males and 51% had blood AChE inhibition between 12 to 50% (Masud 1991).

A retrospective cross-sectional study was conducted over a time period of 22 years (1989-2010) and included all pediatric (<16 years) poisoning cases reported in Emergency of Agha Khan University Hospital. Around 243 pediatric cases were admitted in which 136 (56%) were males and 107 (44%) were females. The most common substance involved in these cases were prescription medicine 64 (26.3%), hydrocarbons 56 (23%) and pesticides in 33 (13.6%) (Khan et al. 2014). Another retrospective study was conducted in Karachi to determine the prevalence of suicide in local population due to chemical poisoning from 2007-2011. Among 11925 studied cases the most common chemical used for suicide was typhone and finis insecticides (62%) followed by kerosene oil (23%) and a group comprises of different chemical agents (15%). The treatment data showed survival of 82% of cases while 18% died in all cases (Imtiaz et al. 2015). Similarly, pesticides and resultant health problems were assessed among 318 cotton farmers and found a large proportion (34%) of the farmers reported multiple intoxication symptoms by pesticide use; the most common were irritation of skin and eyes, headache and dizziness which showed high level of risk exposure to pesticides among farmers. The cotton growing area of Vehari district of Punjab was also highly contaminated with pesticides because most of the imported pesticides are used on cotton to control insect pests. The blood samples of 27 villagers revealed the presence of chlorpyrifos and pyributicarb pesticides. These studies calling upon immediate interventions toward increasing awareness about alternative pest control strategies with less pesticide use and to focus on integrated pest management (IPM) approaches. The studies about pesticide contamination in soil, water, animal milk and food stuff including fruits and vegetables in Pakistan are given in Table 16.4.

15.6. Future Vision

It is clear that pesticides are widely used in Pakistan agriculture. Effective application of pesticides can kill or control weeds, fungi, bacteria, rodents and most importantly insect pests. The use of chemical control has contributed to dramatic increase in yields of many crops including major crops, fruits and vegetables.

In developing countries, the food supply will have to rise around 70% for food security of 6.5 billion people who are expected to be living there by 2020. This will require sustained rise in yields and reduction in crop losses due to pests and pathogens. The future strategies will have to be focused on increasing the productivity of available land and water resources due to the limited opportunities for expanding irrigation and productive land. Use of these resources could hardly be a less efficient than to invest time, money and effort in producing food only to have it totally or partially destroyed by the pests and diseases. For increasing food supply in developing countries and depending upon the levels of losses and costs involved, the improved pest management strategies would seem to be an important component. However, the use of chemical pesticides is more common and will remain in use to reduce the pest problems; and 80% of pesticides in use are applied in developing countries to intensify crop production to meet the national needs.

Although, all of us are consumers and all have a stake in an expanding and prosperous economy, our attitudes towards pesticides and their regulation differs; the chemical manufacturer, the housewife buying vegetables and fruits at the market has different concerns than the farmer who grows the food. Thus, all the substances are exposed to pesticides in different ways. These substances can enter the body through skin contact, ingestion by food, inhalation in polluted environment. The wide variety of these chemicals makes it difficult to assess the exposure of populations, the occupationally exposed population (agriculture farmers) or the general population. Pollution is assumed to be in alarming proportions all over the world and looks like becoming one of the major problems of our time. All reasonable efforts must be made to reduce these dangers.

A serious drawback to formulating a strategy for improving pest management is the inadequate state of knowledge about actual losses from pests and the real and potential gains from pest management. Promoting IPM would be one way to reduce chemical use. It is unlikely that there will be pesticides free agriculture over the next several decades due to current reliance on pesticides along with uncertainties about many non-chemical approaches. Therefore, IPM forms like greater reliance on biological approaches and judicious use of chemical insecticides should be encouraged. More attention should be paid to apply pesticides at appropriate times with right quantities to safeguard the natural enemies of insect pests. Similarly, the use of crop rotation and resistant varieties should also be incorporated in IPM strategies to control insect pests. In addition, the policies that support IMP should be included to remove the existing biases that encourage pesticide use. The public sector research should also focus on the most effective farming systems consistent with IPM. In crop production, another important issue regarding pest management in the future centers is the role of biotechnology. There will be a substantial increase in the use of genetically engineered crops in next 20 years. Some crops are genetically engineered in a way that the herbicides will destroy weeds and not the economic crops and others to resist against pests. Thus, the use of herbicides will increase and the insecticides may diminish. But, there are concerns about the long term health hazard effects of genetically engineered crops both on humans and animals. Overall, the options for improving pest management include the pesticides which are more benign than current products and the practice of IPM to regulate hazardous pesticide use. Most importantly, the governments should commit themselves to promote IMP and launch the substantial educational efforts to persuade millions of producers to modify their approaches towards pest management. They also have to support the research institutes to develop appropriate methodologies and teaching IPM's knowledge-intensive practices.

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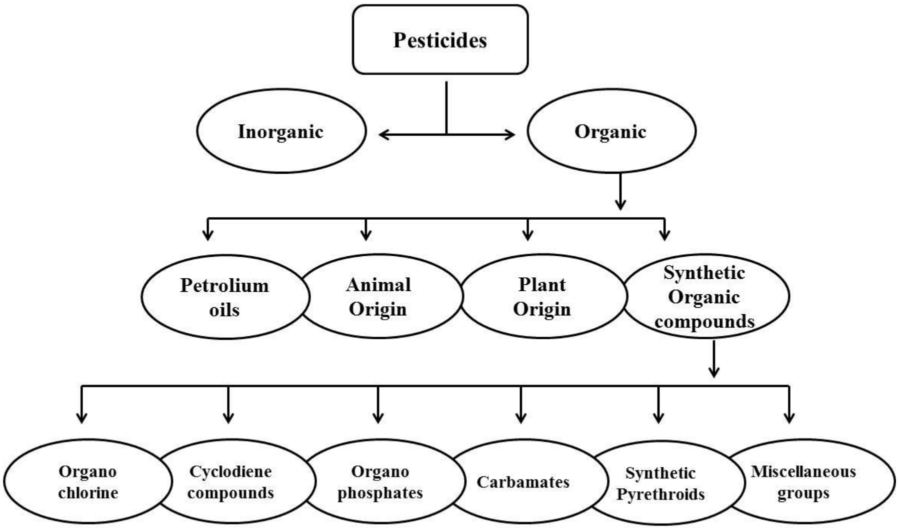

Figure 15.1 Classification of pesticides on the basis of chemical nature

Table 15.1 Classification of Pesticides into different groups on the basis of target pests, mode of entry and mode of action

Based on Target Organisms

Sr.	Pesticide	Target Pests
1	Acaricides	Kill mites, ticks, and spiders that feed onplants and animals. Also called miticides
2	Algicides	Control algae in lakes, canals, swimming pools, water tanks and other sites
3	Antifouling agents	Kill or repel organisms that attach to underwater surfaces, such as boat bottoms
4	Antimicrobial s	Kill microorganisms (such as bacteria, fungi, viruses and nematodes)
5	Attractants	Attract pests, e.g., to lure an insect or rodent to a trap. Food is not considered a pesticide when used as an attractant
6	Avicides	Kill birds
8	Biopesticides	These are certain types of pesticides derived from natural materials as animals, plants, bacteria, fungi and certain minerals
9	Biocides	Kill microorganisms
10	Defoliants	Cause leaves or other foliage to drop from a tree or growing plant, usually to facilitate harvest. Various highly persistent types have been used by the military
11	Desiccants	Promote drying of living tissues, such as unwanted plant tops
12	Disinfectants and sanitizers	Kill or inactivate disease producing microorganisms on inanimate objects
13	Fungicides	Kill fungi (including blights, mildews, molds and rusts)
14	Fumigants	Produce gas or vapor intended to destroy pests in buildings or soil
15	Herbicides	Kill weeds, grasses and other plants that grow where they are not wanted. May be organic or inorganic
16	Insect growth regulators	Disrupt the moulting, maturity from pupal stage to adult or other life processes of insects
17	Insecticides	Kill insects and arthropods
18	Miticides	Kill mites, ticks, and spiders that feed on plants and animals. Also called acaricides

Sr.	Pesticide	Target Pests
19	Microbial pesticides	Microorganisms that kill, inhibit or out-compete pests, including insects or other microorganisms (Entomopathogenic fungi, Entomopathogenic bacteria, Entomopathogenic nematodes and viruses)
20	Molluscicides	Kill snails and slugs
21	Nematicides	Kill plant parasitic nematodes (microscopic, worm-like organisms that feed on plant roots)
22	Ovicides	Kill eggs of insects and mites
23	Pheromones	Biochemicals used to disrupt the mating behavior of insects
24	Piscicides	Kill fish
25	Plantgrowth regulators	Substances (excluding fertilizers or other plant nutrients) that alter the expected growth, flowering or reproduction rate of plants
26	Predacides	Kill vertebrate predators
27	Repellents	Repel pests, including insects (such as mosquitoes) and birds
28	Rodenticides	Control mice and other rodents
29	Synergists	Improve the performance of another pesticide. Usually an inert ingredient
Based on Mode of Entry		
1	Stomach Poisons	Applied in the leaves and other parts of the plant when ingested, act on the digestive system of the insect
2	Contact Poisons	The pesticides which brings about death of the pest species by means of contact
3	Systemic Poisons	Chemicals when applied to plant or soil are absorbed by foliage (or) roots and translocated through vascular system and cause death of pests
4	Translaminar Poisons	Pesticides translocate across the leaves and effective against sucking insects
5	Fumigants	Toxicant enter in vapour form into the tracheal system (respiratory poison) through spiracles
Based on Mode of Action		
1	Physical poison	Toxicant which brings about kill of one insect by disrupting the physical activity

Sr.	Pesticide	Target Pests
2	Protoplasmic poison	Toxicant responsible for precipitation of protein
3	Respiratory poison	Chemicals which inactivate respiratory enzymes
4	Nerve poison	Chemicals inhibit impulse conduction
5	Chitin inhibition	Chemicals inhibit chitin synthesis

Table 15.2 List of pesticides banned in Pakistan as of 15 February, 2016

1	Binapacryl	10	Dibromochloropropane + Dibromochloropropene	19	Propergite
2	Bromophos ethyl	11	Dicrotophos	20	Toxaphene
3	Captafol	12	Dieldrin	21	Zineb
4	Chordimeform	13	Disulfoton	22	Heptachlor
5	Chlorobenzilate	14	Endrin	23	Methyl Parathion
6	Chlorthiophos	15	Ethyene dichloride + Carbontetrachloride (EDCT)	24	Monocrotophos
7	Cyhexatin	16	Leptophos	25	Methamidophos
8	Dalapon	17	Mercury Compound	26	Endosulfan
9	DDT	18	Mevinphos		

Table 15.3 List of Pesticides importing companies registered in Pakistan (DPP, 2015)

There are more than 400 registered pesticide companies are working in the country. The important one are as follow.

Sr. No.	Importer Name
1	Adeel Pesticides and Manufacturing Co.
2	Adil Enterprises (Pvt.) Ltd.
3	AG Services & Supplies, Karachi.

Sr. No.	Importer Name
4	Agri Farms Services.
5	Agricides (Pvt.) Ltd.
6	Agrolet Chemical Industries (Pvt.) Ltd.
7	Ali Akbar Enterprises (Pvt.) Ltd.
8	AQ Enterprises.
9	ArystaLifescience Pakistan (Pvt.) Ltd.
10	Auriga Chemicals Enterprises.
11	Baluchistan ZaraiMarkaz, Quetta.
12	BASF Chemicals & Polymers Pakistan (Pvt.).
13	Bayer Pakistan (Pvt.) Ltd.
14	Chem – Agro International.
15	D' Agro Pakistan (Private) Limited.
16	Du Pont Pakistan Operations (Pvt.) Ltd.
17	Edgro (Pvt.) Ltd.
18	EPAIDCO (Pvt.) Ltd.
19	
20	FMC United (Pvt.) Ltd.
21	Four Brothers Agri Services Pakistan
22	Global Petrochemicals (Pvt) Ltd.
23	Granulars (Pvt.) Ltd.
24	H.E.J Research Institute of Chemistry.
25	Helb Agro Sciences Pakistan (Pvt.) Ltd.
26	Jaffer Agro Services (Pvt.) Ltd.
27	Kanzo AG.
28	Life Technologies (Pvt.) Ltd.
29	Mardan Agro Chemical Co. (Regd.).
30	National Chemicals.
31	New Agri Care.
32	Novartis (Pakistan) Ltd., Karachi.
33	Pak China Chemicals (Pvt.) Ltd.

Sr. No.	Importer Name
34	Pakistan Agro Chemicals (Pvt.) Ltd.
35	Pakistan Council Scientific and Industries
36	R. A. Associate (Pvt.) Ltd.
37	R. B. Avari Enterprises (Pvt.) Ltd.
38	S. Essa (Pvt.) Ltd.
39	Sarhad Farm Services.
40	Sayban International.
41	Sojitz Corporation.
42	Solex Chemicals (Pvt.) Ltd.
43	STEDEC Technology Commercialization Corporation of Pakistan.
44	Sun Crop Pesticides.
45	Swat Agro Chemicals.
46	Syngenta Pakistan Limited.
47	The Planters (Pvt.) Ltd.
48	The Planters (Pvt.) Ltd.
49	United Distributors Pakistan Ltd.
50	Victoria Chemicals.
51	Warble (Pvt.) Ltd.
52	Welcon Chemicals (Pvt.) Ltd.

Table 15.4 Different studies on the contamination of pesticides in Pakistan

Pesticide residues in fruits and vegetables

Location	No. of Samples analyzed	Pesticide residues (%)	Above MRLs (%)	References
Lahore	25	4	100	(Cheema and Shah 1987)
Karachi	250	37.5	18	(Masud and Hasan 1992)
Islamabad	96	50	23	(Masud and Hasan 1995)
Quetta	50	39	5	
	48	100	-	NIH 1984

Location	No. of Samples analyzed	Pesticide residues (%)	Above MRLs (%)	References
Multan	All the samples were found to be contaminated with a degree of variation of pesticides residue studied			(Hussain et al. 2002)
Different cities of Pakistan	127	100	-	(Asi 2003)
Peshawar	193	38.35	2.6	(Khan 2005)
Karachi	320	68.75	55	(Perveen et al. 2005)
Karachi	120	62.5	22	(Perveen et al. 2011)
Nawabsha	All the fruit samples were found contaminated except banana and apple samples were found exceeding the maximum residue limits (MRL)			
Cotton growing area of Sindh and Punjab	24	87.5	28.5	(Anwar 2008)
	27	100	37	
Hyderabad	200	100	61	(Latif et al. 2011)
Pesticide residues in other Food stuff				
Faisalabad	200	40	56	(Muhammad et al. 2012)
Faisalabad	100	50	66	(Muhammad et al. 2013)
Lahore	140	50	-	(Shahzadi et al. 2013)
Rawalpindi/Islamabad (eggs+meat)	30 (egg)	30	10	(Mehtabuddin et al. 2012)
	30 (Chest Meat)	43	23	
Pesticide residues in Soil				
Cotton growing area of Sindh and Punjab	43	100	-	(Anwar 2008)
Swat valley	63	100	-	(Nafees and Jan 2009)
Pesticide store rooms and courtyards from different districts of Punjab, Sindh and KPK	33	100	-	(Ahad et al. 2010)
Nawazbshah	19	84.21	-	(Anwar et al. 2012)

Location	No. of Samples analyzed	Pesticide residues (%)	Above MRLs (%)	References
Bahawalpur	12	100	-	(Anwar et al. 2014)
Pesticide residues in water				
Cotton growing area of Sindh and Punjab	46	100	70	(Anwar 2008)
Cotton, rice belts and municipal areas	21	100		(Asi et al. 2007)
Rawalpindi/Islamabad	3	100	-	(Iram et al. 2009)
Surface and groundwater sources from nearby pesticide store rooms and courtyards of different districts of Punjab, Sindh and KPK	33	100	-	(Ahad et al. 2010)

Section – V

Agricultural Resources of Pakistan

Chapter 16

Water Resources of Pakistan: Efficient Utilization

Muhammad Jehanzeb Masud Cheema♦

Abstract

Nature has blessed Pakistan with sufficient water reserves in the form of rainfall, glaciers and groundwater. All these resources provide water for irrigation, domestic and industrial uses. Now a days, country is facing water shortage in time and space domains due to intensive development in water needs. Irrigation is the largest consumer that is using both surface and groundwater to meet the crop water requirements. The current climate change issues and negligence in developing new reservoirs has put tremendous pressure on groundwater aquifer that is depleting with a rapid pace of about 10 BCM per year. There is a dire need to efficiently utilize these available resources to ensure sustainability of water resources. Finalization of National water policy and its implementation is needed for efficient utilization of available water resources.

16.1. Introduction

Water is essential for sustaining quality of life on earth. But growing population and unrestricted water resources utilization are becoming major risk to spatial and temporal fresh water availability. The threat is more severe in developing countries where the majority of the population practices agriculture such as Pakistan. For instance, the water availability in Pakistan has declined from 5000 m^3 per capita

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during 1950s to 1100 m^3 now and will be 1000 m^3 per capita by 2017 thus categorizing the country as a water deficit (WAPDA 2011).

The situation is becoming even worse due to ongoing climate change that has strongly affected Pakistan especially during the last decade; and as a result, water resources are declining and glaciers are shrinking. Reservoir levels are below average, which has decreased water availability for irrigated as well as environmental flows. Total water flows in the major rivers may decline to 110 km^3 (during droughts); compared to average flows of 180 km^3 that can severely affect irrigation water availability resulting in exacerbated food insecurity (Basharat et al. 2014).

Agriculture, being the key consumer, accounts for 30% of the economy in a country such as Pakistan and uses 90% of available fresh water while rest is being used for domestic and industrial purposes (Cheema 2012). Major portion of it is coming in the form of surface water from rivers (including Indus and its tributaries Jhelum, Chenab, Ravi and Sutlej) and streams flowing due to upstream precipitation and snow melts. For example, 85% of rivers flow is due to snowmelt and monsoon rains in the summer while 15% by winter rains. However, current climate change phenomenon and growing high delta crops at large tracts has resulted in lower availability of these resources.

It ultimately exerts tremendous pressure on groundwater reserves, another precious resource of water. Presently, groundwater is being used in conjunction with surface water and meeting 50% of total crop water requirements. Conjunctive use is in practice on more than 70% of the irrigated areas (Qureshi et al. 2010). Therefore, sustainability of agriculture depends on the timely and adequate availability of water.

On the other hand, irrigation water productivity in Pakistan is much lower than that of many parts of the world with similar agro-climatic conditions. For example, the average wheat production of 0.54 kg per m^3 of irrigation water in Pakistan is lower than that of 1.22 kg in India, 0.85 kg in China, 1.39 kg in the Netherlands, 1.44 kg in USA and 1.52 kg in Egypt (Zwart and Bastiaanssen 2007). A recent study shows that food grain requirement will increase to 40 million tons in the year 2025 against a current supply of about 20 million tons. Major factors limiting the yield are considered to be inadequate availability of irrigation water at farm gate, unreliability and inequity in water supplies. This situation demands a sound strategy to efficiently utilize diminishing water resources of the country.

In the next sections, available water resources including rainfall, glacial ice and snow-melts result in river flows as well as groundwater, will be discussed. Whilst, means to improve utilization potential will also be discussed in detail in the next coming sections.

16.2. Water Resources Potential

The water resources of Pakistan include surface water coming from rain and snow melt, rainfall, and groundwater. The extent of availability of these resources is location-specific. A brief description of water resources of Pakistan is given below:

16.2.1. Glaciers

Snow melt from upstream glaciers of the Himalayan, Karakoram, and Hindu Kush ranges feed water to Indus River and its tributaries which are mainstay of flows available for Pakistan. The catchment area of the Indus river and its tributaries contains some of the largest glaciers in the world, outside the polar regions. Pakistan has total glaciated area of approximately 17,000 km^2 (including 15,000 km^2 of area in northern part of country) out of which 37% area is consisted of the Karakoram region (Shroder and Bishop 2010). More than 5000 glaciers feeding the Indus River are ranged from few tens of meters to more than 70 km long (Rasul et al. 2011). The glaciated area of Pakistan is provided in Fig 17.1. Total flow contribution in River Indus from snow melt is up to 80%, while the rest comes from rainfall. Snow-melt accounts for more than 50% of the flow in the River Jhelum while the considerable proportion is also fed to River Chenab by run off originating from snow-melt.

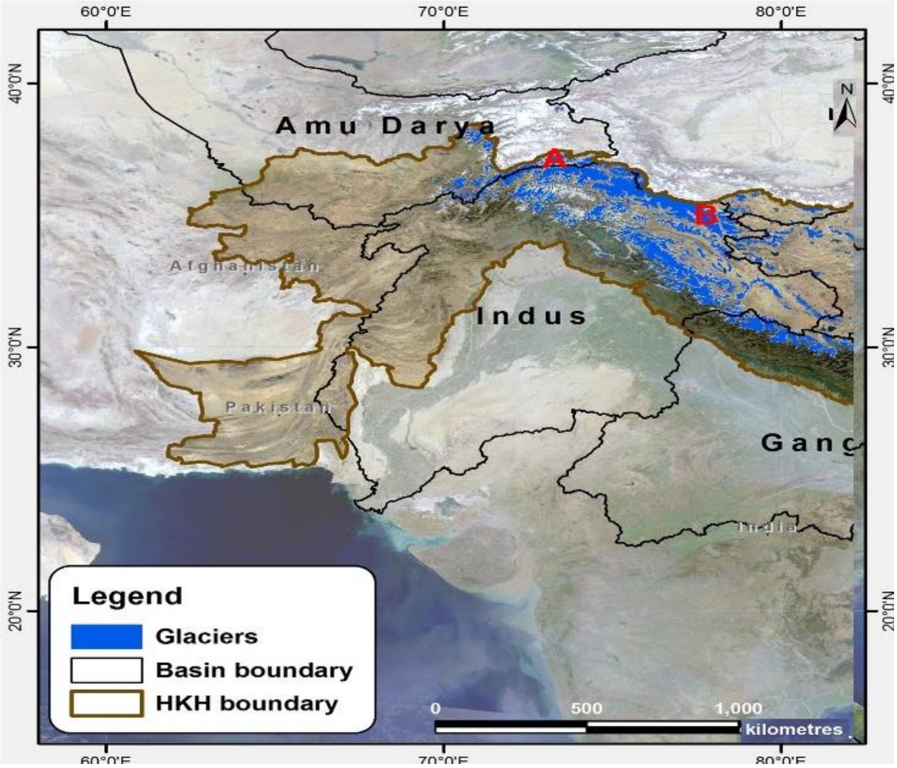

Figure 16.1 Glaciated area (blue) in Indus Basin of Pakistan. (Adopted from Bajracharya et al. 2015)

The glaciers are retreating at a rapid pace and a reduction of 2.15% in snow cover has been observed from 1992 to 2010 (Mukhopadhyay 2012). The reduced snowpack affects the river flows, as contributions of glacial melt and snowmelt to annual river flows can be over 50% and vary annually (ICIMOD 2012) while rest of the flow contribution is from rainfall (monsoon and western disturbances).

16.2.2. Rainfall

Rainfall in Pakistan is markedly variable in magnitude, time of occurrence and its aerial distribution. The major portion of country is dry and located in arid to semi-arid climatic zones. The rainfall varies as we move from the north and northeast to the south of the country. The annual rainfall is higher in the north and the north-eastern tracts (>1500 mm yr^{-1}) and lower toward the middle and the southeast (<300 mm yr^{-1}). There are two sources of rainfall in Pakistan: The Monsoon and the Western Disturbances. The former takes place from June to September and the latter from December to March (Lang and Barros 2004; Bookhagen and Burbank 2006).

The Monsoon season is caused by moist air currents from the Arabian Sea and Bay of Bengal. The moist air from these oceans moves towards the north passing through the hot plains (Houze et al. 2007) which results in convective rainfall (Singh and Kumar 1997) and prevails mostly in the months of June, July and August. While, the weather systems responsible for winter rainfall are mid latitude Western Disturbances (Thayyen and Gergan 2009). They originate over the Caspian Sea and move from the west to east (Singh and Kumar 1997). These are formed due to large scale interaction between the mid latitude and the tropical air masses. This process results in the formation of westerly troposphere synoptic scale waves which cause stratiform rainfall. The orographic effect may cause intensification, resulting in extensive cloudiness, heavy precipitation and strong winds. However, sometimes their movement slows down causing local heavy snowfall over the hilly areas (Dimri 2006; Cheema 2012). Overall, 36% of precipitation occurs in northern parts (upstream) of Pakistan while 64% occurs in plains (downstream) (Immerzeel et al. 2010). The detail of this spatial as well as temporal variability is provided in Figure 17.2.

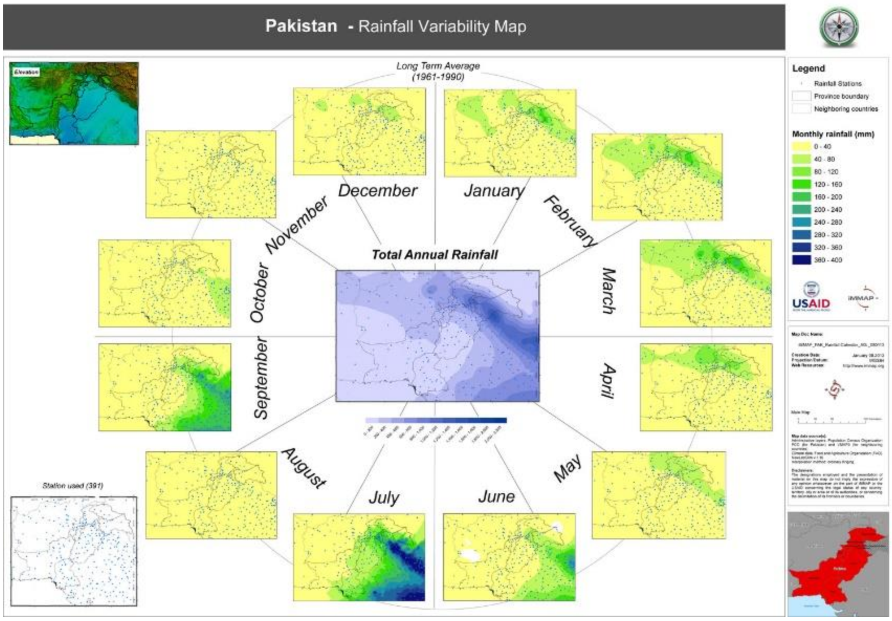

Figure 16.2 Spatial variability of rainfall at annual and monthly scales for Pakistan

(Source: www.immap.org)

Contribution of rainwater to crops in the irrigated areas of Pakistan is about 16 billion cubic meters (BCM), which is around 10% of the mean annual river flows. All these rivers are generally fed by snowmelt and monsoon rains in the summer (85%) and partially by rains in winter (15%). The next section provides details on surface water flows.

16.2.3. Surface water resources

16.2.3.1. River flows

Incident precipitation and river flows are two major sources providing surface water supplies used to meet requirement of agriculture and other sectors. The surface water resources of Pakistan are based on river Indus including its eastern tributaries of Jhelum, Chenab, Ravi and Sutlej and northern/western tributaries of Kabul, Swat, Haro and Soan (Figure 17.3). Water is diverted from the Indus River and its tributaries to irrigate 16 million hectares (Mha) of agricultural land through a large contiguous Indus Basin Irrigation System (IBIS). The inflow to these rivers is mainly derived from snow and glaciers melting and rainfall in the catchment areas of the Himalayan mountains and the Hindukush.

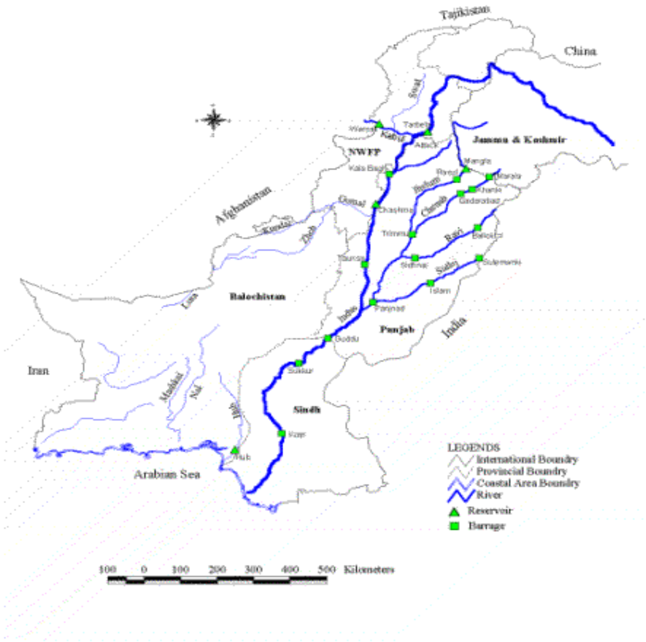

Figure 16.3 Country map with rivers (and control structures) flowing through different provinces

The IBIS was re-designed after signing the Indus Water Treaty by Pakistan and India in 1960 under the auspices of World Bank and United Nations. The water rights of three western rivers (Indus, Chenab and Jhelum) were given to Pakistan while control of three eastern rivers (Ravi, Satluj and Beas) was given to India (Cheema 2012). This division induced severe water shortage to sustain agriculture and environment in the eastern parts of the country. To cope with the situation, two multi-purpose storage reservoirs (Mangla and Tarbela) and a network of main and link canals were constructed as part of IBIS. The link canals were constructed to divert water from western to eastern rivers in order to fulfill water requirement of eastern parts of the country.

This system comprises of three reservoirs, 19 barrages, 12 inter-link canals and 48 independent canal command areas which irrigate all four provinces of Pakistan. The average annual water flow through this network is approximately 139 BCM that may vary (WAPDA Annual Report 2013).

All the diverted water is conveyed to fields through the well-structured irrigation canals (23 in Punjab, 14 in Sindh, 5 in KPK and 3 in Baluchistan) and large number of watercourses and field ditches. The aggregate length of the canals is around 60,800 km. In addition, watercourses, farm channels and field ditches cover another 1.6 million km. As a result of the Indus basin development, the river water diversions for irrigation were increased by 15 to 20% and cropping intensity almost doubled.

However, the available water from surface water resources can meet only less than 40% of the requirements.

Moreover, current climate change and upstream interventions by upper riparian has also affected downstream water availability (Ahmad 2009; Cheema and Pawar 2015). Table 17.1 provides an overview of water flow trends during the last century. The average annual flows of major rivers show decreasing trends for both west- and east-flowing rivers. The average flow of eastern rivers into Pakistan was reduced from historic levels by 75% and 92% during the years 1985-2002 and 2007-2010, respectively. Pakistan can utilize residual flows from these east-flowing rivers, but they are variable and available only during the monsoon season. About a 17% reduction from the historic average flow of the west-flowing rivers was observed during the 2007-10 period. In addition to this reduction, annually more than 25% river water drains into sea.

Outside the Indus Basin, there are smaller river basins. One is the Mekran coast in Baluchistan, drains directly into the sea and a closed basin (Kharan). The total inflow of these basins is less than 5 BCM annually. The Khirthar and Pat Feeder canals of Indus Basin System and Lasbella canal feed the major areas under irrigated agriculture from the Hub dam. Another important source of surface water is the floodwater that flows through the streams. Around 30% of the floodwater is harnessed for agriculture through Sailaba diversions (Rod Kohi System), storage dams and minor perennial irrigation schemes.

Table 16.1 Average flows (BCM) in major rivers of Pakistan during the last century (Sources: Khan 1999; Govt. of Pakistan 2011; Cheema and Pawar 2015)

	River	Rim station	Average Annual Flow 1922-61	Average Annual Flow 1985-2002	Average Annual Flow 2007-10
West flowing rivers	Indus	Kalabagh	114.4	94.1	101.9
	Jhelum	Mangla	28.3	23.7	19.3
	Chenab	Marala	31.9	24.5	23.9
East flowing rivers	Ravi	Below Madhopur	8.6	4.0	1.1
	Sutlej	Below Ferozepur	17.2	2.2	0.8
	Total		200.4	148.5	147.0

16.2.3.2. Rod Kohi System

In Pakistan, Rod Kohi (hill torrents) area comprises of about 48% of the country's total area *(*Figure 17.4). Agriculture through Rod Kohi System of Irrigation (RKSI) is being practiced in piedmont plains of Kohat, D.I. Khan (KPK), D.G. Khan, Rajanpur (Punjab), Larkana, Dadu (Sindh), Barkhan and Kachhi plains of Baluchistan province. The largest area under RKSI of KPK and Punjab lies in adjacent districts of D.I. Khan and D.G. Khan, respectively. Heavy rains in the catchment areas, which extend up to Baluchistan, Afghanistan, Sulaiman ranges, and Bhattani range result in the water rushing into various torrents in the foothill plains.

The RKSI is being practiced since centuries but still less understood and improperly managed due to lack of resources and high-water velocities because of high gradient.

Rod Kohi provides a substantial source of water for irrigation with a potential of approximately 12.3 BCM. It is estimated that 2.43Mha area (which is about 15% of the current area under irrigation) can be developed and brought under cultivation by proper management of Rod Kohi. Its draining upland areas generally have little base flow and rise rapidly after rainfall on the catchment. Rapid runoff coupled with steep stream gradients, results in high peak flows. Serious flooding results when these streams reach the lowlands where the hydraulic gradient is much flatter. Wherever possible, the runoff is harnessed for flood irrigation by weirs or temporary diversion structures. RKSI uses earthen embankments, called “bund” or “ganda”, to divert flow from hill torrents. When the upstream diversions have received adequate water, the bund is allowed to breach and the next farmer receives the water. Rod Kohis can however, regularly causes considerable damage to downstream infrastructure, principally due to shifts in the channel system.

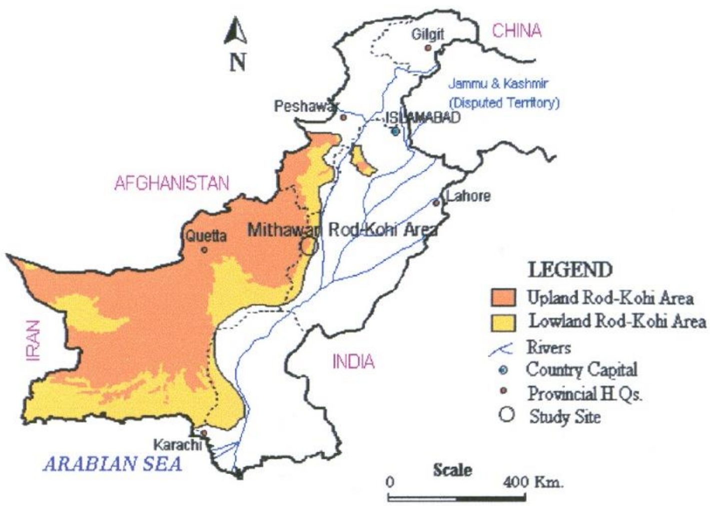

Figure 16.4 Potential areas of Pakistan under Rod Kohi system of irrigation

16.2.3.3. Kareze System

The kareze is a perennial source of water both for domestic and irrigation purposes. Kareze irrigation is successful and meets all criteria of sustainability even today in the Baluchistan province. Approximately 0.65 million acres are being irrigated by small-scale perennial irrigation systems, which have been mainly developed, operated and maintained by the farmers themselves. The main water sources for these minor irrigation systems are karezes, springs, wells, infiltration galleries and diversion structures.

Kareze is an indigenous way of harvesting ground water and guiding it to crops in the fields by gravity flow. Presently, karezes are in decline, partly because they are not adequately maintained and partly because the groundwater levels have drawn down by pumping from open wells and tube wells. In 1988-89, the area irrigated through karezes was 11% of the total irrigated area in the province. But prolonged drought spell and installation of deep tube-wells, adversely affected the kareze system as water table is falling down and threaten the sustainability of karezes in the whole province.

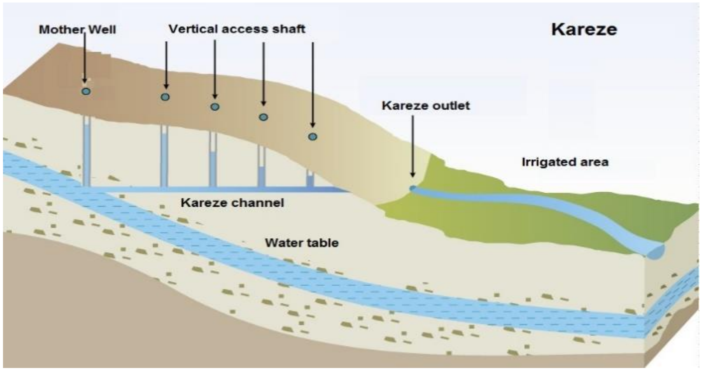

Figure 16.5 A schematic cross section of a Kareze Irrigation System

In Baluchistan province, over exploitation of groundwater resource, through tube-wells, has caused an alarming rate of depletion of water table in the Lora-Pashin, Nari River and Zhob basins. The extended drought preventing any recharge to the aquifer has further aggravated the situation in these overdrawn basins. Lowering of water table has resulted in drying of dug-wells, particularly in the uplands and 70% of the karezes and natural springs. Karezes and springs which are still alive are running at only half to one-third of their capacities, with a drastic reduction in the command area. The residents first dug a well down to groundwater table. In the expected direction of groundwater flow, more wells at distance of 50-100 meters apart dug to check the flowing water. Once kareze is established, it can be used for years. A census in 1998 revealed that there were 493 karezes in Baluchistan. The average kareze can irrigate 10-20 hectares. Karezes, which yield up to 200 L sec^{-1} normally, serve a maximum of 200 shareholders.

A few decades ago, the agricultural economy of Baluchistan was totally dependent upon supply of kareze water. The area irrigated by karezes in Baluchistan has decreased from 14.2% in 1980 to 7.5% in 2000 due to installation of deep well turbines causing un-metered groundwater abstraction.

16.2.4. Groundwater

Inadequate and variable surface supplies forced farmers to start irrigating their fields with groundwater (Shah et al. 2000). Local and readily available groundwater makes irrigation more productive compared to surface water irrigation. Currently 40–50% of agricultural water needs in the basin are met through groundwater (Sarwar and

Eggers 2006). Large numbers of irrigation wells have been added every year, which has resulted in 20-30% increase in groundwater abstractions during the last 20 years (Qureshi et al. 2010). The number of tube-wells in Pakistan has increased from 32,524 in 1965 to over 1.2 million in 2015. As a result, the groundwater withdrawal exceeds annual recharge causing imbalance in groundwater reserves.

Groundwater is also used in conjunction with surface water. Conjunctive use is in practice on more than 70% of the irrigated areas within the Indus Basin of Pakistan (Qureshi et al. 2010). About 29% more area came under conjunctive irrigation during the last 20 years. These values represent the irrigated area in Punjab, Sindh and KPK provinces of Pakistan (Cheema 2012).

Figure 17.6 provides an insight about the major areas where groundwater is being used for irrigation within the irrigated areas of Indus basin including both Pakistan and Indian sides. According to an estimate by Cheema et al. (2014), an amount of 68 BCM is being abstracted from groundwater to irrigate agricultural land within the Pakistani part of Indus Basin, while the surface water contribution is 113 BCM. Thus, about 50% is groundwater contribution as also reported by Sarwar and Eggers (2006).

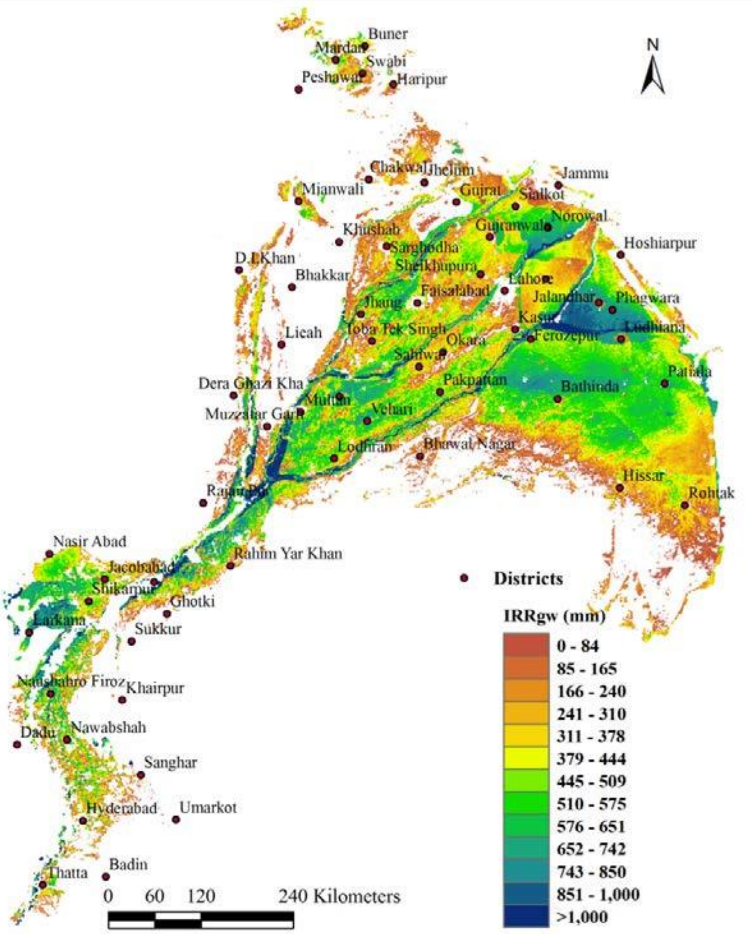

Figure 16.6 Spatial map of gross groundwater abstraction for irrigation in the Indus Basin for one year (Source: Cheema et al. 2014)

On annual basis, an amount of 300 to 900 mm is being abstracted for irrigating crops that is depleting aquifer at a rate of 10 BCM per year. The highest values of groundwater abstractions are observed in middle and northeastern parts of the Indus basin. These areas contain relatively good quality groundwater resources (Arshad et al. 2007) and are located in Punjab province of Pakistan. This higher groundwater use is due to lower water allowance for the canal commands flowing in the middle of Punjab.

Groundwater irrigation in the districts of Multan, Khanewal, Pakpattan, Vehari and Lodhran covering lower Bari *doab* (area between Ravi and Sutlej) ranges between 300–700 mm. The average abstraction in lower Bari *doab* is 400 mm. The middle and lower Rachna *doab* - area between Chenab and Ravi rivers - also shows similar trends and irrigation through groundwater ranges between 200– 600 mm. In the upper

Rachna *doab*, fragmented pockets of high groundwater irrigation (500-700 mm) are observed especially in the districts of Narowal, Gujranwala and Sialkot. Groundwater irrigation is also observed in pockets of the Sargodha district in Chaj *doab* (area between Jhelum and Chenab rivers). Groundwater is mostly saline there but fragmented lenses of fresh water are available. Conjunctive use of groundwater with surface water is a normal practice in these areas.

In Sindh province, groundwater abstraction is fragmented with significant groundwater abstractions occurr in districts of Larkana, Jacobabad and Shikarpur. These areas have high annual *evapotranspiration* because of rice cultivation or high cropping intensities. Groundwater recharge by percolation from fields and canals can be recycled which results in conjunctive use of groundwater and surface water in these northern parts of Sindh province (Siebert et al. 2010).

In Baluchistan, groundwater, extracted through dug wells, tube-wells, springs and karezes, is the main dependable source of water for irrigation of orchards and other cash crops. This is because almost all the rivers and natural streams are ephemeral in nature, with seasonal flows only. It is estimated that, out of a total available potential of about 1.11 BCM, 0.62 BCM is already being utilized, thereby leaving a balance of 0.49 BCM that can still be utilized (Kahlown and Majeed 2003).

The mining of groundwater and lowering of water table is causing a serious concern regarding sustainability of groundwater-irrigated agriculture.

16.3. Future Water Vision

Shortfall in water use would increase from 12.3 BCM to 22.6 BCM during previous decade (2000-2010) even with an increase in overall irrigation efficiency of 44% compared to the current efficiency of 36%. Thus, water resources development and management in the next decade will not make the country self-sufficient in irrigation and non-irrigation water needs. On the one-hand, demand for additional water is increasing rapidly while on the other-hand, opportunities for further development of water resources or maintaining their use to existing levels are diminishing faster than the expected pace. Thus, the challenge for the next decade will be the effective implementation of a state of the art management cum development strategy. Approach encompassing the development of additional reservoirs, integrated water management and use, introduction of water efficient techniques and high efficiency irrigation systems at farm level, rainwater harvesting and recharge, implementation of water conservation practices and containment of environmental degradation will have to be implemented.

16.4. Efficient Utilization of Available Resources

Now the major concern is how we can efficiently utilize the available resources. Here some future options are outlined in order to improve water situation of the country.

16.4.1. Construction of new storage reservoirs

About 40–50 BCM water is being lost without utilization and escapes to Arabian sea while requirement of water flow below Kotri barrage for fish culture and controlling water logging problem in the area is estimated at 10–17 BCM. Thus, a huge amount of precious water (30–36 BCM) is being wasted, in a water scarce country. The river inflows may further be reduced in the near future as India is constructing controlled structure reservoirs at upstream of Indus, Jhelum and Chenab that will ultimately cause reduction of inflows of these rivers. All this will leads to the fulfillment of India's dream of converting Pakistan to a "desert". Thus instead of creating conflicts among the provinces we should have a national approach and construction of new storage facilities should be the priority. Especially Kalabagh, Bhasha, Satpara dams whose feasibility studies have almost been completed should start without further delay. The extra water store in these large dams will be used to irrigate crops in *Rabi* season (a water stress season in Pakistan) and also to produce cheap electricity.

16.4.2. Desiltation of the Tarbela/Mangla dam

The storage loss by the year 2002 due to sedimentation of the Tarbela dam was 3.8 BCM, the Mangla dam 1.45 BCM and the Chashma barrage 0.45 BCM with a total loss of 5.6 BCM which is about 25% of the original storage capacity of 23 BCM. Hence desiltation of these dams is very much necessary to improve the storage capacity and thus life of the dams.

16.4.3. Watershed management

Afforestation of watersheds and catchment areas is the key to check the sedimentation into the dams and rivers. As trees and vegetation help to reduce erosion and thus siltation in the dams can be reduced. For this purpose, Green Water Credits concept should be introduced in upstream that will provide some compensation restricting anthropogenic activities.

16.4.4. Construction of carry-over/delay action dams

This technique consists of constructing dams across streams to store floodwater for recharging of groundwater. The dams delay the passage of floodwater by retaining it behind an impoundment structure. Recharge then takes place by infiltration behind the structures through the bed of reservoir. These dams can be built in the province of Baluchistan especially in district Zhob, Kharan, Barkhan and Kachhi Plains as well as Quetta and Ziarat valley as they are facing scarcity of groundwater resources and it will be a real source for recharging the underlain aquifer. In Sindh province, Kohistan and Thar are prone areas for such intervention.

16.4.5. Rainwater harvesting

The Pothwar plateau and Hazara division in north, while Suleiman and Kirthar ranges in south western part of the country have the potential to harvest rain water. During rainfalls, run off water from the upper parts can be controlled and collected by constructing small/medium size check dam structures and dikes, which can ultimately be utilized for agricultural purposes.

Sites should also be identified to divert flood water for groundwater recharge.

16.4.6. Lining of canals/watercourses to improve conveyance efficiency

Considerable wastage of water occurs in canals and watercourses. The main causes of operational losses are: seepage; overflow; vegetation; and rodent holes. Lining of canals and water courses can improve conveyance efficiency and thus over all irrigation efficiency can be improved.

A significant percentage of irrigation water is being lost (about 40%) from the century old water conveyance system because of their poor maintenance and aging. This is resulting in water shortage at the farm level that has been further aggravated due to climate change issues.

Now government has realized the situation and under different schemes 22,971 (39.5%) out of 58,110 water courses in Punjab have so far been improved leaving a balance of 35,139 (60.5%) still to be improved. Now a mega project entitled "National Program for Improvement of Watercourses in Pakistan" has, accordingly, been formulated by the Federal government to improve remaining 87,000 watercourses overall (28,000 in the Punjab). By virtue of this effort, 243 acre-feet water per watercourse will be saved annually as well as water delivery efficiency would be increased by 38.5%, that would result in 13.4% increase in cropped area and 14.8% increase in cropping intensity thus ultimately the crop yield will be increased by 17%.

It is also the duty of the farmers to take active part in this program and get all the watercourses improved under the scheme.

16.4.7. Improvement in cropping pattern in order to adjust for water availability

As high delta crops like sugarcane and rice not only consume a large portion of available water but also contribute to water logging. Thus low-delta crops such as sugar beet, cotton, and oilseeds should replace the high-delta crops in accordance to the soil and climatic conditions in the areas which are suffering from water shortages.

Figure 16.7 A view of improved water courses

16.4.8. Establishment of water banks

Water ponds at farm level should be introduced to store extra water available during the non-consuming period. This stored water can be used when needed by high efficiency irrigation systems.

16.4.9. Use of high efficiency irrigation techniques

A considerable amount of water wastage also takes place as application losses (about 28%) due to undulated farmer's fields and adoption of traditional agricultural/irrigation practices at the farm level.

Improved irrigation methods like furrows and bed plantation should be encouraged. By bed plantation (2-3 feet beds are formed and seed is drilled on the bed), 40-50% water saving can be achieved.

Drip and sprinkler irrigation systems have higher application efficiencies so their utilization should be encouraged especially for orchards/fruit trees and subsidy should be given to the farmers so that they may be able to adopt these technologies.

Zero tillage technology can also help in conserving water as wheat crop can be drilled directly in the fields without seed bed preparation and first irrigation (commonly called *rauni*) after rice harvesting where the conserved moisture is used for seed growth. By this technique, not only water saving is achieved (25-30%) but additional cost of land preparation can also be minimized as no land preparation is required at all.

Moreover, important factor in improving application efficiency is leveling of the lands. Leveled lands will result in improving time of irrigation and the loss of water to fill depressions etc. can also be avoided.

16.4.10. Revisit of water allocations

Water allocations for different canal commands were fixed 50 years back when cropping intensities were 75% and fresh groundwater zones were available in middle of the IBIS. However, now the scenario has been completely changed as cropping intensities are 200% and groundwater quality has been deteriorated. In some parts, water availability is an issue while in some parts higher allocations resulting in increased water logging.

16.5. Conclusion

In order to improve current situation and to meet ever growing future needs of water, some areas are identified which need to be addressed in the next future. Some recommendations are proposed which require early attention:

1) Comprehensive planning of the water sector coupled with integrated development and management of irrigated agriculture is required to enhance agricultural production.
2) Construction of large reservoirs should be started on priority bases in order to provide storage of the extra water that has continuously been lost and falling to sea un-utilized due to lack of storage facilities.
3) Lining of water conveyance system (canals/water courses) is essential in order to improve the conveyance efficiency and ultimately the overall irrigation efficiency of the system.
4) Use of pressurized irrigation systems (Drip/Sprinkler) should be encouraged. Subsidy should be provided to the farmers to encourage them to make use of this highly efficient technology.
5) More research should be conducted to address issues of water scarcity, inequity and mass awareness programs have to be initiated to motivate domestic and industrial water users' in conservation of water.
6) On-farm water management programs should address both surface and groundwater issues. These must re-orient their technical backstop support system to respond to farmer's organizations.
7) Emphasis should be given on recycling and re-use of water including wastewater management.
8) Improved irrigation methods such as furrow bed should be adopted for row crops while in the rice areas, zero till technology should be initiated.
9) Precision land leveling should be encouraged that improves irrigation application efficiency and increases the uniformity of application with less chances of over or under-irrigation resulting in higher water use efficiency and crop yield.
10) Fragmentation of land holdings is also a cause of water losses as time of reach from one small farm to other has been increased. In some cases it has been noticed that the farmer lost his turn time in bringing water to his field because less farm holding has decreased his irrigation turn time. So plan should be carried out to meet this problem which may include the revision of ancient *Warabandi* system or combine turn for a group of farmers whose land holdings are adjacent to each other.

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Chapter 17

Land Resources and Agriculture Land Utilization in Pakistan

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Abstract

Land has an immense importance as a factor of production and hence economic prosperity of any country depends on her land resources. Pakistan is country rich with natural and land resources. Five rivers flow in this area. Water is ample enough, if used wisely; there will be hundred percent utilization of the land. Uneven and erratic rain fall with non-uniform distribution of irrigation water is a main hindrance in maximum utilization of land. Furthermore, erosion, drought, salinity and water-logging are also the major constraints in the complete utilization of land. However, the key economic resources in the agriculture sector, land and water should be close to maximum utilization. The rainfed, mountainous and sub-mountainous areas are capable of high production through utilization of improved agricultural production system. Moreover, potential for economic growth lies in better management and more productive and sustainable use of the existing land resources rather than an increased availability of resources.

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Keywords: Land resources, Land classification, Land utilization, Land use problems, Waste lands, Range lands

17.1. Introduction

Being situated at one of the best geographic and geostrategic location on the map of world, Pakistan is effluent in the natural land resources and located within the latitude and longitude of 30º 00´ N and 70º 00´ E, respectively. According to 6th population and housing Census-2017, Pakistan have population of 207, 774, 520 peoples with annual growth rate of 2.40% per annum. About 60.9% of population reside in rural areas while 39.1% in urban areas. Pakistan situated in subtropical zone with some area in temperate region and generally has an arid to semi-arid climate which is characterized by cool to cold winters and hot summers with extreme difference between temperature at a given location with slight to heaviest precipitation and flooding. Furthermore, the climate is hot and dry near the coast in Baluchistan and becoming progressively cooler towards the northeastern uplands. The average annual precipitation ranges from 100 millimeters (mm) in Central zone to more than 1250 mm in the Himalyan foothills. As Pakistan's three-fourth area receives sufficient rainfall, therefore the irrigation plays a vital role in utilizing country's land resources for agriculture purpose.

Total area is 79.6 million hectare (mha) and only 73% is surveyed, while other 27% yet to be surveyed (Table 1). During the period of 1970 to 2014, the cultivated area increased from 16.62 mha to 22.07 mha, with 0.9% growth rate per annum (Pakistan Bureau of Statistics 2014). This increase in cultivated area is due to the improved availability of water and increased population. This chapter reviews the land resources, its classification, utilization and problems in land use. After introduction, land resources and agroecological zones of Pakistan are discussed briefly. According to land capability and suitability classification, country's land is divided into eight capability classes. Then, concept of land use and different categories of agricultural land utilizations are described. After that, land use problems such as salinity, sodicity and other issues are summarized. Lastly, trends in land use change are explained.

17.2. Land Resources of Pakistan

Out of total area of Pakistan, only 22.07 mha is under cultivation and nearly 80% of this is under irrigated category, while the rest is rainfed. Forests cover 4.55 mha which is 5.71% of the total area of Pakistan. Whereas, 8.27 mha area is culturable waste land which comprises 10.30% of the total area and about 29% area is uncultivated and is used for storage of agricultural products, cattle shed, farm house, barn, farm roads and water channels.

17.2.1. Geographical Area

The geographical area of Pakistan has vast diversity and it varies from fertile plains with highly productive soil to deserts and forests with important range lands. In its north, there are number of mountains of the Karakoram Range while in south are coastal areas of the Arabian Sea with immense importance for fishery and international trade.

Country is divided into three main geographical zones: 1) the northern highlands, 2) the Indus River plain 3) the Baluchistan Plateau. However, some geographers assign additional major regions and have separated Baluchistan Plateau from some mountain ranges extended along the western border of Afghanistan. Similarly, south of the Sutlej River, the eastern border with India and the Thar Desert is taken as separate area from the Indus Plain.

Table 17.1 Distribution of land resources of Pakistan

Type of Land Use	Area	
	(mha)	(%)
Total area	79.61	100.00
Total surveyed area	57.99	72.84
Forest cover	4.55	5.71
Area unavailable for agriculture	23.10	29.01
Culturable waste	8.27	10.38
Area available for cultivation	22.07	27.72

Source: Pakistan Bureau of Statistics (2014)

17.2.2. The Northern Highlands

Most part of the world's famous mountain ranges; the Himalayas, the Hindu Kush and the Karakoram, are included in the Northern Highlands and the K2, Mount Godwin Austen, the second highest peak (8,611 meters high) in the world is situated in this region. More than one-half of the mountain ranges are over the height of 4.5 kilometers (km) and among them more than fifty mountains have peak height above 6.5 km. The Himalayas Mountains and Northern Highlands to the east have always remained the tough blockades to movement into the area due to their rough topography and the harsh climate.

Safed Koh range comprised the areas of Northern Highlands in south and the Indus plain in the western region along with the border of Afghanistan and Kirthar, and the Sulaiman ranges that specify expansion of the Sindh province in west and extend to the coastal areas in south. The areas in lower reaches have arid climate than those in the north. These high lands are comprised of the ranges that are extended to the southwest of the Baluchistan province. The movement of peoples toward the plains across the Makran coast is widely restricted due to North-south valleys in Baluchistan and Sindh province. Several large passes like Khojak Pass, the Khyber Pass and the Broghol Pass separate them from Afghanistan's border and provide access to the Wakhan Corridor. Northern mountain areas, deserts in southern region and areas of western plateaus are not suitable for agricultural farming. However, due to fertile and highly productive soils of Indus basin in Punjab province and northern

Sindh has great importance from agricultural point of view and play vital role in economy of Pakistan.

17.2.3. The Indus Plain

The word Indus originated from Sindhu word of the Sanskrit language which means ocean. Indus River is one of the biggest rivers of the world and it upsurges in southwestern Tibet up to 160 km west from where Sutlej River originates. Sutlej River first run through Punjab in India and then mix into the Indus River in Punjab province of Pakistan and the Brahmaputra River that flows across China, India and Bangladesh. About 1 million km^2 area is occupied by Indus and all other major rivers of Pakistan i.e. Chenab, Jhelum and Kabul run into the catchment area of the Indus. The Indus plain formed by the very fertile alluvium soil accumulated from Indus and has been subjected to agricultural practices for at least 5,000 years.

17.2.4. Baluchistan Plateau

Geographically Baluchistan is the biggest province of Pakistan, occupies an area of 347,190 km^2 (134,051 square miles) and consists of 48% land area. However, population in this province is very low due to water scarcity and mountainous terrain. It is located at the border of Southwest, South and Central Asia in the east of the Iranian Plateau. The southern and central regions are known as Makran and Kalat, respectively. Northeast corner is dominated by the Sulaiman Mountains are extended to the northeastern side and the Bolan Pass leads to Kandahar in Afghanistan. Sparse desert terrain mostly near rivers and streams occupy the south regions of Quetta which is a big part of the province. Kharan desert is largest desert in this area and it widely occurs in the district of Kharan. Frequent seismic disturbances are experienced in this area due to collision of Indian tectonic plate with the tectonic plate of Eurasia because it remains to arise northward and to thrust the Himalayas ever higher.

17.3. Total Reported Area

Total physical area comprising villages, tehsils and districts referred as total reported area which is 57.07 mha (57.07% of the geographical area). Total reported area in 2009-2010 was 57.15 mha that increased to 57.99 mha in 2013-2014. Only 1.4% increase was observed in the reported in 2013-14. So far 28% area is to be surveyed for exact land use utilization and classification which is hindrance in depicting the true estimate of the country’s land resources.

17.3.1. Forest Area

Forestry is one of the most important sectors which provides ecotourism, wildlife conservation, and is main source timber and fuel wood, paper, medicine as well as food. However, due to arid and semi-arid climate of Pakistan, only less than 5.71% area is covered with forests. Total forest covered area of Pakistan is presented in the Table 17.2.

Table 17.2 Total forest area of Pakistan in comparison with Asia and World in 2000

Parameter	Pakistan (000 ha)	South Asia (000 ha)	Asia (000 ha)	World (000 ha)
Total forest area	2,361	76 665	547 793	3 869 455
Natural forest area	1,381	42 013	431 946	3,682,722
Plantations area	980	34 652	115 847	186,733
Percentage of forest land	~3%	~18.6%	~17.8%	~29.6%

Source: FAO (2000)

Different types of forests are described below:

a) Coniferous Forests

These forests are present on land at high altitudes from 1 to 4 km. Azad Kashmir, Rawalpindi, Abbottabad, Chitral, Upper Dir, Lower Dir, Malakand, Swat and Mansehra districts are mainly covered with these forests. These forests include Deodar (*Cedrus deodara*), pindrow fir (*Abies pindrow*), Chir pine (*Pinus roxburghii*), morinda spruce (*Picea smithiana*) and blue pine (*Pinus wallichiana*). These types of forests also found in hilly areas of Baluchistan, and juniper (*Juniperous macropoda*) and chilghoza pine (*Pinus gerardiana*) are widely present in that province.

b) Sub-tropical Dry Forests

Phulai (*Acacia modesta*), hopbush (*Dodonaea viscosa*) and kau (*Olea cuspidata*) are dominated species included in sub-tropical dry forests. These forests are located up to a height of 1,000 m. In Punjab, they are present in Attock, Gujrat, Islamabad, Jhelum, Rawalpindi and Abbottabad, Peshawar, Mardan, Mansehra and Kohat districts of Khyber Pakhtunkhwa (KPK). While in Baluchistan, they are widely found at Sulaiman Mountains and some other hilly areas.

c) Tropical Thorn Forests

The forests are characterized by xerophytic scrubs and widely distributed in the plains of Punjab province and also confined to some parts in southern and western regions of Sindh and Baluchistan, respectively. Common species included in these forests are kair (*Capparis aphylla*), vann (*Salvadora oleoides*) and khejri (*Prosopis cineraria*). Mostly they are grazed by animals, used a fuel wood and in protecting watershed.

d) Irrigated Plantation

These plantations were first established at Changa Manga near Lahore in 1866 and now this forest occupies an area of about 226,000 ha. Commonly found tree species in this forest area include Eucalyptus, Populus, Sheesham, Babul and Mulberry/Shahtoot.

e) Rivarian Forests

Rivarian forests are common in Sindh and also in the Punjab province alongside the Indus River. Babul, khejri, shisham (*Dalbergia sissoo*), *Populus euphratica* and *Tamarax dioica* are usually found in these forest and these tree are mostly used for timber.

f) Mangrove Wetlands

Saltwater wetlands found in the delta of Indus River and on the coastal area of Baluchistan, widely support mangrove forestry. The *Avicennia marina*, bamboo and Marsh grasses like apluda and cenchrus are commonly present in mangrove wetlands.

17.3.2. Area Not Available for Cultivation

It is the area not used for agricultural farming. It includes the area under store house, farm house, barn, animal shed, roads in farms and water channels.

17.3.3. Culturable Waste

It include that farm areas which are suitable for farming however it was not cultivated during the surveyed year or in the year before because of any problem like unavailability of irrigation water, un-leveling of land, salinity or sodicity, water logging or funds shortage etc.

17.3.4. Area Cultivated for Agriculture

It is the main area used for agricultural crop production. Cultivated area was 21.25 mha in 2009-2010 that increased to 22.07 mha. This increase is because of water availability for irrigation. The current cultivated area is 27.72% of the total geographical area.

17.4. Agro-ecological Zones

Pakistan can be distributed into ten agro-ecological regions as described below:

17.4.1. The Indus Delta

The climate is arid tropical with adequate hot summers and immensely warm winters. The average daily highest temperature varies between 34-45°C in summer and 19-20°C in winter. The average monthly summer rainfall (July-September) is nearly 75 mm and in winter (December-February) it is below 5 mm.

17.4.2. The Southern Irrigated Plains

The climate is arid subtropical and continental with hot summers and moderate winters. The average daily temperature varies between 40-45°C during May to July.

The average daily lowest temperature in winter is around 8.5°C. The average monthly rainfall is around 16-20 mm in summer, with slight rain in winter.

17.4.3. The Sandy Desert

The climate is arid subtropical with immensely hot summers and moderate winters. The average daily summer highest temperature between 39-41°C and in winter, the average daily lowest temperature is around 7°C. The monthly rainfall deviates from 32 mm in the north to 46 mm in the south. There is no rain in winter. Dust storms are frequent during summer.

17.4.4. The Northern Irrigated Plains

This region is characterized with semi-arid subtropical continental climate. The average daily highest temperature in summer is 39.5°C, and in winter, the average daily lowest temperature is 6.2°C. The average annual rainfall varies between 300-500 mm. Average monthly summer rainfall fluctuates from 108 mm in the east to 75 mm in the southwest, while in winter, it deviates from 14- 22 mm per month.

17.4.5. The Barani Lands

The climate of this region is semi-arid with hot summers and cold winters and with a short dry season in early summer. In summer, the average daily temperature is 38°C. In winter, the average daily temperature varies between 3-6°C. The average monthly rainfall is roughly 200 mm in summer and 36-50 mm in winter.

17.4.6. The Wet Mountains

The mostly eastern part of this area could be categorized as humid, with mild summers and cold winters. In summer, the average daily highest temperature is about 35°C. The monthly rainfall in summer is around 236 mm and in winter 116 mm. The western part of the zone is sub-humid Mediterranean, with dry summers and rainfall limited to the winter and spring seasons only.

17.4.7. The Northern Dry Mountains

This area comprises of elevated mountains surrounded with snow. The average daily lowest temperature fluctuates between 1-7°C. The average monthly rainfall varies from 25-75 mm in winter and from 50-100 mm in spring. In summer, it ranges from 10-20 mm.

17.4.8. The Western Dry Mountains

The most of this area is semi-arid highland with mild summers and cold winters. Rainfall and snowfall is limited mainly to the winter season. The average monthly rainfall in summer varies from 5-15 to 45-95 mm in the northern area. In summer, the average daily highest temperature range is 30 to 39oC and in winter, the average daily lowest temperature fluctuates from -3°C to +7.7°C.

17.4.9. The Dry Western Plateau

This area has an arid (desert) tropical climate with persistent dry season. The average monthly highest temperature range is 38-44°*C*. In winter, the average daily lowest temperature varies between 3- 6°*C* in the north and 11.5-15°*C* along the coast. The average monthly rainfall in summer is inadequate (2-4 mm) besides in the extreme southeastern region where it is around 36 mm.

17.4.10. The Sulaiman Piedmont

The climate of this area is sub-tropical continental and is arid and hot. The average daily highest temperature in summer is 40°*C*. The average daily lowest temperature in winter varies between 5.7-7.6°*C*. The monthly rainfall in winter is around 13 mm, while in summer it is around 21-38 mm.

17.5. Land Capability and Suitability Classification

17.5.1. Land Capability Classification

Lands are utilized for multiple purposes; they are mainly used for agriculture, pastures and forestry. Depending on the nature and properties of soils, they are suitable for one or other uses. Land capability classification can be defined as "field analysis of soil characteristics, slope, level of soil erosion and patterns of land use change that are essential for future soil and water conservation planning". Based on the capability or limitations, the lands are grouped into eight classes by the US Soil Conservation Service (1992). The classes are defined as follows:

Class I: Land has few limitations that confine its use and it is most easily farmed.

Class II: Land holds average limitations that minimize the preference of crops to be cultivated. It only requires the implementation of soil and water conservation measures and also soil management practices.

Class III: Land holds extreme limitations for use and thus it requires vigorous soil and water conservation programs. Terraces are developed on medium level slopes.

Class IV: Land holds very serious limitations. The implementation of soil and water conservation measures is very problematic.

Class V: Land keeps all the properties of class I land with the limitations of low water, stoniness, rockiness or unfavorable climactic conditions that make it inappropriate to grow crops. Though, lands are used for grazing, forestry and pasture development.

Class VI: Land is characterized with similar limitations as for class IV land, but they are more intense and the land is steeper.

Class VII: Land is characterized with intense limitations for grazing and forestry. The land is very steep and either too wet or too dry and also characterized with erosion and gullies. The land is suitable for vegetation and forest purposes and for restricted grazing.

Class VIII: Lands are highly steep, stony or barren.

Among them, the first four classes of lands are used for agriculture or cultivation of crops. These four classes are differentiated based on the extent of soil slope, erosion, depth, structure, soil reaction and drainage. The classes from V to VIII are not capable of supporting cultivation of crops. They are for growing grasses, forestry and supporting wild life. The last four classes are delineated based on problems like stream flow, flooding, ponding, rocky nature, short growing season, snow cover etc. Classification of soils based on land capability helps in estimating soil resources available for different purposes and for appropriate use of soils without deterioration. Province wise land capability classification of Pakistan is shown in the Table 3.

Table 17.3 Land capability classification of Pakistan (Thousands hectares)

Class/Sub-class	Province						Pakistan	%
	Punjab	Sindh	KPK+FATA	Baluchistan	GB	AJK		
I	3486.4	1105.3	187.3	598.9	2.4	-	5380.3	6.10
II	3679.4	2336.2	524.4	481	145.3	14	7180.1	8.14
III	2395.1	1498.8	665.8	315.4	77.2	200.9	5153.2	5.84
IV	1439.9	838.5	581.6	929.2	105.5	225.8	4120.5	4.67
V	-	-	70.1	-	101.1	-	171.2	0.19
VI	261.8	8.3	827	84.6	114.6	306.6	1602.9	1.82
VII	4610.6	2454.2	2603.8	9294.7	869.4	20.9	19853.6	22.51
VIII	4159.7	3372.3	2974	22699.5	4364.1	510.4	38080	43.17
Total Classified	20032.7	11613.6	8434	34403.3	5779.6	1278.6	81541.9	92.45

Source: Soil Survey of Pakistan (2015)

The capability classification offers three main classes of soil:

17.5.1.1. Capability unit

A capability unit is collection of single or multiple soil mapping units that are characterized with similar capacities and continuing limitations. The soils in this class are appropriately uniform to (a) cultivate the same crops and grazing plants with similar conservation measures, (b) involve similar management and conservation measures under the same kind and condition of vegetative cover and (c) have equivalent production capacity. The capability unit combines and clarifies the information of soil so that individual tracts of land can be planned field wise. Capability unit with the class and subclass provides the complete knowledge about the level of limitation, conservation issues and the management practices required.

17.5.1.2. Capability Subclass

Subclasses are categories of capability unit that have similar conservation issues, such as:

Subclass e: This subclass includes the soils which are susceptible to erosion that ultimately affects their use. Soils in this subclass are mainly affected by erosion.

Subclass w: This subclass includes the soils which are characterized by excess water that limits their productive utilization. Low soil drainage, high moisture level, high water table and runoff are the major issues that devastate the soils included in this subclass.

Subclass s: Soils in this subclass have limitations within the root zone, like low depth of root zone, low fertility, low water holding potential and high salinity.

Subclass c: This subclass includes the soils that have limited use due to climatic factors like high temperature and low moisture. The class and subclass categories give detailed information about the level of limitation as well as the hurdles involved for planning and implementation of conservation programs.

17.5.1.3. Capability Class

The capability class is category of capability subclass or capability unit that has the same level of limitations. The risk of limited use of soil gradually increases from class I to VIII. The capability class provides the complete guidance on the soil map to the users. The classes show the available area, location and suitability of the soils for agricultural purposes. Information about soil limitations for agricultural purposes is obtained from capability class.

17.5.2. Land suitability classification

Land suitability is the potential of a fragment of land to produce the crops in a sustainable way. Its assessment offers the complete detail on the restrictions and opportunities for land utilization and thus helps for best utilizations of resources that are necessary for land use planning and development. Furthermore, such assessment helps to identify the major limiting issues for the agricultural sector and helps the decision makers like land users and planners to minimize such restraints by developing crop management. Land can be classified into spatially distributed agricultural productive areas on the basis of land use and soil properties (Bandyopadhyay et al. 2009).

Suitability of soil is evaluated by following the FAO framework:

S1: Extremely suitable land with no major limitations can be utilized for a certain purpose.

S2: Reasonably suitable land with limitation relatively severe for sustained utilization.

S3: Slightly suitable land with limitation severe for sustained utilization.

N: Not suitable land having limitation but can be improved with appropriate knowledge at minimum cost.

Such limitations are so adverse that land cannot be utilized in a successful manner without implementation of soil management techniques.

17.5.3. Suitability Sub-class

The sub-class describes the type of limits in a class. The factors for these limits are given below:

s- Soil texture;

d- Drainage;

c- Soil depth; low fertility

t- Slope (topography);

e- Erosion;

g- Coarse fragment;

f- Flood risk; and

n- Nutrient status

17.6. Concept of Land Use

Internationally, land is referred to as "a definable domain of the earth's terrestrial layer, including all characteristics of the biosphere directly beyond or under this layer, involving those of the near surface climate, the soils and the terrain types, the surface water bodies (including lakes, rivers, marshes, and swamps), the near surface sedimentary deposits, related groundwater reservoir, the plant and animal species, trend of urbanization and all effects of past and present human activities. Land is the most important natural resource that is essential for human existence and prosperity. Its precise use and organization affects both the extent and worth of the production and on-farm workforce;

i. The level of contamination/deterioration of land, water and air resources; and
ii. Stability of the biological frameworks that is fundamental for human existence (Siddiqui 1997).

Careful utilization of the prime resource not only certifies sustained provision of fundamental human necessities of food, fiber and shelter, but also refines the environmental conditions. Functions of land vary from time to time; people use the land for different purposes according to their preferences. The salient uses of land can be simplified and should be considered when defining land uses as follows:

- Land is a warehouse of all basic materials for human use.

- Land is used for the establishment of agricultural and industrial units to produce food, fibre, fuel and other biotic materials (production factor).
- Land provides space to build recreational areas, human settlement and social infrastructure.
- Land purifies the anthropogenic contaminants and also a source and a sink for gases that cause global warming.
- Land supplies water sources (surface and ground).
- Land delivers living environments for all living organisms.
- Land is fundamental for livelihood and security (a place to stay).
- Land is home for families and a base of social identity.
- Land is an area of spiritual and religious importance.
- Land stores the evidences from past records (fossils, evidence of past climate, archaeological remains, etc.).
- Land is essential to understand the individual liberty.
- Land is an entity of investment.
- Land is an entity to be taxed.
- Land is a basis of power and dependency.

Land use includes the four variables land, water, air and man and each has its specific role in its life history. Land establishes its body, water flows through its veins like blood, air provides it life and man behaves as a multifunctional agent to demonstrate its classes, configuration and distribution. In fact, man the user of land himself is the product of atmospheric behavior, hydrological action and lithospheric expressions.

"Man can survive without air for a few minutes, without water for a few hours and without food for a few days". The use of land likewise was limited. As human population increased, its demands also multiplied and became complicated. Accordingly, the utilization of land also enhanced. Consequently, the ways and technology of land use also modified. Man was making his own foot print upon the earth surface to depict his association, adjustment, construction and demolition. Land use requires a multi-disciplinary approach to arrive at sustained land use planning. Land use survey information should include details of physical, social and economic aspects along with environmental aspects in detail to find out the suitability, productivity, capability and potentiality for suitable land use planning, especially in the field of agriculture.

The concept of land use is a wide and complex which is linked with land, water, air and man. It has been used by man since time immemorial to fulfill his changing demand with the passage of time. Land with its varied topography, slope, field pattern, soil, temperature, precipitation, natural cover and countless creatures has to be planned suitably to engrave an economy whereby man can maintain a satisfactory standard of existence.

Sauer (1919) defined "Land use as the use to which the entire land surface is put". Land use is the most important resource for a human being. Man started using land since his origin to meet his requirements; such as food, fodder for the cattle, fuel and timber etc. With the continuous process of development, land utilization was determined according to human needs, which later on was converted into the land use pattern. Though there is a mutual conflict between the different forms of land use pattern; land is only a limited resource. But its ecology is also limited. The available land has certain priorities. Stamp (1962) stated that, the land as a whole must be so used as to satisfy to the possible extant the needs and legitimate desires as to satisfy of the people of the nation as a whole.

17.6.1. Major Concepts of Land Use

There are nine leading ideas regarding land use, these include:

1) Location or the relation of a scientific specific parcel of land to the poles, the equator and the major oceans and landmasses. There is also a connection between several territories of land and also political site.
2) Different actions on the land (for what reason the specific area of land is used).
3) Natural properties of land, containing all the features (above and below the subsurface) and its negative cover.
4) Developments on the land. It is linked to the activity.
5) Land use intensity (extent of activity per unit of area).
6) Land tenure, i.e. who owns the land and who manipulate it.
7) Land charges, land market interests and credit as applied to land.
8) Inter-connection among different social, economic and other activities on the land.
9) Inter-connection in the use among different areas of land.

Vink (1975) described the land use as any type of constant or periodic human involvement to fulfil human demands, either material or spiritual or both, from natural or artificial resources, which in combination constitutes land use classification. The five categories were forests, which are not suitable for growing crops, and other uncultivated land except current fallows, fallow land and net area sown.

Principles of Land Use

Land use principles provide the backbone of the directed growth strategy. They serve as a general framework by which future land use decisions will be guided. Each land use principle serves a purpose unto itself; however, when followed as a cohesive guide, the principles will best enable residents to achieve the desired future outcome.

17.6.1.1. Principle of Physical Determinism

The land use practice is influenced mainly by physical forces and processes. Diverse relief features (mountains, plateaus and plains etc.) give rise to different land use practices. All relief features are not equally suitable for a particular type of land use as each of them reflects its own peculiar physical characteristics and limitations.

Undoubtedly the plain is much more suitable than the plateau and mountain in regard to land utilization.

17.6.1.2. Socio-economic Determinism

Though the physical factors mainly control the land use practices, the role of socioeconomic factors can never be ignored. The socio-economic attributes include level of education, social behavior, economic status, infrastructural facilities, government policies, needs and desires of the people etc. Because of the difference in socio economic factors, land use pattern greatly varies between developed and underdeveloped countries. “Planning is best defined as an exercise, which attempts to harmonize the activities of different units of society,” (Gupta 1973).

The need for land use planning is urgent. If land use changes presented in the plan are to be accepted by the people involved, there must be political will and ability to put the plan into effect. Through proper planning the needs of individuals of the present generation and those of future generations can be identified in order to bring about the desired changes. “The land use is a historical process of development. For the future judicious utilization of land one needs, initially, to be fully aware of what happened in this regard in the past” (Graham 1946).

The two principles, which should dictate rational land-use planning are i) The land should be used for the purposes for which it is well suited, and ii) Land of high value for existing land use should not be modified, which are difficult to reverse.

17.7. Agricultural Land Utilization of Pakistan

Agricultural land is the area that is fertile and frequently with or without irrigation and agricultural land utilization involves all types of lands used for the production of crops. In developing countries, agriculture plays a central role in economic growth. For example, in Pakistan, about 70% population lives in rural sectors and depends on farming for their maintenance. Agriculture sector adds 21.4% to the country’s GDP and involves 45% of labor force (MOF 2014). With a total geographical area of 79.6 mha, Pakistan has currently 27% of it under cultivation, of which, 80% is irrigated. The country is blessed with largest percentage of irrigated lands used for agriculture crops or cultivated area in the world. The area under cultivable wastelands (8.9 mha) can be used for cultivation and cropped/cultivated area is also growing. In Punjab, land is mainly used for agriculture and 12 mha or 58.46% of the total land area is cultivated area. Categories of agricultural land use in Pakistan are described below:

17.7.1. Farm Area

Agricultural Census 2010 assessed that there were 8.26 million farms in the country covering an area of 52.91 million acres. The classification of farm area between small and large farms was extremely inclined. Farms consisted of 5 acres in size, comprised 64% (5.35 million) of the total farms but they covered only 19% (10.18 million acres) of the total farm area. However, the farms consisted of 25 acres and above in size, comprised only 4% (0.30 million) of the total farms but they covered 35% (18.12

million acres) of whole farm area. The normal size of farm in the country was 6.4 acres with 5.2 cultivated acres area. Pictorial categorization of farm area is shown in Figure 18.1 and province wise allocation of all the farms and farm region is presented in Table 4.

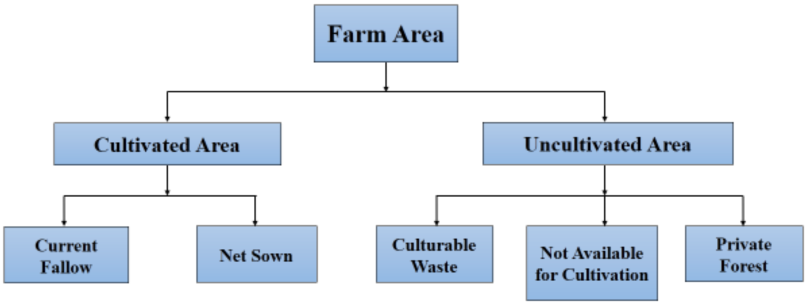

Figure 17.1. Pictorial classification of farm area

Table 17.4 Number of Farms and Farm Area by Province

Administrative Unit	Number of farms*		Farm area*		Average size (in acres) of farm	
	Number	%	Total	%	Farm Area	Cultivated Area
Pakistan	8.26	100	52.91	100	6.4	5.2
Khyber Pakhtunkhwa	1.54	19	5.57	11	3.6	2.9
Punjab	5.25	64	29.33	55	5.6	5.1
Sindh	1.11	13	9.87	19	8.8	6.9
Balochistan	0.36	4	8.14	15	22.7	9.7

Source: Agricultural Census (2010)

** = Number in million & Area in million acres*

17.7.2. Cultivated Area

Cultivated area is further divided into irrigated and rainfed areas on the basis of water availability. While on the bases of crop land use it is divided into net sown area and current fallow area. With an overall geographical area of 79.6 mha, Pakistan has currently 27% of it under cultivation, of which, 84% is irrigated and 16% is rainfed. In Pakistan, the proportion of irrigated agricultural cropped/cultivated region is too much in the world.

17.7.2.1. Irrigated Area

The area under irrigation during 1947-48 was about 8.71 mha that is expanded to 12.02 mha in 1966-67, illustrating the pre-storage time span. This was expanded to 13.63 mha in 1975-76 and more expanded to 19.02 mha during 2005-06. The irrigated area was doubled in 60 years that was mainly due to improved water supply system throughout the country. Province wise distribution of irrigated areas of Pakistan is shown in Table 5.

During 1947-48, the area under cropping was 11.63 mha that was expanded to 16.41 mha in 1966-67. This tremendous increase in the cropped area is because of the enhanced accessibility of the water through canals after Indus Water Treaty between Pakistan and India. Improvement in the uplifting of ground water for agriculture uses is also the cause of this increase. Similarly, country was cropping on 18.02 mha land area in 1975-76 that was expanded to 23.13 mha in 2005-06 that can be linked to availability of enhanced water supplies mainly from groundwater resources.

17.7.2.2. Rainfed Area

In the rainfed regions of Pakistan, the rainfall fluctuates between below 100 mm and above 1000 mm; with an average of around 400 mm. Pakistan has a dynamic climatic range from the most arid areas of the Kharan desert to the few warmest in the world in Jacobabad, Sibi to severe. Approximately 4.95 mha (12.23 acres) or 25% of all the cultivated area of the country is classified as rainfed. Roughly, rainfed agriculture was practiced in 15% of Punjab's total cropped area, 45% of area under Sindh province, 56% of KPK, 55% area of Baluchistan, 50% of FATA, 94% area of Azad Kashmir and certain regions of Northern areas.

Rainfed area in 1947-48 was about 2.92 mha and it was increased to 4.39 mha in 1966-67. This was remained same in 1975-76 and decreased to 4.11 mha during 2005-06. Province wise distribution of rainfed areas of Pakistan is shown in Table 5.

17.7.2.3. Net Sown area

The area sown is the land that has been sown at least once in a given year. According to agricultural census 2010, net sown area of the Pakistan was 41.06 million acres which was 96% of the cultivated area. While the KPK, Punjab, Sindh and Baluchistan have 97, 98, 98 and 79% of total cultivated area as net sown area, respectively (Table 6).

17.7.2.4. Current Fallow area

The fallow land is the land that has not been sown in a given year but was sown at least once in the preceding year. The division of cultivated area, net sown area and current fallow of different provinces of Pakistan is presented in Table 6.

Table 17.5. Province wise distribution of irrigated areas of Pakistan

Province	Land Area (mha)	Irrigated Area (mha)	Rainfed area (mha)
Punjab	20.63	13.8	3.09
Sindh	14.09	3.52	7.60
Balochistan	34.72	0.81	19.44
KP	10.17	0.89	5.59

Source: Asim et al. (2002)

Table 17.6. Cultivated Area by Province (Area in million acres)

Administrative Unit	Cultivated Area			Net Sown Area as % of Cultivated Area
	Total	Net Sown	Current Fallow	
Pakistan	42.62	41.06	1.56	96
Khyber Pakhtunkhwa	4.45	4.33	0.12	97
Punjab	27.04	26.45	0.58	98
Sindh	7.64	7.51	0.14	98
Baluchistan	3.49	2.77	0.72	79

Source: Agricultural Census (2010)

17.7.3. Rangelands

On the basis of aridity, 60% of the country is considered as rangelands, 48% of these rangelands are degraded. Rangelands are huge natural landscape of grassland, shurbland, wetland and desert. Rangelands are different from pastures because they grow as natural vegetation rather than plants established by humans. Rangelands are mostly used for livestock grazing in northern Pakistan. Baluchistan, which is around 45% of total country area, mainly depends on livestock production from its rangelands. Rangelands are an important part of the agricultural system of Pakistan that provide fodder for more than 93.5 million livestock population, fuel and timber and also a source of habitat for wildlife. These regions cannot be used for cultivation due to arid and semiarid climatic conditions and inadequate irrigated services. But, this enormous natural resource has pronounced potential for livestock grazing and dry afforestation. Different rangelands of Pakistan are presented in Table 7. Most rangelands in Pakistan are overused due to certain practices, customs and problems (Government of Pakistan 2007). Therefore, from time to time, the Government of Pakistan has issued a number of policy directives and recommendations for the effective management of rangelands in the country.

Table 17.7. Rangelands of Pakistan

Range Source	Area (mha)
Western Balochistan ranges	18.50
Central Balochistan ranges	8.00
Desert range lands	7.97
Eastern Balochistan ranges	5.00
Trans-Himalyan grazing lands	3.50
Kohistan ranges	2.38
Alpine pastures	1.68
Pothwar scrub ranges	1.68
Suleiman mountain ranges	1.50
Himalayan forest grazing lands	0.67

Source: Farooq et al. (2007)

The Ministry of Agriculture and Works, Government of Pakistan, issued the first Range Policy Directive in 1962. The Ministry of Environment, Government of Pakistan, drafted a new National Forest Policy in 2002, which has been submitted to the Cabinet for approval. This policy suggests technical and financial assistance of the Federal Government to the Provincial Governments for rehabilitation and conservation of rangelands in different parts of the country. Rangeland improvement measures include; **a)** Micro-catchment water harvesting methods like ridge development for shrubs formations, **b)** V-shape plants rehabilitation designs, **c)** Fodder reserves establishment for grazing by planting shrubs tolerant to drought stress such as atriplex and acacia species, **d)** Growth of grass species such as *Symbo* and *Chryso* in provinces of Baluchistan and Punjab. Further expansion of the development measures for utilization of these range lands is yet restricted. To fully make use of these lands require the participation of local community and motivation through social parameters.

17.7.4. Wastelands

Wastelands are uncultivated or barren lands which have been used for cultivation in the past, restrained and devastated by some unexpected and sudden environmental changes as flood, storm, or war due to which further use of these pieces of land found to be impossible (Stamp 1962). Complete loss of uppermost fertile soil makes an area ecologically unstable; growth and development of both annul crops and trees badly affected due to accumulation of toxic substances in the root zone (Bhumla and Khare 1987). Wasteland classification scheme is shown in the Figure 18.2 where they are grouped into two classes as culturable and unculturable wastelands.

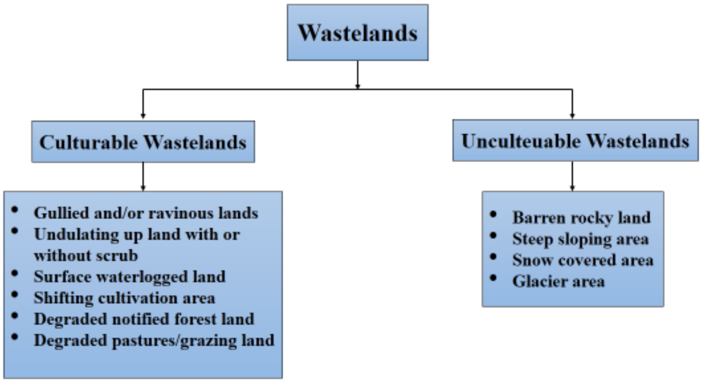

Figure 17.2 Wasteland classification scheme

17.7.4.1. Culturable Wastelands

Culturable wastelands are those areas which can be brought under cultivation after suitable amendments. Generally, these lands have potential to develop vegetation but not being used due to various biotic and abiotic constraints. Growth of different type of vegetation depends upon land capability which ultimately depends upon factors like soil topography, climatology, land proprietorship and tenure system etc.

There are six types of wastelands which are described below:

Gullied land/Ravinous Land

A gully is a landform shaped by running water, eroding sharply into soil, usually at sloping sides of mountains. Gullies appear like large ditches or small valleys and are meters to tens of meters deep and wide. During the development of gully, the water flow rate can be considerable, triggering the substantial deep cutting action into soil. Gullies are first step towards undue land segmentation trailed by making network of gullies which further developed into Ravinous land. Large number of gullies runs more or less parallel to each other in deep alluvium and enters an adjacent river flowing much lower than the surroundings called Ravinous land.

Undulating Upland With or Without Scrub

This land is of undulating type vulnerable to deterioration. This may or may not have scrub cover. Topographically such lands are located at high places with 3° to 10° slope having flat tops just like stand stones, laterite and basaltic plateau regions having gentle tops and gentle to moderate slopes.

Surface Waterlogged Land

This land has water table either at surface or near the surface and water usually stands for long time period throughout the year. Waterlogging arises from the increase of sub-soil water table and approximately all irrigated areas suffer from this situation. Usually, this issue happens in the areas that have canal irrigation system and as a result of seepage of water, the sub-soil becomes water-saturated and also in the areas of defective drainage often liable to inundation either due to bank flows of river water or lake or sea water etc. Waterlogging can also be viewed as the phenomenon due to rising trend in the sub-soil water either due to massive irrigation or storage of rain water in lower areas as a result of seepage from the unlined canal banks retarding the plant growth.

Shifting Cultivation Area

Such land develops due to cyclic land use including felling of trees and burning of forest zones for cultivation of crops. This situation causes land degradation due to immense soil losses.

Degraded Notified Forest Land

Lands as declared according to forest act and those lands with different forms of forest cover in which denudation of vegetation cover is below 20% of canopy cover are considered as degraded land.

Degraded Pastures/Grazing Land

All those grazing areas in non-forest zones, whether or not they are permanent pastures or meadows, that have converted to degraded lands as a result of inadequate soil conservation and drainage strategies grouped in this class.

17.7.4.2. Unculturable Wastelands

These are the land areas that cannot be employed for vegetative cover. The land that is infertile and cannot utilized intensively like agriculture and forest cover is unculturable wasteland. These include barren rocky lands, steep sloping areas and areas covered by snow or glaciers.

17.8. Land Use Problems

The main problem of land use includes under-utilization, over-utilization and mis-utilization of land. The land available for agricultural and other purposes is finite and limited. The ever-increasing pressure of population and decreasing land-man ratio poses challenging problems to the land-use planners and agricultural geographers. To avoid some of the problems, a critical examination of land-use is essential. Non-agricultural uses such as housing colonies, industrial estates and roads are putting ever-increasing competitive demand on land, especially the prime agricultural land around cities. In addition to this, degradation process of soil erosion and water logging are also adversely affecting the productivity of this valuable resource. Land being the key element and basic resource for agricultural production system has to be exploited in a manner that harmonizes with climate and soil characteristics for providing sustenance on long term basis. Soil damage through degradation process such as soil compaction, salinity and sodicity associated with poor drainage has affected the agricultural productivity. A scientific approch is the basic requirement for a viable land use plan. There are innumerable problems, which may affect land use in a particular area e.g.

i) Soil Erosion

Soil erosion involves the loss or exclusion of surface soil matter due to moving water, wind or ice. The range of area damaged by water and wind erosion is presented in Table 8 and 09, respectively. Different classes of soil differ in their vulnerability to erosion. Soil erosion mostly prevails in Alfisols, Entiosols, Inceptisols and Mollisols. Water erosion frequently occurs either in active flood-plains or on sloping hills. The soils in Indus basin are contemporary and immature. Nearby highlands have some of the world's largest slopes. Extreme summer rainfalls, along with melting of snow at high hills, add to the threats of soil erosion. Land use systems, vegetative cover, type and composition of soil are other most important aspects regarding soil erosion. For example, loose soils of Pothowar Plateau are susceptible to water erosion and have possibility for gully formation, extensively removing fertile topsoil.

Table 17.8 Areas affected by water erosion in Pakistan

Degree of erosion	Province (area in "000" hectares					Pakistan
	Punjab	Sindh	KPA+FATA	Baluchistan	G.B	
Slight (Sheet and Rill)	61.2	-	156.3	-	180.5	398.0
Moderate (sheet, Rill)	896.8	-	83.8	1805.0	25.8	3581.4
Severe (Rill, Gully, steam bank)	588.1	58.9	1765.1	829.6	504.2	3745.9
Very severe (gully, pipe, pinnacle)	357.9	-	1517.0	-	1571.6	3446.5
Total	1904.0	58.9	4292.2	2634.6	2282.1	11171.8

Source: Soil Survey of Pakistan (2015)

Table 17.9 Areas affected by wind erosion in Pakistan

Degree of erosion	Province (area in "000" hectares)					Pakistan
	Punjab	Sindh	KPA+FATA	Baluchistan	G.B	
Slight	2251.4	295.0	13.1	36.0	-	2595.5
Moderate	279.1	70.2	3.8	143.6	-	496.7
Severe to very severe	1274.0	273.8	19.6	100.9	-	1668.3
Total	3804.5	639.0	36.5	280.5	-	4760.5

Source: Soil Survey of Pakistan (2015)

Wind erosion takes place in low rainfall zones, like Thar, Thal, Cholistan and in massive parts of Balochistan. The proximate physical reason of erosion is the overall aridity. Erosion is pronounced in occupational areas and also in those livestock grazing areas that are closed to watering points. The prime cause of degradation is the misuse of rangelands for fuel wood production and livestock grazing. Globally, influence of wind erosion is dominant in regions where sand dunes are flattened for irrigation of crops. These areas assumed the form of 0.5 m to 4 m high moving sand dunes causing hazard for cultivated land structure. Approximately, 3.5 mha are severely deteriorated by wind erosion. The extent of soil removed by wind is around 28% of total loss of soil. Strong windstorms force the movement of sand-dunes, setting down dense covers of sand on roads, railway tracks and croplands and threat the local citizens. Organic matter and other soil nutrients including soil particles are misplaced during movements.

ii) Salt Affected Soils

Pakistan lies in arid and semiarid climatic areas of the world. High evapotranspiration in these regions is the main reason for setting of salt at soil surface. Mean summer temperature in plain areas of the country goes upto 40°C and sometimes as high as 50°C in Jacobabad, and the minimum winter temperature ranges between 2°C and 5°C in hilly areas. Most of the rainfall is in moonsoon in the month of August and September and mean annual rainfall ranges from 100 mm in southern parts of Pakistan to 760 mm in some northern parts. The evaporation is usually very high and exceeds precipitation by a factor of more than 3 and 22 in Northern and Southern regions, respectively.

Table 17.10 Soils affected by salinity and sodicity in Pakistan

Degree of erosion	Province (area in "000" hectares)					Pakistan
	Punjab	Sindh	KPA+FATA	Baluchistan	G.B	
Surface patchy						
Irrigated	472.4	118.1	5.20	3.0	-	598.7
Un irrigated	-	-	-	-	-	-
Gypsiferous saline sodic						
Irrigated	152.1	743.4	-	76.6	-	972.1
Un irrigated	124.5	428.8	-	160.1	-	713.4
Porous saline sodic						
Irrigated	790.8	257.0	25.7	29.4	-	1102.9
Un irrigated	501.0	150.1	7.8	73.5	-	732.4
Dense saline sodic						
Irrigated	96.7	32.5	0.9	-	-	130.1
Un irrigated	530.0	379.7	8.9	159.5	-	1078.1
Total	2667.5	2109.6	48.5	502.1	-	5327.7

Source: Soil Survey of Pakistan (2015)

Insufficient and erratic rainfall coupled with high evaporation and shallow depth of ground water in Pakistan enhances the upward movement of salts in soil surface. Irrigation water is another source that causes salinization. Although irrigation water depletes salts for some time at soil surface, yet the eventual influence of irrigation water is to improve salts. Inadequate irrigation water to leach salts completely, the problematic is further intensified. In Pakistan, soil solution consists of Ca^{+2}, Mg^{+2}, Na^{+1}, CO_3^{-2}, HCO_3^{-2}, SO_4^{-2} and Cl^-. High temperature and low rainfall resulted in increased concentration of these ions and precipitation of $CaCO_3$ and $CaSO_4$ and coupled with upward movement and accumulation on the soil surface. Pakistan's agriculture is facing sever salinity problems. Sindh and Southern Punjab regions are facing these problems more severely as compared to the others. The degree of salt affected regions is presented in Table 10.

iii) Waterlogging

Water logging is the phenomenon in which underground water reaches at the land surface and in certain cases it stores at the land surface and may become the streams. Consequently, the lands become unable to support the plant growth. In some cases, the underground water does not reach at the land surface but remains moderately lower and salts accumulated in the rhizosphere and also cause salinity problem. About 38% of Pakistan's irrigated lands are waterlogged and 14% are saline. Irrigated agricultural areas are most probably facing waterlogging conditions in Sindh. Salt accumulation in the soil profile and oxygen deficiency problems decreases the soil productivity. Drought situation considerably helpful in lowering waterlogging conditions as drought reduced waterlogged area 42% and 32% in 1980 and 2003, respectively and it continuously on decline in area having water table depth of more than 3 m (WAPDA 2006).

Table 17.11. Province-wise waterlogged area in Pakistan during 2006

Areas	Total surveyed area (million ha)	0-1.5 m	1.5-3.0 m	Total <3 m	>3 m
Punjab	10.0	0.56 (6%)	1.38 (14%)	1.94 (20%)	8.03 (80%)*
Sindh	5.7	3.04 (53%)	1.60 (28%)	4.63 (81%)	1.10 (19%)
KPK	0.4	0.40 (100%)	0.02 (0.5%)	0.40 (100%)	
Balochistan	0.6	0.02 (3%)	0.13 (22%)	0.15 (25%)	0.44 (75%)
Total	16.7	4.01 (24%)	3.11 (19%)	7.12 (43%)	9.56 (57%)

*Area with percent of area to the total surveyed area in parenthesis

Source: Salinity and Reclamation Directorate, SCARP Monitoring Organization (SMO), WAPDA, Lahore, 2006.

Water and Power Development Authority (WAPDA) categories land as water logged having water table depth of less than 3 m. Areas having depth of water tables ranges from 0-15 m and 1.5-3 m are categories as severely and less severely waterlogged areas, respectively. Extent of waterlogged areas is presented in Table 11.

iv) Leaching

Leaching is a process by which soluble materials such as mineral salts and organic matter are washed out from the upper layer of soil into the lower layer by percolation of rainwater. High temperature and heavy downpours favor the degree of decomposition of rocks, which causes exhaustive leaching within the soil profile. For example in the Laterite areas of the tropical region leaching is predominant. Heavy leaching arising out of high rainfall accelerates the process of humidification and mineralization, which keeps the surface low in organic matter thereby affecting the land use is affected.

v) Bad Effect of Pesticides

Use of pesticides deteriorates the quality of land-use through the contamination of air, water and soil. There are some of the direct consequences arising out of pesticides on land. When pesticides are exposed to environment, these not only destroy the harmful insects but also destroy the microbes beneficial to the plants, nitrogen enriched green foliage of plant tissues attract the insects. Due to the lower intensity of solar energy during winter, blight and crop diseases are caused, pesticide residues on plant tissues/ leaves/ soil undergo photo-chemical reaction under broad daylight and thereby cause photo-toxicity, pesticides hinder the microbial activity in the soil and thus the organic matter synthesis is hampered. The humus formation in soil, as a result, becomes impossible. Consequently, soil suffers from prolonged nutrient deficiency.

vi) Drought Hazards

Any type of land-use practice needs water. Drought is an environmental hazard, which reflects deficiency of water in a particular region. It may be mentioned that prolonged dryness causes drought conditions, which depend on the amount of rainfall, its departure from the normal annual average and demand of water for multipurpose uses. Drought poses a serious bearing in the biospheric system. The cumulative effects of prolonged drought cause extensive and enormous damage to natural vegetation and agriculture. Thus, deficiency of water hinders optimum utilization of land.

17.9. Trend of Land-use Change in Pakistan

17.9.1. Land-Use Change

Land-use change or land-cover change is referred to as the transformation of the terrestrial canopy of the Earth. It can be defined as change in activities on the land that result in conversion of one type of land cover to another. Yet human beings are modifying land for their purposes such as to obtain food, housing and other necessities for centuries however rate, extent and intensity of land modification in the recent past has no bound and this modification in land use, ecosystem and environmental processes is increasing uncontrolled.

Land use is getting high pressure on it due to increasing population and growing socio- economic needs. Due to such pressure, dramatic changes occur in land use (Seto et al. 2002).

Most of the agricultural and vegetation areas are converting into urban areas. The conversion of agricultural land into urban areas invites more population towards it, resulting in multiple issues. Higher the population in an area more is the land consumption demand and so is for food. These changes in land use usually result, when management fails in handling agricultural and urban fields and resources, which in turn result in the form of critical environmental anomalies. Every patch on surface of earth possesses a unique cover. Despite of being diverse in its nature, land use is quite closely linked with the characteristics of the surface of earth. Any alteration in the land use directly affects the land. It is not imperative that this change always occurs in the form of land degradation. Nevertheless, this change is result of large number of social causes, somehow affects the climatic conditions and biosphere too (Dewan and Yamaguchi 2009; Ahmad et al. 2013). Measuring the land use change of an area is much more important in monitoring, preserving, evaluating and planning of the land resources of that area. It also provides quantitative data for interpreting and forecasting the future change and its possible effects. It's a major issue for eco-friendly sustainable development. History, culture, political situation and economy of any area have direct impact on the land use patterns. Modification in land for human needs causes changes in natural land features like forest cover, water bodies, concrete cover and soil cover.

Need for food and other utilities for a population exceeding six billion people requires more land resources which are engulfing the forest and natural vegetative area (Turner et al. 2007). Nearly whole of the world is under the influence of rapid land use for cropping, housing, industrialization, and other human activities. This tremendous increase in the use of land for agricultural and population pressures making the resources limiting and scars. Therefore, to study, observe and measure the land use changes is the dire need of the day for better utilization and planning of land resources. This will help to combat the increasing demands of humans for food and other basic needs.

17.9.2. Impacts of land use change

(i) Socioeconomic Impacts

For the economic and social development of a country, land use change is crucial and necessary. But for this transformation, a nation has to pay a lot. Alteration of forest area and vegetative cover into cities decreases the land area being used for food, timber and lumber production (Lubowski et al. 2006). At one hand, land use change paves the way for urban development socially and economically while on the other hand society has to bear massive cost for these benefits. The importance of land conversion cannot be denied for long term progress of a society for economic growth and sustainable urban development.

Socioeconomic Impacts of Land-Use Changes are described below:

- Urban development decreases the "critical mass" of farmland essential for the economic existence of local agricultural economies.
- Urban development has evaded to some rural areas in such a way that communities in those areas have lost their identity.
- Excessive land use control, however, may hamper the role of market forces.

- Deforestation and agricultural production degrade the soils which results in eroded, saline and deserted soil. All this lowers the land quality which ultimately causes reduction in crop production.
- Urban development designs directly affect the way of living of individual human and also disturb the ordered society.
- Laws and regulations regarding land use in urban areas will increase the prices of land and house which will create a problem for lower income class.
- Alteration of natural forests into cities will reduce the natural open space and will affect the local environment of the area.
- Modification of forests and farmlands into cities will reduce the land for food, timber and lumber productions.
- Urbanization will also draw a line between communities on the basis of income.

(ii) Environmental Impacts

Land-use change is conceivably the most prevalent socioeconomic force driving variations and degradation of ecosystems. Environmental effects of land-use changes are given below:

- Natural resources such as water, soil, air etc. have been affected by alteration in land use.
- Agriculture through artificial irrigation has disturbed the water cycle which consequently lowers level of the groundwater in many parts of the world.
- Runoff from agriculture is polluting the terrestrial and oceanic water bodies.
- Intensive farming and deforestation may cause soil erosion, salinization, desertification, and other soil degradations.
- Draining of wetlands for agricultural purposes and diverting the irrigation water had disturbed the habitat of many wildlife species.
- Urban development causes air pollution, water pollution, and urban runoff and flooding.
- Deforestation for agriculture and urbanization increase the greenhouse effect. It also disturbs the water cycle resulting in climatic changes that leads to soil erosion, floods, runoff and landslides. It has serious threat not only for human life but also for other terrestrial and marine life.
- Urbanization has destroyed and fragmented the natural habitat for wildlife which is the basic reason for their population reduction and species extinctions.

17.9.2.1. Methods for assessment of land-use change

Remote Sensing (RS) and Geographic Information System (GIS) both have been considered the most operative tools and are extensively implemented in recognizing the spatio-temporal dynamics of land-use and land-cover (LULC). RS is a cost effective method to obtain multi-spectral, multi-temporal and real time statistics and converts it into information that is important for interpreting and monitoring land development trends and systems, and for building land-use data sets. GIS has powerful function of storing, analyzing, and displaying geo-referenced data important for change analysis. The collective use of RS and GIS has immense benefits in contrast to conventional methods and is highly successful in analyzing dynamic alterations of the land use/land cover.

With the help of RS, the investigators can have productive multi-temporal data for observing land-use trends and processes while GIS techniques are used for analyzing and mapping of these patterns. GIS and RS technologies are important mechanisms for analyzing modifications in land-use. Remote sensing data with improved resolution at different time interval supports in evaluating the rate of changes and also the causes behind such changes (Ramachandra and Kumara 2012). Both, GIS and RS tools have been collectively applied in recognizing the land use changes which are simple and less time consuming than conventional method of surveying (Dacosta et al. 1999).

(iii) Main Drivers of Land-use Change

The leading reason of land use modification is change in social preferences and intensified needs for human existence. Human behavior is contributing a prime role to land use modifications and also other global dilemmas like climate change and environmental degradation through contamination (Turner et al. 1995). Land-use change has become an indispensable concern for researchers in the areas of natural resource management and environmental protection. Since the last 40 years, the forest land has altered into agricultural land and the main reason of land use change has been increased requirement of food due to population growth and other economic developments (Prakasam 2010).

17.9.2.2. Population growth

With population expansion, people tend to shift from less developed areas to urban regions. So as to meet the requirements of people, forests are cut down to develop agricultural areas. With rapid population growth, the industrial and urban sectors demand more water. On the contrary, ground and surface water sources are depleting day by day. Vegetation has great importance for survival of people in terms of food and shelter.

Pakistan is an agricultural country. According to estimate of 2015, population of Pakistan was more than 191.71 million (Pakistan Census 6 2015). Environmental, physical and human aspects are the main sources of land use change in Pakistan. This rapid growth in population causes fast urbanization and transformation of agricultural zones into built up areas and the forest land into both agricultural and built up areas. Because of enhanced advancement, educational betterment, and urbanization, Pakistan is suffering from widespread land use conversions since last ten years. The percentage of total population residing in urban sectors has expanded from 17.8% in 1951 to around 32.5% in 1998 and 37% in 2011 (Govt. of Pakistan 2011). Increasing population growth and density are the main causes of (land use/land cover) LULC changes and urban sprawl. Urban population growth requires more urban services like construction of residential and commercial areas, public utility and road network infrastructures. As a result, agricultural, forest, farm and barren lands are causing LULC changes and urban sprawl.

According to the 1998 Census Report, Pakistan's urban and rural population growth rates were was 4.4% and 2.6% per annum, respectively. In 2013, the population of 15 cities of Pakistan was more than one million, while in 2020 the population of more than 20 cities will be above one million. By the year 2030, the urban population of Pakistan will be around 49.8% and still there is no national urban planning to manage the land for sustainable utilization (United Nations 2009). Population expansion is one of the substantial phenomenon that leads towards the extension of cities in any direction. Besides population growth, economic and technological developments are causative factors of rapid urban growth in terms of sub-urban expansion and also cause alterations in the city center. Therefore, an understanding of land use pattern is the need of time for natural resources utilization planning and the provision of infrastructure facilities (Sudhira et al. 2004).

17.9.2.3. Fast growing urbanization

Urbanization requires more and more land that eventually put pressure on suburban rural land and alters the way of land use of specific area. As urbanization intensifies, conflict between agricultural and non-agricultural land becomes more problematic (Lynch and Carpenter 2003). The process of urbanization is one of the key dimensions of economic, social and physical changes in developing countries can be defined as "when growth rate in cities is greater than rural areas, it is called urbanization". The process of urbanization causes modifications in land surface and atmospheric characteristics of a particular area because vegetation decreased and replaced by asphalt and concrete (Oke 1987).

Pakistan's urban population has increased from 25% to 35% during the time period of 1975-1995. According to an assessment of United Nations, the urban population will intensify from 35% in 1995 to 60% in 2025. Rapid urbanization brings several environmental problems like air, water and noise pollution and waste disposal, global warming and runoff and all these problems result in poor living environment (Weber 2003). Globally, abruptly growing population density has caused severe surface and ground water contamination problem. These changes seriously influence the local and regional environment that finally influences the global environment.

Unrestrained urban sprawl is engulfing vegetative cover of landscape which in turn altering the way of land use of urban periphery. Urbanization is a potent leading cause of LULC changes. Rapid population and economic developments also influenced the expansion of urban areas (Shalaby and Tateishi 2007). Thus, the urbanization that is linked with economic and social infrastructure is considered as the transformation process of agricultural based society to a current metropolitan society. In Pakistan's point of view urbanization can also be viewed as the segment of people lived in urban zones of any country later on converted to settlement, which comprises of 5000 or more people, covered with specific criteria comprises civic services, socioeconomic base and access of basic infrastructure.

Urbanization also promotes tourism industry that has modified the natural land covers into complex network of roads and recreation buildings (Baban and Yusof

2001). Like other developing countries, Pakistan is also facing a rapid intensification in urbanization and population since the recent decades and land use conversion will continue to increase dramatically for coming years.

17.9.2.4. Deforestation

Forests deliver lot of services related to ecosystem. They provide natural habitat to wildlife thus sustain biodiversity. Forests absorb CO_2 from the atmosphere, intercept precipitation, and retard surface runoff, and decrease soil erosion and flooding. Forests also provide construction timber, fuel wood and medicinal plants and protect land and soil on steep mountain slopes (Khan 2009). These vital ecosystem services will be reduced when forest areas are transformed into agricultural systems or urban areas. Likewise, deforestation due to urbanization, agricultural growth and other human actions has considerably reduced the earth's vegetative cover. As a result, global atmospheric concentration of carbon dioxide has increased and energy balance of earth's surface has changed that affect local, regional, and global climate (Marland et al. 2003).

Clearing the forest land for cultivation of crops and construction of buildings is a traditional practice (Ramankutty and Foley 1999; Acevedo et al. 2008). The global forest area is about 3952 mha (30% of the world's land area), but the rate of deforestation between 2000 and 2005 was 12.9 mha per year, that was attributed to agricultural and urban development (FAO 2006). The prolonged tenure of lessening of cover of tree's canopy lesser than 10% threshold or alteration of forest for several land use practices is broadly considered as 'deforestation' (Anonynous 2007).

Table 17.11 Forest cover change (Conifer) from 1992-2010 in Pakistan

Province/Territory	Status of vegetation cover (000 ha)					Annual change rate % (Base year 1992)
	1992	1997	2001	2005	2010	
Khyber Pakhtunkhwa	940	805	858	840	845	-0.56
Punjab	30	34	34	38	41	1.22
Sindh	NF	NF	NF	NF	NF	
Balochistan	42	39	35	32	30	-0.6
N.As.	660	312	318	301	285	-0.08
AJK	241	289	267	288	272	0.71
Total forests	1913	1479	1512	1499	1473	-1.27

Source: Soil Survey of Pakistan (2015); NF = Not found

In Pakistan, conifer forests are primarily found in KPK, Azad Jammu and Kashmir (AJK), Northern Areas, Balochistan and northern Punjab. They are established at heights ranging from 1,000 to 4,000 m. The areas like Mansehra, Dir, Swat, Malakand, and Abbottabad districts of KPK, and Rawalpindi district of the Punjab are primarily surrounded by these forests. Alteration in conifer forest cover in different provinces of Pakistan from 1992 to 2010 is presented in Table 12.

The forests are being transformed into agriculture and other land uses with expanding density of human population. This change is an alarming risk to existing forest yield (Daniel et al. 2005). Forest area is highly vulnerable to land use transformations due to a number of reasons like natural, cultural, social and economic pressures (Lambin et al. 2003). About 6 mha of the world's forest area has a possible hazard to be transformed into agriculture land for human subsistence (Verburg et al. 2006).

17.9.2.5. Natural disasters

Pakistan suffers from various natural disasters like floods, earthquakes, landslides and droughts that are responsible for thousands of deaths and widespread destruction of land and other natural resources. In Abbottabad region of Pakistan, the significant cause of land use change has been 2005 earthquake that tend the people to move from nearby affected areas to this region. This situation has intensified the demand of residential and commercial areas. Consequently, forest, agricultural and grass lands have been converted into housing and commercial areas.

Due to lack of suitable land-use planning and policies for sustainable development, the hazards of commercial developmental and construction projects have led to sinking water table, contamination of water sources, and flood like conditions during heavy rains and increasing traffic and air pollution problems. These issues traditionally were not attributes of district Abbottabad. These changes have the capacity to undermine the long-term harmonious people-environment interaction. Therefore, it is indispensable to analyze the alterations in land use for planning and implementation of land use schemes.

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Chapter 18

Problem Soils in Pakistan

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Abstract

The difference of soils depends upon the intended uses of those soils and none of them can be categorized as good or bad soil. However, the soils which have specific inherited characteristics that resist to its desired use can be categorized as problem soil for that specific desire i.e. agricultural use in this scenario. The soils which have lost their inherited characteristics due to unwise use or unsustainable management interventions are being categorized as degraded soils. In the recent scenario, problem soils term will be used for both problem as well as degraded soils. Problem soils can be further classified to salt affected soils, waterlogged soils, eroded soils, compacted soils, desertified soils, low fertility soils and low organic matter soils. Pakistani soils are facing many of these problems; however, in this chapter salt-affected, waterlogged and eroded soils will be discussed along with their management strategies.

18.1. Introduction

Soil is the upper most loose layer of earth crust which supports the life; as it provides habitat for millions of the living organisms. Soil is the basic component of agroecosystem which provides us food, fiber and fuel. It plays important role in water filtration and purification, growing medium for plants, improves the biodiversity and provides the antibiotics to control the diseases. The soil has immense importance for

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a civilization and it is the base of agriculture productivity and acts as a habitat for human beings (Zachar 1982). It supplies the nutrients and moisture for growth of plants as a basic requirement (Okigbo 1991). In short, the global study related to food production and other natural resources is associated with soil (Hartemink 2003). World population is rapidly increasing that in turn increases the food demand and large part of the world's population has inadequate nutrition. Therefore, it is a necessary to enhance and sustain the food production to combat the need of increasing population which can be attained by sustainable and judicious use of soil resources. Thus, healthy soils can play a key role in sustaining life.

Soil sustainability must be achieved by using affordable and available resources of the farmers and this is necessary for the government to accept it as a challenge and create good policies for farmers, and for the development of healthy environment. There are many problems that affect the soil quality and become the main cause of reduction in crop production; like soil erosion (wind and water) (Lal 1998), desertification due to anthropological activities and poor soil covering (Gad and Abdel-Samie 2004).

The loss of organic matter and deterioration of soil quality are the result of soil issues, such as salinity, waterlogging, soil erosion, and ultimately decreased crop yield, if not managed properly (Gachimbi et al. 2002). The major constraints to soil sustainability due to nutrients losses are basically related to these aforementioned soil problems (Okigbo 1991; Gomes et al. 2003).

Soil salinity and sodicity, waterlogging and soil erosion are the major problems of Pakistani soils which reduce the crop yield and soil quality. Salinity is a major threat to Pakistani soil in arid and semi-arid regions where annual rain fall is insufficient to leach the salts from rhizosphere. When the precipitation is lower than the evaporation, the upward movement of underground water accumulates the salts in the root zone, ultimately causing the nutrient imbalance and decreasing water potential. The economic utilization of such soils with state-of-the-art practices, evaluation tools and policy interventions are direly needed (FAO 2017).

The leakage of the water from main canals, distributaries, main water courses is the major reason of raised water table in many areas of Pakistan. Apart from it, during monsoon season the construction of buildings, roads and other engineering works cause the hurdle to move excess water to down lands and it raises the ground water table causing, ultimately, water logged situation. When excess amount of water is stored in the root zone, it affects the plant growth and reduces the yield.

Around 16 million hectares (ha) land of Pakistani soils is affected by soil erosion directly or indirectly, that is 20% of total Pakistan area. From it 11.2 million ha are affected by water erosion only. In Potohar region, annually rain water is lost in a huge amount. This is because of high intensity of rainfall and lack of awareness to manage and harvest of this water by the farmers. The fertile cover of the soil is removed by the beating action of rain water as well as flood severity in the down land region.

18.2. Salt-affected Soils

Salt-affected soils are characterized by the excess of soluble salts, exchangeable sodium or both which have been accumulated on soil surface or in the root zone. Problems due to accumulation of salts in soils are critical in the middle and far-east countries where population is increasing at a rapid rate, e.g. India, Pakistan, Bangladesh and China. Salt-affected soils are generally divided into three main classes, i.e. saline, sodic and saline-sodic.

A soil having enough amounts of soluble salts to adversely affect the growth of most crop plants, but not containing excessive amount of exchangeable Na^+ is termed as **saline soil**. Most of the soluble salts in saline soils are composed of cations (Na^+, Ca^{2+} and Mg^{2+}) and of anions (Cl^-, SO_4^{2-}, and HCO_3^-). Small quantities of cations K^+ and NH_4^+, and anions NO_3^-, CO_3^- and BO_4^- are also present in these soils. Saline soil extract has EC > 4 dS m^{-1}, SAR < 13 (mmol $L^{-1})^{1/2}$, ESP < 15 and soil pH < 8.5. These soils are also called as "***white alkali***" and in Pakistan these soils are also called as "***Thur***".

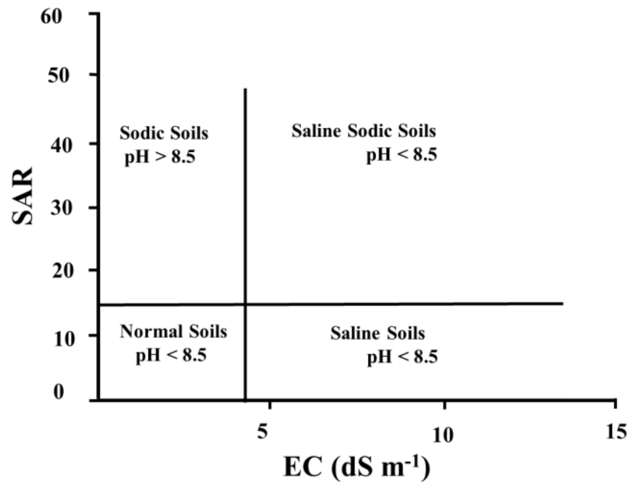

Figure 18.1 Diagram illustrating the classification of normal, saline, saline sodic and sodic soils in relation to Soil pH, electrical coductivity (EC) and sodium adsorption ratio (SAR). (adapted from Brady and Weil 2014)

A soil having enough amount of Na^+ at exchange sites of soil particles to adversely affect the growth of most crop plants, but does not contain excessive soluble salts is known as **sodic soil**. Soil structure, aeration and hydraulic conductivity are deteriorated by the excessive amount of exchangeable Na^+. Sodic soil extract has EC < 4 dS m^{-1}, SAR > 13 (mmol $L^{-1})^{1/2}$, ESP > 15 and soil pH ≥ 8.5.

A soil having both soluble salts as well as exchangeable Na^+ in sufficient amount to adversely affect the growth of most crop plants is termed as **saline-sodic** soil. A saline-sodic soil has $EC_e > 4$ dS m^{-1}, SAR > 13 (mmol $L^{-1})^{1/2}$, ESP >15 and soil pH ≥8.5. These soils are called as "**black alkali**" and in Pakistan also named as "**bara**".

The province-wise distribution of salt-affected soils in irrigated and non-irrigated areas of Pakistan is given in Table 18.1.

Table 18.1 Distribution of salt-affected soils in irrigated and non-irrigated areas of Pakistan (M ha)

Soil type	Punjab	Sindh	Khyber Pakhtunkhwa	Baluchistan	Pakistan
Saline	0.51	1.34	0.50	0.18	2.52
Sodic	-	0.03	-	-	0.03
Saline-Sodic	2.08	0.95	0.02	0.13	3.174
Total	2.59	2.32	0.52	0.31	5.72

Source: *adapted from Muhammad (2013)*

18.2.1. Sources and Origin of Salts

The main source of salts in soils is the primary minerals in exposed rocks or layers of the earth crust. Soil salination may originate from a combination of frequently interrelated sources. However, weathering of rocks and minerals in the earth's crust is the primary and chief source of all soluble salts present in soils and seas. Although, the salts currently occurring in the ocean arise mainly from the weathering processes of the earth's crust and, thus, ocean functions as an important source for redistribution of salts. The main origin of salts for a specific area can be any one or combination of several sources as described below.

i. Parent material and weathering processes

Salt formation in soils occur mainly due to weathering processes, however under humid conditions, salts leach through soils and are transported to the nearby streams and rivers. Therefore, inland salt-affected soils are rarely formed in humid areas. But under arid and semi-arid conditions, these weathering products accumulate *in-situ* and result in the development of salinity/sodicity. This process of formation of salt-affected soils because of accumulation of salts released during weathering is called primary salinity. Whereas physically transported salts are deposited along with parent material, e.g. salts in soils in the piedmont plains, NaCl and $CaSO_4$ in the salt range belt of Pakistan. Mineral weathering *in-situ*, i.e. transformation of soil minerals and dissolution of sparingly soluble salts deposited along with the parent material as well as those formed later, e.g. gypsum, lime etc.

ii. Irrigation water

All the natural waters contain dissolved salts. The expected effects (adverse or favorable) are highly dependent upon type and amount of salts and amount of water used. Canal water in Pakistan is considered as the best quality water but does contain salts varying from 120 to 200 mg L^{-1}. Just its single irrigation of 10 cm will add salts in the range of 120-180 kg ha^{-1}. Other common source of irrigation and salts is ground water, which is mostly brackish in arid regions of Pakistan but the levels of EC, SAR and residual sodium carbonates (RSC) are quite variable. On an average, ground water in Pakistan contains 1250 mg L^{-1} of salts. An irrigation of 10 cm with this water will add 1.2 tons of salts ha^{-1}. Such additions of salts in soils highly depend upon ground water depth, volume of water used, and type of salts as well as upon the evaporative demand of the atmosphere. Rainfall as a source of salts is of minor significance but there is a reasonable temporal and spatial variation in type and amount of salts, e.g. initial shower of rain after a long dry spells and around industrial town may contribute reasonable quantities of salts.

iii. Flood waters and waste effluent

Flood water mostly transfer/redistribute the already present salts but may become important in some parts of the world like during monsoon in Pakistan. Similar is the case with sewage water as a source of salts, particularly in the third world countries where untreated sewage is used to irrigate the crops, mainly vegetables, around the cities or disposed of into the existing irrigation channels. Such irrigation water is of special concern with respect to heavy metals entry into food chain of human beings and many other pathogens as well as organic materials.

iv. Sea water

Sea water, containing high salt concentrations (EC = 45-50 dS m^{-1}, SAR = 50-55), intrusion as well as sea water sprays could contribute large quantities of salts, but action is a bit localized along the coasts and almost is the mode of inland saline seeps to contribute salts. However, importance of playas (lakes having input but no out put of effluent) needs special consideration in some areas of the world. In coastal areas, the soil generally gets enriched with salts through:

- Inundation of surface soil with sea water during high tide
- Ingress of sea water through rivers, estuaries, etc.
- Ground water inflows
- Salt-laden aerosols, which can be transported even many kilometers inland from the sea coast and deposited as dry fall-out or wash-out by rain showers. Inland deposition of NaCl at rate of 20-100 kg ha^{-1} $year^{-1}$ is quite common and values of 100-200 kg ha^{-1} $year^{-1}$ for near by coastal areas have been reported. Although this amount may appear small, but regular deposits over a longer period may lead to salination of the soils.

v. Lacustrine and marine deposits

According to geological information, once whole of the Indian sub-continent was under sea. Gradually sediments from Himalayas produced up-lands which were later developed for agriculture. Hence, some of the salts could be considered as fossil salts. Because of irrigation, salts already present in the soil profile are transported to the surface which is left behind upon water evaporation. Thus, over a prolonged period, salts that are previously evenly distributed in the whole profile may selectively accumulate on the surface and give rise to saline soil. Accumulation of salts-loaded run off water and its subsequent evaporation in the un-drained basins is the cause of salinity in many low-lying areas.

vi. Fossil salts

Salt accumulation in arid regions often involves fossil salts those derived from earlier deposits or entrapped in former marine or lacustrine deposits. Salt release may occur naturally or may result from human activities. An example of the former is the rise of salt bearing ground water through an originally impervious cap (which became permeable because of weathering process) over lying saline strata. Examples of the latter are the building of canals or water works in saline strata and use of ground water for irrigation. In Rajasthan, India, a canal built on an under lying gypsum layer has resulted in development of salinity in the area within a few years of its construction. This has been due to the perched water table and contribution of the salts from the underground gypsum layer.

vii. Chemical fertilizer and waste material

The use of chemical fertilizers is increasing and that of organic manure is decreasing in agriculture fields but their contribution to the overall salts build up in soils is insignificant. However, certain situations such as dumping of cow dung slurry, sewage sludge or industrial byproducts can contribute to excessive accumulation of certain ions which could limit soil productivity.

18.2.2. Causes of Salination/Sodication

Successful and sustainable agriculture, especially in the irrigated dry regions mostly depends upon the salt and water balance. Positive salt balance promotes the formation of salt-affected soils while negative salt balance induces de-salination/de-sodication. Positive water balance causes rise in ground water-table or even waterlogging which promotes salt accumulation in the root zone and surface soil layers. Negative water balance, if continues for longer periods causes draw-down, subsoil drying, and crops need relatively more irrigation water. Although draw-down is thought useful for irrigated agriculture in dry areas provided good-quality irrigation water is available. Otherwise, more and more ground water will be pumped for irrigation bringing salts from deeper soil layers onto the surface since, as a thumb rule, quality of ground water deteriorates with soil depth and distance from rivers. Consequently, draw-down could result of ground water in several countries which induces subsoil drying to adversely affect crops.

i. Inappropriate salt balance

Under the agro-climatic conditions of Pakistan, salt balance remained positive, intensity of which has been increased during the recent years. Similarly, water balance also remained positive up to few years back because of which large areas were waterlogged. However, from 1999 onward, water balance has become negative resulting in draw-down, subsoil drying, and thus decreased drainage effluent have promoted soil salination, sodication and increased irrigation demands. In turn, increasingly more brackish ground water is being used for irrigation which is promoting soil salination and stagnant or even decreased crop yields at several instances. Although exact recent figures are not available in Pakistan that how much soils are being salinized during last decades, however, it is obvious that rate of salinization is very high considering the increased use of brackish water for irrigation and low availability of good quality canal water to leach the salts.

ii. Nearness to sea

Nearness to sea is also one of the major causes of salt accumulation in soils but impacts are localized. Importance of this process becomes significant if there is draw-down in the areas touching to the sea coast. Middle East countries, especially Morocco, Oman and United Arab Emirates are seriously confronted to this situation.

iii. Untreated municipal effluent

Continuous use of untreated sewer water/municipal effluent or other drainage water for longer periods has the potential of inducing soil salination followed by sodication if scientific management is not practiced. Such scenario prevailed in Pakistan where discharge from SCARP tube wells and sewage was used for irrigation due to which secondary salinity developed in large areas.

iv. Arid climate

Arid climate is generally accompanied by hot temperatures which induces high evaporation and capillary action causing salt accumulation on soil surface and precipitation of salts (lime, gypsum etc.) in the root zone. Excessive precipitation of lime in subsoil, along with other factors, give rise to dense layers in many soils in Pakistan.

v. Lack of land leveling

Land leveling is essential for uniform distribution of irrigation and rain water. Micro-level unevenness of fields results in different percolation of water (rate and amount). After few years, lack of precise land leveling help the appearance of patchy salinity followed by sodicity (so called slick-spots) just because of uneven distribution of irrigation and/or rainwater.

vi. Extra crop coverage

Extra crop coverage to meet the food requirements of increasing population over years, give rise to salt build up in soils. For example, if allocated canal water is enough to meet 75% requirements of irrigated area, realizing 100% cropping intensity will be just extra crop coverage. This will demand exploitation of some additional water resources, mainly brackish ground water, or decreasing water input leading to insufficient salt leaching and resulting in salination/sodicity.

vii. Poor apprehension of water quality guidelines

Ignorance of irrigation water quality standards (IWQS), insufficient agricultural extension service and poor knowledge and skills of the farming communities are obvious in many developing countries. So far, in Pakistan no water classification scheme exists which is tested through extensive experimentation under different agro-climatic zones of the country. Disobedience of IWQS, proposed by agriculture departments or WAPDA on the part of the farmer is common and thus the problem of salination/sodicity is increasing since the creation of Pakistan despite the private and public efforts to control the salt accumulation problem.

A common occurrence in arid and semi-arid condition is the presence of salt-loaded ground waters that are increasingly exploited for irrigation. These are a direct source of salts on otherwise superior quality lands. A striking example is the use of high-sodium waters, which may lead to poor permeability and sodicity of soils.

viii. Absentee landlordism

Un-attendance and socio-economic factors are important in this reverence. Landlords are not taking care of their lands and a huge part is often left uncultivated/un-cropped that may be subjected to salinization/sodication with time.

ix. Shallow water table

Under inadequate drainage and inappropriate management of water, during both transport from dams and canals and on-farm use, the water table rises following introduction of irrigation into an area. In the several irrigation command areas rise in water table at the rate of 1-2 m per annum is common, rise being faster in the beginning which slows down with time. Mostly ground waters in arid regions are mineralized but to different extent and because of capillary effects, water continuously rises upward and enriches the surface soil with salts, following evaporation, and perhaps is the major cause of development of salty lands in irrigated areas.

The salination risk of shallow water table (which may also rise from other causes) is, however, related to combination of salinity and depth. Generally, it is happened only the presence of salty water at critical depth. Knowledge of this phenomenon is of course quite important for irrigation and drainage operation in arid zones.

x. Socio-economic factors

Vested interests of different sections of the society, political interventions, lack of stable government policies, instable government, and lack of will, lack of soil/farmer-friendly policies and non-implementation of policies are the areas which are increasing salination in several countries.

xi. Seepage from up-slopes containing salts

Under certain situations, seepage resulting from water input in the up-slope areas can cause severe salinity of the down-slope areas especially when the sub-surface water flow takes place through the strata that are rich in salts/marine deposits.

18.2.3. Genesis of Salt-affected Soils

Theoretically, ideal salt balance means that Salt input = Salt output, i.e.

$$S_{PM} + S_{iw} + S_{rw} + S_{fert.} + S_{mw} + S_{misc.} = S_{L} + S_{ppt.} + S_{crop} + S_{vol.} + S_{misc.}$$

Where:

PM = Parent material, iw = irrigation water, rw = rainfall water, fert. = fertilizer, mw = mineral weathering *in-situ*, L = leaching, ppt. = precipitation, crop = crop removal, vol. = volatilization, misc. = miscellaneous and S = salts. In the equation of salt balance, components S_{iw}, S_l, and S_{ppt}. are controlled by human activities to a certain extent.

When salt input becomes greater than the salt output, salts start accumulating in soils (salination). All natural waters contain a variety of salts. Upon concentration of soil solution, Ca^+ compounds (mostly lime and gypsum) precipitate leaving preponderance of Na^+ in soil solution which must promote Na^+ adsorption at the cost of divalent cations. Hence, sodication follows salination, i.e. first soils are salinized and then precipitation of salts, like $CaCO_3$, $CaSO_4$ and $MgSiO_3$ induce the Na^+ in soil solution causing more adsorption of Na^+.

18.2.4. Human Role in the Development of Soil Salinity/Sodicity

Sustainable agriculture is not possible without the involvement of man whose activities practically provide directions to the salinity/sodicity problems. Agricultural soils can sustain productivity if properly managed like in old irrigated areas of Egypt, Iraq and China. On the other hand, good agricultural soils have been salinized because of several faulty human activities like:

i. Construction of roads/buildings, dams and canals blocked the natural surface and subsurface drainage of the area and promoted waterlogging and salination followed by sodication.

ii. Irrigation with saline ground water without providing adequate drainage and amendments.

iii. Faulty transport and mismanagement of on-farm use of irrigation water leading to high seepage, over irrigation and ultimately secondary salination and sodication. It may be mentioned that *"if the construction of the storage and conveyance system is the end of the beginning of irrigated agriculture, the appearance of salinity is the beginning of the end"*. Many farmers tend to over-irrigate because of uncertain canal supplies, and ignorance about the proper depth and frequency of irrigation leading to rise in water table. Similarly, some soils may be well drained and salt free under natural conditions initially, but drainage might not be adequate for irrigation.

iv. Change in cropping pattern from forest land to agricultural land (there are strong evidences around the world that flow off spring water has been increased after clearing forest lands), water sparing crops like millet to high water requiring crops like rice, rainfed agriculture, and increase in cropping intensity and cultivation of marginal land lead to more percolation losses of applied irrigation water causing rise in water table and the salination coupled with sodication of many areas. Simultaneously for high cropping intensity, more and more brackish ground water is pumped for irrigation which brings considerable quantities of varieties of salts from safe depth into root zone and soil surface. On the other hand, leaving land fallow encourages more accumulation of salts on the soil surface particularly under arid and semi-arid conditions.

18.2.5. Salt Tolerance of Crops

A soil containing an excess amount of soluble salts/exchangeable Na^+ adversely affects most of the crops. Generally, $EC_e \geq 4$ dS m^{-1}, ESP ≥ 15 or SAR ≥ 13 are the diagnostic limits for the salt-affected soils. The adverse effects of salts on plant growth are mainly due to following reasons:

- Reduction in osmotic potential of soil solution, thereby reducing water availability to plants
- Increase in the concentration of ions either has toxic effects directly or promotes imbalance in plant nutrient metabolism
- Salts affect the properties of soils making it less suitable for plants, e.g. soil disturbances due to Na^+ may occur much before the osmotic or specific ion effects appear

An increase in osmotic pressure or a decrease in osmotic potential results in lower crop yields and the effects are more important than the type of electrolytes in soil solution. A decrease in water absorption under saline soil conditions compels plants to spend more metabolic energy to absorb water at the cost of growth.

The impact of high EC on nutrient uptake is usually considered a secondary negative effect on growth relative to osmotic effect. However, passive nutrient uptake is related to lower water uptake, and any decrease in water availability should be reflected in reduced nutrient uptake. The imbalances in composition of saline soil solution can affect the absorption of nutrients, e.g. excess of Cl^-, Na^+, or Mg^{2+}, decreases the uptake of NO_3^-, K^+, Zn^{2+} and Ca^{2+}. The tolerance of a crop to EC is measured in terms of yield obtained under non-saline conditions. Because of the complex physiological interactions, absolute salt tolerance of plants cannot be measured. A linear yield decrement function due to EC is generally given by the equation

$$Y \text{ (Yield)} = 100 - B\,(EC_e - A)$$

Where,

A = The EC threshold value above which yields decrease.

B = the rate of yield decreases with a unit increase in EC or slope of yield decrement line.

Table 18.2. Salt tolerant species prevailing in Pakistan

Crop	Threshold EC_e ($dS\ m^{-1}$) at 25˚C	EC_e ($dS\ m^{-1}$) at which yield decreased by		
		10%	25%	50%
Wheat	5.0	5.9	7.2	9.9
Cotton	5.9	8.7	12.7	17.1
Sugarcane	1.8	3.0	5.5	9.9
Rice	4.0	4.6	5.8	7.4
Barley	7.0	8.9	11.6	15.7
Oilseeds	4.0	5.2	6.8	9.7
Berseem	1.2	2.4	5.4	12.0
Lucerne	1.5	2.9	5.0	9.0
Oats	4.2	5.5	7.6	11.7
Mash	4.0	5.2	7.1	10.0
Lentil	1.6	3.0	5.7	12.0
Kallar grass	9.0	12.4	14.0	16.0

Source: *California Fertilizer Association (1980), Ayers and Westcot (1985)*

Salt sensitivity or salt tolerance varies considerably with plant growth stages as well. Relatively, more tolerant cotton and sugar beet are much salt sensitive at germination stage than later developmental stages. Many crops respond favorably to the on-farm seed priming with Ca-salts, e.g. wheat germination was significantly improved when seed was soaked for 3-6 h in 15 $mmol_e\ L^{-1}$ gypsum solutions. Some crop plants become dramatically more salt tolerant during reproductive phase. It has been observed that cotton yield was only slightly reduced at salinity of irrigation water up to TSS of 9000 $mg\ L^{-1}$ despite a significant reduction in biomass, i.e. vegetative growth but the mechanism is not yet clear. Regulation of salt balance at leaf level is crucial for whole plant responses to salts. For soluble salt sensitive species like rice, Na^+ supply to expanding leaves exceeds the demand for osmotic adjustment at high salt stress which leads to excessive Na^+ accumulation in leaves. Sodium could accumulate in cell walls of leaves or reach extreme intercellular concentrations, leading to specific ion toxicity. High Na^+ or salts in leaf cell walls could easily cause loss of turgor followed by dehydration but mostly in older leaves of non-halophytic plants leaving low concentrations in younger leaves of rice.

It is worth noting concern that in many natural arid region soils, high EC is accompanied by high SAR or ESP as is the case in Pakistan and India. Almost similar is the case regarding the EC and SAR as well as RSC of ground water commonly pumped for irrigation in these countries. It has been well reported in Pakistan that high EC of soil/irrigation water coupled with high SAR is more harmful for plants because of unbalance Na^+ and (Ca^{2+}+ Mg^{2+}) ratio leads more Na^+ uptake which ultimately cause the ion toxicity in plants.

18.2.6. Reclamation and Management of Salt-affected Soils

Pre-requisites of soil reclamation are good surface drainage, deep ground water, land leveling and availability of enough superior quality water (Ghafoor et al. 2004).

i. Saline soils

The reclamation of saline soil is easy to achieve if copious amount of good-quality (low EC) water is available and surface as well as internal drainage is possible. Embankments are made around the saline field and field is flooded with water. This water moves down into the deeper soil and leaches the soluble salts out of the root zone making it favorable for plant growth. The quantity of water required to move the salts below root zone depends on: **a**) how deep the salts are to be washed, **b**) how leaching is done (constant or intermittent ponding), and **c**) what percentage of the salts is to be removed.

If it is not possible or practical to remove all salts from soil (due to high cost or short supply of water) then either some salt-tolerant plants are grown, or salt damage can be minimized by controlling water and following proper planting techniques. Planting position should be such to avoid salt build-up in the immediate zone of seed placement. This can be done by placing the seed on the shoulder of the double bed furrow. Maintaining a high-water content (near field capacity) in the soil dilute salts and reduce their toxic effects. Soil should be irrigated lightly and frequently during salt-sensitive germination and seedling stages.

ii. Sodic soils

Addition of some amendments supplying soluble calcium in the soil either directly (like gypsum) or indirectly (like H_2SO_4, etc. in calcareous soils) followed by heavy irrigation to leach the exchanged Na^+ (from the soil's exchange complex) and soluble salts out of the root zone is practiced for reclaiming sodic soils.

Gypsum ($CaSO_4$. $2H_2O$) is considered the best and cheapest source of calcium in the country. When gypsum is added to a sodic soil, Ca^{2+} solubilized from gypsum replaces Na^+, forming soluble Na_2SO_4, which is then leached out of the root zone.

Sulphuric acid (H_2SO_4) may also be used in place of gypsum in calcareous sodic soil as it releases Ca^{2+} from soil that replaces Na^+ just like Ca^{2+} released from gypsum.

iii. Saline-sodic soils

The reclamation of the saline-sodic soil is same as of the sodic soil, i.e. application of same amendment followed by leaching. These soils should not be leached without any amendment otherwise these soils could be converted into sodic soils due to leaching of soluble salts present in the saline-sodic soils.

18.3. Waterlogged Soils

Waterlogged means saturated or nearly saturated with water. Waterlogged soils are defined as soils that are saturated with water (due to a high or perched water table) for a sufficiently long period of time annually which is detrimental to most field crops. Waterlogging may be natural or induced by human beings. This condition imposes salinity and oxygen stress on plant under arid climates. Perched water table means the water table of a saturated layer of soil which is separated from an under lying layer by an unsaturated layer. Perched water-table is generally developed when hard pans are developed in the soil.

18.3.1. Extent of Waterlogging in Pakistan

The extent of waterlogged soils in Pakistan mentioned by various organizations, *viz*. Directorate of Land Reclamation, WAPDA, Soil Survey of Pakistan, Colombo Plan, etc. shows lot of variation similar to that of the salt-affected soils. Some researchers have classified waterlogged soils in association with soil salinity. The two categories developed are, a) saline-waterlogged, and b) non-saline-waterlogged. In Pakistan most soils are saline-waterlogged due to arid climatic conditions.

18.3.2. Causes of Waterlogging

i. Seepage from water transportation system

At present canal irrigation system of Pakistan covers a gross area of 16 million ha. According to an estimate, 30-50% water losses occur during transport from head works to the farm gate. The major forms of water losses include seepage and evaporation from the soil surface. However, seepage of water is responsible for many waterlogged soils in Pakistan.

ii. Poor drainage

Poor drainage in the country is due to, a) poor natural drainage because of lower slope of 30 cm per 1609 meter, i.e. one foot per mile, b) poor vertical drainage in fine textured soils, and c) hard and impermeable pan existing in the soil, which results in perched water table.

iii. Over irrigation

No control on water supplies, e.g. during monsoon season canals continue to flow and farmers are bound to take their turn, resulting in over irrigation and thus raised water table.

iv Intended irrigation

More water is applied for leaching of saline soils or for high delta crops or even to control soil temperature. This may result in localized waterlogging in the adjacent low-lying areas.

Table 18.3 Total waterlogged area in Pakistan (M ha)

Water table (m)	Province				Total
	Punjab	Sindh	NWFP	Baluchistan	
<1.5	0.6958	0.6246	0.0918	0.1421	1.5543

Source: *adapted from Muhmmad (2013).*

18.3.3. Remedies and Management of Waterlogged Soils

Waterlogging is a serious problem in the irrigated areas. Various solutions to this problem have been practiced. The most important of these is the SCARP (Salinity Control and Reclamation Project). The main feature of this project was the installation of tube wells in the waterlogged areas. Huge expenditures have been incurred for the installation of the tube wells. The SCARP has not met with much success due to poor operation and maintenance (Qureshi et al. 2008)

The most important drainage project undertaken in recent years is the LBOD (Left Bank Outfall Drain). Following remedies and management practices might be useful, in general, for the waterlogged soils:

i. Surface drainage

These are open, dug up, channels which collect and carry away the surplus flood, rain or irrigation water from an area. It is most suitable for fine textured (clay) soils both on the small and large scale. However, a careful cleaning, weeding and maintenance is very important to get the desired benefits.

ii. Subsurface drainage

This is an underground lined channel to collect the water through perforations and to dispose it away, e.g. tile drains, pipe drains. The mole drain is unlined underground channel and is suitable in clay soils only.

iii. Vertical drainage

This practice or technique includes installation of tube wells, wells etc. This is a bit costly approach, however can work very efficiently.

iv. Planting of hydrophytes and hydrophilic plants along the water channels

Hydrophytes are plants which absorb and transpire water in much higher quantities and their growth rate is also high, e.g. Ipil Ipil, Mulberry, Eucalyptus. Planting these trees along canals and water courses may be more useful. This will help to maintain the underground water levels and will also provide some income.

v. Lining of water courses and canals

Lining of water courses, canals etc., though expenditure incurring, is a very desirable and useful technique to get rid of waterlogging.

vi. Tree planting

Where crops fail to grow, higher plants can manage to grow. These plants include Kiker, Mulberry, Gul-i-Nishtar, Ipil Ipil, Juntar, and Popular spp., Simal, Castor and Frash etc. Such plants will provide income to the farmers and also help to solve the fuel and timber problems at national level. Mound planting will help the establishment of young plants.

18.4. Soil Erosion

Removal of soil particles by the movement of water or wind is called as erosion. It is one of the major concerns of modern agriculture world-wide. Among major contributors to soil erosion are land misuse, deforestation, overgrazing, mismanagement of arable land and poor water management. Often upper layers of soils are eroded through above mentioned agents, which mean loss of fertility and decline in crop yields. Transportation of soil particles is a natural process and cannot be stopped. It is not harmful if removal of soil equalizes the soil deposition and called as geological erosion, however, when it is accelerated through various stimulants and removal is more than deposition then it deteriorates the soil resources and is called as accelerated erosion.

18.4.1. Extent of Soil Erosion in Pakistan

Among 79.61 M ha, ~20.79 M ha of Pakistani land is under cultivation. It has been estimated that more than 75% of total area of Pakistan is affected by wind or water erosion. About 53% is caused by wind and 47% is caused by water in Pakistan. Every year about 40 M tons of soil is lost into the dams shortening the life and storage capacity of dams, which send more than 10000 ha land out of cultivation (Khan et al. 2012).

Wind erosion leading the vast area of Thal, Thar and Cholistan towards desertification. Wind erosion occurs in those areas where rainfall is less, and soils are sandy in nature. Wind erosion not only erode the soils but also damage the standing crops and filling the waterways.

Water erosion is the worst in northern areas where rainfall is more, and the catchment of water is not sufficient which increase the runoff water. Furthermore, deforestation and nontechnical methods of cultivation on slopes aggravate this issue.

18.4.2. Causes of Soil Erosion

Causes of erosion are multiple and variable from area to area. It is very significant to know about the factors accelerating soil erosion, because to manage and reduce the erosion losses, it is worth-knowing the causes of soil erosion. Among the major factors rainfall, land slope, soil properties and vegetation are important to discuss further.

i. Rainfall

There is a direct relationship between amount of rainfall and soil erosion caused by water. More the rainfall, more will the runoff and more water erosion from the soil. In Pakistan, rainfall is very variable and unpredictable since last 2-3 years. However, it is estimated from 125 mm to ~1000 mm per annum. High rainfall areas are northern areas like Gilgit, Naran, Murree, Swat etc. whereas the Sind area has mostly less rainfall.

An optimum rainfall in Thar and Thal area can decrease the wind erosion as well, however, both aspects must be considered while planning new projects and conducting research studies.

ii. Slope of land

Slope of the area has also direct relation with the intensity of soil erosion. More the slope, more will the water flow and runoff which ultimately cause the water erosion. Gentle slopes are generally favorable to stop the erosion. Longer slopes also develop more momentum for water to flow rapidly; therefore, it provides more erosive power to water.

iii. Soil Type

The ability of soil to infiltrate water and then to retain water are basic characteristics of soil in context to soil erosion by water. These abilities of soils depend upon the soil texture, amount of organic matter, tilth and porosity. Porous and deep soils are less prone to water erosion, whereas loess soils in Potohar area are more prone to erosion.

Sandy soils are more prone to wind erosion as compared to heavy soils with high clay content. Soils with more organic matter are also less prone to wind erosion as well.

iv. Vegetation cover

Vegetation reduces the erosion losses caused by both wind and water; therefore lack of land cover or vegetation is one of the major causes of both kinds of erosion. It reduces the rainwater interception, improves the soil organic matter by addition of plant litter, reduces the runoff and improves the physical properties of soil.

18.4.3. Remedies and Management Practices

The basic strategies to reduce the soil losses through water and wind erosion include the use of land as per its capability so that no land is unattended, because unattended or naked lands are more prone to erosion. Soil surface should be covered with vegetation throughout the year. Rainwater should be preserved to minimize the runoff. Furthermore, soil fertility should be maintained to sustain its productivity for cultivated crops. The main aim should be to conserve the soils; nevertheless, conservations measures are highly site-specific depending on soil characteristics, topographic conditions, rainfall patterns etc. Following measures can be adapted as per conditions available.

i. Maintaining vegetative cover

Maintaining soil cover by crops or other vegetations, especially, during monsoon is very effective to reduce the soil erosion. Vegetation on soil surface also keeps the soils protected from wind erosion. It has been reported that vegetative cover can reduce the runoff up to 25% as compared to bare soils. Bare soils are prone to detachment of soil particles by rain drops and then transportation by rain water.

ii. Tillage depth

Shallow ploughing along the slope of land is very drastic for water erosion. Because these faulty ploughing reduces the moisture absorption and accelerate the erosion. Nevertheless, tillage practice should be as per soil characteristics. The soils containing plow pan are more responsive to deep plowing for reduced soil losses through water erosion.

iii. Mulching

Covering the soil with plant residues or any other plastic material reduces the moisture losses keeping the soils less prone to erosion. Furthermore, crop mulches also reduce the water runoff and keep the soil conserve from wind erosion.

iv. Raising of field boundaries

Agricultural fields should be kept away from water runoff by keeping the boundaries up. It is really a successful practice in many districts of Pakistan.

v. Crop rotation and cropping system

Crop rotation must include such crops which will improve the soil quality such as leguminous crops. Cropping system should consider the capability of soil to keep the soils healthy and to occupy the fields for extended period.

vi. Water disposal system

Excessive canal water and rainfall water should be disposed of properly to avoid the uncontrolled runoff having potential for water erosion.

vii. Improvement in soil quality

Improvement in soil physical properties, as well as soil fertility helps to conserve soil. Roughening the soil surface reduces the soil erosion and deposition of soil particles can happen. Improving soil organic matter can improve the soil structure and aggregation which not only reduce the wind erosion but also decrease water erosion.

viii. Terrace farming

In hilly areas, terraces across the slope reduce the water runoff velocity and increase the water infiltration. This is very common practice in Pakistan as well as throughout the world. Terraces are formed to decrease the slope length, which ultimately decrease the gullies formation.

ix. Water interception or diversion

Especially in non-arable lands the steep slopes can be interrupted to decrease the water velocity. The water speed can be interrupted by planting trees or making ditches and channels to diver the water direction.

x. Establishment of wind barriers

Wind barriers are very common practice to avoid the wind erosion. Paved wind barriers can be constructed, however planting dense trees strips at specific distance can reduce the wind speed significantly and it is more economical as well.

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Chapter 19

Farming and Cropping Systems

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Abstract

Agriculture is playing a vital role in ensuring food security, reducing poverty and improving economic growth, and industrialization within a country. The climate of Pakistan is well suited for production of several cereals, fiber, sugar, pulses, oilseeds and fodder crops. Crop production is the integral part of farming system; in order to make the cropping system more productive, the selection of crops and their judicious rotation is quite vital. The most common cropping systems used in Pakistan are cotton-wheat, rice-wheat, mixed crops, maize/wheat-oilseeds, pulses-wheat and orchards/vegetables-wheat etc. Due to ever rising demographic pressure of the country and unbalanced supply and demand of food, there is a dire need to understand the concept of cropping/farming systems, their types, principles and factors affecting them. The description of various planting methods used for raising crops in above mentioned cropping systems and concepts of multiple cropping and crop rotation along with their advantages and disadvantages are also elaborated in this chapter.

19.1. Introduction

Agriculture includes the cultivation of crops and rearing of livestock to fulfill the food and fiber needs of human beings (Pimentel and Hogan 2014). Agriculture is the backbone of Pakistan, and it is one of the major employment and income generating sector of country (Beintema et al. 2007). In Pakistan, agriculture is

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playing vital role in ensuring the food security, reducing poverty and improving the economic growth, and industrialization within country. Pakistan has been blessed with diverse climatic conditions which are well suited for the production of cereal crops (wheat, rice, maize, sorghum, millet, rye), fiber crops (cotton), sugar crops (sugarcane, sugar beet), pulses (chickpea, lentil, mungbean, mashbean, soybean, faba bean), oilseeds (rapeseed, mustard, sunflower, peanut, castor bean), and fodder crops (sorghum, millet, guar, berseem, lucerne, maize, jantar). These crops are being grown in various farming and cropping systems across the country and are the source of food, fiber, and income for the farmers. Besides growing the crops in specific regions at specific times, the farmers also rear the animals like cows, buffaloes, sheep, goats, and camels, which not only provide the milk and meat for house use; but are the source of income for farmers. Traditionally, increased food production has come from putting more land under cultivation. However, in large areas of the world, especially in Asia including Pakistan, all the land that can be economically cultivated is already in use. In future, most of the extra food needs must come from higher production from land already being farmed. A major share of this increase is likely to come from increasing the number of crops produced per year on a given land using improved crop cultivars. Such multiple cropping offers potential not only to increase food production but also to reduce land degradation (Parr et al. 1990). The system approach allows enhancing production without deteriorating the resource base. The ultimate objective of designing any farming/cropping system is to increase the productivity and profitability through conservation of natural resource base, protection of the environment, and improvement in health/safety on long term basis (Parr et al. 1990). The production of agricultural crops depends on soil, air, water, energy and biological resources and there is a dire need to understand the complex interaction among these resources so that they can be handled as an integral system. In this chapter, we have discussed the concept of cropping/farming systems, their types, principles and factors affecting them. Various planting methods used for raising crops, and the concepts of multiple cropping and crop rotation has also been discussed. We have also discussed the pitfalls in farming and cropping systems research and suggestions to improve these pitfalls.

19.2. Farming systems

A system is defined as "arrangement of various interrelated components which interact among themselves according to some process and convert inputs into outputs". In other words, a system is a "group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks" (Rana and Rana 2011). For example, the human body is a system. It has skin (outer boundary) which encloses various components viz. lungs, heart, lungs, and they interact (heart pumps blood to lungs) for a common purpose i.e. to maintain and operate the human body.

However, a framing system can be defined as "a decision making unit comprising of farm household, livestock and cropping systems that convert capital (inputs), land, and labour (including the genetic resource and knowledge) into useful outputs/products that can be consumed or sold". It means that a farming system comprises the household systems, livestock systems and cropping systems (Fresco and Westphal 1988), and the waste product of one system can be used as input for other one. In other words, a farming system can be defined as "a population of individual farm systems that have broadly similar resource bases, household livelihoods, enterprise patterns, and constraints, and for which similar interventions and development strategies would be appropriate". A farming system can also be defined as "an established way of operating a piece of land to raise crops, livestock or both and includes everything done on farm and outside the farm related to farm operations" (Shaukat 2013). A farming system can include few dozen households to several millions. Indeed, farmers within a farming system (whether small or large), produce not only the major crops but also minor crops, fruits, and vegetables. They have shade trees at their farm used for fuel or timber. They rear cattle or buffaloes for meat and milk, and own sheep/goat and chickens, which are necessary for their livelihood. In Pakistan, there are over five million farms and majority of of these farms are small (81 % below 5 ha) (FAO 2004). The average land holding in Pakistan is given in table 1.

Table 19.1 Average land holding in Pakistan

Size of farm	Percent of farm	Farmed area (%)
> 20 ha	7	40
5 - 10 ha	12	22
< 5 ha	81	39

Source: Govt. of Pakistan (2003)

19.2.1. Principles

The farming systems classification is based on following two principles (adopted from http://www.fao.org/farmingsystems/description_en.htm)

19.2.1.1. Available Natural Resource Base

The choice of any farming system depends on available natural resource base i.e. land, water, forests, pastures; climate, especially the height from seas level; landscape of the area e.g. slope; size, tenure type and organization of the farm.

19.2.1.2. Pattern of Farm Activities, and Household Livelihood

The choice of any farming system also depends on prevailing array of household livelihoods and farm activities including field crops, trees, livestock, aquaculture, gathering and hunting, processing, off-farm activities; and taking into account technological implementations which not only determine the production intensity and crops integrations, but also includes livestock and other activities at the farm.

19.2.2. Types

Various types of farming systems are practiced in Pakistan, which are briefly discussed below.

19.2.2.1. Irrigated Systems of Indus Basin

The irrigated systems of Indus plains are equipped with well-organized irrigation system which is the largest one in world and is spread over an area of 16 million hectares (80% of the cultivated area) in Pakistan (Byerlee and Husain 1993). These irrigation plains are the main food bowl and the majority of the agricultural export earning comes from this area. Due to better irrigation facilities, the double cropping is most common in these areas and even the small farmers are self-sufficient in daily food grain commodities. Wheat is the primary winter (*rabi*) crop being consumed as staple food and is cultivated in these plains on more than 80% area in *Rabi* season. In *Kharif* season, the crop rotated with winter wheat may vary depending on soil, climate, and market scenarios (Byerlee and Husain 1993), mostly the rice, cotton and sugarcane. The three main cropping systems of irrigated Indus irrigated plains include rice-wheat, cotton-wheat and mixed (sugarcane, maize, rice, wheat, cotton, potatoes) cropping. This farming system is the early beneficiary of green revolution as the farmers adopted the green revolution technologies very rapidly. However, double cropping in irrigated plains have severe implication for weeds, pests, diseases, crop residue management and soil fertility which may affect the productivity of companion crops grown in rotation. The average land holding in Indus irrigated plains is 8 hectare (ha); while 57% of farm holdings are less than 5 ha (Byerlee and Husain 1993). The major source of income of irrigated Indus plains is the growing of cash crops. About 19% farmers have no access to rural roads. In the whole Indus plains, rearing of livestock's at farm level is common but crop-livestock interaction is less common than rainfed and mountainous areas. The main reason for low crop-livestock interaction includes the replacement of draught power by tractors, organic manures with chemical fertilizers due to increased labour charges associated with the application of organic manures and enhanced demand of animal dung for fuel purpose (Byerlee and Husain 1993). The farmers in these plains also plant a separate field for fodder to fulfill the feed needs of animals and the demand and market price of wheat straw remains low. In cereal yields, the co-efficient of variation is about 25%. The values of crop by products and intercrops are 10-20% in relation to value of grain. A vast majority (60-80%) of the farmers depends on the hired tractors to perform farm operations (Byerlee and Husain 1993).

Due to the introduction of short duration semi-dwarf cultivars of wheat in green revolution era, increased use of chemical fertilizers and growing of early maturing crop cultivars has tremendously increased the cropping intensity (135-160%) in irrigated plains of Indus basin; nonetheless it has resulted in the time and edaphic conflicts due to short turnover time from one crop to another and differential soil requirement of the both crops grown in rotation (Byerlee and Husain 1993). Delayed cotton picking, late harvesting of sugarcane and the excessive soil pulverization after harvesting of puddled transplanted rice delay the planting of the succeeding wheat crop which is main food cereal in this region (personnel observation). Experiments have shown that if wheat sowing is done after mid-November then a day's delay in sowing of wheat causes a yield loss of 1-1.5% per hectare (Nasrullah et al. 2010; Hussain et al. 2012a). Late emergence of seedlings, uneven and patchy crop stand, reduced tillering and short duration for grain development stages may be the possible reason for reduction in wheat yield due to late sowing (Ortizmonasterio et al. 1994; Hussain et al. 2012b). This late planted wheat has poor stand establishment and may also suffer heat stress at reproductive and grain filling stages which drastically reduces the yield of wheat in this region (Nawaz et al. 2013). To solve the issues of time and soil conflicts in Indus plains, resource conservation technologies (RCTs) like direct seeding of rice in aerobic environment, conservation tillage (CT) wheat, relay cropping of wheat in cotton, introduction of early maturing varieties of wheat, rice and cotton needs serious intention of plant breeders, agronomists and policy makers. Although the RCTs have been tested widely in experimentation; nonetheless these have not been rapidly taken up by the farmer. The reasons for low uptake of these RCTs may include the socio-economic constraints, heavy weed, pest and disease infestation, poor stand establishment and lower crop yields than the conventional productions systems of these crops.

19.2.2.2. Rainfed Systems of Northern Plains and Plateaus

The rainfed systems of northern plains and Plateaus cover an area of below 1000 m altitude and these plains spread from Northern Punjab (Chakwal, Jhelum, Attock, Rawalpindi etc.) to Southern Khyber Pakhtunkhwa (Dera Ismael Kahn, Tonk, Karak, Bannu, Lakki Marwat etc.). Crop production in rainfed plains is fully dependent on rainfall which average from 300 mm to 1000 mm. The main crops of rainfed areas include wheat, millet, oilseed and pulses. Monocropping is quite common in these regions. Wheat is grown as major *rabi* crop for subsistence and in drier regions, the pulses like chickpea and lentil are cultivated in *rabi* season. Mustard, maize and kharif pulses are the important crops which are grown in the higher rainfall areas, while groundnut, sorghum/millet and *rabi* pulses are grown in lower rainfall areas. The cropping intensity in rainfed areas is greatly influenced by rainfall, land type, farm size, power constraints and livestock ownership (Byerlee and Husain 1993). In monsoon season, the farmers grow the fodders like guar, millet, sorghum, cowpea etc. which not only fulfill the feed demands in that season but is also saves as hay by the farmer to use it in fodder short period (personnel observation). In these areas, the underground water table is very deep and the farmers have faced many difficulties to manage the water even for drinking purposes for themselves and their animals. Water harvesting structures were constructed to collect water during monsoon which was used by animals. However, the provision of electricity to majority of farmers in rainfed area during the Pervez Musharraf government has enabled the farmers to withdraw water from huge depths by using submersible electrical water motors. Use of these submersible electrical water motors has not only fulfilled the drinking water needs of the rainfed farmers but also have enabled the farmers to grow the *rabi* (berseem, barely) and *kharif* fodders (sorghum, millet, maize), and vegetables (onion, garlic, spinach, lady finger etc.) for household needs (personnel observation). Farming and introduction of new agricultural innovation is quiet as difficult task due to seasonal and annual variation in rainfall, small size land holdings (average farm size ~ 3 ha), fragmentation of farm operations, poor infrastructure and marketing facilities which force the rainfed farmers for out-mitigation and preference of off-form work (Byerlee and Husain 1993). For example, the majority of youth of northern Punjab is serving the armed forces and getting employment in abroad, and their majority is quite high than irrigated areas (personnel observation).

In rainfed plains, 85% of farms possess land less than 5 ha. For farm operation, a vast majority (88%) of the farmers depends on the hired tractors to perform farm operations; however, the large land holders in these areas have their own tractors. About 32% of the rainfed farmers have no access to roads (Byerlee and Husain 1993). The values of crop by products and intercrops are 40% in relation to value of grain. In rainfed areas, most of the farmers are net food purchasers and the maximum farmers grow wheat crop for subsistence and grow chickpea, lentil, and peanut to earn cash (Byerlee and Husain 1993).

Rearing of animals is quite common in rainfed areas and the crop-livestock interaction further increases in low rainfall rainfed areas. Livestock in rainfed areas have important implications for crop production. For example, wheat straw in irrigated plains just accounts for 10% of the total gross value of wheat (Byerlee and Iqbal 1987), while in rainfed areas, the value of wheat straw and other crop by products reach upto the half of total gross value of cereal grains. These high prices of crop by products are due to less availability of fresh fodder as compared to livestock reared. The co-efficient of variation in cereal yields is 40-65% in rainfed areas which might be attributed to uncertain rainfall spells, and incident of frost in winter in some years (Byerlee and Husain 1993). The crop-livestock interaction has also strong influence on crop management practices in rainfed areas. For example, most farmers fulfill the fodder needs from crop residues and intercropping green fodder in food crops. Common example is the intercropping of mustard in wheat and chickpea which is removed in winter months to feed animals when the other fodders are scare. Other example is planting maize crop at 3-5 times higher than the optimal density for grain purpose and then thinning of maize for fodder to continue the fodder chain (Byerlee and Husain 1993). In rainfed areas, crop-livestock interaction is strongly related to use of organic manures for improving the soil quality. The farmers usually apply the organic manures to the field which is close to their home, known as "*lepara fields*". Application of manures to these fields improves soil structure and water holding capacity of the soil which allows the rainfed farmers to harvest more yields from this field and also enable them to increase cropping intensity in these fields than the fields which are far away from the home and are not supplied with organic manures. Although *lepara fields* accounts one quarter of the total farm area but they provide half of the total farm income (Sheikh et al. 1988).

Although the technological innovations uptake is not so rapid in rainfed areas as in irrigated areas; yet these innovations (improved varieties, use of synthetic fertilizer, mechanical tillage implements) are widely accepted by the farmers which have resulted in improved yields of wheat, pulses and oilseeds in these areas in recent years. The use of synthetic fertilizers in rainfed is very low and farmers prefer long slender varieties with low per hectare grain. However, the high wheat straw prices may compensate the low yields as straw price is half to the grain produced. Moreover, these old varieties have longer coleoptile length and the seeds can be planted at deeper depth in moisture deficient conditions (Byerlee and Husain 1993). On the other hand, when semi-dwarf varieties are grown with low fertilizer, although they yield somewhat more than traditional wheat cultivars but lower straw yield makes them less economical than traditional cultivars in rainfed areas. This is the reason for not cultivating semi dwarf cultivars by the farmers in rainfed areas (Byerlee and Husain 1993). However, proper recommendation of synthetic fertilizers for rainfed areas may enhance the cultivation of semi dwarf wheat cultivars. It has been observed that the input use for all crops in rainfed areas is low as compared to irrigated areas and there is large scope of increasing the productivity of this farming system through input intensification. The cropping intensity in rainfed plains is quite low (118%) than irrigated plains and the major source of cash for farmers are the off-farm work and livestock (Byerlee and Husain 1993).

19.2.2.3. Farming System of Mountain Areas

Farming systems of mountainous areas cover an area above 1000 m altitude forming an inverted crescent around the north and west of Pakistan and vary according to rainfall (125-1000 mm), topography and vegetation. In low rainfall areas, the source of irrigation water is only the snow and glacial melts. Maize-wheat rotation is practiced upto an altitude of 1850 m; above which single cropping dominates (Byerlee and Husain 1993). Only small areas are available for cultivation in mountain areas, however, rangelands are common which enable the farmers to rear the animals (most commonly cow, sheep, and goat). A huge difference in micro-climate exists even at shorter distances which make it tough to devise suitable agriculture technology in these areas. Monocropping is most dominant in these regions against double cropping. Crop-livestock interaction has same implication for crop production, crop management and income of the farmers as for rainfed areas discussed in section 7.2.2.2.

19.3. Cropping systems

Cropping systems, an important component of a farming system represents "a cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology that determine their makeup' (Andrews and Kassam 1976; Rana and rana 2011). In general, a cropping system usually refers to a combination of crops in space and time and their interaction with farm resources and environment. Combination in times occurs when crops occupy different growing period, and combinations in space occurs when crops are interplanted. When annual crops are considered, a cropping system usually means the combination of crops within a given year (Palaniappan and Sivaraman 1996). Cropping system approach helps to enhance the benefits by efficient utilization of both natural (soil, water, land, solar radiation), and socio-economic (credit, labour, power resources, energy, market demand) resources for crop production. Crop production is a diverse and integrated system which includes the renewable resources i.e. farm or community derived, and off farm resources that are purchased. Renewable resources are those resources which are available at farm or from the neighboring environments. These resources include rainfall, soil nutrients, fixed nitrogen, family labour, and subsistent local farm management. The cropping systems that involve an effective combination of these low cost internal elements may sustain the productivity on longer bases (Francis and King 1988). However, for the cropping systems based on external inputs, high productivity can only be achieved if those resources are easily accessible and the farmers have money to purchase them. Production systems based on external resources show dominance on the production systems based on natural environment. Hence, it is very necessary to design such a cropping system which includes a logical balance of both external and internal farm resources which not only ensures the profitability of a specific farming operation, but also is useful on sustainable basis. It is only possible if somebody has detailed information about the efficient application of internal resources, crop and pest biology, and interaction among various components (internal as well as external).

19.3.1. Principles

Cropping system principles are discussed below. (adapted from http://www.reap-canada.com/online_library/Reports%20and%20Newsletters/International%20Development/19e%20Cropping%20Systems%20(English).pdf)

19.3.1.1. Choose crops that complement each other

For making the cropping system more productive, always choose the crops which share the resources and do not cause nutrient deficiencies for other neighboring crop or subsequent crops. For example, the crops which need more nitrogen should be planted after legume crops and the crops which require better soil structure for better growth should be grown after soil restoring crops. Crops such as peas, flex and lentil which can perform better even at low fertile soil should be used at the end of crop rotation when soil fertility has declines due to nutrient extraction by previous crops grown in that rotation.

19.3.1.2. Choose crops and crop rotation which utilizes available resources efficiently

For setting a cropping system in an area, one should have the complete knowledge of the factors in that area which may limit the crop production in those areas. These factors include animal draught power, availability of agricultural equipment and machinery, irrigation facilities, labor availability and incident of solar radiation in that area. After looking on all these factors, such a crop rotation should be selected which made efficient utilization of available resources with minimum production risk. For example, the heat tolerant crops should be included in cropping system if heat is a problem in summer. The other strategies includes selecting crops having different nutrient uptake rate, rooting pattern, height for light interception, and having different plant structures and different harvest times.

19.3.1.3. Choose crops and a cropping system that maintain and enhance soil fertility

Those crops should be selected which maintain the carbon and nitrogen reserves in the soil. For example, inclusion of approximately 30-50% nitrogen fixing crops in rotation may sustain the nitrogen reserves of that system. However, if the organic manures are also added to the soil, this percentage can be increased. Row crops should not typically exceed 30% of nitrogen fixing crops in the rotation, otherwise it will difficult to maintain the organic matter reserves in the soil. Moreover, those crops should also be included in the cropping system that produces huge quantity of organic matter in both above and below ground e.g. millet and perennial forages. The crops rotation should also include deep rooted and large rooted crop so that they can be ploughed back in the soil to add organic matter.

19.3.1.4. Choose crops which have diversity of growth cycles

An ideal crop rotation should consist of early spring seeded, summer seeded, fall planted and perennial hay and pasture crops. This however may not be possible if climatic conditions are unfavorable for crops like winter wheat, or it is difficult to establish the perennial forages because of moisture limitations.

19.3.1.5. Choose a diverse species of crops

The more diverse the rotation, and the longer period before which soil is re-seeded with the same crop, the more likely pest, diseases and weeds problems will be avoided. One should try to grow as many crops as possible keeping in mind the management facilities which the farmers have at his farm. For example, it is a good idea to rotate the field between grassy and broadleaf crops for pest and disease prevention. For some disease sensitive crops, it is a good idea to not grow the crop on the same field for at least 3 years after the last planting.

19.3.1.6. Keep the soil covered

Those crops should be included in crop sequences which can capture the solar radiation more efficiently and can minimize the risk of soil erosion. For example, the winter cereals can be planted after peas/pulses.

19.3.1.7. Strategically plan and modify your cropping system as needed

For selecting the crops to be included in crop rotation, one should consider the entire farm planning goals, including the household food security, livestock feed requirements, animal draught power, management and labour skills and availability of farm equipments and machinery. Diversified cropping systems need very good management skills and specialized equipments. One should keep an eye on the climatic and market conditions of the cropping year sequences.

19.3.1.8. Monitor your progress

Make a plan for your cropping system and keep a record. Learning from your own mistakes will result in more efficient crop production.

19.3.2. Types

In Pakistan, various cropping systems are being followed in various agro-ecological zones in all provinces. Some cropping systems practices in Punjab, Sindh, Khyber Pakhtunkhwa (KPK) and Balochistan are summarized in Table 2. Detailed discussion on some main cropping system is given below.

19.3.2.1. Cotton-wheat Cropping System

Cotton-wheat cropping system is the largest cropping system which is being followed on an area of 5.5 million hectares (Mha) in Punjab and at 1.6 Mha area in Sindh

(Table 2). The cotton-wheat cropping system is being followed in the southern Punjab including the districts of Vehari, Multan, Lodhran, Rahim Yar Khan, Bahawalpur, D.G. Khan, Mozaffargarh, Rajanpur, Khanewal, Pakpatan and Bahawal Nagar etc. In Sindh, this system dominates in the districts of Hyderabad, Mirpurkhas, Tharparkar, Nawabshah, Sanghar, Naushero, Khairpur, and Sukkur and Ghotki. However, the Punjab province is the main producer of cotton in Pakistan with 80% of the total cultivated area under cotton crop (Sabir et al. 2011). The uniqueness of cotton-wheat cropping system is the combination of grain plus cash cropping, which improves the economy of farmers through the cultivation of cotton as an industrial commodity and wheat as a component of food security. Therefore, this system is not only ensuring the food security of the region, but is also a major source of foreign exchange earnings.

The optimum time of sowing of wheat in this region is from last week of October to mid of November; and any delay in wheat sowing after mid November causes marked reduction in wheat yield (Hussain et al. 2012a). However, in this system, shortage of labour for cotton picking, late flowering span of cotton cultivars coupled with time needed for seedbed preparation delays the wheat sowing (Hussain et al. 2001; Hameed et al. 2003; Buttar et al. 2013), which reduced wheat yields in this system. Low productivity of late sown wheat reduces the profit margins at farmer field in this system. In this scenario, relay cropping of wheat in standing cotton perhaps offers most pragmatic way of ensuring the timely wheat sowing in cotton-wheat system with enhanced yields (Figure 4D; Khan and Kahliq 2005). In relay cropping, the second crop is started amidst the first crop before it has been harvested. This can raise production of wheat by 2-3 million tons (PAIS 2014). In cotton-wheat cropping system, the lower seed cotton yield was due to the presence of immature bolls, which remained unopened on the plants at the time of last picking. However, in case of relay planting treatments, majority of immature bolls were fully open by the time of pulling out of cotton sticks and thus provided more seed cotton yield. Likewise, due to exhaustive nature of both crops in this system, soil fertility level is depleted. However, to compensate this loss and to improve the cropping intensity in cotton-wheat cropping system, some legumes can be intercropped with cotton as cotton is grown in wide rows which will not only add towards the soil fertility but will also increase the cropping intensity and farmer profitability. In an earlier study, Saeed et al. (1999) reported that the intercropping of sesame, mashbean, mothbean, mung bean and cowpea with cotton increased the cropping intensity and famer profitability in cotton-wheat cropping system. Moreover, the growing of some crops belonging to cucurbitaceous family (water melon, musk melon etc.) within cotton may be beneficial from the farmer benefits point of view as well working as a cover crop to lessen the rapidly depleting soil moisture in summer. Moreover, the cotton growers are also suffering the problems of poor seed germination in some areas and water logging in other areas due to heavy monsoon rains which needs serious attention of plant breeders and crop scientists. In Sindh, some farmers have been shifted from cotton cultivation to rice and sugarcane cultivation due to high crop loss in cotton due to heavy rains and floods (Khan 2013).

However, cotton crop in this system is heavily infested with variety of sucking and chewing insect pests causing about 30–40% yield reduction (Men et al. 2003; Abro et al. 2004). Therefore a lot of pesticides are used in this system to control insect pests attacking on cotton crop in this region. For instance, Pakistani farmers are using US$300 million worth of pesticides annually, out of which more than 75% is used on cotton to control pests, especially bollworms (Rao, 2007). To tackle the problem of insect pest infestation in cotton, transgenically tailored cotton (BT cotton, which expresses insecticidal protein derived from Bacillus thuringiensis Berliner) was launched as a safe and valuable tool to control cotton pests, bollworms in particular. Hence the frequency of sprays on cotton crop has been declined markedly by adding of BT cotton in this system (Men et al. 2003). Hence, BT cotton adopting farmers attained pesticide reductions of about 40% with yield gains of 30–40% (Sadashivappa and Qaim 2009). BT cotton is gaining popularity among farmers owing to better yield and less use of pesticides (Abdullah 2010). But this increase in yield is associated with its long growing period, which enforces the growers to plant BT cotton during early March. Hence, after the addition of BT cotton in cotton–wheat cropping system; wheat is being evaded from this system due to an overlapping time of about 30–45 days between wheat harvest and sowing of cotton. Wheat cultivation is being reduced in South Punjab as majority of the farmers are shifted towards BT cotton cultivation in early March to get its maximum production potential. Meanwhile, about 70% of wheat growers are shifted towards BT cotton production (Sabir et al. 2011).

This situation created some serious concerns about future food supply to the Pakistani residents as over 50% of total wheat production comes from this region. In this situation, some management alternatives are needed to get rid of the time conflict between wheat and cotton in this system. Cotton can be intercropped in standing wheat during early or late March by growing cotton in furrows and wheat on ridges or beds. The seedling phase of cotton and the reproductive phase of wheat overlap over a period of approximately 6–7 weeks between the sowing of cotton and harvest of wheat and immediately after the harvest of cotton at the end of October, wheat is sown again (Zhang et al. 2007). Intercrops reduced yield of cotton crop by 8–31% however total crop productivity and net return per unit area were greater in intercropping than sole cropping (Khan et al. 2001). Recently, Shah et al. (2016) concluded that intercropping of BT cotton during early March in bed sown wheat may be opted to manage the time conflict and improve the economic productivity of BT cotton–wheat cropping system without wheat exclusion from the system.

Likewise, transplanting of 30-45 days old seedlings of BT cotton just after the harvest of wheat is the other option to tackle this serious concern without compromise in net economic returns. Transplanting is beneficial due to removal of thinning process, optimized use of limited water resource and adjustment of other crops in existing cropping pattern of the particular area. Raising nursery seedlings in plastic paper pots (Jahromi and Mahboubi 2012) and transplanting in the main field help in maintaining the required crop stand, escaping early season abiotic stresses, achieving earlier maturity and harvesting better yield (Rajakumar et al. 2010; Jahromi and Mahboubi 2012). Results of the latest study conducted by Shah et al. (2017) confirmed that transplanting 45 days old seedlings of BT cotton on beds during late April after harvest of bed sown wheat may be opted to manage the time conflict and improve the productivity of BT cotton-wheat cropping system.

Table 19.2 Area, source of irrigation and average rainfall in various cropping systems practiced in Pakistan

Province	Cropping system	Area (Mha)	Source of irrigation water	Average rainfall (mm)
Punjab	Rice-wheat	2.80	Canal, tubewell	800
	Cotton-wheat	5.50	Canal, tubewell	156
	Mixed crops	4.10	Canal, tubewell	446
	Maize/wheat-oilseeds	1.20	Rainfed	900
	Pulses-wheat	1.90	Canal, rainfed	300
Sindh	Rice-wheat	1.10	Canal	58
	Cotton-wheat	1.60	Canal	50
	Mixed crops	1.30	Canal, dry	123
KPK	Mixed crops	0.53	Canal	520
	Maize-wheat	0.90	Rainfed	1050
	Pulses-wheat	0.36	Canal, dry	500
Balochistan	Rice-wheat	0.35	Canal	-
	Mixed crops	0.40	Tubewell, Karez	180
	Orchards/vegetables-wheat	0.30	Tubewell, Karez	115
	Peri-urban	0.02	Tubewell, Karez	167

Source: FAO (2004)

19.3.2.2. Rice-Wheat Cropping System

Rice-wheat cropping system (RWCS) is the second largest system after cotton-wheat in Pakistan and it is being followed on an area of 2.8 Mha in Punjab, 1.1 Mha in Sindh and 0.35 Mha in Balochistan (Table 2; FAO 2004). In Punjab, RWCS is being followed in the districts of Sheikhupura, Nankana Sahib, Gujranwala, Sialkot, Hafiz Abad, Chiniot, Gujrat and some parts of Lahore and Faisalabad. In these districts, about 73% of wheat is rotated with rice. In Sindh, this system is spreaded in the districts of Larkana, Shikarpur, Jacobabad, and some parts of Dadu, Thatta and Badin. In this system, rice is grown as main *kharif* crop. In Sindh, high yielding coarse gain varieties are grown. However, in Punjab, higher value, fine grain, late maturing basmati varieties are grown.

In RWCS, puddling is done in rice fields followed by rice nursery transplanting in the puddled soils. After harvesting rice, wheat is sown in well-pulverized soil after several preparatory tillage operations. This shows an edaphic divergence in conventional soil management practice for rice and its subsequent wheat crop (Farooq et al. 2008). Puddling in paddy field helps in maintaining water/ nutrient resources, weed suppression and better yields. The resource utilization efficiency is also increased due to puddling (Naklang et al. 1996; Surendra et al. 2001). However, studies indicated the negative effects of soil environment created due to puddling in rice fields on the crops following rice (Sharma and DeDatta 1985). Puddling usually results in erratic crop establishment owing to poor contact of seed with soil in cloddy post-rice puddled soils (Farooq et al. 2008). Puddling affects the total porosity and distribution of pore size in soil which changes the moisture retention properties of soil in post rice crops (McDonald et al. 2006). Puddling also increases the bulk density and has a depressive effect on growth of shoot and root of post rice crops (McDonald et al. 2006). Puddling results in the formation of hardpan at shallow depth resulting in subsurface compaction (Saharawat et al. 2010), which serve as a barrier for root development of winter wheat crop (Ray and Gupta 2001). Nitrogen uptake is reduced by 12-35% in wheat following puddled rice due to sub soil compaction (Ishaq et al. 2001). Moreover, flooded rice fields are major contributor of atmospheric methane (CH_4) owing to anaerobic decomposition of organic matter (Neue et al. 1990), which is causing the global warming. In conventional rice production, 3000-5000 liters of water are applied to produce one kilogram of rice (Belder et al. 2004; Geethalakshmi et al. 2011), which is 2-3 times higher than that of other cereals like wheat, sorghum, maize and barley (Barker et al. 1998; Bouman et al. 2007). The sources of water, both underground and surface water, are declining and water availability has been limited for rice production (Farooq et al. 2009). The profit margins in conventional rice production system has been reduced due to high requirement of water by the transplanted rice, high costs of labor required for transplanting of rice nursery and reduced availability of labor force for transplanting (Pandey and Velasco 1999). Moreover, in RWCS, the rice growers grow the basmati varieties of rice. Basmati varieties mature late as compared to coarse rice varieties. Due to late maturation of basmati varieties, the harvesting of rice is delayed. This late harvesting of rice accomplished with poor structure of soil created due to puddling and previous rice crop residues creates problems for good seed bed preparation for wheat and thus wheat plantation is delayed mostly (Byerlee et al. 1984). In addition, if rainfall occurs at this time accomplished with low temperature, wheat sowing is further delayed up to 2-3 weeks (Aslam et al. 1993). This late plantation of wheat is the major limitation to wheat production (Ahmed and Meisner, 1996). Delay in wheat sowing after mid-November results in yield reduction by 1-1.5% per hectare per day (Nasrullah et al. 2010; Hussain et al. 2012a). Late emergence of seedlings, uneven and patchy crop stand, reduced tillering and short duration for grain development, (Ortizmonasterio et al. 1994; Hussain et al. 2012b), and heat stress at reproductive and grain filling stages (Nawaz et al. 2013) may be the possible reason for reduction in wheat yield due to late sowing.

In this scenario, CT in wheat offers an ecofriendly option to resolve the edaphic and time conflicts in the conventional RWCS (Hobbs et al. 2007). For example, the yield of post rice wheat can be enhanced, with decrease in production cost if we only eliminate puddling operation in rice (Timsina and Connor 2001). Aerobic direct seeded rice and alternate wetting and drying (AWD) are the rice production systems, which not only help in resolving the soil conflict in RWCS but also reduce water/labor input, and emission of greenhouse gases (Oliver et al. 2008; Farooq et al. 2011). Rice produced by these systems also matures earlier than the conventional systems thus allowing the timely sowing of crops following rice (Farooq et al. 2009).

Pictorial view of direct seeded rice grown at district Nankana Sahib and district Sheikhupura is shown in Figure 20.1.

Figure 19.1 Direct seeded rice crop grown at farmer field in district (A) Nankana Sahib and (B/C) Sheikhupura

For wheat following rice, CT in wheat allows earlier wheat planting, reduces production costs (Hobbs and Gupta 2004; Erenstein and Laxmi 2008), helps in water conservation, increase wheat yield from "6-10%" (Laxmi et al. 2007; Erenstein and Laxmi 2008). The CT practices improve soil water storage capacity, soil organic carbon, improve soil quality and reduce soil erosion (Madejon et al. 2007). Conservation tillage also increases various soil enzymes activity (Masto et al. 2006; Lupwayi et al. 2007), soil respiration (Zhang et al. 2005) and soil microbial carbon (SMC) (Liu et al. 2010). In RWCS, the rice is grown in *Kharif* season and the wheat is grown in the *Rabi* season. There is a short fallow period of 40-70 days between harvest of wheat and planting of rice. Wheat is harvested in the last week of April to first week of May and rice is planted in the second or third week of July. This fallow period of about 2 months between wheat harvest and rice planting can be used effectively for raising a suitable summer fodder or grain legume crop. Various summer legumes have been attempted to raise in the intervening period between wheat and rice. This practice not only provides pulse grains but also benefits the succeeding cereal crops through improvement in soil fertility (Shah et al. 2011). The involvement of summer legumes/green manures (sesbania, mungbean, soybean, cow pea, pigeon pea) in RWCS has shown positive impacts in Pakistan (Mann et al. 2000; Shah et al. 2011). In a study, the wheat-Janter-rice-wheat rotation improves the soil fertility (www.hrmars.com/admin/pics/243.pdf). Likewise, at some farms of Sheikhupura district, the rice-pea-okra + wheat cropping pattern is common. The farmers in this area grow short-duration, and non-aromatic rice from June to September, and pea from end of September to early December (Haqqani et al. 2000). The cultivation of black gram is also getting momentum in those areas of RWCS where water is scanty (Haqqani et al. 2000). Sesbania is a potential green manure legume for the RWCS in Pakistan. Its green manuring can be done between the wheat harvesting and rice planting. This sesbania is then incorporated into the soil which increases yields of succeeding crop by improving the soil fertility (Haqqani et al. 2000). In a study, Ibrahim et al. (2000) concluded that green manuring of sesbania and guar in RWCS enhanced the yield of rice and wheat.

19.3.2.3. Mixed Cropping System

The mixed crop rotation is being followed in the central Punjab, some parts of Sindh province, and Peshawar Valley of Khyber Pakhtunkhwa. Maize and sugarcane are important *kharif* crop in this system. However, the other crops like cotton, rice, potatoes, sunflower, wheat and other vegetables are also grown. This system dominates in the districts of Faisalabad, Sargodha, Sahiwal, Jhang, Kasur, Toba Tekh Singh and Okara in Punjab. This zone is vastly affected due to salinity. Sugarcane and maize cultivars that can perform better under saline conditions needs to be selected for various crop rotations in this area. Besides soil salinization, poor soil fertility status, shortage of canal irrigation water, brackish underground water in most parts of this zone and uncertain market facilities etc. are the major constraints of this cropping system. Nonetheless, mixed cropping system has high cropping intensity compared with cotton-wheat and rice-wheat cropping systems. This system is highly diversified (more number of crops belonging to diverse families) compared with both aforementioned cropping systems and therefore mixed cropping system is less prone to risks of complete crop failures (personnel observation). Farmers can keep their fields under continuous production in this cropping system, which will help in reducing the effects of adverse weather conditions for the farmer as planting and harvest is at different times of the season. There is more land to be farmed with the same amount of labor and machinery because different crops are sown and harvested at different parts of the year. However, under this system, soils are under continuous stress of depleting nutrients as the soil may not remain fallow to restore its fertility. Therefore, inclusion of some leguminous crops like sesbania in this rotation is necessary to maintain soil health and quality.

Sugarcane is the main crop of mixed cropping zone and it can be sown twice in a year. It is a high input demanding crop. The share of mixed zone in wheat acreage (production) in Punjab is 21% (Byerlee and Husain 1993). Under agro-climatic conditions of Faisalabad, mixed-wheat cropping system is being followed where sesbania, rice, cotton, maize, potato, mixed fodder, radish and spinach are grown in *kharif* while wheat as main crop in *rabi* season. However, experimentation conducted in this area proved that bajra-potato-maize and sesbania-potato-maize cropping systems are economically efficient and restore more soil fertility than existing pattern. Moreover, sesbania based cropping system improved more fertility status of the soil. So it is recommended that sesbania as green manure crop should be included in mixed cropping system. Farmers in Sindh province are now practicing intercropping of sugarcane with numerous high return crops such as onion, fodders, chilies, tobacco, and melons etc. to enhance input use efficiency of farm resources. The same trend of sugarcane intercropping can be adopted in Punjab to boost up the farmer profitability and increase the cropping intensity. In the past few years, sugarcane growers in Sindh have started planting wheat and paddy, or and sunflower instead of sugarcane due to water shortage (Khan 2013). Lentil and gram intercropping in September sown sugarcane may also be a good option to increase the cropping intensity and famer net annual income (Kanchannainwal 2014). These legumes can also add the nitrogen within the soil thus saving plenty of nitrogen fertilizer used in sugarcane crop.

19.3.2.4. Sugarcane/Maize/Tobacco-Wheat Cropping System

This cropping system is being practiced in the irrigated plains of district Mardan in KPK province. Sugarcane, maize or tobacco is grown in *kharif* season while wheat is grown in winter season. These plains consist of fine alluvial deposit, the composition and depth of which is spatially variable. The climate of this area is hot subtropical continental with average annual rainfall of 944 mm. The winter rainfalls are influenced by cold fronts moving in from the Hindu Kush Mountain Range, which flanks the area on the northwestern side, while the summer rains result from warm fronts from the Indian Ocean. The region is located at an altitude of 270 m. The soils of this zone are slightly to moderately calcareous and horizon boundaries are smooth and clear. The whole agriculture is based on irrigation water with moderate to high cropping intensity.

19.3.2.5. Sorghum/Maize/Pulses/Fallow-Wheat Cropping System

This cropping system is being followed in the rainfed plains of northern Punjab especially in Chakwal, Attock, Jhelum and some parts of Rawalpindi. Usually monocropping is done in rainfed areas. In *kharif* season, the fields remain fallow and wheat in planted in winter in the residual moisture of monsoon rains. However, if plenty of rainfall occurs in winter, the sorghum, maize and pulses are grown after wheat harvest. In the last few years, rainfall pattern has been changed in this region and a plenty of rainfall occurs even at the wheat and chickpea harvest. Even, during this year, heavy rainfall is occurring and more rainfall is expected in these Barani areas in coming days. This changing rainfall pattern affirms that sufficient soil moisture will be available to grow the *kharif* crops like sorghum, maize and pulses which can increase the cropping intensity of the rainfed cropping system and thus adding towards the farmer income. The farmers following this cropping system has access to improved seeds of maize and wheat, fertilizers and mechanical technologies for land preparation and threshing of these crops. The examples includes the use of *rabi* drill for wheat sowing, drill for chickpea sowing and harvesting of chickpea and oilseeds with combine harvesters especially by the large land lords of rainfed areas.

19.3.2.6. Maize/Rice-Wheat/Fodder Cropping System

This cropping system is being practiced in the mountainous areas of Swat valley in KPK province. Maize and rice are cultivated in *kharif* season while wheat and winter fodder are cultivated in *rabi* season. Maize cultivation in rotation is common in areas having an altitude between 900 and 1800 m. Maize is grown by nearly every farmer in the *kharif* season in this region. After maize, rice is the second largest crop grown by farmers in Swat valley and most of the rice is grown in rotation with maize. However, delays in early establishment of nurseries and transplanting significantly reduce the yields of rice in this region. About half the farmers above cultivate wheat for grain at an altitude of above 1500 m. Wheat and rice can only be raised in a few of the low-lying areas. The summer season is short, and fields produce only one crop a year. Interestingly, increasing altitude in this region is associated with decreasing cropping intensity especially on irrigated lands. Larger farms tend to have lower cropping intensities. Enclosed by high mountains, the Swat valley is characterized by extreme aridity with mild summer and cold winter. In the Swat valley, farm size is very small; 62% farmers having less than 1 ha of land and 80% having less than 1.5 ha (Byerlee and Husain 1993). Most of the farmers do not meet food needs from their own crop production, and they supplement farm income with off-farm work. In Swat valley, farmyard manure, subsistence milk production, and draft power are more important than cash income from livestock. The farmers following this cropping system has access to improved seeds of maize and wheat, fertilizers and mechanical technologies for land preparation and threshing of these crops. In this region, cultivation is carried out on every possible bit of land; the ground surface is rough and stony due to which fields are laid out in terraces and strips, one above the other, the boundary walls being formed of stones collected from surface. It requires specific engineering skill for their construction of these terraces and strips. By this arrangement, the soil is cleared of stones and made level to retain water led onto it for irrigation. Large quantity of rice produced in this valley is exported to British territory.

19.3.2.7. Maize-Wheat/Fallow Cropping System

This cropping system is also being practiced in the mountainous areas of Swat valley in KPK province. Maize is either cultivated in *kharif* season with wheat in *rabi* in double cropping system, or the farmers grow maize in *kharif* and keep the fields fallow in the post maize season. The farmers following this cropping system has access to improved seeds of maize and wheat and fertilizers but the mechanical technology for land preparation and threshing of these crops is limited in this area. The other crop and soil management practices remain same as discussed in section 7.3.2.7.

19.3.2.8. Maize-Wheat/Fodder Cropping System

This cropping system is also being practiced in the mountainous areas of Gilgit in Gilgit Baltistan province. Maize is either cultivated in *kharif* season which is followed by some fodder in *rabi* season in double cropping system. The farmers following this cropping system has access to some improved seeds of maize and wheat and fertilizers but the mechanical technology for land preparation and threshing of these crops is limited in this area. More precisely, the climate of the area is cold in winter, and hot in summer at the relatively low elevations. The rainfall in the areas is scanty and non-homogeneous with an average annual of 254 mm. About 70% of the precipitation occurs during summer, while October and November are relatively dry months. Radiation is another important factor which influences photosynthetic potential, temperature, evaporation and the water balance. This area has a high incident radiation level because of the rain shadow effect reducing the cloud cover, especially in summer, when 70% of the maximum possible sunshine hours are received. Owing to the aridity and temperature of the air, higher evaporation rates in the villages are anticipated in this region. Cropping intensity in *rabi* is 50% while in *kharif*, it is 48%.

19.3.3. Factors affecting cropping systems

The following factors affect the cropping system of an area (adapted from Shaukat 2011).

19.3.3.1. Soil

Soil characteristics which affects the choice of a cropping system includes soil texture, soil slope, depth, soil erosion, soil fertility, soil pH, mineral nutrients, fertility, acidity, salinity, alkalinity and drainage etc.

19.3.3.2. Climate

Cropping system is influenced by climatic variables like temperature, solar radiations and photoperiod, precipitation, humidity, winds, storms, air pollutants and irrigation facilities available in that area.

19.3.3.3. Resources

The choice of crop cultivation in any cropping system depends on capital, seed, fertilizers, labor, farm machinery, technology, pesticides, and storage facilities available at farm.

19.3.3.4. Capabilities of Plants and Animals

The genetic potentials and production of the selected animals and plants in relation to the selected place for setting up the farm also influence the cropping system.

19.3.3.5. Ecology

Crops, pests, animals, diseases and trees, etc. of the selected location for setting up the farm have massive impact on cropping system.

19.3.3.6. Social, Political and Economic Factors

Markets, consumer choice, agro-based industry in vicinity, farm inputs/outputs, demand, prices, transportation, etc. influence the choice of crops in a cropping system in any locality.

19.4. Planting methods

Various planting methods used in various crops are discussed below

19.4.1. Broadcasting

In this method, crop seeds are broadcast followed by harrowing to cover them. However, the seed depth and seed distribution is not uniform in this method and frequent irrigations may be needed for proper moisture availability to crop. In this method, germination is relatively poor resulting in irregular crop stand (Figure 20.1A). Some seeds may get wasted when it is left on the surface and can be picked up and eaten by birds. This method is being used by the farmers in irrigated plains for sowing of wheat. In some areas, the broadcasting of rice seeds is also done which is termed as water seeding. This is the most common method of sowing of fodder crops like berseem, oat, barely, sorghum, millet, guar etc. in rainfed and irrigated plains. In this sowing method, it is not possible to maintain proper plant to plant and row to row distance (Figure 20.1A).

19.4.2. Behind local plough

In this method, the crops seeds are dropped manually by hand into the furrows (opened with local plough) (Figure 20.1B). When the crops seeds are dropped directly by hand in furrows, it is called 'kera' method. However, when seeds are dropped through a special attachment (Pora/Nai/Hazara) with local plough, it is termed as 'Pora' method. Seeds are dropped at a depth of 5-6 cm and germination is satisfactory in this method. The Pora method is very common in rainfed areas for sowing of peanut, gram and brassica species. In this sowing method, it is possible to maintain proper row to row distance, but not possible to maintain plant to plant distance.

19.4.3. Drilling

In this method, the crops seed are sown by using a seed drill (Figure 20.1C), or seed cum fertilizer drill. Sowing of crops by seed drill results in uniform stand establishment because the seed can be dropped at any required depth. Before drilling, seed bed should be fine pulverized, and well leveled, free from clods and weeds for the use of seed drill or seed cum fertilizer drill. These drills are easily accessible and are available in every kind of agricultural machinery market. They may be either bullock driven, or tractor driven. Seed cum fertilizer drill is used to ensure uniform depth of sowing, as well proper fertilizer placement at the same time. Seed drills and seed cum fertilizer drills are used for the sowing of wheat and cotton etc. in irrigated and rainfed areas. Recently, seed drills have also been introduced for sowing of chickpea and peanut in rainfed areas and they have provided very satisfactory results regarding uniform stand establishment and maintenance of row to row distance in both these crops. Scientists are also trying to fabricate seed drill for direct sowing of rice in RWCS which will save the labor resources used for transplanting of rice nursery. Zero tillage drills like zone disk tiller, happy seeder and turbo seeder are also becoming popular among the farmers for direct sowing of wheat into rice stubbles without any preparatory tillage which will save the production cost and will ensure timely wheat sowing. In this sowing method, it is possible to maintain proper row to row distance, but not possible to maintain plant to plant distance.

19.4.4. Dibbling

This method of crop sowing is practiced when the seeds to be sown are limited, and are bold. Sowing of seed is done with the aid of a small implement, called 'Dibbler', which is made up of iron or wooden frame and have pegs (Figure 20.1D).

Figure 19.2 Pictorial view of (A) broadcasted seeds (B) behind local plough sowing (C) wheat drilling (D) dibbling

The frame is gently pressed into soil and is lifted, and then one or two seeds are dropped manually in each hole. It is not a common method because it is a very time-consuming process. Sowing of hybrid maize by dibbler is a common example of this method. In this sowing method, it is possible to maintain proper row to row and plant to plant distance.

19.4.5. Transplanting

In this method, nursery of a specific crop is grown and then it is transplanted in the field after specific time by maintaining a special planting geometry. Transplanting of rice and tobacco are the common examples of this method. In this sowing method, it is possible to maintain proper row to row and plant to plant distance.

19.4.6. Bed sowing

In this method specific beds are made manually and with the help of bed planter and then crop is sown. This method may be used for sowing of wheat (Figure 20.2A), cotton, rice, maize and vegetables etc. This method can save plenty of irrigation water as the water is needed only in furrows and not the whole area of a plot is watered. Using raised bed planting technology, 20-30% irrigation water can be saved with higher productivity. In this sowing method, it is possible to maintain proper row to row distance, but not possible to maintain plant to plant distance (Figure 20.2A). However, plant to plant distance can be adjusted through thing in this method.

Figure 19.2 Pictorial view of (A) bed sowing in wheat (B/C) pit plantation in sugarcane (D) ridge sowing in cotton (D) ridge sowing in wheat

19.4.7. Pit plantation

This method of plantation is used for sugarcane cultivation (Figure 20.2B). It is also called “ring pit method”. It is very cost effective and also helps the farmers to enhance the yield than other methods. In pit method, specific pits of variable dimensions are digged out manually or mechanically through specially designed tractor drawn power tillers by marinating specific pit to pit distance (Figure 20.2B). The depth of pit may vary from 1.25 feet to 1.5 feet. The pit method of sugarcane cultivation is more nutrient and water efficient as it reduces water use, and enhances the nutrient use efficiency.

19.4.8. Ridge sowing

In this method, specific ridges and furrows are made manually or with the help of ridgher and then the crops are planted on ridges and water is applied in furrows (Figure 20.2C/D). This method is used for planting maize, cotton (Figure 20.2C), sugarcane, tobacco, vegetables and some times wheat as well (Figure 20.2D), and can save surplus water than flat sowing. In this sowing method, it is possible to maintain proper row to row distance, but not possible to maintain plant to plant distance (Figure 20.2C/D). However, plant to plant to plant distance can be adjusted through thinning in this method.

19.5. Farming and Cropping Systems Research

Farming and cropping system research aim at increasing the production and the profitability of a farmer on sustainable basis by making efficient use of available technology, and physical/socio-economic resources of the farmers. The input use efficiency of these resources can be measured by the quantity of output obtained in response to the unit input used in a unit time (Lynam and Herdt 1989). Farming system research aims at sustaining the productivity of various enterprises in the farm, while cropping system research aims only to increase the crop production by efficient utilization of resources. But these changes are not strictly compartmental in the sense because any change in the cropping system may bring about an inevitable change in the farming system (Palaniappan and Sivaraman 1996).

The productive base of any cropping system is crop growth and yield; crop yield can then be considered as function of the management factors and the environment. For the cropping system researcher, management includes choice of variety, the crop types and their arrangement in time and space (cropping pattern), stand establishment method, management of pests and harvesting activities. Environment is composed of land and climate related variable such as rainfall, soil, irrigation, temperature, solar radiation, and availability of such resources such as labor, power and cash (Harwood 1975). Economic factors such as cost of inputs, price of produce, interest rate etc. should be included in the environment component, if they cannot be altered for that time or should be included in the management term if a researcher is suggesting a change in policy. Hence, it is evident that management term is treated as variable and the environment term as invariant. A cropping system researcher studies the interaction between management factors and environments and seeks to determine how he should vary his cropping pattern and management factors to optimize the returns for different production environments. In this concept, environment becomes a fix constraint and the interaction between environment and management factors gets merged with management factors (Palaniappan and Sivaraman 1996). The implication is that cropping system is location specific and to develop an alternate cropping system for a location, the prevailing environment of that location should be clearly understood. In suggesting an alternate cropping system for a location, it is generally assumed that the available physical resources are not fully exploited and hence by intensification of cropping, this lacuna can be removed. The farming and cropping system research in irrigated and marginal areas needs serious attention as has been discussed below.

19.5.1. Research for Irrigated Plains of Indus Basin

The seed and fertilizer technologies optimized by the researcher for the farming and cropping systems of irrigated areas have been adopted by the farmers rapidly. Now, there is a need to find the future sources to further enhance or enhance the productivity of current crops. For example, the productivity of rice-wheat and cotton-wheat system is threatened due to time conflicts in both systems which delays wheat planting and yields. It is the responsibility of the breeder to introduce the short duration and early maturing varieties of cotton and rice to ensure timely wheat plantation. Although, cotton cultivars "NIAB-78" an early maturing cotton cultivars, was introduced and was adopted by the farmers (Byerlee et al. 1987). Likewise, Pak-81 was introduced in RWCS because of its better performance under late sown conditions and was widely adopted by the farmers. However, it is well established fact that the crops cultivars are gradually neglected by the farmers with the passage of time due to decrease in yield potential and enhanced incidence of insect pest and diseases. It needs serious attention of the crop breeders to develop the early maturing cotton and rice cultivars continuously which can replace the existing cultivars. It also needs the close link of plant breeders of the crops grown in irrigated plains to develop the varieties of companion crops because change in maturity date of cotton and rice, or change in management practices or marketing price of these crops might have strong implication for the breeders of wheat. In some cases, the time conflict in both these systems can be resolved by growing the other crops like oilseeds rather than sowing wheat in late months but it may impact the food security; as wheat is the staple food of the region needs vast experimentation (Tetlay et al. 1990). Aside from plant breeding, the irrigated systems also needs experimentation on crop and resource management to sustain productivity, enhance input use efficiency and system productivity while maintaining the soil quality and protecting environment. Research on crop rotations, weed and pest control, tillage methods, method and timing of fertilizer application, fertilizer nutrient balances, and efficient utilization of water needs keeping in mind the climatic and socio-economic conditions of the farmers needs serious attention to enhance the input use efficiency and sustainability of irrigated plains (Byerlee and Husain 1993). For example, the land type is different in various districts of rice-wheat and cotton-wheat zone but only single or two/three recommendations of fertilizers on the basis of soil fertility has been made. It needs experimentation to recommend the doses for each crop keeping in mind the land type and the crop rotation in which crop is grown. The weeds types and irrigation practices dominate in that area should be considered while making fertilizer recommendation. Chemical weed control methods must be optimized and transferred to the farmers in irrigated plains. Moreover, in RWCS, productivity of rice grown by conventional method (plouging, planking, puddling, nursery transplanting) is threatened due to diminishing water resources and labor force for transplanting of nursery. The flooded paddy fields have also serious concern about the global warming due to emission of methane, and impact on soil quality. There is a dire need to priorities the research on ecofriendly, water, labor and energy saving rice production systems which will also maintain the soil quality and yield levels as traditional rice systems. Although, this type of experimentation have been carried out but has not been disseminated to the farmers by the extension agents due to poor collaboration between the research and extension wing. To solve the dilemma of late sown wheat, conservation tillage in wheat is the most pragmatic option (Farooq and Nawaz 2014). This technology not only saves the cost of land preparation but also allows early wheat planting. Although, this technology is adopted by some farmers but its diffusion is not so rapid. The farmers have serious concerns about the rice residue management and lodging problems in conservation tilled wheat. It needs strong collaboration between the researchers and the machinery manufacturers to develop such prototypes of drill which can manage crop residues. The drills like zone disc tiller, happy seeder and turbo seeder has been developed which can easily manage crop residues. The farmers should be provided subsides to purchase these drills and the survey should be conducted by extension worker to find out the other possible reasons for poor uptake of these conservation tillage technologies in wheat. To address lodging problem of conservation tilled wheat, experimentation must be done to optimize the crop and fertilizer management practices which can reduce lodging. The yield level of semi dwarf varieties has been stagnant in last few years. The experiment must be conducted to optimize the crop management practices for improving yield of these cultivars. The micronutrients levels in soil and soil disease problems must be addressed to correlate them with yield stagnation and to find suitable strategies to solve them. Sugarcane is a major cash crop in irrigated plains of Indus basin (Byerlee and Siddiq 1990). It occupies field for longer time so the farmers have to wait for produce for longer time. The research must be prioritized on intercropping of legumes or some cucurbitaceous plants which can provide additional income to the farmers with substantial improvement in soil quality. In cotton areas, the farmers are facing severe problems of poor seed germination, immature boll falling and low boll formation due to excessive rainfall in these areas in the last few years. The future research must include the techniques to improve the cotton seed germination, to reduce the immature boll falling to enhance the tolerance of cotton against water logging (personnel observation). In my opinion, the biggest reason for stagnant crop yield in irrigated plains is the non-collaboration of various research wings with each other and the poor link between extension and research wing. The management of effective crop and resource management in irrigated plains needs better integration of the various disciplines viz. soil science, agronomy, irrigation water management, agricultural engineering, agricultural extension, entomology, plant pathology and social sciences. There is also very dire need of setting strong collaboration between the research and the extension wing to spread the innovation made for crop improvement by the researcher to the farmers. In nut shell, the research system in irrigated plains must emphasize on enhancing the input use efficiency through improved method and timing of application, improvement in cultural practices and better management of input support systems including irrigation.

19.5.2. Research for Marginal Environments

The research for marginal environments is different from that of irrigated plains of Indus basin. Due to extreme variation in time and space in marginal areas than irrigated areas, it is difficult to identify homogenous strata on the basis of which recommendation will be made. If these strata are identified, they are too small and cannot be recommended for whole marginal areas. As crop-livestock interaction has strong implications for marginal areas and the crop growth progresses on depleting soil moisture, so there is a need to see for system intervention for a wide range of conditions such as techniques to conserve the soil moisture, inclusion of fodder and cash crops in the system to fulfill animals feed needs and enhance farmer income and introduction of early maturing varieties to boost up the cropping intensity. During last few years, plenty of rainfall has been observed at the end of *rabi* season which might helpful for increasing the cropping intensity in rainfed areas. In this changing scenario, it is dire need to conduct experimentation on various aspects which may enhance the cropping intensity and productivity in marginal lands with positive impacts on soil quality. The summer sowing of mung bean or other leguminous crops will not only improve economic conditions of farmer but also enhance fertility of the soil. Millet/legume cropping system can be easily intensified and also made more productive by appropriate choice of cultivars, manipulating agronomic factors such as row management and densities of component crops in rainfed areas. Spatial intercropping system in which maturity time of two crops is identical, but the two crops differ invariably in crop canopy or root systems deserve focus in rain-fed areas. Millet/groundnut is typical example of spatial intercropping system and may be adopted keeping in view the soil and environmental conditions. Moreover, maize/groundnut is typical example of spatial intercropping system and may be adopted keeping in view the soil and environmental conditions. Moreover, growing of some cucurbitaceous crops like musk melon and water melon within the peanut or maize/millet can fetch some profit for the farmers of the rainfed zones. The non-matured fruits of the water melon are used as a vegetable, so intercropping of water melon in these crops may fulfil some vegetable demands of rainfed areas on family or commercial basis. Growing of peanut in wide rows and planting of mung bean within the peanut may be useful for increasing the cropping intensity and farmer profitability. In sub -humid and humid regions the sequential cropping system may be adopted. The sequential cropping system is sowing two consecutive crops, second one sown after the harvest of first crop. During the summer rain, maize and sorghum can be sown while wheat, chickpeas can be sown during winter months. This will be the most productive system, as cropping intensity will be 100 per cent and two crops will not be subjected to competition with each other (DAWN 2007). Several intercropping systems like canola with wheat, canola with gram and wheat, canola with lentil and wheat, and canola with linseed and wheat can be checked in rainfed areas for their feasibility. Some crop rotations like sunflower-rapeseed-wheat and rapeseed-fodder-pea can get promotion in rainfed areas if rainfall remained sufficient as is happening since the last few years. The intercropping of groundnut with red gram, castor, sorghum, chilli, sunflower and pearl millet is being practiced in India (http://vasat.icrisat.ac.in/?q=node/110), and it needs to be practiced in our rainfed areas and needs wide experimentation.

The experiments on moisture conservation in rainfed areas may involve the use of several primary tillage implements like mould bold plough and disk plough and their impact on soil aggregation, soil biology and nutrient retention. In mountainous areas at high altitudes, the low cropping intensity may be attributed to lack of early maturing varieties of wheat and maize which needs serious attention of plant breeders. In marginal areas, it has been observed that the most of monsoon rains occurs in July and August and the wheat is sown in the residual moisture of these rains by preserving the soil moisture upto November. The author has personally observed that after wheat sowing, no rainfall is occurring since last few years and crop have to suffer an early drought of about 60-100 days. However, developing of wheat cultivars with good heat tolerance at seedling stage might allow earlier wheat planting in this region for more efficient use of residual moisture. Those crop cultivars must be developed which provide fodder and grain to the farmers of marginal lands. Research on fodder is also missing in marginal areas. It needs strong interrelation of crop and livestock researcher to develop those cultivars which will not only provide grain to the farmers but also can provide fodder to feed to livestock's. Finally given the importance of farm yard manure in the system, more research is needed to analyze the allocation of manures to various uses and to document long term trends in farmers' use of manure and their implications for system productivity. In marginal areas, the input use is quite small and there is a wider scope for research through on farm trials to enhance the productivity. Crop management, livestock management and fodder production are the three important aspects which need research side by side. In marginal areas, the input distribution is very low from public as well as private sector which must be boosted up.

In conclusion, research on efficient utilization and conservation of available resource and exploiting the potential of marginal lands may be useful for enhancing the productivity of crops and raising the income level of farmers.

19.6. Multiple cropping

The intensification of cropping in spatial and temporal dimensions; growing two or more crops on the same field in one year is called the multiple cropping. It refers to as practices that enhance the production in a unit area of land in a farming year through growing crops simultaneously, sole crops in sequence and a combination of sole and mixed crops in sequence (Andrews and Kassam 1976). Multiple cropping systems can, therefore, combine several species or cultivars simultaneously in the same area or sequentially in the crop sequence. Multiple cropping systems depend largely on socioeconomic conditions, irrigation facilities, and access to input, machinery, and labor. Multiple cropping also promotes biodiversity in the agro-ecosystem and quantifies food web complexity by offering new habitats for a number of animals and soil organisms (Sokos et al. 2013). Multiple cropping includes various crop intensification techniques like intercropping, sequential cropping, relay cropping, and ratoon cropping. The most common advantage of multiple cropping is to produce a higher yield from a given piece of land by achieving more efficient use of the available natural resources for crop growth that would otherwise not be utilized by each single crop grown alone. Therefore, in terms of land use efficiency, intercropping is regarded as more productive than sole cropping. Higher nutrient uptake and better water use efficiency (WUE) have also been suggested, but probably need to be tested for each different combination of crops used for intercropping systems. Better use of solar radiation by multiple cropping was attributed to increased interception of photosynthetically active radiation resulting in higher radiation use efficiency. Multiple cropping has been identified to conserve water largely because of early high leaf area index (i.e. initial fast leaf expansion) and higher overall combined leaf area of both crops (Ogindo and Walker, 2005). By selecting relevant plant species, multiple cropping systems can modify pest foraging or reproduction directly or increase the abundance of the natural enemies of the pests which are mainly insect herbivores. Multiple cropping systems may contain species that produce biochemical cues that disrupt the development of diseases, pests, root parasitic nematodes, and weeds (Ratnadass et al. 2012). In multiple cropping system crop production increases with increasing use of fertilizers or pesticides, which in return causes pollution and ultimately degrades water or air quality and the biogeochemical cycles of nutrients. Land management practices such as fertilization or crop rotation can drive changes in one or several ecosystem services (Bennett et al. 2009).

Resource competition may occur between species when they are grown in mixtures, e.g. cereal/legume systems, and perennial based multi-species cropping systems where two or more crops are harvested separately. The total biomass production per unit land area of land when more than one species is present will frequently be greater than that produced by one of the species grown alone at the same density. This is because, species of different habits are able to utilize the resources more efficiently, chiefly by better spatial distribution in the aerial and soil environment (e.g. by forming a more efficient leaf canopy or tapping a greater depth of soil for water and nutrient uptake). In general, greater the difference in the habit of components species, greater will be the yield advantage of mixtures and conversely, less will be the degree of competitive pressure between the component species. The yield advantage is exploited by crop mixtures but may be disadvantageous in crop-weed situations depending on the degree of weed competition. The major advantage of multiple cropping systems includes better utilization of space, labour resources (Baldy and Stigter 1997), environmental resources which ensure highest yield stability in various environments under variable soil conservation practices.

A thorough understanding of the competition for a certain resource requires the knowledge of-

1) Size of the pool from which the competing species of plants are obtaining the resource
2) How the resource is shared between the plants, and how the presence of one plants alters the supply to the other
3) How the altered supply of resource influences the growth, reproduction and survival of plants (adapted from Newman 1983). Various multiple cropping systems are discussed below.

19.6.1. Intercropping

Intercropping is defined as "*growing two or more crops simultaneously on the same field; crop intensification is in both temporal and spatial dimensions*". There is intercrop competition during the all or prat of crop growth. Intercropping system tends to be low input, risk reducing under dryland farming situations for crop diversification and fulfillment of subsistence objectives. At high input level, it will be necessary to re-valuate and recombine various activities (Palaniappan and Sivaraman 1996). When intercropping is done, the canopy architecture of intercrops should be kept in mind to get maximum benefits from intercropping systems. In intercropping, the both companion crops are planted in a way to minimize the light competition (Okigbo 1981), which may otherwise affect photosynthesis. The light competition can be minimized by proper choice of crop cultivars being intercropped; the shorter components being shade tolerant, and one the components being able to harvest sufficient light so that the later harvested component is not greatly affected. Spatial arrangement of intercrops is an important management practice that can improve radiation interception through a more complete ground cover. The availability of water is one of the most important factors determining productivity in cereal-legumes intercropping systems. Improvements of WUE in these types of systems led to an increase in the uses of other natural resources. Yield advantages from intercropping are often attributed to complementation between component crops in the mixture, resulting in a better total use of resources when growing together rather than separately (Khan et al. 2012).

Adjustment of population density, proportion of each component in the mixture, and planting pattern can also be done to minimize the competition and to increase the light use efficiency; otherwise, light interception may be affected. For example, canopy light interception was reduced in peanut when it was intercropped with millet (Marshall and Willey 1983), or sorghum (Harris and Natarajan 1987; Harris et al. 1987). However, if the components crop grown in intercropping has different growth duration (temporal difference), the peak demand of light will occur at different times which will result in more efficient utilization of light in intercrops than sole crops. For example, if maize is intercropped in sugarcane, the light will be efficiently utilized as maize is a short duration crop and sugarcane is long season, and the light interception will vary in both crops at specific time (Wallace et al. 1990). Intercrops also remove greater amount of nutrient than the sole stands, because each crop has its own zone of absorption, which would otherwise remain untapped if a sole stand of a single crop is sown. Experimentation has shown that legumes intercropping can be most beneficial if they are grown with other crops in an appropriate geometry (Ahmad and Saeed 1998; Jabbar et al. 2010). Legume intercropping with non-legumes especially cereals may benefits non-legumes from the legume nitrogen fixation (Saeed et al. 1997), and hence no competition with cereals for nitrogen resources (Adu-Gyamfi et al. 2007). Legumes when intercropped with cereals also favor the growth of cereals by improving soil quality (Aslam and Mehmood 2003). The canopy structures of cereals and their root systems different than that of legumes, which indicates that the both type of crops have different temporal and spatial use of environmental resources especially radiation, nutrients and water (Willey 1990). This indicated that cereal-legume intercropping may enhance the productivity of low external input farming systems (Bhatti et al. 2008). The advantages of intercropping includes efficient utilization of light, water and nutrients resources, greater stability of yield over different seasons, better disease and pest control, control of erosion because of continuous leaf mulch on soil and enhanced soil quality and agro-eco system function. Moreover, when crops are intercropped, one crop provides shelter and physical support to the other crop and thus prevents crop lodging. On the contrary, adverse resource competition among crops, allelopathic effects of one crop on another, and obstacles in use of machines for intercultural operations may reduce the yields of crops when grown as interop. Intercropping can be of various types as discussed below (adapted from Palaniappan and Sivaraman 1996).

19.6.1.1. Mixed intercropping

Mixed intercropping is defined as "*growing two or more crops simultaneously with no distinct row arrangement*". It is also called mix cropping. Usually, fodder crops are sown in such intercropping system. The examples include the mixed intercropping of lucerne with oat (Figure 20.3A), berseem with barely, and sorghum with millet/guar and cowpea in irrigated and rainfed areas for forage purposes.

19.6.1.2. Row intercropping

Row intercropping is defined as 'growing two or more crops simultaneously where one or more crops are planted in rows; often refer to as intercropping" (Palaniappan and Sivaraman 1996).

Figure 19.3 Pictorail view of (A) mixed croppping of lucern with oat, (B) row intercrop of maize with flax (C) chickpea with sugarcane, (D) sunflower with soybean

Intercropping of chickpea/lentil with wheat in rainfed areas (Chakwal, Attock, Rawalpindi, Jhelum) of Pakistan, and intercropping of sugarcane with chickpea (Figure 20.3B), onion, fodders, onion, melons, and chilies in Sindh, maize with flax (Figure 3C), and sunflower with soybean (Figure 20.3D) are the practical examples of row intercropping system.

19.6.1.3. Strip intercropping

Strip intercropping is defined as "growing two or more crops simultaneously in different stripes wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically" (Figure 20.4A; Palaniappan and Sivaraman 1996). In other words, strip cropping is "growing of two or more crops in the same field, planted in strips such that most plant competition is within each crop rather than between crops". This practice has elements of both monocropping and intercropping, with the width of the strips determining the degree of each. e.g. groundnut + redgram (6:4) strip cropping. Strip cropping is very useful for sloppy lands where alternate strips of soil conserving crops (sods) and row crops can be grown on the same slope, perpendicular to the wind or water flow to reduce the soil erosion. When soil is detached from the row crops by the forces of wind or water, the dense soil conserving crops trap some of the soil particles and reduce wind translation and/or runoff (http://milford.nserl.purdue.edu/weppdocs/overview/wndprot.html).

19.6.2. Relay cropping

Growing two or more crops simultaneously during the part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest (Figure 20.4B/C/D). An excellent example of relay cropping in Pakistan is relay cropping of winter wheat in cotton (Figure 20.4D; Mushtaq et al. 2007). Before the last picking of cotton, the wheat seeds are broadcasted in the standing cotton. Wheat seed emerge and continue their growth in standing cotton. Meanwhile, the last picking is done in cotton and the sticks are removed from the field and wheat crops nourish in the same field. In relay cropping, the relay sown crop may have competition for light from the standing crop resulting in lanky growth of seedlings. However, this competition can be minimized by proper choice of crops, crop varieties, and adjustment of time/method of planting. The other examples of relay cropping includes relay cropping of mungbean in maize (Fig 20.2B), soybean in wheat (Figure 20.2C), and broadcasting of cover crop seed in soybean.

Figure 19.4 Pictorial view of (A) strip cropping (B) relay cropping of soybean in wheat (C) relay cropping of Mungbean in maize (D) relay cropping of wheat in cotton

19.6.3. Sequential cropping

Sequential cropping is defined as "growing two or more crops in sequence on the same field in a year: the succeeding crop is planted after the preceding crop has been harvested; and the crop intensification is only in the time dimension; there is no intercrop competition" (Palaniappan and Sivaraman 1996). Sequential cropping systems are customarily encountered where resource endowments, especially water availability, are adequate than in intercropping systems. Sequential cropping systems utilize higher inputs and income maximization is a more important objective than in case of intercropping. Sequential cropping systems may be double (two crops on the same land in a year in sequence e.g. rice-wheat, rice-cotton; rice-potato), triple (three crops on the same land in a year in sequence; rice-rice-pulse; rice-potato-groundnut; cowpea- mustard- jute) or quadruple (four crops on the same land in a year in sequence; tomato-ridge gourd-Amaranthus greens-baby corn; kharif groundnut-leafy vegetables-wheat-summer green gram (Palaniappan and Sivaraman 1996). Competition for light, water and nutrients as observed in mix crop stands do not occur when crops are grown in sequence i.e. one crop grown after the harvest of other crop. However, for better utilization of light in sequential cropping, the crops with longer duration and having ability to develop the canopy very rapidly should be included in the crop rotation. On the other hands, the crop residues of preceding crop may affect the C: N ratio, nitrogen reserves or may show allelopathic affects which may influence the stand establishment of upcoming crops. For example, the cotton crop grown after legumes performs better than grown after sorghum. In a study, sowing cotton after ragi (Eleusine coracana), and ragi after sunflower improved the yield and nitrogen uptake (Palaniappan and Sivaraman 1996). On the other hand, sorghum has depressive effect on the following crops especially cereals (Arnon 1972). In another study, significant reduction in cotton seedling emergence was observed when cotton seeds were in direct contact with wheat straw residues (Hick et al. 1989).

19.6.4. Ratoon cropping

The cultivation of crop regrowth after harvest, although, not necessarily for grain purpose. It is one of the important methods of intensive cropping, allowing the stubbles of the original crop to strike again after harvesting and to raise another crop (Palaniappan and Sivaraman 1996). The examples include sugarcane: ratoon; sorghum: ratoon (for fodder).

19.7. Crop Rotation

Crop rotation is defined as “the repetitive cultivation of an ordered succession of crops, or crops and fallow, on the same land keeping in view that the fertility of soil may not be adversely affected” (Palaniappan and Sivaraman 1996). Crop rotation can also be defined as “the strategy of raising crops from a piece of land in such an order or succession that the fertility of land suffers minimally and the farmer’s profits are not reduced”. This practice is in contrast with the practice of growing same crop year after year. Various crop rotations are being followed in Pakistan and some are centuries old. The principle objective of crop rotation is to enhance crop production on sustained basis by maintaining or enhancing the fertility of the soil without compromising the net income of farming community. It has reported that modem crop rotation was first time introduced in England in 1730.

Excellent crop rotations are those which maintain/improve the soil fertility/productivity, make balanced use of fertilizers, and include a legume crop to enhance nitrogen fixation, an intertilled/cultivated crop for control of weeds, and a legume/grass cover crop for maintenance of soil humus. Various climatic, socio-economic and management factors such as soil, weather conditions (rainfall, temperature, humidity, sunshine), labor/water availability, market demands, weeds, insets pests, diseases, and prevalent system of farming affects the choice of crop rotation in an area.

19.7.1. Advantages of Crop Rotation

An ideal crop rotation is one which maximizes famer benefits, makes efficient utilization of farm equipments and ensures timely field operations. The advantages of crop rotations are listed below (adopted from http://www.slideshare.net/abrar09/cropping-patterns):

- Timeliness of agricultural operations for all the crops owing to less competition for resources.
- Restoration of soil fertility through atmospheric nitrogen fixation and enhanced activity of soil microbes.
- Insect's pests, weeds, and diseases are managed easily.
- Efficient utilization of on-farm and off-form resources as labour, equipment, machines, and power, are well-employed across the whole year.
- Farmers get better price of the produce due to enhanced market demand.
- Reduce risk for crop failure.
- In crop rotation, crops belonging to different nature are grown which ensures efficient utilization of soil fertility, soil moisture, and organic residues. Crop rotation also improves soil structure, water percolation and minimizes the chances of hard pan formation in sub-soil zone.
- Improved food and financial security.

19.7.2. Principles of Crop Rotation

The crops to be grown in rotation are selected on the basis of specific accepted principles/guidelines. These principles are discussed below (adapted from http://agriinfo.in/?page=topic&superid=1&topicid=669).

1) The crops having taproot root system should be rotated with the crops having fibrous root system to ensure proper and uniform nutrient utilization from soil, and to reduce competition between roots for nutrient uptake.
2) A deep-rooted cash crop, shallow-rooted grain crop, and a legume crop (restorative crop) should be included in crop rotation to ensure the cash, food, and fodder, supply to the farmers while maintaining soil fertility/productivity.
3) The crops of the legume family (mungbean, mashbean, cowpea, chickpea etc.) should be planted after the crops of non-leguminous families because legume crops enhance organic matter by fixing the atmospheric nitrogen. Amide this, the legume crops need less nitrogen and more phosphate, while non-legume crops need less phosphate and more nitrogen. This may reduce the cost of production (save in fertilizer cost) at farmer field.
4) Soil conditions, climatic conditions and market demand should be kept in mind while selecting crops for rotation.
5) More exhaustive crops (potato, maize, sugarcane etc.) should be planted after less exhaustive crops (pulses, oil seeds). The exhaustive crops need more inputs such as better tillage, frequent irrigations, high fertilizer, high insecticides, and better management care than less exhaustive crops which need less inputs and less care.
6) Under irrigated conditions, 2 or 3 crops are grown in a year on the same piece of land depending on the availability of irrigation water. However, a

dry crop (having very low water requirement) should be included in this rotation to lessen the damage to the soil due to continuous irrigation.

7) In rain-fed farming where the crops complete life cycle on depleting soil moisture; crop requiring less soil moisture must grow after the harvest of kharif crops. e.g. green gram or black gram in kharif followed by *rabi* sorghum or *rabi* gram.
8) The selection of crops to be planted in the crop rotation should be problem oriented. For example, erosion promoting and erect growing crops like millet should be rotated with erosion resisting crops such as legumes on sloppy soils prone to soil erosion. However, for such type of rotations, the farmer's financial conditions should be kept in mind.
9) The crops having dense canopy should be included in crop rotation for weed control. For example, tobacco and legume or forage crops not only help to lessen weed pressure but also check soil.
10) The crops belonging to the same family should not be rotated with each other due to enhanced risk of weeds, pests and disease incident.
11) While selecting the crops for crop rotation, the effect of earlier crop on subsequent crop should be kept in mind for harvesting better yield and quality of produce. For example, the allelochemicals released by sorghum may affect the stand establishment and the growth of post-sorghum crop.
12) Crop rotation should be flexible upto the extent that if pest or diseases destroys one crop, it can be substituted by another crop.
13) The well-drained and fertile soils should be used for rotation of important crops like cash crops and food crops. Less fertile land should be used for growing of soil improving crops such as legumes, and the salt tolerant crops should be rotated on saline/alkali or acidic soils.
14) The ideal crop rotation should be built up around a hub crop for which the greatest comparative advantages exist. e.g. in areas of dairy industry oil seeds like groundnut or pulses will supply cattle feed (oil cakes and roughages) or in irrigated areas near cities, growing of vegetables or floriculture will be profitable.
15) While selecting the crops to be grown in specific rotation, the market demand of that crop must be kept in mind to fetch more benefits.

19.8. Cropping Patterns and Cropping Systems

Cropping pattern is defined as "the yearly sequence and spatial arrangement of crops and fallow on a given area" (Andrews and Kassam 1976). In other words, cropping pattern is defined as "the pattern of crops for a given piece of land or cropping pattern means the proportion of area under various crops at a point of time in a unit area". Cropping patterns consider variables such as seasonal/annual rotation, geometry of planted area, fallow periods, and polyculture verses monoculture planting. Choice among these patterns will affect the ability of soils to regenerate, the ability to sustain water supplies over an indefinite period and the total demand on external resources needed to sustain the activity. For example soil regeneration of one centimeter in depth requires approximately one millennium (Pimentel and Hogan, 2014). The cropping pattern and cropping system differ in following ways (adapted from Rana and Rana 2011):

- Cropping pattern is the crop rotation practiced by a majority of farmers in a given area or locality; while cropping system includes cropping pattern and its management to derive benefits from a given resource base under specific environmental conditions.
- Cropping pattern includes the type and management of crops in time and space; while a cropping system includes the cropping patterns used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine their makeup.
- Cropping pattern includes the yearly sequence and spatial arrangement of crop or crops and fallow on a given area or the proportion of area under various crops at a point of time in a unit area; while cropping system encompasses pattern of crops taken up for a given piece of land, or order in which crops are cultivated on a piece of land over a fixed period, associated with soil, management practices such as tillage manuring and irrigation

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