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ADOPTION OF AGRICULTURAL TECHNOLOGIES AND PRACTICES

A DESK REVIEW

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A DESK REVIEW

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ACRONYMS

ADB	Asian Development Bank
AI	Artificial Insemination
AusAID	Australian Agency for International Development
BVD	Bovine Viral Diarrhea
DAP	Di-Ammonium Phosphate
DM	Dry Matter
EGA	Economic Growth and Agriculture
EM	Effective Microorganisms
EPF	Entomopathogenic Fungi
FAO	Food and Agriculture Organization (part of the UN Network)
FBD	Food Borne Disease
FFS	Farmer Field Schools
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GoP	Government of Pakistan
HYV	High Yielding Varieties
hp	Horsepower
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
ISO	International Standards Organization
MAF	Million Acre-Feet
MF	Micro-Finance
MT	Metric tons
NHDR	National Human Development Report
PATTA	Pakistani Agricultural Technology Transfer Activity
PMT	Proxy Means Test
TDN	Total Digestible Nutrients
TMA	Tehsil Municipal Administration
UHT	Ultra-high Temperature
USAID	United States Agency for International Development
WHO	World Health Organization

EXECUTIVE SUMMARY

The Economic Growth and Agriculture (EGA) office of USAID/Pakistan is designing an activity aimed at stimulating the availability and use of modern agriculture technologies and practices in Pakistan. The working title of the activity is the Pakistani Agricultural Technology Transfer Activity (PATTA). Its objective is to stimulate the introduction of modern agriculture technologies and practices to the agricultural sector in Pakistan. This report presents the findings of a desk review of existing literature on the availability, adoption, and barriers to adoption of modern agriculture technologies. The specific questions the desk review addresses are:

1. What modern agricultural technologies and practices are currently available in Pakistan?
2. What modern agricultural technologies and practices have been adopted by producers, processors, and traders/exporters?
3. What are the factors that inhibit adoption of new technologies and practices?

Desk Review Methods and Limitations

There is an overwhelming amount of data available on modern agricultural technologies and practices internationally and some within Pakistan. More than 250 articles and papers were reviewed for this purpose. The bulk of the research concentrates on exploring the impact of using different inputs and practices and the efficiency gains and cost saving from using various technologies. Apart from a few studies, which were very specifically focused on the research questions, most were not directly related to the topic but discussed it obliquely or tangentially. Given these findings, a two-stage approach was used in the current review. In the first stage the relevant literature was organized around the main sub-sectors of the agriculture sector and specific questions that emerged during the process were addressed (see the literature review in Annex 1). In the second stage, a more synthesized version of the findings was attempted according to the research questions which is presented in this report.

Current Status of the Agriculture Sector in Pakistan

The agriculture sector is key for growth and poverty alleviation in Pakistan. The sector currently accounts for 20.9 percent of gross domestic product (GDP) and is a source of livelihood for 43.5 percent of the population. The agriculture sector has changed over the last few decades in several significant ways, including a decrease in its contribution to GDP in proportionate terms and changes in the sector composition with a substantial increase in the livestock sector's contribution. The agricultural sector is largely of a subsistence nature with a large majority of smallholders and little commercial orientation. The profile of the bulk of the farmers can be characterized as either falling below the poverty line or close to the line, with high rates of illiteracy, especially among rural men and women, and extreme vulnerability to natural disasters. There is a significant yield gap in the crop, horticulture, and livestock sectors. In addition, the agriculture sector suffers from significant post-harvest losses due to use of traditional harvesting and processing methods. The realization of the sector's true potential offers a significant opportunity for future agricultural growth and development in the country.

Findings and Conclusions

Question 1: What modern agricultural technologies and practices are currently available in Pakistan?

The story of the availability of modern agriculture technologies and practices in Pakistan, as elsewhere, is invariably traced to the green revolution, which marked the advent of modern technologies in the agriculture sector. There is general availability in the country of most modern agriculture technologies and practices, but their quality and quantity are both limited. The private sector actively participates in the production and distribution of all key inputs such as seed, fertilizer, pesticides, and farm machinery. The availability of improved quality saplings and plants for horticulture crops is not well documented in the literature. Most of these are available from the private sector, but limited quantities are also available from government research farms. The two most important elements of mechanization of agriculture are the use of tractors and the tube-wells which have transformed farm operations. There is a large variety of technologies, implements, and practices available for increased efficiency and conservation in the use of water. Other technologies, such as those used for precision agriculture, greenhouses, and hydroponics, and the more sophisticated computerized remote technologies are limited in terms of their availability and use.

Pakistan has some of the best animal breeds available locally, but animal production is compromised as a result of poor management practices and low levels of investment in the sector. The increase in productivity in the livestock sector has come more as a result of an increase in the total number of animals rather than increases in productivity. The levels of skill and knowledge in management of livestock are limited. There are shortages of fodder and good quality feed and limited outreach of animal health and reproductive services. There are high rates of animal morbidity and mortality due to poor breed selection, inadequate veterinary services, and lack of awareness about animal disease and nutrition management. Women, who have a key responsibility for managing livestock, often have very limited interface with government extension services staff which does not have a cadre of women extension agents. The capacity of the private sector to provide livestock services is highly variable and often unreliable.

There is an acute shortage of infrastructure, equipment, and other appropriate facilities for harvesting, sorting, grading, collection, storage, cold storage, slaughtering, and transport. This lack of facilities results in heavy losses of all major produce and a deterioration in the quality of the more perishable products, especially fruits, vegetables, and dairy. There is a shortage of technical support services that can guide farmers in new production techniques in all the sub-sectors of agriculture. The outreach of the agriculture extension services is limited, and their own knowledge and understanding of the most advanced technologies is limited. Private sector dealers provide guidance in the use of some improved inputs, but their advice cannot always be trusted due to their bias towards encouraging over-use. The government has tried to encourage the provision of a range of services that includes innovative financial services such as microfinance, value chain financing, warehouse receipt financing, and crop and livestock insurance. However, despite the State Bank's proactive role in the encouraging financial institutions' uptake of these services, they are not being offered on any appreciable scale, and there appears to be limited demand for them.

Question 2: What modern agricultural technologies and practices have been adopted by producers, processors, and traders, exporters?

The literature review provides a very fragmented picture of the adoption of modern agriculture technologies and practices in the country. Most of the literature is based on the findings from studies with very small sample sizes and confined generally to Punjab. The empirical studies are often dated and

cover a small area. They focus on the impact of adopting a specific technology and much less on the overall adoption rates. While some do identify specific reasons and determinants for technology adoption, it is not always clear the extent to which the findings would be applicable in the widely divergent farming systems prevalent in the country. The literature does not contain a comprehensive view of the current situation with respect to the use of a particular technology or practice. In addition, the literature generally focuses on farmers, and there are few studies on the other players in the agriculture value chain.

The most comprehensive survey available at the moment that records the adoption of some of the modern agriculture technologies and practices is the agriculture census conducted in Pakistan periodically. This gives the overall use of inputs, especially fertilizers, insecticides, pesticides, tractors, and tube-wells. There is limited adoption of post-harvest handling, cold chain storage, and transportation due to their limited availability and poor access of farmers to these technologies. Most farmers still use fairly primitive ways of harvesting crops and incur significant losses. The actual adoption of modern management and production technologies and techniques in the livestock sector is at a very low level. There is little knowledge of animal diseases, new and improved feed, advances and innovation in animal healthcare, and the feed and management requirements of new breeds that are introduced, and limited access to vaccination and modern breeding technologies. Technologies offered by the livestock sector have yet to gain wider acceptance and are at various stages of diffusion and adoption in different agro-ecological zones of the country.

Question 3: What are the factors that inhibit adoption of new technologies and practices?

There is considerable literature on the factors that inhibit adoption of new technologies and practices internationally. The literature contains theoretical models of adoption and diffusion of new technologies in both the developed and developing countries. This is also juxtaposed against empirical studies available from a range of countries. The explanatory indicators that were generally identified were found to vary from study to study based on their contextual applicability. However, the factors which tend to be common among most studies include: (i) farm size, (ii) risk exposure and capacity to bear risk, (iii) human capital, (iv) labor availability, (v) credit constraints, (vi) tenure, and (vii) access to commodity markets.

In the context of Pakistan, some of the most significant barriers to adoption were the characteristics of the farming system itself, lack of physical infrastructure, risks inherent in the agriculture sector, financial limitations, institutional factors, and certain traditional and cultural constraints. The availability of water has been a key driving force in the development of agriculture in the country, but the lack of physical, transport, and energy infrastructure are constraints to the use of modern practices. There are a host of institutional factors which also act as barriers since they inhibit investment by the private sector investors as well as small famers. There is limited availability of technical services and support that can provide consultancy services to farmers to use a range of modern technologies and practices. The lack of farmer organization also represents a critical constraint in adoption of modern technologies and practices.

There are some very long-standing cultural norms, attitudes, and practices that can also be detrimental to the adoption of modern agriculture technologies and practices in Pakistan. Among the most significant of these are the very sharp distinction in roles and responsibilities regarding gender, deeply ingrained traditional practices in both crop and livestock production, and the system of inheritance in the country which continues to fragment landholdings and reduces the incentives to invest. There is a strong prejudice regarding borrowing on interest, and many consider it “haram” to give or to earn any interest payments on loans. There are strong kinship patterns and norms which dictate the relationship

between the landlord and the tenant and lead to sub-optimal arrangements in terms of adoption patterns of modern technology and practices. Women undertake much of the work in the agriculture sector, especially in livestock, but despite their active engagement in the sector, their role is seldom recognized or acknowledged, and they are given few opportunities to enhance their skills or access to equipment that might ease their workload.

Recommendations

The key recommendations that emerge from a review of the literature and project experience which can help in stimulating the availability and adoption of modern agriculture technologies and practices include the following:

i. Identifying realistic avenues to explore in addressing the barriers, as some of them are likely to be beyond the scope, time frame, and resources of the project;

ii. Careful selection of appropriate modern technologies based on local adaptability, understanding of constraints, and learning from past experiences where technologies that were inappropriate for local conditions were imported;

iii. Consideration of supply and demand side elements given that a review of the literature indicates that there are both supply-side constraints on the availability of modern technologies and practices and demand-side constraints on their adoption;

iv. Participatory process of engagement which recognizes differences in characteristics of farmers and their constraints on adoption;

v. Adoption of a gender perspective to ensure the inclusion of women, who are often the "forgotten farmers" in the country; and

vi. Addressing the lack of farmer cooperatives by forging appropriate links with the private sector in order to ensure well specified ownership rights, incentives, and responsibilities for individual participation.

STUDY PURPOSE AND QUESTIONS

The Economic Growth and Agriculture (EGA) office of USAID/Pakistan is designing an activity aimed at stimulating the availability and use of modern agriculture technologies and practices in Pakistan. The working title of the activity is the Pakistani Agricultural Technology Transfer Activity (PATTA). The objective of PATTA is to introduce modern agriculture technologies, equipment, inputs, and practices to dealers, producers, processors, and traders/exporters, covering both large and small agribusinesses. Modern agriculture technologies and practices include many inputs (e.g., improved seeds, fertilizers or nutrients, animal breeds, or plants), equipment and machinery, crop production techniques, processing, and marketing practices capable of increasing the quantity and/or quality of agricultural and livestock products.

PATTA will focus on introducing or enhancing adoption of existing technologies and practices in the agricultural sector. This desk review will form the basis for a survey-based examination of access to modern agricultural technologies and practices in Pakistan, as well as barriers to adopting them.

Research Questions

The study statement of work and assignment work plan specify three research questions:

1. What modern agricultural technologies and practices are currently available in Pakistan?

   Explanation: This section will explore the current state of availability of modern agricultural and livestock technologies and practices in Pakistan.

2. What modern agricultural technologies and practices have been adopted by producers, processors, traders, exporters?

   Explanation: This section will include a discussion of the current level of technological advancement in the Pakistani agriculture and livestock sectors and from the perspectives of large and small agribusiness and, where possible, include a regional perspective as well. If it comes up in the relevant literature, without widening the scope of the research, the report should also note the potential productivity improvements that could result from adopting modern technologies and practices in Pakistan.

3. What are the factors that inhibit adoption of new technologies and practices?

   Explanation: This section should identify the cultural attitudes, physical barriers (access), financial limitations, or other barriers that affect producers' and processors' willingness or ability to adopt modern agricultural technologies and practices.

METHODS AND LIMITATIONS

The desk review was initiated as a literature review exercise to assess what was available within Pakistan and internationally regarding the availability and adoption of modern agriculture technologies and practices. The literature review was undertaken in a sequential manner and followed a systematic approach to identification of the relevant research. In the first stage, key words in the research questions were used with different combinations and permutations to identify the research specific to Pakistan. The research was made specific to the different geographic areas by focusing on key research

words but with a focus on identifying research specific to the different provinces of the country. When searching for studies on Khyber-Pakhtunkhwa, the search also used its former name "North West Frontier Pakistan" to locate research that may have predated the name change. In the second stage, the research was expanded to include literature available internationally to assess the types of specific technologies being used. In the third stage, when the gaps in the literature became evident and specific questions emerged after a review of the initial set of studies, the research was narrowed to identify studies that were linked to a particular agriculture sub-sector (such as horticulture or livestock) and a particular technology being investigated (such as breed improvement, artificial insemination (AI), supply of improved seeds and plant materials, fertilizer and pesticide use, post-harvest losses, or financial and insurance products).

While the initial intent was to have a geographical focus in organizing the results of the review, this approach had to be abandoned due to the fact that most of the literature in Pakistan focuses on Punjab. There are few studies that report the empirical results of farmer practices and adoption in other parts of the country. Within Punjab, the locus of many of the studies is in and around Faisalabad because it is home to the Agriculture University of Faisalabad from where most of the research originates. The overall quality of the literature produced in Pakistani journals was not always very strong theoretically, and its empirical basis hinged on a limited sample size. The conclusions or recommendations of the studies did not always seem to emanate from the results of the research. Furthermore, the figures presented in the research were mostly dated and would not be very valuable for the purposes of a project which intended to form a current impression of availability and adoption and plan its interventions on that basis.

There is an overwhelming amount of data available on modern agricultural technologies and practices internationally. Initial research provided over 250 journal articles and research papers that present both theoretical models and empirical research on a large range of modern technologies and practices for the agriculture sector. More than 170 research papers and articles are referenced in this review (Annex 2). However, most of the literature does not directly address the specific research questions regarding availability and adoption of modern technologies and practices. There were a few good studies available on Pakistan and internationally on the diffusion and adoption of modern technologies. The bulk of the research concentrates on exploring the impact of using inputs and practices and the efficiency gains and cost saving from using various technologies. A considerable interest has also been generated in producing theoretical models on the dissemination of technologies. Apart from a few studies, which were very specifically focused on the research questions, most were not directly related to the topic but discussed it obliquely or tangentially. While these papers contained fragments of information relevant to the questions at hand, they did not always discuss them in a clear or concise manner.

Given the vast amount of literature consulted, it was felt that it would not be feasible to import the findings of the literature review directly into answering the research questions. A more studied two-stage approach would have to be applied in which the literature review would be presented separately. In the second stage, the key findings from the desk review would be synthesized and presented in a separate concise document, which addressed the research questions and presented the conclusions and recommendations. Furthermore, in order to satisfy the objectives of the research, it was decided to use the latest sources of information on the agriculture sector in Pakistan, such as those available through the agriculture census and the economic survey, so that the availability and adoption of agriculture practices could be compared with the latest agriculture statistics. As such, the principal researcher has prepared two sets of documents: (i) a detailed literature review which is given in Annex 1 and (ii) the main report which presents a more succinct analysis of the findings and conclusions.

CURRENT STATUS OF THE AGRICULTURE SECTOR IN PAKISTAN

The agriculture sector is key for growth and poverty alleviation in Pakistan. The sector accounted for 20.9 percent of gross domestic product (GDP) in 2014-15 and is a source of livelihood for 43.5 percent of the population (Economic Survey, 2014–2015). There is considerable analysis that shows that it is agriculture growth that can effectively reduce poverty in Pakistan (Mellor, 2001). However, the performance of the sector has been highly variable over the last 67 years. The sector has lost significant growth momentum as its growth slowed to 2.7 percent in the 2000s, compared with 4.4 percent in the 1990s and 5.4 percent in the 1980s. Growth in the sector has been low in recent years; in 2014–2015, its growth was reported at 2.1 percent (Economic Survey, 2014). Major factors underlying this poor performance include: slow rates of technological innovation; limited adoption of progressive farming techniques; problems with quality, quantity, and timeliness of input supply; limited investment in construction and maintenance of infrastructure; marketing and trade restrictions; pest and livestock disease problems; limited amounts of credit for agricultural production and processing; and the lack of agriculture-specific financing (Government of Pakistan, 2015).

The agriculture sector has changed over the last few decades in several significant ways. First, the contribution of the agriculture sector to GDP in proportionate terms has been decreasing. The sector's contribution to GDP fell from 38.9 percent in 1970 to its current level which represents a reduction by almost 50 percent in the last 35 years. Secondly, the sector's composition has changed, with the livestock sector's contribution increasing steadily from 27.3 percent in 1970 to the current 55.9 percent of total agriculture GDP in the country. Cereal and cash crops contribute 25.6 percent, and other crops, which include fruits and vegetables, contribute around 11.6 percent, with a small contribution from the fisheries and forestry sectors. The focus in Pakistan, in terms of both policy and the literature, has initially been on the crop sector, and only recently has attention shifted to the livestock and horticulture sub-sectors in recognition of their potential for growth, income generation, and export revenues.

The agricultural sector is characterized by a majority of smallholders and is of a subsistence nature with little commercial orientation. There were reported to be 8.6 million farms in the country cultivating an area of 21.4 million hectares with an average farm size of 2.58 hectares. Approximately 64 percent of the holdings were reported to be less than 2.02 hectares in 2010. The pattern of tenancy indicates that 82 percent of the farms are operated by the owners, 7 percent by owner-cum-tenants, and 11 percent by tenants only (Agriculture Census, 2010). A similar pattern is seen in the livestock sector, where 82 percent of the farmers own less than 4 milk animals (Livestock Census, 2006). The size and pattern of holdings have been consistently discussed as factors that can potentially impact the adoption of new technologies and practices in the country. Further, another significant aspect of the profile of the farming household is its poverty status. A majority of farmers can be characterized as either falling below the poverty line or close to the line. Other characteristics include high rates of illiteracy, especially among rural men and women, extreme vulnerability to natural disasters, and high patterns of animal and human morbidity.

Increase in sector production has in the past been attributable mostly to an increase in cropped area which rose from 12.21 million hectares in 1949–1950 to 21.4 million hectares in 2010, an increase of about 80 percent at a growth rate of just under one percent per annum. The national average cropping intensity increased from about 122 percent in 1980 to 159 percent in 2010 (Agriculture Census). Cropping intensities have increased in all the provinces except Balochistan, but are declining in relation to increase in farm sizes. The average cropping intensity in irrigated areas is expected to be even higher and in certain areas may be in the vicinity of 200 percent. This implies that the pressure on land resources is mounting over time, especially on small and marginal farms (5 hectares or less). Further

increases in agricultural production by increasing cropped area or cropping intensity are likely to be minimal (Iqbal and Ahmad, 2004).

There is a significant yield gap due to general inefficiency of the agricultural production system. The national average yields of most of the agricultural crops are far below the demonstrated potentials at progressive farms and at research stations. Milk yield per animal is anywhere between 50 percent and 90 percent lower (GOP, 2011; FAO, 2004). In addition, the agriculture sector suffers from significant post-harvest losses due to use of traditional harvesting and processing methods. The realization of this unachieved potential offers a significant opportunity for future agricultural growth and development in the country (Iqbal and Ahmad, 2004).

KEY FINDINGS

Findings for Question 1: Availability

Question: What modern agricultural technologies and practices are currently available in Pakistan?

Crop Sector

The story of the availability of modern agriculture technologies and practices in Pakistan, as elsewhere, is invariably traced to the green revolution, which began the advent of modern technologies in the agriculture sector. The green revolution can be divided into two sub-periods in Pakistan (Mahroof et al., 2011). From 1960 to 1964, water availability increased due mainly to the rapid expansion of tube-well installations, mostly in the private sector, as well as some increase in the supply of surface water. From 1964 to 1969, water supply continued to increase, and breakthroughs in high-yielding varieties (HYV) of wheat and rice, fertilizers, pesticides, and mechanization also drove agricultural growth (Ahmad and Chaudhry, 1987).

Public expenditures and subsidies propelled much of the growth, but eventually the agriculture sector experienced diminishing returns due to inefficiency (Greer, 2006). Production rose again in the late 1970s, due mainly to favorable weather conditions, better input distribution, and more appropriate farm price incentives. Since the 1980s, key drivers of Pakistan's agricultural growth include non-cereal crops and livestock, reallocation of land to high-value crops, and the use of new seeds. Modern technologies and practices are available in Pakistan to some extent, but they are not widespread. (See also Annex 1, paragraphs 6–10.)

Availability of Improved Seeds

The seed business has seen rapid growth since 1994, when the GoP gave it the status of an industry to encourage investment, and there are now approximately 750 seed companies in Pakistan (Iqbal, 2015). The informal sector (farmers, commission agents, retailers, and shopkeepers), however, supplies more than 90 percent of the seed in the country (Hussain and Bhutta, 2002) – approximately 23 percent of vegetable seed, 45 percent of cotton, 90 percent of wheat, rice, and maize, and almost 99 percent of the legumes.

As Table 1 shows, there is a shortage of most seeds in the country, with farmers generally using seed produced on farms. There is general agreement that the quality of seed available in the market is poor (Iqbal, 2015), especially in Kyber Pakhtunkhwa and Balochistan.

While a system of seed certification and inspection exists, it is inadequate (Hussain and Bhutta, 2002), and a large volume of indiscriminate seed is being sold by unauthorized traders. Private national seed companies are not regulated, and they are subject to no stringent system of checks and balances (Iqbal, 2015).

Pakistan offers few incentives for agricultural research, impeding the development of seed varieties adapted to the local soil and climate. There is inadequate research support for the private seed sector, limited availability of pre-basic and basic seed from research centers and public seed corporations, lack of proper seed storage facilities, and high interest rates on credit. The lack of a dedicated national seed program for vegetables and flowers also leads to the need for large imports (Hussain and Bhutta, 2002). (See also Annex 1, paragraph 21.)

TABLE 1: AREA UNDER DIFFERENT CROPS, TOTAL SEED REQUIREMENT AND AVAILABILITY OF APPROVED SEED FROM PUBLIC AND PRIVATE SOURCES AND IMPORTS (2012-13)

Crop	Area (million hectares)	Total Seed Requirement (tons)	Seed Availability (public) (tons)	Seed Availability (private) (tons)	Imports (tons)	Total Availability (tons)	Gap (tons)	Gap (%)
Wheat	9.05	1,085,400	72,111	187,779		259,890	825,510	76%
Cotton	3.2	40,000	800	38,000		38,800	1,200	3%
Rice	2.7	42,480	4,862	21,951	7,715	34,528	7,952	19%
Maize	1.06	31,914	312	1,521	10,715	12,548	19,366	61%
Pulses	1.33	47,495	339	889		1,228	46,267	97%
Oilseed	0.83	10,582	62	128	1,065	1,255	9,327	88%
Fodders	1.9	40,137	11		13,314	13,325	26,812	67%
Vegetables	0.25	5,070	21	296	5,135	5,452	-382	-8%

Source: Iqbal et al., 2015.

Fertilizer Availability

Much of the soil in Pakistan is deficient in nitrogen, phosphorus, potassium, and micronutrients (FAO, 2015). The GoP encouraged and subsidized the use of fertilizers during the green revolution, but phased out the subsidies and lifted restrictions on imports in the 1980s and 1990s. Today the private sector's share of the fertilizer market is almost 90 percent, and farmers pay international market prices to buy imported products. (See also Annex 1, paragraphs 23–24.)

Pesticide Availability

Pesticide availability has grown steadily in Pakistan, particularly since 1980, when the GoP transferred control of pesticide import and distribution to the private sector. Prior to 1980, the government offered subsidies but sold large packages and required farmers to pre-pay. The private sector offers pesticides on credit and allows smaller purchases. It also provides advisory services and ensures that its products are available in time for the crop season. Since 1980, pesticide consumption has increased steadily. (See also Annex 1, paragraphs 29–31.)

Farm Mechanization

The most important technologies in use in Pakistan are tractors and tube-wells, which have significantly altered farm operations and productivity. The use of tractors in farm operations increased at an average rate of over 14 percent during the 1970s and 13 percent in the first half of the 1990s (Mahroof et al., 2011). The Agricultural Development Bank of Pakistan offers low-interest loans for their purchase, and the GoP reduced import duties and taxes to encourage their use. (See also Annex 1, paragraphs 38–39.)

Some literature also mentions the availability of seed and seed-cum fertilizer drills, planters, mechanical rice trans-planters, and vertical conveyor reapers, which are generally used by landlords and other large-scale farmers only (Iqbal et al., 2015). Small-scale farmers may use zero-till drills and raised bed planters, laser land levelers, and turbo happy seeders, although statistics are not available on the volume of production or use. Solar technology, especially solar-powered tube-wells and electricity-generating panels, is being introduced due to the acute energy crisis in the country, but only a few progressive farmers are using it.

Pakistan produces agricultural machinery locally, including machines for land development, seedbed preparation, seeding, planting, inter-culture, reapers, wheat threshers, maize shellers, sprayers, farm trolleys, and tractors. Local workshops offer maintenance and repairs. The GoP encourages production and charges no sales taxes for locally produced farm equipment, but the quality of the equipment is often poor due to workshop layout; lack of managerial, engineering, and technical manpower; poor designs; improper manufacturing techniques; lack of availability of quality raw material components such as gears and sprockets; and lack of finance and marketing skills. (See also Annex 1, paragraph 41.)

Laser-controlled land-leveling equipment, a significant advance in surface irrigation technology, has not yet gained popularity across South Asia, but the government of Punjab is promoting its use. The provincial government has subsidized the purchase of laser units, and farmers now practice land-leveling on 7 percent of the total irrigated land in Pakistan. (See also Annex 1, paragraph 42.)

Water Efficient Technologies

In Pakistan, irrigated agriculture covers 74 percent of the total cultivated land. The increased availability of irrigation since the 1960s has facilitated the adoption of fertilizers and new seeds, particularly wheat and rice. Irrigation practices are inefficient, however, and increasing crop intensities, rising water

scarcity, and deteriorating infrastructure threaten the sustainability of irrigated agriculture. (See also Annex 1, paragraphs 47-52.)

To meet the increased demand for irrigation, many farmers have used groundwater. From 1960 to 1987, groundwater usage increased at 10 times the rate of canal-supplied water, rapidly depleting aquifers. Further exploitation of groundwater will exceed the natural recharge rate, and further exploitation of surface water will require construction of surface storage and better regulation of river flows. (See also Annex 1, paragraphs 43 and 49.)

As water resources become scarce, demand has emerged to develop and adopt production methods and practices that can save water, reduce production costs, and improve production of agricultural crops at the same time. Water conservation technologies include land leveling, bed/ridge sowing, sprinkler irrigation, drip irrigation, and zero tillage. Some modern irrigation technologies are capital-intensive, and many farmers will need subsidies to afford them (World Bank, 2009). Others can be adopted with little additional cost and effort. (See also Annex 1, paragraphs 50 and 54.)

Rain-fed areas of the country require different types of irrigation technologies. Several projects have promoted water harvesting, which requires only simple equipment that is generally available. (See also Annex 1, paragraph 55.)

Tunnel Farming Technologies

Pakistan does not have any sophisticated greenhouses on any scale, but low-cost tunnel farming technologies are beginning to be introduced partly on the initiatives taken by progressive farmers and partly based on the promotion and support of the government. Tunnel farming is gaining popularity and being practiced in many areas in Punjab and Khyber Pakhtunkhwa. The Government of Punjab has actively supported the promotion of this technology to help vegetable and fruit growers enhance their production (Government of Punjab, 2012). Factors that reportedly influence low adoption rates of the technology include lack of capital, low education level of farmers, lack of awareness among farmers regarding the project, and responsiveness of vegetable growers (Muhammad et al., 2014). (See also Annex 1, paragraph 56.)

Integrated Pest Management (IPM)

In Pakistan, research and development in IPM was initiated in the 1970s. The initial efforts to implement IPM were reportedly not very successful, but this may be because most studies concentrated on measuring immediate impacts, such as the effects on pesticide use and yield. A number of studies, however, have attempted to capture a range of developmental impacts, including changes in the social and political domain. Based on the literature, IPM appears to be used on and off through projects. (See also Annex 1, paragraphs 33–35.)

Precision Agriculture

Some researchers believe that precision agriculture can increase efficiency and crop yields in Pakistan (Bakhsh, 2011), improving the livelihoods of equipment operators and farmers (Mondal and Basu, 2009; Srinivasan, 2001). Laser land leveling has been used in Pakistan successfully for a few years but Pakistan is lagging behind in promoting this technology (Tanveer et al., 2013) which requires effective coordination between the public sector, private sector, and growers. (See also Annex 1, paragraphs 57–59.)

Horticulture Sector

Pakistan enjoys an agro-ecological environment suitable for the cultivation of almost thirty kinds of fruits, including citrus, mango, dates, guava, apple, melons, and banana (Sharif et al., 2005). While

neighboring India is seeing a significant rise in horticultural production, however, production of fruits and vegetables in Pakistan is declining (Jawad, 2015), and Pakistan also has much lower yields than international averages for many fruit crops. Issues highlighted in the literature include a lack of information, losses experienced both pre and post-harvest, harvesting at the incorrect maturity, under or over ripe fruit, poor grading, physical damage, high disease incidence, blemishes including sap burn, and poor packaging (Mazhar et al., 2010). (See also Annex 1, paragraph 73.)

The literature on the horticulture sector is focused on the availability of specific technologies that could increase the production of horticulture crops, reduce post-harvest losses, and introduce some very specific techniques to reduce pest infestation and improve the prospects for the export of fruits and vegetables. Pakistani exporters also lack an awareness of global food safety standards (Mirza, 2012). Complying with international standards is key to Pakistan's becoming more competitive in the international market for horticultural produce (Khan, 2010). Training farmers on input use and good practices often benefits those farmers who are trained, but has not proven to be scalable or sustainable, except where good practices are linked to eligibility for export.

The available literature on the horticulture sector is more focused on the availability of specific technologies that could increase the production of horticulture crops, reduce post-harvest losses, and introduce some very specific techniques to reduce pest infestation and improve the prospects for the export of fruits and vegetables. This includes using Entomopathogenic fungi (EPF) as bio-control agents as suggested by Qazi and Khachatourians (2010). EPFs are suited to both the environment and climatic situation of Pakistan. EPFs infect the pests and although this method has been used for over a century (Qazi, 2010), many new strains of the fungus are being studied with various levels of efficacy. One proven methodology of increasing productivity is effective micro-organisms (EM), which consists of mixed cultures of beneficial and naturally-occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plants (Higa and Parr, 1994). EMs have been tested extensively in both field and greenhouse environments in Pakistan since the 1990s and were found to have increased the levels of soluble sugars, fruit juice content, and overall weight of two varieties of oranges by a considerable percentage. (See also Annex 1, paragraphs 74–75 and 78–79.)

Poor harvesting and post-harvesting practices result in significant income losses due to lost quantity and lower quality. Post-harvest losses in fruits range from 12 to 40 percent (Iqbal and Ahmad, 2004). Heat, humidity, and improper packaging lead to losses during harvesting, packaging, transportation, and marketing. Reducing post-harvest losses could bring about potentially large gains to export earnings. For example, hot water treatment of exportable mangoes which can effectively kill fruit flies but can significantly deteriorate the quality of fruit during the post-storage period (Faheem et al., 2012). (See also Annex 1, paragraphs 80–84.)

The Livestock Sector

Livestock is a key element in the mixed farming system of smallholders and has a high potential for growth and poverty alleviation in Pakistan. The sector has the highest potential for reaching landless men and women who have few other assets. The full potential for growth and development of the livestock sector is not being realized due to a host of factors which include low productivity due to non-descript breeds, poor feed and water intake, traditional management practices, limited capacity to provide balanced feed and mineral supplements, limited awareness of modern production practices, poor animal disease management, and limited access to quality health care. Productivity in the milk sector in Pakistan is one-third of the international average, and meat production is half of the international average and much below the productive potential of the local livestock.

Livestock is a major store of capital and assets for rural households. Farmers tend to diversify their risk by keeping a larger number of low-productivity animals, which has a detrimental impact on the natural

resource base. The overwhelming majority of milk-producing animals also do not receive feed according to their maintenance and production requirements, which in turn leads to lower animal productivity. In the mountains areas of northern Pakistan and Azad Jammu and Kashmir, extensive systems of livestock management are followed. Elsewhere in the country, the practice of free grazing of animals to economize on animal feed limits the productivity of livestock and reduces the marketable surplus due to limited holding capacity of rangelands. Access to water sources is also highly variable, and traditional feeding practices limit the water given to animals due to both water and labor scarcity and lack of knowledge of optimal water requirements (Hussein, 2012). (See also Annex 1, paragraphs 89–90 and 100.)

To narrow the feed gap, research institutions have evolved nutritional technologies that have proved economical and biologically viable. Unfortunately, the livestock extension system is not efficient in disseminating the technologies to bring a breakthrough in the national situation of feed scarcity. It is therefore important to disseminate and test these technologies on farmers' fields. (See also Annex 1, paragraph 102.)

There is a high degree of animal mortality and morbidity due to insufficient veterinary services and lack of farmer awareness about animal vaccination and disease management. Women, who have the major responsibility for managing livestock in the villages, have limited access to government extension staff, which does not have a cadre of women extension agents. Women are also hesitant to enhance their poultry flocks due to the high incidence of disease-induced mortality despite the significant potential to earn a regular income from sale of eggs and birds (IFAD, 2012). The capacity of the private sector is highly variable and unreliable. The right kind of livestock services can make an important difference to poor livestock farmers struggling to manage their limited resources and reduce poverty. These services include veterinary care, access to quality feed, reliable water sources, improved livestock infrastructure, breeding technologies, and access to a range of market services. (See also Annex 1, paragraphs 86 and 89.)

Pakistan is home to some of the finest breeds of livestock in the region (Iqbal et al., 1999), but it has not capitalized on its stock. The government has infrastructure for AI services, but the actual coverage of AI services to adult buffalo and cattle has not increased more than 3 percent. In another estimate of the coverage of reproductive services, it is assessed that in Punjab, AI overage in cows is 13 percent and in buffaloes it is only 7 percent (Director General, Livestock Development Department Punjab, 2011). It is much the same story in other parts of the country. (See also Annex 1, paragraph 94.)

Nearly 57 percent of the total increase in Pakistan's livestock production is attributable to increasing numbers of animals rather than rising productivity per animal (Chaudhry et al., 1999). Quantitative improvements in roughages, fodder, and animal feeds, in aggregate, accounted for another 21 percent, with 22 percent assumed to result from technological progress. Technological progress peaked at 3.0 percent from 1989–90 to 1994–95. During other periods, it was either negative or hardly exceeded 1.0 percent per annum. The livestock sub-sector also has fewer government price controls than the crop sub-sector, allowing it to experience relatively higher growth rates (Chaudhery et al., 1999). (See also Annex 1, paragraphs 96–98.)

To enhance the productivity of the smallholder, it is essential to improve poor farmers' and livestock keepers' knowledge, skills, and technology. Iqbal et al. (1999) conclude that for rapid and continuous development of the livestock sector, the economically viable tested technologies developed at research stations are to be transferred to the farmer's field. Technologies developed in the fields of nutrition, vaccination, and AI are readily available for the extension system.

Livestock Marketing

Unhygienic conditions are common in the production and marketing of both meat and dairy products. A lack of infrastructure in rural areas limits the expansion of the milk marketing system, and the country also lacks proper abattoirs for meat and storage facilities for meat and dairy products. About 95 percent of milk is either consumed in villages or sold in the cities through intermediaries called "Gawallas," and the ultra-high temperature (UHT) processing industry processes less than two percent of the total milk produced in the country (Iqbal et al., 1999). (See also Annex 1, paragraphs 122–128.)

The Tehsil Municipal Administration (TMA), which is the local government institution responsible for livestock markets, is oriented towards revenue generation rather than protecting the interests of smallholders or providing for the welfare of animals. The TMAs contract out the livestock markets to large private sector contractors who do not provide any supportive facilities. The animals brought to the market undergo extreme stress, and there is little regard for animal welfare. This discourages small farmers from engaging in direct marketing at these locations, and often they are in a hurry to complete the transaction and leave. The TMAs responsible for establishing and managing these markets have limited experience and knowledge about the types of services they should provide or require the contractor to provide (IFAD, 2014).

There is a large amount of data on the credit needs of farmers and on the lack of financing as a major constraint to investment in the agriculture sector. While the literature is not conclusive in establishing the demand and need for credit, it is generally assumed that there is a large unmet credit demand (Hussein and Hussain, 2009). The State Bank of Pakistan has been proactive in promoting a range of innovative financial services—including value chain financing, credit guarantee schemes for small and marginalized farmers, crop and livestock insurance, and warehouse receipt financing—and in issuing guidelines for their adoption by commercial banks and micro-finance banks. (See also Annex 1, paragraph 135.)

There is growing literature on crop insurance as a means of mitigating the risks inherent in the agriculture sector. At 0.7 per cent of GDP, Pakistan's insurance penetration rate is one of the lowest in the world, and it has seen no growth in the past 10 years (Ali 2013). The initiatives taken by various governments to promote agricultural insurance in the country have had limited success. An important 2008 initiative attempted to introduce a market-based crop loan insurance scheme. Challenges to creating a feasible crop loan insurance framework included cost of insurance, premium collection mechanism, claim trigger, role of government, reinsurance treaties, willingness of farmers to pay for insurance, perils to be covered, and lack of recorded historical data to evaluate probability of calamities. (See also Annex 1, paragraphs 141–142.)

Findings for Question 2: Adoption

Question 2: What modern agricultural technologies and practices have been adopted by producers, processors, and traders, exporters?

The literature review provides a very fragmented picture of the adoption of modern agriculture technologies and practices in the country. Most of the literature is based on the findings from empirical studies with very small sample sizes, mostly concentrated in Punjab. The studies are often dated and cover only a small area. They focus on the impact of adopting a specific technology and much less on the overall adoption rates. While some do identify specific reasons and determinants for technology adoption, it is not always clear the extent to which the findings would be applicable in the widely divergent farming systems prevalent in the country. The literature does not contain a comprehensive view of the current situation with respect to the use of a particular technology or practice. In addition,

the literature generally focuses on farmers, and there are few studies on the other players in the agriculture value chain.

The most comprehensive survey available at the moment, which records the adoption of some of the modern agriculture technologies and practices, is the agriculture census conducted in Pakistan periodically. The last census was undertaken in 2010. This gives the overall use of inputs, and reports that out of a total of 8.26 million farms in the country, 3.35 million farms (41 percent) reported using fertilizers only, 2.45 million farms (30 percent) reported using both fertilizers and manures, and 0.22 million farms (3 percent) reported using manures only. The remaining 26 percent of farms did not report using any fertilizers and/or manures. The use of insecticides was reported by 2.75 million farms, representing 33 percent of the total farms in the country. There was significant variation in the use of these inputs by province. Sindh had the highest proportion of farmers reporting the use of fertilizers, while Khyber Pakhtunkhwa had the lowest. Punjab had the highest proportion of farmers reporting the use of insecticides, while Khyber Pakhtunkhwa again had the lowest.

Fertilizers

The FAO (2015) has identified an imbalance in the use of fertilizers in Pakistan. The five major crops—wheat, cotton, sugarcane, rice, and maize—account for about 87 percent of fertilizer consumption (FAO, 2015). Wheat accounts for about 45 percent, followed by cotton with a share of 23 percent. Fruits and vegetables account for 5.6 percent. The crop-wise per hectare use of fertilizer generally varies with farm size, sources of irrigation, educational level, land tenure, and cropping system. The use of site-specific recommendations by farmers is negligible. Farmers apply fertilizers according to their financial resources, the availability of water, the types of fertilizers available, and expected financial returns.

While almost all farmers with access to canal or tube-well irrigation use fertilizers, only around half of farmers in rain-fed areas use them. Ninety-two percent of small-scale farmers use fertilizers, but application rates decrease as farm size increases. Less than 2 percent of farmers apply potash, whereas 92 percent apply nitrogen and 83 percent apply phosphate. Rates of nitrogen application approach recommended rates on irrigated wheat and cotton but are well below the recommended rates for rain-fed wheat. Half of farmers apply farm yard manure, and almost 5 percent apply micronutrients, whereas the use of green manures, crop residues, and bio-fertilizers is negligible. (See also Annex 1, paragraphs 25–29.)

Farmers' use of fertilizers is based on incomplete information and pricing decisions; for instance, urea is locally produced in Pakistan and its price is much lower than other types of fertilizers, so it tends to be overused. The price of DAP, the second largest fertilizer product used after urea, is volatile and depends on international trends. Price disparities lead to high use of urea, and thus to imbalanced fertilizer use. (See also Annex 1, paragraph 24.)

Pesticides

Farmers often cannot afford pesticides, and their use of pesticides has varied both over time and by crop. The use of herbicides and fungicides is less heavy. The main use of pesticides in Pakistan is for the cotton crop (60 percent), followed by paddy (7 percent), cereals (4 percent), and sugarcane (2 percent) (Kang 2013).

Pest attacks are more likely to occur in plants nurtured by fertilizer and cultivated from HYV seeds, so the need for pesticides is increasing as farmers embrace these technologies. However, due to a lack of knowledge within the farming community and the absence of appropriate regulatory agencies, pesticides in Pakistan are not used in ways likely to maximize benefits, except in the case of cash crops such as cotton. Most of the farmers generally use pesticides without considering the infestation level and often

spray the crop unnecessarily. The indiscriminate use of a wide range of pesticides is creating health and environmental hazards. There is need for extension departments in the provinces to circulate required information regarding the safe and correct methods of pesticide application (Mahroof et al., 2011). (See also Annex 1, paragraphs 28–32.)

Farm Mechanization

Mechanization in Pakistan is low at 1.50 hp per hectare compared with India's 2.50, China's 3.88, and Japan's 7.0. The concept of mechanization in Pakistan has often remained limited to the use of tractors (Iqbal et al. 2015). In 2010, approximately 72 percent of farmers in Pakistan used tractors, while the rest used a combination of tractors and draught power (Agriculture Census, 2010). A majority of farmers use tractor-drawn blades, ridgers to prepare seed-beds, and cultivators. The other most common use is to operate threshers and haul inputs and produce to and from market. Tractor-drawn implements such as mould board plows, seed planters, fertilizer dusters, pesticide sprayers, and harvesters are in limited use. Of all farms in the country, 7.88 million (95 percent) who reported cultivating land, 6.04 million (77 percent) reported using tractors only for cultivating land, covering an area of 37 million acres, which is 77 percent of the total farm area (Agriculture Census, 2010). (See also Annex 1, paragraph 39.)

The use of tube-wells has spread rapidly. Approximately 15,504 large-capacity public tube-wells and 469,546 low-capacity private tube-wells are currently installed in the country (Bhutta, 1999). Indiscriminate pumping without proper monitoring has led to the pollution of the aquifers, and in many places, the salinity of tube-wells has increased (Chandio, 1999). Moreover, Pakistan's groundwater resources are at the brink of exhaustion, and several water conservation programs are being implemented in different parts of the country. In Balochistan, which relies almost exclusively on ground water, the water table has been decreasing by 2-3 feet on an annual basis. (See also Annex 1, paragraph 45.)

Pakistan has a growing market for the production of a large variety of agriculture implements. There are more than 500 agricultural implement manufacturers, which serve a large local market (about USD $200 million annually) and a smaller export market (USD $7 million annually) for low-end implements. However, these use very basic production systems, and their limited technical and management capacity, obsolete production technology, poor quality control, low skill level of labor, and inefficient production processes limit the sector's growth (Krieger et al., 2014). To improve the competitiveness of the sector in local and export markets, the USAID Firms Project helped 18 manufacturers upgrade equipment and modernize production processes. The project helped the manufacturers adopt assembly line production methods and trained managers and workers in planning, lean production, quality control, material selection, and other topics to improve production efficiency. On a cost-share basis, the project also helped manufacturers upgrade obsolete technology and install inventory and production management software. The project also helped manufacturers obtain International Standards Organization (ISO) 9000 certification and linked them to potential foreign buyers (Krieger et al., 2014).

Cereal and Horticulture Crops

There is little systematic data available on the actual adoption of other available technologies in cereal and cash crops, fruits, and vegetables. Thus while it is easy to identify the availability in the market of a range of different technologies, their actual adoption is uncertain. There is a large gap in the use of improved seed and plant materials mainly because of farmers' inability to identify good seed and plants. On-farm technologies such as pruning, proper varietal selection, grading, and packing were not adopted on any significant scale. Similarly, while the technologies for the use of improved farming practices such as plastic tunnels and pressurized irrigation systems are available, actual adoption rates are low. There is

little use of state-of-the-art technology such as modern greenhouses or computerized production systems that can assist in improving productivity in the sector.

As with other crops, fruit and vegetable growing is highly dispersed, with a large number of usually small farmers involved in producing these crops. In the horticulture sector, the main issues center on non-standardized nursery plants, non-availability of disease-free seeds, poor management and cultural practices, and high post-harvest losses. Iqbal and Ahmad (2004) report that farmers usually use poor planting material of different species, and many among them follow diverse and usually unstandardized cultivation practices. As a result, the quality of fruits and vegetables is not uniform. This affects the quality of processed products and their acceptability to consumers, specifically in international markets. Moreover, no distinct varieties are being developed for table consumption and processing purposes.

Harvesting of horticulture crops is undertaken manually with age-old implements which causes considerable fruit injuries during harvest. There is little, if any, use of pre-cooling techniques, and most of the growers/contractors use conventional methods of storing in shade and sprinkling with water. Grading of the produce is generally undertaken by visual inspection. Farm-level storage facilities are not appropriate, and markets usually lack adequate cold storage capacity. The limited cold storage capacity available in the country is mostly confined to Punjab. Horticulture products often have short shelf lives, and the quality usually falls short of being suitable for processing. Post-harvest losses are reported to be more than 30–40 percent for horticultural crops, causing a loss of over Rs. 49 billion every year. There is a long chain of marketing agents in the marketing of horticulture crops. These marketing intermediaries claim a major share of the revenues, leaving the growers with very low returns. A major share of the total production of vegetables and fruits is consumed or exported in raw or fresh form, and only a small proportion of it is processed. The processors depend on a large number of markets and growers to meet their needs, resulting in operational difficulties of coordinating with a large number of growers and monitoring raw material quality. The processing industry consists of generally small cottage businesses, though there are also large-scale processing units. The traditional technologies used for preservation and processing, especially in small units, are fairly basic and need to be improved (Iqbal and Ahmed, 2004).

In the horticulture sector, the literature focuses more on the losses that result from not adopting improved production, harvesting, and post-harvesting facilities and the benefits that might accrue from using modern agriculture technologies and practices. There are a large number of reports from several projects working in the horticulture sector which document their experiences with improved technologies and identify the need for further improvement. Management Systems International (2012) reports on the experience of USAID in Balochistan and identifies the need for supply of good quality fruit plants, silos for storing grain, and plastic tunnels. USAID's experience in Pakistan also documents the poor adoption of modern technologies and practices in the horticulture sector. However, in some of the main production areas for some fruits (e.g., citrus) and vegetables (e.g., potatoes), mechanical grading has started. A few projects have also introduced improved grading, sorting, and packing practices (Krieger et al., 2014).

Krieger et al. (2014), report on a few selected horticulture crops such as mangoes, dates, peaches and potatoes. For the mango crop, they report on the lack of capacity for proper post-harvest handling, cold chain storage, and transportation which significantly reduces the quality and shelf-life of mangos before they reach markets or export centers. The project interventions in the date crop showed that there were very basic practices being followed in the drying of dates. The report noted that Pakistan's date farmers typically dry their dates on mats on the ground where they are subject to contamination with dirt and damage from rain. Thus the project-level interventions focused on supplying and encouraging the adoption of very basic production and post-harvest handling tools and equipment (e.g., cutting tools, sprayers, drying tables, crates, solar dryers) designed to reduce losses during harvest, reduce drying

time, and improve quality (Krieger et al., 2014). In the case of the potato and peach crops, the practices that were promoted by the project were very basic, illustrating that there was a lack of adoption of such practices.

Livestock

Both the meat and dairy industries are operating below capacity. Present methods of sheep and goat farming, slaughtering, processing, and marketing result in low carcass yield, heavy losses of by-products, and supply of poor quality meat to consumers. Currently, all of Pakistan's milk plants are operating well under their productive capacity, resulting in higher per unit costs. Policy-makers and planners pay little attention to the marketing of dairy products, but if the dairy industry is to survive and grow, the milk marketing system will have to be improved.

The major constraints limiting livestock production include shortage of fodder coupled with its poor quality, poor genetic potential, nondescript breeds, long gestation period, long calving interval, lack of proven sires, low adoption of AI and vaccination, low yielding fodder varieties, inadequate health care, poor management practices, and inadequate marketing facilities. The actual adoption of modern management and production technologies and practices in the livestock sector is at a very low level. The management of livestock is undertaken in a very traditional manner, and it has proven very difficult to break the traditional practices in the management of the animals. The housing of animals, feeding, and watering practices are all shaped by economizing on the labor and other inputs invested in livestock management. In many parts of Pakistan, especially in the rain-fed and semi-desert, desert, and mountain areas with a limited natural resource base, the animal population exceeds the carrying capacity of the land. In order to compensate for the low productivity and the risk inherent in livestock production, most smallholders keep more animals than they can feed as a measure of risk mitigation. This also contributes to the low level of adoption of modern management practices.

There is little knowledge of modern animal health requirements and little adoption of regular vaccination regimes or modern breeding technologies. There are many fatal diseases in the country, such as foot and mouth disease, parturient hemoglobinuria, bovine viral diarrhea, and black quarter. Farmers do not regularly vaccinate their animals against the fatal diseases, which enhances morbidity and mortality patterns and lowers the productivity of the animals. Every third cow/buffalo suffers from mastitis, which can lead to significant losses in milk yield estimated to be in the range of USD $200 to $250 per animal on an annual basis (Ashfaq et al., 2015). External parasites such as ticks also lower production in this sub-sector. The regular use of animal vaccinations is not practiced because of limited farmer knowledge and inadequate supply of vaccines within the public extension system. In addition, long calving intervals further erode the overall productivity of the sector. Farmers use non-descript breeds, and often there is little understanding of the importance of using high-quality local breeds and the poor suitability of importing breeds with poor capacity to adapt to local conditions. Few farms are managed on a commercial basis and follow modern management practices.

The adoption of modern practices and technologies has generally been promoted by projects in the livestock sector or by a few initiatives of the government. The adoption rates of animal vaccinations, AI, deworming, fodder chaffing, and crossbreeding show differential adoption rates between areas within the country. (See Annex 1, paragraph 108.) Project teams are generally the ones to promote and encourage the adoption of modern livestock management, feeding, and breed improvement programs; initiatives are seldom taken by farmers themselves, particularly small farmers. Projects have generally focused on promoting practices to improve the quality of feed, such as training on urea treatment of wheat straw, which enhances the nutritional value of the fodder or production of silage. Projects have also tried to provide advice on vaccinations and AI services. Most recently, projects have tried to focus on livestock markets and assist in improving livestock markets.

The lack of infrastructure in rural areas limits the expansion of the milk marketing system. The existing milk marketing system for commercial dairies is not capable of adjusting to the seasonal fluctuations in the supply and demand for milk (Iqbal et al., 1999). When urban demand for milk is higher (in summer), the supply is relatively inelastic (basically due to limited capacity of the milk vendors). Conversely, when supply increases in winter, the demand is relatively inelastic (due to less consumer demand for processed milk). The most limiting factor in expanding the milk marketing system is the lack of infrastructure in rural areas. About 95 percent of the country's milk output is consumed in the villages and or sold in the cities through intermediaries called "Gawallas" in unhygienic conditions and without any quality standards. There is also significant loss due to lack of proper storage facilities. (See also Annex 1, paragraphs 122 and 126.)

A major portion (about 70 to 80 percent) of milk is converted into milk products (e.g., ghee) due to transport difficulties in shipping fluid milk from villages to distant urban markets. Thousands of traders, most of whom belong to the poorer segments of the society, collect small quantities of milk from rural producers to trade. (See also Annex 1, paragraphs 128–129.)

The private sector has made major investments in both the milk and meat sectors, but due to the fragmentary nature of production, their links with the producers entail high transaction cost. The entire UHT industry is using less than two percent of the total milk produced in the country. (See also Annex 1, paragraphs 122–128.)

Financial and Insurance Services

The uptake of financial and insurance services which are being encouraged in the country has so far been very limited. Where farmers have subscribed to the insurance services, it is because these services are usually offered as a tied service with loans that are being offered by the commercial and micro-finance banks and institutions. Farmers on their own typically do not use the services that exist. The adoption of the warehouse receipts and value chain financing has been promoted through a few donor-funded projects. The availability and uptake of these innovative financial services is very limited.

Findings for Question 3: Barriers to Adoption

Question 3: What are the factors that inhibit adoption of new technologies and practices?

There is considerable literature available on the factors that inhibit adoption of new technologies and practices internationally. The literature contains theoretical models of adoption and diffusion of new technologies in both developed and developing countries. This is juxtaposed against empirical studies available from a range of countries. Hayami and Ruttan (1984) formalized and empirically verified their theory of induced innovations that closely linked the emergence of innovations with economic conditions. They argued that the search for new innovations is an economic activity that is significantly affected by economic conditions. New innovations are more likely to emerge in response to scarcity and economic opportunities. For example, labor shortages will induce labor-saving technologies; environmentally friendly techniques are likely to be linked to the imposition of strict environmental regulation; and drip irrigation and other water-saving technologies are often developed in locations where water constraints are binding. Similarly, food shortages or high prices of agricultural commodities will likely lead to the introduction of a new high-yield varieties, and perceived changes in consumer preferences may provide the background for innovations that modify product quality.

Pravan (undated) reviews the literature with respect to the factors that affect adoption of new technologies. The explanatory indicators that were identified were found to vary from study to study based on their contextual applicability. However, the factors which tend to be common among most

studies include (i) farm size; (ii) risk exposure and capacity to bear risk; (iii) human capital; (iv) labor availability; (v) credit constraints; (vi) tenure; and (vii) access to commodity markets. Complicated and sometimes unobservable relationships between different elements influence levels of adoption (Feder et al., 1982). Farm size can be a surrogate for a number of factors that may have contradicting effects, so its relationship to adoption is not always straightforward. In other cases, studies may show conflicting findings because they consider innovation adoption in dichotomous terms (adoption/non-adoption), even though farmers' actual decisions are defined over a continuous range or spectrum (e.g., quality of fertilizers used). Other times, confusion may occur because of the simultaneous nature of many of the decisions on adoption when a package of new practices is promoted. Such a situation requires appropriate econometric tools. (See also Annex 1, paragraphs 158–162.)

Conventional wisdom would suggest that constraints to the rapid adoption of innovations involve factors such as lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relive labor shortage (thus preventing timeliness of operations), chaotic supply of complementary inputs (such as seed, chemicals, and water) and inadequate transportation infrastructure. Studies from Pakistan also identify several constraints, including poverty, education level, illiteracy, and credit. Labor supply problems may also sometimes inhibit adoption of labor-intensive innovations, but labor-replacing innovations were adopted quite rapidly in areas where labor supply was a seasonal and uncertain (Pravan, undated). May development projects have sought to remove some of these constraints, but they have met with only partial success (Feder et al., 1982). (See also Annex 1, paragraphs 163–164.)

According to Demeke (1999), the profitability of technology depends on three main factors: (i) the response rate to technology application; (ii) the price of output; and (iii) the cost or the price of the technology or inputs applied. The response rate depends on the quality of the technology, the natural growing conditions, management factors, and availability of complementary inputs. Since superior technologies are less risky and generate large economic benefit, farmers typically tend to adopt such innovations with enthusiasm. The price paid to farmers depends on the performance of the output marketing system. Physical infrastructure, such as roads and market sites, also reduces transaction costs and ensures more competitive prices. The increase in farm wholesale prices resulting from more competitive price formation acts as a production incentive. The cost of improved seeds, for instance, includes the performance and efficiency of seed multiplication, processing, and marketing, but a competitive wholesale and retail operation ensures access and reduces the cost of seeds. Deregulation and liberalization policies are expected to increase the efficiency of both production and marketing of seeds.

Farming Systems in Pakistan

The most common reasons identified in the literature are attributed to the characteristics of the farming system; personal attributes of the farmer such as level of education, awareness, information level, risk perceptions and risk appetite, and income level; and those related to the technology or practice itself. The most significant factor affecting adoption and use of existing technologies and practices in Pakistan is the subsistence nature of the farming systems in the country with respect to both crop and livestock farming. In 2010, there were more than 8.26 million farmers in Pakistan, of which approximately 64 percent had holdings of less than 2.02 hectares. In the livestock sector, 82 percent of the livestock owning households possess on average fewer than four milk animals (Livestock Census, 2006). Productivity in both these sub-sectors continues to be low relative to the developed and many developing countries with a similar resource base. In addition, in the last three or four years, major crops and livestock have both suffered as a result of natural calamities such as floods, earthquakes, and droughts; these high risk factors can themselves inhibit adoption.

In the livestock sector in Pakistan, smallholder farmers use a combination of intensive and extensive management systems for livestock production. Those who have examined livestock economics in the context of the smallholder production systems that exist in the country have quickly realized that the rationale for including livestock as a key element in the smallholder's production decision derives from key crop-livestock interactions. In the smallholding households, livestock rearing is an economically viable activity because it is able to absorb the surplus labor from the crop sector and is also able to effectively utilize crop residues. Women undertake much of the work of managing livestock within the homestead, and their labor is undervalued in any case (IFAD, 2012). In many parts of the country there are also patterns of livestock production on a shared basis in which those with the capital invest in the livestock, and let those with the labor manage them; they share the produce in well specified arrangements. The low livestock holding capacity of the large number of small family farms, their poverty, and their literacy status exert a major influence on their understanding of more sophisticated technologies and practices and on their adoption of the technologies and practices.

Physical Infrastructure

The availability of water has been a key driving force in the development of agriculture in the country. It was the large-scale investment in the irrigation sector and tube-wells which made the wide-scale adoption and use of the complementary inputs of the green revolution possible. The Indus Basin irrigation system covers two-thirds of the country's cropped area and is the largest contiguous irrigation system in the world; it includes 22 dams and barrages, 57,000 km of canals, and 107,000 watercourses. Those who have examined the connection between investments in infrastructure and their impact on agriculture growth and development have traced the increase in agriculture output to the large-scale investments in the irrigation sector as a key contributing factor (Looney, 1994). The proper operation and maintenance of the irrigation infrastructure is essential for continued growth in the sector. The constraints to the adoption of modern agriculture practices are evident from the fact that those areas of the country which are not connected to this system have lagged behind in agriculture growth and development.

Pakistan is predominantly an arid country with 80 percent of its land area in arid and semi-arid regions. About 75 percent of the cropped area is irrigated, and the rest is rain-fed. Rain-fed areas sustain 80 percent of the livestock population and contribute 12 percent of wheat, 27 percent of maize, 69 percent of sorghum, 21 percent of millet, 25 percent of rape and mustard, 77 percent of gram, 90 percent of groundnut, 53 percent of barley, and 85 percent of pulses (Zia et al. 1996). Resource conservation technologies and practices have the potential to enhance the productivity of these arid lands, but farmers in these areas are reluctant to risk using high-cost inputs. They use obsolete methods of irrigation, resulting in poor application and distribution efficiencies. (See also Annex 2, paragraphs 66–67.)

The lack of physical, transport, and energy infrastructure acts as an additional constraint to the use of modern practices. Physical access to many parts of the country is difficult, especially the more isolated Northern Areas, Chitral, large tracts of land in Balochistan with a scattered population, and other areas which are not near commercial centers or hubs. These factors affect both input and output prices and therefore are critical to the adoption decisions of farmers. There has been little investment by the public or private sector in warehouses, cold storage, or processing capacity for agriculture produce. The government has instituted a system of procurement of wheat from farmers at an agreed support price and is subsidizing the cost to consumers through flour mills. This system of procurement is extremely cumbersome and inefficient and is generally monopolized by large farmers with connections. Small farmers do not get the bardana or the sacks to provide the wheat to government depots, the procurement and storage system leads to losses and adulteration (Ahsan and Walker, 2015), and there are high post-harvest losses as a result. The energy crisis in the country also affects use of the installed

capacity and inhibits the investment in new facilities; high energy costs and extensive load shedding can result in damage to the stored produce.

Inherent Risks in the Agriculture Sector

Studies which have tried to empirically establish the role of perceived risk and risk aversion in explaining adoption of innovations have usually been afflicted by measurement problems. In some cases, proxies, which measure access to information (e.g., contact with extension), or ability to decipher information (education, literacy) are used to infer on the role of uncertainty, with obvious difficulties in interpretation. Perceptions of risks get compounded when a majority of the farmers are poor. The exact estimates of poverty in Pakistan are sensitive to the choice of poverty line and methods employed to estimate it. However, the estimates of poverty range from 60 percent if the poverty line is fixed at $2 per day, to 45.6 percent if a multi-dimensional index of poverty is used, to 35.6 percent based on primary data from the Pakistan Integrated Household Survey, to 28.5 percent using the proxy means test, and 17 percent based on the use by Planning Commission of Pakistan's national poverty line using Household Income and Expenditure Survey data (Hussein, 2015). Farmers are much more likely than others to fall within the category of the poor. This affects their decision-making, capacity to bear risk, and level of investment in the agriculture sector.

The risks inherent in the agriculture sector have increased as a result of the frequency of natural disasters in Pakistan. In the last decade there have been regular occurrences of floods, earthquakes, droughts, cyclones, and landslides on an almost annual basis. Many parts of Pakistan are prone to earthquakes, the frequency of which also appears to have increased. Balochistan and the desert areas of Sindh are prone to droughts, while the coastal areas have been struck by cyclones. In addition to the deaths and injuries which are caused by these events, they have a devastating impact on crops, livestock, and infrastructure, particularly housing. The 2000 drought in Balochistan lasted 10 months, and it was estimated that at least 1.2 million people and much more livestock were affected. In 2005, a 7.6-Richter scale earthquake struck the Kashmir region and parts of northwestern Pakistan, again killing countless people and livestock. The 2007 cyclone Yemyin struck the coastal areas of Pakistan, displaced 350,000 people and affected 1.5 million, and more than two million livestock perished. The floods since 2010 have continued to affect millions of people, livestock, and crops on an annual basis. The frequency of these also impact peoples' decisions regarding investment in a sector so prone to damage by these natural disasters.

Financial Resources

Many studies suggest that lack of credit is a major barrier to the adoption of improved inputs in the agriculture sector, although some literature shows that credit supply is not necessarily an obstacle to adoption. Evidence on this matter is mixed. Some studies found that the increase in remittance income has been an important source of financing of mechanization on small and medium-sized farms in Pakistan (Iqbal et al, 2015). The available studies in Pakistan assert that demand for credit may have been over-estimated in some literature on the country. For instance, in assessing credit demand in Pakistan, the Asian Development Bank's Micro-Finance Sector Development Review (ADB, 2003) asserted that there were 6.3 million poor households in Pakistan, that all of them were potential clients for financial services, and that government considered half the adult poor population as potential micro-finance clients. However, estimates of credit demand based on the largest credit survey in the country which was conducted in 1998 by the Applied Economic Research Centre which found that 76 percent of the households did not apply for a loan as they did not see any reason to borrow (59 percent) and did not like asking for a loan (17 percent). There was not much variation in the response by landowning pattern, tenancy pattern, occupation, or sex. The National Human Development Report on Poverty, Growth and Governance (NHDR, 2003) also found that 70 percent of the rural households never applied for any

loan. From among these, 33 percent replied that they did not need a loan, and 43 percent did not want to pay interest for religious reasons. These results are quite contrary to the general contention of a widespread demand for credit. However, the demand for credit can also be influenced by the high interest cost of credit, especially microfinance loans which typically cost between 20 and 36 percent, have high transaction costs, and require either some form of guarantee or collateral. The credit demand from the formal sector is also influenced by the fact that people generally prefer to borrow from informal sources. The middleman in the village is often a source of credit for farm inputs such as fertilizer, seed, pesticides, and other inputs. Often the farmers are interlocked in tied transactions with moneylenders or the middlemen. Furthermore, even though people may not demand credit, they may still lack resources to invest in the agriculture sector.

Institutional Factors

There are a host of institutional factors which are barriers to the adoption of modern agriculture technologies and practices. These barriers inhibit investment by private sector investors as well as small famers. There is general lack of regulatory and supervisory services and a strong enforcement regime that can ensure that there is proper provision of quality services and inputs in the agriculture sector. Farmers are never sure of the quality of seeds, fertilizers, pesticides, or vaccines. This limits his use of improved inputs as the quality is difficult to assess. Furthermore, there is no system for certifying the qualifications of private sector veterinarians or pharmacists, and their advice is not always considered trustworthy. Farmers and middlemen engaged along the value chain all suffer from weak government will or capacity to enforce existing laws. The system of wheat procurement designed to provide farmers a support price is hijacked by the better-off, and small farmers are unable to use the support mechanism with ease. The sugar mills in the country also flout the sugarcane purchase payment system. For years they would pay farmers by weight rather than sucrose content, which would entail a huge loss as sugar mills intentionally made trolleys filled with sugar cane wait outside their factories as a delaying tactic. A recent notification issued by the Punjab High Court directed the sugar millers to pay by both weight and sucrose content but these instructions are not being followed. These factors cause considerable uncertainly in the agriculture sector regarding the quality of inputs and services available and the marketability and price of the produce. As a result there is reluctance to invest in the sector.

The overall business environment in the country does not encourage private sector investment. The registration of a business is difficult as, in the past, licenses and loans have been disbursed as political favors rather than based on the strength of the enterprise. There are high transaction costs to establish a business in the country. Furthermore, there is no bankruptcy law in the country, and thus there is no room to fail in business in Pakistan. Willful bank defaulters are treated in the same way as those whose businesses have not succeeded for one reason or another. The process of political victimization of businessmen holding opposing political views has become institutionalized through the agency of the National Accountability Bureau generally led by a supporter of the party in power. The rising energy costs and the energy crisis have further discouraged private investment. Poor enforcement of existing laws and weak protection of the private sector investor have all served to discourage the entry of investors in modernizing the agriculture sector.

There is limited availability of technical support and services that can provide consultancy services to farmers to use a range of modern technologies and practices. Consumer demands for safe products are growing as consumers become more discerning and increasingly sophisticated. Pakistan does not have the institutional set-up to cater to this market as yet. The main sources of information for farmers on the use of modern technologies or practices are government extension staff or suppliers of equipment and inputs who have a vested interest in their promotion. There are no well-established institutions that can assist farmers with understanding the requirements of the different certification regimes such as Global Gap or Halal. Pakistan's share in the rapidly growing halal industry is negligible and stands at less

than 0.3 percent of total global business. The government has not formulated any regulatory framework to run the industry and channelize halal trade despite its potential in the production of meat by-products, milk, and allied industries. The country also lacks international standards, a system of certifications, standard operating procedures, guiding principles, and skilled human power (Khan, 2014). There has been very little propagation of these certification regimes except those introduced by projects such as those funded by USAID, FAO, or IFAD.

The lack of farmer organizations also represents a critical constraint in adoption of modern technologies and practices. The literature is full of examples from many countries across the world where the cooperative movement has been instrumental in achieving transformation in the agriculture sector (James and Joshua, 2014). In many countries, agricultural cooperatives have been playing significant roles by way of disbursing farm credit, distributing fertilizer and farm supplies, and marketing and agro-processing (IFAD, 2014). In Morocco, farmer-organized cooperatives were instrumental in the adoption of modern agriculture practices, such as the automated use of irrigation water, fertilizers, and pesticides, and the use of high-cost technical expertise in production and marketing techniques, such as sorting, grading, and packing based on Global Gap practices for export to the European countries. In Japan, cooperatives were instrumental in assisting farmers with establishing cooperative stores, grading facilities, and distribution centers. The strength of the Japanese agriculture cooperatives lay in agro-processing, which made extensive use of high technology and strong linkages with wholesale and retail markets (Prakash, 2003). The spread of the community organization approach in Pakistan has led to a widespread euphoria of the advantages of collective action. While the community organization approach has some advantages in helping farmers reduce their transaction costs and achieve economies of scale, these efforts have generally been artefacts of donor-financed projects and have not been sustained beyond the project life in Pakistan.

Cultural Attitudes

The use of modern technologies and practices is influenced by a host of factors which include deeply ingrained traditional practices in both crop and livestock production. There are very strong cultural norms, attitudes, and practices that can also act as a significant barrier to adoption of modern agriculture technologies and practices in Pakistan. Among the most significant of these is the very sharp distinction in roles and responsibilities regarding gender and the system of inheritance in the country, which continues to fragment landholdings and reduces the incentives to invest in the land by the next generation whose share in the landholdings continues to diminish. There is a strong prejudice regarding borrowing on interest, and many consider it "haram" to give or get any interest payments on loans. Despite this view, there is a strong tradition to spend lavishly on weddings and funerals, and family honor is considered compromised if this is not done. People tend to borrow from informal sources and incur significant debt for these expenditures. The same priority is not assigned to expenditures on on-farm investments.

Projects that have tried to include improved production practices have found that despite the intensive efforts at changing farmer behavior in housing, feeding, and watering animals, they quickly revert back to traditional practices. The main barriers in this case are reported to be a strong belief in traditional production patterns. Farmers' level of education has often been used in the literature to explain trends in adoption of modern technologies and practices. The overall literacy rate in the country in 2013–2014 was one of the lowest in the world and was reported to be 60 percent nationally with a female literacy rate of 48 percent. These rates are much lower in rural areas. The situation of women, who play an important role in agriculture, is virtually ignored with only a few projects and government schemes targeted to women. These scenarios are compounded by the fact that there is little proper analysis of the costs and returns from any specific investment and lack of clearly observable results of the improved practices on yields. Animals have low yields, in any case, due to many factors such as poor quality of

breed, inadequate fodder, and losses due to diseases, and in such an environment the adoption of one or two practices may not make a significant difference in yields. This further inhibits overall adoption of modern technologies and practices.

There are strong kinship patterns and norms which dictate the relationship between the landlord and the tenant and lead to sub-optimal arrangements in terms of adoption patterns of modern technology and practices. The tenancy laws in the county are not enforced because of the strong position of the landlord in the country and the complete subservience of tenants to the landlord. Often this relationship is further clouded when the landlord also happens to belong to the family which is regarded as the spiritual leader of the clan and on whose lands the tenant family has lived for decades. This is quite frequent in Southern Punjab and Sindh and in some parts of Balochistan as well where the Sardar or clan leader exercises virtual control over his tenants who dare not engage in any kind of negotiation with him. The traditional crop and livestock sharing arrangements are often determined by these power dynamics. The absentee landlord makes the decisions regarding planting, varietal selection, and input use. These decisions are outside the realm of those who work on the land or in animal production as share-croppers.

Women undertake much of the work in the agriculture sector, especially livestock. Ahmed et al. (1988), have reported that female participation in livestock-related operations ranged from 65 to 70 percent. Masood and Mahjabeen (1989) reported that women in Barani areas are engaged in 10 out of 14 livestock production and management activities. Freedman et al. (1988) have also pointed out that livestock production and management is mainly the job of women in Barani agriculture. In the crop sector, women are involved in many of the production tasks and much of the post-harvest and storage activities. Despite their active engagement in the sector, their role is seldom recognized or acknowledged. The culturally prescribed position of women limits their full participation in decision-making, asset ownership, access to services, and mobility. Women who undertake much of the work in the agriculture sector (Ahmed and Khan, 1990) have a low socio-economic profile and the lowest levels of literacy, education, or training. Women are not given their inheritance rights and have very tenuous rights over any assets even if they own them legally. Despite this there is little analysis of the motivation and incentives of women to work in the sector. They have few opportunities to enhance their level of awareness and skills regarding modern management practices or access to any technologies. Most extension efforts by the public sector ignore women, and the private sector has few dealings with them. There are a few projects that have tried to encourage women's participation in training activities for the agriculture sector, but these efforts are not very widespread, and their impact and sustainability are limited given the strong prejudice towards women which has actually grown worse in the last two decades.

CONCLUSIONS

Question 1: Availability

The story of the availability of modern agriculture technologies and practices in Pakistan, as elsewhere, is invariably traced to the green revolution, which began the advent of modern technologies in the agriculture sector. Most modern agriculture technologies and practices are available in Pakistan, but the quality and quantity are limited. The private sector actively participates in the production and distribution of all key inputs, such as seed, fertilizer, pesticides, and farm machinery.

The entry of the private sector in the seed sector has enabled rapid expansion of the seed industry. There is a shortage of most seeds in the country, with farmers generally using seed produced on farms. There is a large volume of indiscriminate seed being sold by unauthorized traders. There is general agreement that the quality of seed available in the market is poor and, while a system of seed certification and inspection exists, it is not adequate. The multinationals have a monopoly on the production of hybrid seed, which is expensive. The research and development system has not been very active in producing varieties suitable for the widely divergent agro-ecological zones in the country.

The availability of improved quality of saplings and plants for horticulture crops is not well documented in the literature. Most of these are available from the private sector, but limited quantities are also available from government research farms. The role of the government in their provision is gradually reducing and the private sector is gradually taking over. The major issue in their provision is that the quality of these is unreliable.

The provision of fertilizers and pesticides in the country is also currently being managed by the private sector, which is actively involved in the production and distribution of fertilizers and pesticides. The government has gradually withdrawn its subsidy for fertilizer and is now trying to encourage a more balanced use to address micronutrient deficiencies in the soils. This is inhibited as a result of a lack of knowledge about the specific soil conditions and inadequate resources and soil testing laboratories to identify specific soil conditions.

Pakistan has some of the best animal breeds available locally, but animal production is compromised as a result of poor management practices and low levels of investment in the sector. The increase in productivity in the livestock sector has come as a result of increases in the number of animals rather than increases in their productivity. There is a low level of skill in management of livestock, shortage of fodder and good quality feed, and limited outreach of animal health and reproductive services. As a result, productivity of both milk and meat is much below its potential, and the mortality and morbidity rates are high.

The two most important elements of mechanization of agriculture are the tractor and the tube-well, which have transformed farm operations. There has been rapid growth in the local manufacturing industry, which is producing a long list of farm machines, equipment, and implements for the farming sector. This has been actively encouraged with the government providing incentives by reducing import duties and taxes and the provision of low-interest loans advanced through public sector banks. However, the locally produced machinery and implements lack standardization and quality control.

There are a large variety of technologies, implements, and practices available for increased efficiency and conservation in the use of water. Pakistan has a growing market for a large variety of agriculture implements. These include land leveling, bed/ridge sowing, sprinkler irrigation, drip irrigation, and zero

tillage. There is growing diffusion of technologies regarding precision agriculture, conservation agriculture, and other production techniques. The advent of the laser-controlled land leveling equipment has marked one of the most significant advances in surface irrigation technology. Various provincial governments, especially the government of Punjab, have been trying to promote the use of this technology.

There is limited availability and use of other technologies, such as the more sophisticated technologies used for precision agriculture. Low-cost plastic tunnel technologies are available, although the spread of the highly sophisticated greenhouses, remotely controlled drip and temperature systems, and hydroponics has not emerged in the country on any scale. The private sector is also increasing its production of equipment powered with solar energy, but this has high investment costs.

There is an acute shortage of the infrastructure required for proper post-harvesting of agriculture produce, such as sorting, grading, storage, cold storage, and transportation. There is limited availability of proper milk chillers, milk transportation facilities, slaughter-houses, and proper livestock markets. This lack of facilities results in heavy losses of all major produce and deterioration in the quality of the more perishable types of crops, especially fruits, vegetables, and dairy.

There is an acute shortage of technical support services which can guide farmers in the new production techniques in all the sub-sectors of agriculture. The outreach of the agriculture extension services is limited, and their own knowledge and understanding of the most advanced technologies is limited. The private sector dealers provide guidance in the use of some improved inputs but their advice cannot always be trusted due to its bias towards over-use.

The government has tried to encourage the provision of a range of services, including innovative financial services such as microfinance, value chain financing, warehouse receipt financing, and crop and livestock insurance. However, despite the state bank's proactive role in the uptake of these services by the commercial banks, microfinance banks, and microfinance institutions, these services are not being offered in any appreciable scale. The insurance services which have been provided so far are offered as a compulsory element to borrowers.

There is a large institutional infrastructure in the country for research into cereal crops, horticulture, and livestock. However, Pakistan has among the lowest number of scientists per capita and its development spending on research has actually gone down in the last decade compared to most other regional countries. From its existing budget for research, 90 percent is spent on administrative costs and only 3 to 9 percent of the budget is actually used for research (Afzal, undated). The major focus of research has been on cereal crops, principally wheat and rice, to the neglect of livestock and horticulture. There is a long gestation period between approval of varieties and the availability of the varieties for use by farmers.

The literature maintains that while conventional breeding needs to be continued in the future, it no longer offers any significant breakthroughs in the yield potentials or in providing a solution to newly emerging problems such as pests, diseases, and drought stress. Therefore, the application of recent advances in the field of agricultural biotechnology is crucial to increase crop and livestock productivity, improve nutritional quality, broaden crop tolerance against biotic and abiotic stresses, and enhance crop resistance against pests and diseases. The tools of modern biotechnology are more precise and involve shorter time for development of new strains of improved crop and livestock. It is envisaged that the next breakthrough in agricultural productivity would be due to recent developments in plant molecular biology, genetic engineering, and rapid advancement in genomics.

Question 2: Adoption

The literature review provides a very fragmented picture of the adoption of modern agriculture technologies and practices in the country. Most of the literature is based on the findings from studies with very small sample size mostly concentrated in Punjab. The studies are often dated and cover a small area. They focus on the effects of adopting a specific technology and much less on overall adoption rates. While some do identify specific reasons and determinants for technology adoption, it is not always clear the extent to which the findings would be applicable in the widely divergent farming systems prevalent in the country. The literature does not contain a comprehensive view of the current situation with respect to the use of a particular technology or practise. In addition, the literature generally focuses on farmers and there are few studies on the other players in the agriculture value chain.

The most comprehensive survey available at the moment, which records the adoption of some of the modern agriculture technologies and practices is the agriculture census conducted in Pakistan periodically. The last census in 2010 gives the overall use of inputs, and reports that out of a total of 8.26 million farms in the country, 41 percent reported using fertilizers only and 30 percent reported using both fertilizers and manures. The use of insecticides was reported by 33 percent of the total farms in the country. Five major crops, namely wheat, cotton, sugar cane, rice and maize account for about 87 percent of fertilizer consumption with wheat alone accounting for 45 percent of the fertilizers. There is significant variation in the use of these inputs by province. However, there is an imbalance in the use of fertilizers in Pakistan due to lack of specific knowledge about soil conditions.

During the past four decades, pesticides have played a pivotal role in plant protection but have also generated problems of pesticide resistance in pests, persistence of toxicants in ecosystems, and hazards to field applicators, food consumers, and dealers. Due to a lack of knowledge within the farming community and absence of appropriate regulatory agencies, pesticides in Pakistan are not used in ways likely to maximize the benefit, except in cotton. Most of the farmers generally use pesticides without giving consideration to the infestation level and often spray the crop unnecessarily. The indiscriminate use of a wide range of pesticides is creating health and environmental hazards. There is need for extension departments in the provinces to circulate required information regarding the safe and correct methods of pesticide application.

The two most important elements in the mechanization of farms in Pakistan are tractors and tube-wells. Around 72 percent of the farmers are currently reported to be using tractors while the rest were using a combination of tractors and draught power (Agriculture Census, 2010). Pakistan's per hectare use of horsepower is well below other regional countries. The use of tube-wells has rapidly spread in the country. There is indiscriminate pumping without proper monitoring and lack of knowledge about the underground chemistry and hydrodynamics which has contributed to the pollution of the aquifers. Pakistan's groundwater resources are at the brink of exhaustion and there is a need to conserve this invaluable resource.

There is limited adoption of post-harvest handling, cold chain storage, and transportation due to its limited availability and poor access of farmers to these technologies. Most farmers still use fairly primitive ways of harvesting crops and incur significant losses at harvest and during post-harvest handling. There is limited knowledge of different certification regimes such as Global Gap and Halal and farmers are unable to capitalize on the high demand in regional or European markets. Very few farmers have been trained in the adoption of these practices.

The actual adoption of modern management and production technologies and practices in the livestock sector is at a very low level. There is little knowledge of animal disease, modern animal health and feed requirements, and little adoption of regular vaccination regimes or modern breeding technologies. The

adoption of modern practices and technologies has generally been promoted by projects in the livestock sector or by a few initiatives of the government. Just like in other regional countries, the adoption rates of animal vaccinations, AI, deworming, fodder chaffing, and crossbreeding shows differential adoption across the country.

The technologies offered by the livestock sector have yet to gain wider acceptance. These technologies are at various stages of the diffusion-adoption process in different agro-ecological zones of the country. There is a need to assess the technological gaps, actual adoption of these technologies, constraints faced by farmers in adopting these technologies, and the way forward for these selected technologies. There is a need to document the field experiences with respect to many technologies, so as to have a comprehensive picture based on empirical evidence collected through systematic efforts. Moreover, these technologies alone are not enough to bring about widespread change in livestock systems.

The marketing system is highly skewed in favor of the middlemen and against the smallholder who often gets around half the final retail price. The private sector has made major investments in the milk and meat sectors, aimed at both domestic and export markets. However, due to the fragmentary nature of production, their links with the producers entail high transactions cost. The local government institution responsible for livestock markets is oriented towards revenue generation rather than a service orientation to protect the interests of the smallholder or provide for the welfare of the animals.

The uptake of financial and insurance services which are being encouraged in the country has so far been very limited. Where farmers have subscribed to insurance services it is because these services are usually offered as a tied service with the loans that are being offered by the commercial and micro-finance banks and institutions. The adoption of the warehouse receipts and value chain financing has been promoted through a few donor-funded projects but the uptake of these innovative financial services by the service providers is very limited. There is a low level of demand from farmers who do not avail of the services that exist as they do not appear to them to be appropriate in terms of their costs and the benefits.

Question 3: Barriers to Adoption

There is considerable literature on the factors that inhibit adoption of new technologies and practices internationally. The literature contains theoretical models of adoption and diffusion of new technologies in both the developed and developing countries. This is juxtaposed against empirical studies available from a range of countries. The explanatory indicators that were generally identified were found to vary from study to study based on their contextual applicability. However, the factors which tend to be common among most studies include (i) farm size, (ii) risk exposure and capacity to bear risk, (iii) human capital, (iv) labor availability, (v) credit constraints, (vi) tenure, and (vii) access to commodity markets.

In the context of Pakistan some of the most significant barriers to adoption were the characteristics of the farming system, physical infrastructure, risks inherent in the agriculture sector, financial resources, institutional factors, and cultural barriers. The principal barrier in the farming system is the small size of land and livestock holdings. In both the crop and livestock sectors, a majority of the farmers own less than two hectares and less than four milk animals. Productivity in both these sub-sectors continues to be low relative to the developed and many developing countries with a similar resource base. In addition, in the last three or four years, major crops and livestock have both suffered as a result of natural calamities such as floods, earthquakes, droughts, etc. These high risk factors can inhibit adoption.

The availability of water has been a key driving force in the development of agriculture in the country. It was the large-scale investment in the irrigation sector and tube-wells which made the wide scale adoption and use of the complementary inputs of the green revolution possible. Those who have

examined the connection between investments in infrastructure and its impact on agriculture growth and development have traced the increase in agriculture output to the large scale investments in the irrigation sector as a key contributing factor. The behavior of farmers in the arid areas is a clear indication of the reluctance of farmers to risk using high cost inputs in rain-fed areas.

The lack of physical, transport, and energy infrastructure acts as a further constraint to the use of modern practices. These factors affect both input and output prices and therefore are critical to the farmers' adoption decisions. The lack of appropriate post-harvest and processing facilities and the system of procurement and price setting also act as a disincentive to invest when they affect the price and quality marketed. The energy crisis in the country also affects the use of the installed investment capacity and inhibits investment in new facilities because of high energy costs and extensive load shedding.

There are a host of institutional factors which act as barriers to adopting modern agriculture technologies and practices. These barriers inhibit investment by private sector investors as well as small famers. There is a general lack of regulatory, supervisory, and a strong enforcement regime that can ensure proper provision of quality services and inputs in the agriculture sector. The overall business environment in the country does not encourage private sector investment. The poor enforcement of existing laws and weak protection of private sector investors have all served to discourage the entry of investors in modernizing the agriculture sector.

There is limited availability of technical support and services that can provide consultancy services to farmers to use a range of modern technologies and practices. Consumers are growing more sophisticated in their demand for safe products. Pakistan does not have the institutional set-up to cater to this market as yet. The main sources of information for the farmers on the use of modern technologies or practices are the government extension staff or suppliers of the equipment and inputs who have a vested interest in their promotion. There are no well-established institutions which can assist farmers with understanding the requirements of the different certification regimes such as Global Gap and Halal.

The lack of farmer organizations also represents a critical constraint in adoption of modern technologies and practices. The literature is full of examples from many countries across the world where the cooperative movement has been instrumental in achieving transformation in the agriculture sector. The spread of the community organization approach in Pakistan has led to a widespread euphoria of the advantages of collective action. While the community organization approach has some advantages in helping farmers reduce their transaction costs and achieve economies of scale, these efforts have generally been artefacts of donor financed projects and have not been sustained beyond the project life in Pakistan.

There are very strong cultural norms, attitudes and practices that can also act as a significant barrier to adoption. Among the most significant of these is the very sharp distinction in roles and responsibilities regarding gender; the system of inheritance in the country, which continues to fragment landholdings and reduces the incentives to invest; and deeply ingrained traditional practices in both crop and livestock production. There is a strong prejudice regarding borrowing on interest and many consider it "haram" to give or get any interest payments on loans. Despite this view, there is a strong tradition to spend lavishly on weddings and funerals and family honor is considered compromised if this is not done. The same priority is not assigned to expenditures on on-farm investments.

There are strong kinship patterns and norms which dictate the relationship between the landlord and tenant and lead to sub-optimal arrangements in terms of adoption patterns of modern technology and practices. Tenancy laws in the county are not enforced because of the strong position of the landlord in the country and the complete subservience of tenants to the landlord. The traditional crop and livestock

sharing arrangements are often determined by these power dynamics. Decisions regarding planting, varietal selection, or input use are beyond the decision-making realm of those who work on the land or in animal production as share-croppers and are taken by the absentee landlord.

Women undertake much of the work in the agriculture sector, especially livestock, but despite their active engagement in the sector, their role is seldom recognized or acknowledged. The culturally prescribed position of women limits their full participation in decision-making, asset ownership, access to services, and mobility. Women who undertake much of the work in the agriculture sector have a low socio-economic profile and the lowest levels of literacy, education, or training. Women are not given their inheritance rights and have very tenuous rights over any assets even if they own them legally. They have few opportunities to enhance their level of awareness and skills regarding modern management practices or access to any technologies.

RECOMMENDATIONS

Identifying realistic avenues to explore: There are a wide range of factors identified as barriers to the adoption of modern agriculture technologies and practices. While many of these barriers can be addressed through a project modality others are beyond the project scope, resources, or timeframe. Thus project goals in terms of identification of investment areas have to be carefully and realistically selected. The barriers to adoption which stem from the underlying structure of the farming system are not amenable to quick change. The small size of holdings, tenure and tenancy pattern, crop-livestock sharing arrangements, cultural factors, etc., can only be changed over the medium to long-term when economic factors and market dynamics lead to the transformation of the structure of farming systems as is happening in many countries where rapid land consolidation is taking place. There are other constraints which can only be partially addressed, such as those related to lack of physical infrastructure and the weak institutional infrastructure which is responsible for a weak regulatory and certification regime and influences availability and adoption rates. The barriers related to low level of investment in market infrastructure can be addressed by improving the investment climate in the country and can be influenced through a supportive policy environment, technical support, and provision of financing. Still other constraints can be more directly addressed such as the lack of farmer awareness about modern technologies and practices and the lack of availability of improved inputs. It is recommended that the project begin by exploring those avenues of investment that are relatively easy to address in combination with some more medium-term but high-pay-off areas of change through leveraging its influence on the policy and regulatory environment in the country.

Careful selection of appropriate modern technologies: In the past some of the technologies and practices used in other countries have been indiscriminately introduced and applied. Often the use of these improved inputs or practices is encouraged through the provision of subsidies. However, the underlying reasons and constraints to their adoption are not fully recognized or assessed. The result is that these technologies are spread within the project area for a short period of time through project support and their adoption comes to an abrupt halt at the end of the project life. In some cases, the technology which is encouraged is completely inappropriate for local conditions and should never have been encouraged. An example of this is the introduction of exotic breeds such as Holstein-Friesian cows in Indonesia (Amir, undated) and in Pakistan (Hussein, 2012) through subsidized loans for importing high producing animals. While these animals were high producers initially, they were not adapted to local conditions, had high feed requirements and high disease susceptibility and had to be maintained at high cost in enclosed spaces with its own attendant environmental issues and their production eventually dropped. The supportive facilities and equipment was often also not available such as milking machines, skilled manpower, etc. In some cases, technologies practiced by progressive farmers, when properly extended, may find greater acceptance than imported technology that is unfamiliar under village situations and has little scope of local adaptation. On-farm testing and evaluation can help ensure that inappropriate technologies are not introduced by projects (Iqbal and Ahmed, 2004).

Inclusion of supply and demand side elements: A review of the literature indicates that there are both supply-side constraints on the availability of modern technologies and practices and demand side constraints on their adoption. Thus the sector requires investments on both these aspects. However, the supply side investments will have to be chosen carefully given the timeframe of the project and the capacity and willingness of the partners to engage in project activities. On the supply side, the major players are public sector agencies, the private sector in its capacity as the provider of modern inputs and services, technical specialists, and research institutions. On the demand side, the key players are farmers

and the market intermediaries along any specific value chain. The suggested focus of investments for each of these players is in keeping with their relative strengths and constraints and is outlined below:

- **Public Sector in its capacity as a regulator**: The changing pattern in the provision of modern technologies and practices shows that government has largely handed over to the private sector the role of provision of most agriculture inputs. This is true of all major inputs such as seed, saplings, plants, fertilizer, pesticides, farm equipment, AI services, and many of the vaccines. However, often the quality of these inputs is not properly certified and the services provided by the private sector veterinary specialists, artificial inseminators, etc., are not of the requisite quality. Government should be assisted in strengthening its capacity to undertake the task of regulation, certification and supervision as the lack of quality is a major constrain in the sector and farmers do not use these inputs because of quality concerns. There is also a need to certify private para-veterinarians or livestock health specialists to ensure they have the requisite qualification and experience to practice veterinary medicine. Proper checks on quality will enhance farmer confidence in these inputs and service providers and lead to greater use of their services.

- **Public Sector to provide policy support**: One of the principal constraints on the transformation of the agriculture sector to a modern system stems from the existing policy environment. In the aftermath of the 18th Amendment, the responsibility for the agriculture sector has been shifted to the provinces and special area governments. This represents an opportunity to work with those governments which have a higher level of commitment for reform and can demonstrate to the others the impact of the policy change. While projects have generally not had a significant impact on policy reform it is nevertheless important to identify a few key dimensions of policy that can help to encourage the availability and adoption of modern technologies and practices. The project can initiate a policy dialogue with the government and assist in assessing how some of these changes can help to transform the agriculture sector. The key policy areas with a high-pay-off could include issues such as implementation of the law regarding stricter enforcement in regulation of the quality of inputs in the agriculture sector, use of proper facilities in processing such as use of abattoirs with some quality standards, prohibition of land-fragmentation below a certain level upon inheritance, encourage investments in the agriculture sector by local and foreign businesses through tax concessions and other incentives including a bankruptcy law to safeguard the interest of those who want to invest in the sector but are afraid of the risk of failure, changing the procurement policy regarding wheat and sugarcane, and investing the funds in areas which can generate greater growth in the sector.

- **Public Sector in its role as an agriculture extension agent**: Private livestock veterinary and production services are limited and have not developed in the same manner as the private service provision in the areas of education or human health care. Most graduates from the veterinary colleges in Pakistan prefer to join the public sector. A few of them also join the fledgling commercial dairy and meat companies which are being established in the country. There are very few private sector veterinarians providing veterinary services in rural areas. These service providers tend to focus on animal health and few have been trained on production extension. Some of the para-vets who have been trained by donor funded projects or a host of other agencies are performing services for which they are not always properly qualified. Private sector providers generally deliver an uncertain quality of service at a high cost. Smallholders are not able to discern the quality of care provided by such para-vets. There is no formal regulatory or oversight mechanism to regulate the quality of services by private sector providers. Given the paucity of private sector provision and the dubious quality of care, it appears that the government will have to continue to provide livestock extension and

production services in the short to medium-term. For the long-term, there is need to develop a strategy in which the growth and development of private veterinary and animal production services is properly guided and overseen by the public sector. In many isolated areas there is no presence of private sector providers and limited government presence. In these areas there is a need to develop a cadre of community livestock extension workers. It is recommended that the proposed project explore these areas of intervention.

- **The Private Sector**: The private sector needs support to establish and invest in the wide range of modern inputs, and technologies expected to be produced by them. The project could provide technical assistance in the establishment of modern facilities for provision of quality seeds, saplings, plant materials, farm implements and machinery and other agriculture inputs, post-harvest facilities such as warehouses, cold-storage, abattoirs, milk chillers, processing and transportation facilities, etc. A well designed project can assist in enhancing productivity significantly through providing production and marketing support and linkages with the range of private entrepreneurs along the dairy and livestock value chains. It is recommended that the proposed project capitalize on the presence of an emerging and rapidly growing private sector which provides a range of opportunities to link smallholders with markets. Experience of various government and donor agencies with establishing market infrastructure and providing market information has demonstrated the high value added of these investments for the smallholder in terms of increase in the production, quality, and price of milk, enhanced bargaining power, and convenience of delivering to regular and reliable buyers. The provision of grants could assist in defraying some of the initial capital cost and could be matched with a financial institution willing to provide financial services. Given that the State Bank of Pakistan is very actively encouraging the commercial and microfinance banks to provide innovative financial products for the agriculture sector, opportunities could be explored to assess if grants could be matched with loans from the financial sector under coordination by the proposed project. The increased availability of these services will address the existing barriers related to limited capacity in these areas and help to reduce post-harvest losses.

- **Technical Specialists**: There is a lack of technical support and advisory services for farmers that can assist them in a better assessment of the types of improved inputs and practices that would be appropriate for them. The public extension service has provided some of the technical support but this capacity is not very strong and over time the extension agencies within the public sector do not have the outreach or the latest knowledge about modern methods. There is need to develop this capacity in the private sector, which has emerged in other countries as an important means for assisting farmers in enhancing production, installing and using modern production methods, and adhering to the quality standards required for certain markets. These types of technical specialists would be more appropriate for the larger and more commercially oriented farmer but could also be used by groups of farmers who could collectively engage the services of the technical specialist. There is likely to be a growing demand for these services when the producers are linked to the more sophisticated markets with exacting certification and quality standards.

- **Research Institutions**: There is a large institutional infrastructure in the country for research into cereal crops, horticulture, and livestock. It is not recommended that projects with a short time frame get involved with producing new varieties or new research but what would be useful is to assess what has already been developed and is ready for dissemination. It was beyond the scope of this review to examine the research agenda of these institutions. However, some of these institutions like the Barani Research Institute have had considerable success in the adaptation and propagation of certain horticulture crops (olives in the Barani Agriculture

Research Institute), fodder varieties, oilseeds, etc. During implementation of the proposed project, USAID could examine the modern technologies and practices emerging from some of these institutions and assess how it could further disseminate the knowledge from this experience to smallholder farmers.

Participatory Process of Engagement: The stimulation of the availability and use of modern agriculture technologies and practices in Pakistan would require a very participatory process of engagement with small and large farmers and other actors in the value chain to understand their overall growth objectives, identification of technologies and practices which make sense for them, and assist them in meeting their objectives. The theory of induced innovation guides us in understanding that the investment decisions of the different actors are likely to be influenced by relative resource endowment of the farming community and is likely to be very context specific. That is why a carefully crafted strategy which takes into account different farmer characteristics in terms of land holding, tenure pattern, risk appetite, access to financial resources, and willingness to invest have to be properly understood. Based on these area specific dialogues and diagnostics, the project could develop a package of investments which could include, technical assistance, training using the farmer field school methodology, grants and exposure visits with the aim of helping farmers experiment with new technologies and practices to enhance their level of confidence and underwrite the risk of testing these with project support. The package of technologies should be demand led and could include the entire production cycle and the value chain actors of the key crops identified. The purpose would be for them to understand the benefits and costs of the different technologies and practices. If relevant, farmers could also be given training in precision and conservation agriculture, drip irrigation, Global Gap, and Halal production.

Gender Perspective: Women are often the forgotten farmers in the country. Despite the fact that they do much of the work in the sector they are provided with limited opportunities for enhancing their knowledge and skills in the use of modern technologies and practices. Women can make an important difference in increasing the productivity of the sector. For instance, women are the ones involved chiefly in the care of livestock and in post-harvest management of crops. Their training in proper storage of crops could help reduce wastage. Due to their primary responsibility for the care of animals, they are often the first to spot signs of Mastitis or other ailments in livestock and can help to prevent loss through early detection. Given women's low socio-economic status, limited mobility and cultural barriers which frown on their open participation in project activities, a very careful approach will have to be developed for the participation of women in a culturally sensitive manner. Opportunities to train women need to be tailored to their current level of literacy and education and organized in locations and at times suitable for them. Pedagogical methods need to cater to the fact that most women and men farmers have had few opportunities for formal training, have limited recall, and would need regular engagement in short practical modules over a prolonged period following the principles of the farmer field school approach with regular follow up.

Addressing the issue of lack of farmer cooperatives: The fact that farming is undertaken by a large number of smallholders with limited resources is a principal constraint in the adoption of modern agriculture technologies and practices. The farming community does not have strong farmer cooperatives which were instrumental in the adoption of many of the existing technologies in developed countries. It was the agriculture cooperatives in Europe which helped establish the warehouses, packing and sorting centers, cold storage facilities, and assisted farmers in aggregating their produce. When small farmers aggregate their produce they become an attractive option for the private sector. The cooperative movement failed in Pakistan for many reasons. Many projects have tried to create community organizations as a quasi-cooperative. While the community organizations have had limited success in some areas of collective action, they cannot behave like cooperatives because their founding principles are structured very differently from the cooperative model. Many projects have tried to grant

modern equipment to these organizations in the expectation that they will manage them effectively as if they were cooperatives. These experiments have had partial success. Where the ownership rights and individual costs and incentives of participation were clearly established these have succeeded but the large majority of these efforts have failed or been hijacked by a few. While it is tempting for projects to initiate the process of community organization and grant them equipment as this process can show quick short-term results, the more sustainable approach would be to make the provision of these facilities available to farmers through investment in the private sector or link the private sector with farmers.

ANNEX 1: LITERATURE REVIEW

ACRONYMS

ADB	Asian Development Bank
ADBP	Agricultural Development Bank of Pakistan
AEA	American Economic Association
AI	Artificial Insemination
AJK	Azad Jammu and Kashmir
AKRSP	Aga Khan Rural Support Program
AR	Aerobic Rice
ARS	Aerobic Rice Systems
AusAID	Australian AID
CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CLEW	Community Livestock Extension Workers
DM	Dry Matter
EM	Effective Microorganisms
EPF	Entomopathogenic fungi
FAO	Food and Agriculture Organization of the United Nations
FBD	Foodborne Disease
FFS	Farmer Field Schools
FSR	Farming Systems Research
FVDP	Fruit and Vegetable Development Project
GB	Gilgit-Baltistan
GDP	Gross Domestic Product
GoP	Government of Pakistan
GTZ	German Technical Cooperation Agency
ha	Hectare
HYV	High-Yielding Varieties
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
LMIC	Low and Middle-Income Countries
MAF	Million Acre Feet
PASM	Pakistan Agricultural Sector Model
RCT	Resource Conservation Technologies
SBP	State Bank of Pakistan
SPSS	Statistical Package for Social Sciences
SSLF	Support Services for Livestock Farmers
TDN	Total Digestible Nutrients
TMA	Tehsil Municipal Administration
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VCF	Value Chain Financing
WHO	World Health Organization
WHR	Warehouse Receipt

Introduction and Background

1. The agriculture sector is key for growth and poverty alleviation in Pakistan. The sector accounted for 20.9 percent of the Gross Domestic Product (GDP) in 2014–15, and is a source of livelihood for 43.5 percent of the population (Economic Survey, 2014–15). The yields of all major crops are estimated as being between 20–40 percent lower than the global benchmark, and milk yield per animal is anywhere between 50–90 percent lower (GoP, 2011; FAO, 2004). Additionally, the sector has significant postharvest losses. Considerable analysis shows that agriculture growth can effectively reduce poverty in Pakistan (Mellor, 2001). However, the sector's performance has greatly varied over the last 67 years. This literature review presents the current situation with respect to the availability and use of modern technologies and practices in the agriculture and livestock sectors in Pakistan. The review also examines the barriers in adopting modern technologies and practices and identifies successful approaches to overcoming them, where information on this aspect was available.

2. The modern agriculture technologies and practices that were reviewed include improved seeds; fertilizers; chemicals; equipment and machinery; more productive animal breeds; and production, processing, and marketing practices capable of increasing the quantity and quality of agricultural and livestock products. The information on these is very uneven and the review naturally reflects the deficiencies in the research. This review also includes a range of new practices that are being increasingly propagated due to the scarcity of water, climate change, and varied rainfall patterns, but about which the evidence is not very clear, such as conservation agriculture, precision agriculture, resource conservation techniques. Given that access to credit is identified as a critical factor in the adoption of modern techniques and practices, this review also examines the availability and use of conventional credit in addition to the availability and use of innovative financial services such as value chain financing and warehouse receipt financing. There is a high degree of risk inherent in the agriculture sector, which has been made even more severe in Pakistan as a result of the increasing incidence of droughts, floods, and earthquake. Additionally, the crop, horticulture, and livestock sectors are all characterized by a high degree of crop loss and a pattern of morbidity and mortality in livestock is seen. As a result of these risks, the availability and use of insurance services are also part of this review.

3. The literature on the adoption of modern agriculture technologies and practices often delves into the attributes of the farming enterprise such as land size, land tenure, and the attributes of the farming households such as family size, education level, income level, and family status etc. The literature also explores particular diffusion methods such as the role of public agriculture extension services, private sales agents and dealers, and experience with community based livestock extension agents and para-veterinarians. An attempt was also made to explore the literature on the efficacy of these different extension approaches. There is a considerable degree of romanticism regarding the role of community organizations, especially in project reports produced by different donor-financed projects. The extent to which the literature reports on the use of community participation as an effective device for organizing smallholder farmers was also studied. There is a growing body of literature on the spread of information technology and the use of print media, electronic media, mobile phones, and websites to disseminate these technologies. This literature is also part of this review.

4. While the initial intent was to have a geographical focus in organizing the results of the review, this idea had to be abandoned because most literature in Pakistan focuses on Punjab. Few studies report empirical results of farmer practices and adoption in other parts of the country. Within Punjab, the locus of many of the studies is in and around Faisalabad because it is home to the

Agriculture University of Faisalabad. This literature review initially focused on literature from Pakistan; however, the overall quality was not always theoretically strong and its empirical basis hinged on a limited sample size. The conclusions or recommendations of these studies did not always seem to emanate from the results of the research. Thus the review made use of the vast body of literature available on the adoption and diffusion of modern technologies internationally and identified studies of particular reference to the small holder in Pakistan. Donor-funded programs have always been at the forefront in introducing modern technologies in the country, even though their outreach tends to be limited to a very small segment of the farming community. Nevertheless, the experience from a host of donor agencies such as the World Bank, International Fund for Agriculture Development (IFAD), United States Agency for International Development (USAID), Australian AID (AusAID), and the Asian Development Bank (ADB) were used to fill the gap in literature.

5. The literature review is organized into several sections; the first section gives a general overview of the availability and use of modern technology in the agriculture sector. Given that there is a large amount of literature on the crop sector and that some of the modern inputs and practices that are used are common between the cereals, cash crops (cotton and sugar cane), and horticulture sector, the crop sector is discussed first. The second section focuses on the available literature on the horticulture sector; the third section on the livestock sector; the fourth section focuses on the availability and use of financial and insurance services, and the fifth section poses a series of questions which the literature has attempted to answer with regards to the adoption of modern technologies and focuses on farm size and tenure patterns, farmer attributes, dissemination approaches, and the impact of the rising cost of energy on innovation and adoption of energy saving technologies in the agriculture sector. There is no separate section on the barriers to adoption as the barriers are discussed as an integral part of each sector.

The Crop Sector

6. One of the more comprehensive studies on technological changes in the agriculture sector in Pakistan (Mahroof, et al., 2011) investigates structural change, technological innovations, and performance of the agriculture sector in Pakistan using data from 1948–2008. The review notes that immediately after independence, there was stagnation in agricultural production which led to food deficits in the 1950s. These were attributable to the highly unequal distribution of land and the attendant problems with incentives and constraints on the adoption of new technologies and the absence of any integrated policy framework to tackle them. However, accentuation of shortages of food and the need for foreign exchange and raw material for industrial development towards the end of the 1950s forced planners to contemplate a policy of agricultural development (Batsin, 2008; Hamid, 2008). This policy aimed at achieving self-sufficiency in food, increasing production for both domestic use and export, and reducing unemployment in the country. The increased emphasis on agricultural and rural development in government policy during the early 1960s coincided with the advent of the so-called 'green revolution.' This revolution started with the scientific and technological breakthrough in high yielding varieties (HYVs) of wheat and rice seeds combined with the use of fertilizers and pesticides, and the rapid expansion of agricultural mechanization and intensive use of irrigation water and farm power from tube-wells and tractors, respectively (Kemper, 2003; Kuriakose, 2005; Acumen, 2008).

7. In Pakistan, the green revolution period can be subdivided into two periods with regards to the use of these inputs (Mahroof, et al., 2011). During 1960–64, increased water availability due to greater supply of surface water and, more importantly, rapid expansion in tube-well installations, mostly in the private sector, was the cutting edge of development. But in the second phase, i.e.,

1964–69, high yielding varieties of seeds, fertilizers, pesticides, farm mechanization, and continued increases of supplementary water supply contributed to the breakthrough in the agriculture of the country (Ahmad and Chaudhry, 1987). The liberal subsidization of inputs and higher output price incentives provided the needed motivation to farmers, in the form of higher profitability for adopting new technologies. As a result, while the agricultural sector grew at an annual rate of only 1.8 per cent during the first plan period, its growth rate jumped to 3.8 per cent per annum during the second plan, and to 6.0 percent during the third plan period. The peak growth of 11.0 per cent was registered during 1967–68 (Mahroof et al., 2011).

8. This tempo of high growth rate could not be maintained for long. The rate of agricultural output growth plummeted from 7.5 per cent per year during 1966–70, to 1.9 per cent during 1970–78. The green revolution came riding on a wave of significant increases in public expenditure on subsidies, propelling the initial state of the breakthrough. But since the concomitant development of support services—like agricultural extension service and education and training—did not take place, the agricultural sector began—despite the greater availability of most key inputs like fertilizers, high yielding varieties of seeds, and water—to experience diminishing returns due to inadequate attention paid to their efficient use (Greer, 2006). However, agricultural production once again showed a rising trend in the late 1970s, mainly because of favorable weather conditions, better input distribution, and more appropriate farm price incentives. Since the 1980s, livestock and non-cereal crops have emerged as the prime mover of agricultural growth. During 1984–85 and 1989–90, cotton and livestock production witnessed accelerated growth. In the 1990s, the agricultural growth rates fell further to less than 4 percent in 1989–90, to 3 percent in 1994–95, and 4.1 percent in 2000–08. This was primarily due to the slower growth rates of cotton, rice, and wheat. Although sugarcane and livestock showed improved output performance, it was not sufficient to offset the decline in the performance of cotton, wheat, and rice. Consequently, agricultural output growth subsided during the 1990s. Over the past 16 years, agriculture has grown at an average rate of 3.7 percent per annum. However, volatility in the sector is high, with the range of growth varied between 6.5 percent and 1 percent; the fluctuation has been largely dependent on the contribution of major crops and in 2014–15, the sector recorded a growth of 2.9 percent.

9. Technology has made a positive contribution to the higher growth rate of agriculture. Mahroof, et al. (2011) presents documented evidence of private tube-well installations increasing cropping intensity by 50 percent (Muhammad, 1965). The shorter duration of the HYVs of wheat and rice and the availability of chemical fertilizers produced similar results (Gill, 1973). The quickness of operations permitted by tractor cultivation augmented the cropping intensity effects of tube-wells and HYVs (Lawrence, 1970). The yield-increasing effects of the above technologies were equally important. Tube-wells and HYVs of wheat and rice each raised crop yields by 50 percent (Muhammad, 1965; Gill, 1973). The new varieties of cotton introduced in the 1980s, have a yield potential of three to four times that of traditional varieties (Chaudhry, 1994; Chaudhry, 1995).

10. The use of modern varieties of rice and wheat has increased across Pakistan. Relatively, the use of the new varieties of wheat and rice is more widespread in Punjab and Sindh than in other provinces. Similarly, the use of fertilizer and pesticides, etc. has also increased over time, indicating the occurrence of technological change in the country's agricultural sector. Chronological data show that agricultural productivity has been growing due to the use of new seed varieties and application of modern technologies. Application of modern production techniques shows first that an important part of productivity land growth is attributed to the use of new seeds in Pakistan. Secondly, land reallocation toward high value crops is the key source of agricultural growth during the post-green revolution period. Predictable patterns of the engine of productivity land growth

are generally consistent with the prospect that the use of new varieties of seeds and improvement in agricultural technology are important factors to the realization of farmers' economic rationality (Mahroof et al., 2011).

11. The adoption of new technologies and practices can result in significant transformations in farming systems, agricultural landscapes, and the socio-economic situations of farmers. This is particularly apparent in the production of cereal crops, where the use of new technologies, such as hybrids, chemical fertilizers, herbicides, seeding and harvesting equipment, disease and drought resistant crops, and minimum till techniques have increased production and decreased costs (Gardner, 2002; Henzell, 2007). The green revolution of the 1960s and onward is perhaps the best example of the successful diffusion and adoption of new technologies that led to an intensification of crop farming, especially in irrigated areas where rice, wheat, and sugarcane production is prominent. The major components of the green revolution were technology, services, public policies, and above all the enthusiasm of farmers, which led to significant transformation in Indian rural society as a consequence of adopting the technologies and package of practices recommended by research institutions.

High Yielding and Improved Varieties of Seed

12. Shah et al. (2007) conducted a detailed investigation to analyze the marketing of improved seed of wheat in Punjab. The study based its findings on collecting information of wheat seed production and distribution by public and private sectors for eight years prior to 2004. For the purposes of this study, farm level inquiry was based on the primary data collected from three districts, namely Faisalabad, Vehari, and Rawalpindi in 1999. The study reports that despite the crucial importance of improved seed in bettering the welfare of small-scale farmers, access to this technology can be constrained by many factors, including an undeveloped seed industry. The seed industry essentially consists of all enterprises that produce or distribute seed (Pray and Ramaswami, 1991). At a minimum, the industry has four components: (i) plant breeding research, (ii) seed production and multiplication, (iii) processing and storage, and (iv) marketing and distribution. The study identifies two sub-systems of seed distribution; a) farmer based or an informal system consisting of farmer to farmer exchanges and purchases from the local market, and b) a formal system consisting of public seed agencies and private seed companies. In spite of a mushroom growth of private companies in the country, the seed supply of wheat remained around 13 percent of the total requirements. The use of quality seed by average farmers purchased from seed dealers remained about 16 percent in the study area while 4 percent of the seed was purchased from village fellows, 5 percent from progressive growers, 1 percent from research institutes and directly from seed depots, and the remaining 74 percent of wheat seed was used from their own produce from the year before.

13. In another study on the subject of HYV seeds, Wasim (2007) measured the contribution of HYVs to major food crops, namely wheat, rice, *bajra*, *jowar*, and maize production in Punjab. The study is based on secondary data for 44 years in two periods from 1951–1995. He divided this period into four separate groups and undertook a comparison of growth rates for production, yield, and area between period I (1951–1964) and period II (1965–1978), between period II and period III (1979–1994), and between period I and period IV (1951–1994). The study showed that the influence of HYV seed on production, yield, and area for major food crops in Punjab is mixed. The contribution of HYVs to production, area, and yield growth for wheat is remarkable. The adoption of HYVs has helped to accelerate the growth rate for production and yield for rice and maize in period II. In case of *jowar*, despite the decrease in production and area, its yield increased in period II which may be attributed to the adoption of HYV seeds.

14. Ahmad et al. (2004) examined the adoption and constraints in the use of HYVs by the farmers in district Peshawar and Charsada during 2004. These districts are famous for sugar cane, wheat, and all types of vegetables and fruit production. The authors note that while climatic conditions are favorable for agricultural production, farmers do not get proper profit from their agricultural yield due to the failure of adopting new agricultural technologies. The results of the study showed that 66 percent of the respondents were using HYVs of wheat, 40 percent of sugarcane, and only 10 percent of maize in the selected four villages of the selected districts. The primary constraints in the adoption of HYVs can be attributed to the unavailability of seeds and the absence of the necessary knowledge. The primary limitations reported by the respondents were access to water supply, lack of capital, shortage of cultivated land, shortage of labor, lack of technical know-how, and lack of inputs

15. Heisey et al. (1989) studied seed replacement choices and found that seed replacement choices differ from decisions about other inputs, such as fertilizer, because the farmer can reproduce seed. Assumptions about rates of improvement in yield potential and depreciation of retained seed are combined with behavioral assumptions and price and technical information to develop a model predicting the number of years before a farmer will buy new seed. Parameter estimates for wheat in Pakistan were fed into the model and results compared with observed replacement times. They conclude that in order to speed varietal change, better information for farmers is likely to be preferred to seed subsidies.

16. In an interesting study from the Indian Punjab but with important implications for Pakistan, Smale et al. (2008) report that variety change and genetic diversity are important means of combating crop losses from pests and diseases in modern agricultural systems. Since the green revolution, genetic diversity among wheat varieties released in India has increased but variety change on farms continues to be slow. Their findings support the hypothesis that slow variety change has offset the positive productivity effects of diversifying the genetic base in wheat breeding during the post-green revolution period. They suggest that policies that speed the rate of variety change and contribute to a more equitable spatial distribution of modern varieties could support increased wheat productivity.

17. Wasim (2007) concludes that in order to improve the growth rate of area, production, and yield, the following steps are necessary: (i) information on production technology should be popularized through mass media like regional newspaper, radio, television, leaflets, bulletins, booklets, etc.; (ii) a new thrust on research must be in the direction of evolving high yield cum high stability varieties suitable for rain-fed as well as irrigated area; (iii) all out efforts are required to improve the management practices and input use in respect of crops; (iv) critical inputs should be made available in time and in assured quantities; (v) mixed cropping should be encouraged; (vi) adequate credit facilities should also be provided to the farmers; (vii) training programs should be organized on a large scale in the villages on production technology and use of agricultural implements; (viii) cultivation should be extended to the areas of marginal productivity; and (ix) extension services should be made available to the farming community.

18. Iqbal (2015) undertakes an investigation into improved seed availability in the country and its constraints and prospects in Pakistan. The seed industry in Pakistan currently consists of both public and private sector actors and provides seed for all major crops. The private sector was allowed to enter the seed business in 1979 and in 1994, the government declared the seed business at par with other industries. As a result of this policy, a wave of investments was generated, resulting in the sector's rapid growth. There are approximately 750 seed companies in Pakistan and Punjab hosts most of them, including four public sector seed companies and five multinational companies. There are about 600 private national seed companies in Punjab followed

by Sindh where there are about 79 national private seed companies. The multinational seed companies include Monsanto, Pioneer, ICI, Syngenta, and Bayer. Four of these multinational seed companies are based in Punjab and one is working in Sindh. He identifies the systems in place for variety testing, approval, registration, and release. The maximum number of registered varieties was for wheat (134), followed by cotton (109), sugarcane (39), rice (35), maize (25) and barley (10), fodders (37), oilseed (60), crop and pulses (72), vegetables (57), and fruits (35).

19. Table 2 summarizes seed availability for major crops produced in Pakistan. The highest cropping area comes under wheat crop with about nine million hectares in 2012–13 and the quantity of approved seed was just over 0.25 million tons against the requirement of over one million tons indicating that there was only one fourth of the required seed available in 2012–13. Cotton was cultivated on an area of 3.2 million hectares in 2012–13, with a total seed requirement of 40,000 tons, while the availability of approved seed was over and above the requirement as most private seed companies in Pakistan are dealing in the cotton seed business. The area under rice was 2.7 million hectares with a total seed requirement of 42,000 tons, but the availability of approved seed from both public and private sectors was just over 34,500 tons, resulting in a net deficiency of about 8,000 tons of both fine and coarse rice, even after imports of about 7,700 tons. Similarly, maize was grown on an area of one million hectares and approved seed availability was only 12,000 tons, of which 10,000 was imported against the requirement of 32,000 tons. Maize is the single largest crop whose seed is being imported in the largest quantity. Like other major crops, fodders, oil seed crops, and pulses seed are available in much lower quantities than the requirement and farmers use their farm-saved seed of unknown genetic potential year after year which results in significant yield loss. The approved seed market holds huge potential as Pakistan has been unable to provide the approved seed of even major crops like wheat, rice, and maize.

TABLE 2: AREA UNDER DIFFERENT CROPS, TOTAL SEED REQUIREMENT AND AVAILABILITY OF APPROVED SEED FROM PUBLIC AND PRIVATE SOURCES AND IMPORTS (2012-2013)

Crop	Area (million hectares)	Total Seed Requirement (tons)	Seed Availability (public) (tons)	Seed Availability (private) (tons)	Imports (tons)	Total Availability (tons)	Gap (tons)	Gap (%)
Wheat	9.05	1,085,400	72,111	187,779		259,890	825,510	76%
Cotton	3.2	40,000	800	38,000		38,800	1,200	3%
Rice	2.7	42,480	4,862	21,951	7,715	34,528	7,952	19%
Maize	1.06	31,914	312	1,521	10,715	12,548	19,366	61%
Pulses	1.33	47,495	339	889		1,228	46,267	97%
Oilseed	0.83	10,582	62	128	1,065	1,255	9,327	88%
Fodders	1.9	40,137	11		13,314	13,325	26,812	67%
Vegetables	0.25	5,070	21	296	5,135	5,452	-382	-8%

Source: Iqbal et al., 2015.

20. In outlining the constraints in the seed sector, Iqbal (2015) identifies the prices of approved varieties being a key problem, adding that prices are fairly high and debt-ridden farmers are not in a position to purchase newly released or approved varieties, preferring to sow their farm-saved seed, or buying it from companion farmers at nominal prices. Farmers are not aware of modern production technology, so they are unable to achieve the full potential of approved seed and continue to consider their farm-saved seed at par with approved seed. Farm inputs like fertilizers, pesticides, and irrigation are not given their due importance which undermines the performance of approved seed and farmers blame approved seed and consider it a waste of money. Furthermore, substandard seed that is being sold in local markets has eroded the image of new and approved seed as markets are infested with substandard seed that does not ensure the required physical and genetic purity. Farmers repeatedly complain about the poor quality of seed provided by different local companies at substantially high price. There is limited, if any enforcement of quality control.

21. In identifying the constraints on the supply side, Iqbal (2015) reports that private national seed companies are not regulated and there is no strict check and balance on them. Secondly, there are limited incentives for researchers to develop new varieties suitable for local soil and climatic conditions. The critical need is for the public sector to develop a problem-oriented breeding program with proper incentives provided to breeders. Furthermore, research is not field-oriented and farmers are not given solutions in the form of improved seed varieties, resulting in them not using approved seed. Research institutes in Pakistan are typically understaffed and have limited operational budgets. An illustration of this, Pakistan has not been able to develop a cotton variety that is resistant to heat and that does not shed flowers during the severe summer heat. Water scarcity and global warming have raised the importance of developing drought and heat resistant varieties. The author also recommends the provision of seed to farmers at subsidized rates along with the proper use of other inputs to realize the potential benefits from improved seed. He also points to the need for a taskforce to formulate stringent laws regarding seed standards, along with continuous seed testing by provincial agriculture departments regarding physical and genetic purity as well as germination.

22. Hussain and Bhutta (2002) prepared a report on the state of the seed industry in Pakistan and outlined the elaborate institutional arrangements for seed production, certification, and inspection. They report that in 1973, the Government of Pakistan formulated a national seed development plan with the assistance of the Food and Agriculture Organization of the United Nations (FAO) and the World Bank, which strongly recommended the participation of the private sector. In 1976, a seed industry project was designed and initiated at a cost of $56 million with the technical and financial assistance of the World Bank. The Seed Act (No. XXIX of 1976) provided a regulatory framework for variety registration and seed quality control by setting up the institutional infrastructure which included the National Seed Registration Department and the Federal Seed Certification Department, as executive arms of the National Seed Council. In 1997, these two departments were amalgamated into the Federal Seed Certification and Registration Department. The National Seed Council and the Provincial Seed Councils were also established. The necessary infrastructure for the seed sector now exists at both the federal and provincial levels. The report describes the existing seed production and inspection system and outline recommendations for both the public and private sectors. They also highlight the role of the informal sector which is the major seed supplier in the country as more than 90 percent of the seed comes from farmers (or other sources like commission agents, retailers, and shopkeepers). The informal sector provides approximately 23 percent of vegetable seed, 45 percent of cotton, 90 percent of wheat, rice, and maize, and almost 99 percent of legumes. The sector invites the

attention of policymakers, donors, and the scientific community to revolutionize agricultural production through the provision of infrastructure, financial incentives, and improved marketing.

Fertilizers

23. The use of fertilizers was first encouraged as a necessary input with the high yielding seed varieties of the green revolution (Mahroof, et al., 2011). During the early stages, the focus was on introducing and encouraging the use of fertilizers through simple fertilizer trials and demonstrations on farmers' fields and by subsidizing fertilizer prices. Retail prices were fixed by the government and were kept uniform throughout the country. With the increase in the level of fertilizer use, the emphasis changed to a more balanced use of fertilizer nutrients. However, as the subsidy burden increased, the government started to phase out the subsidy under the Structural Adjustment Program and economic reforms. In 1986, all subsidies on nitrogenous fertilizers were removed, followed by phosphate fertilizers in 1995 and potassium fertilizers in 1997. Provincial quotas were abolished, provincial supply organizations in the public sector were abandoned, and import controls were lifted. The government stopped importing and the private sector took over. Farmers had to pay international prices for imported products, apart from urea which was locally produced in sufficient quantity to meet local demand. The share of the private sector in fertilizer marketing is 89 percent, compared to 11 percent for the public sector. The private sector handles about 90 percent of the urea and 100 percent of the DAP, the two major fertilizer products consumed in the country. A dealer network of about 8, 000 retailers exists in the country. Fertilizer companies select and train the dealers. Under the fertilizer acts promulgated by provinces, fertilizer quality is monitored by the Provincial Governments.

24. It is assessed that almost all the soil in Pakistan is deficient in nitrogen, 80–90 percent is deficient in phosphorus, and 30 percent in potassium. Widespread deficiencies of micronutrients are also appearing in different areas. The FAO (2015) has identified a key problem in this area related to the imbalance in the use of fertilizers in the country. There is little specific data available on the nutrient deficiencies of the soils in different locations. Soil testing laboratories are not adequately equipped in terms of manpower and equipment. Micronutrient deficiencies are affecting yields in many parts of country. Fertilizer recommendations from research and extension services, or the private sector, are often too general and the use of fertilizers by farmers is based on incomplete information and pricing decisions. For instance, urea is locally produced in Pakistan and its price is much lower than other types of fertilizers; resultantly, it tends to be overused. The price of DAP, the second largest fertilizer product used after urea, is very volatile and depends on international trends. Price disparities lead to high use of urea, and thus to imbalanced fertilizer use at the farm level. The decisions by farmers on the quantity of fertilizer to use for a specific crop are linked with commodity prices; higher fertilizer prices combined with lower crop prices can cause farmers to use low fertilizer rates. The economics of fertilizer use have always been the overriding consideration in the demand for fertilizers by farmers, especially the relationship between the commodity and input price (FAO, 2015). The support price of the major crops are not regularly revised by the government, further acting as a disincentive for farmers to use high quality inputs.

25. According to the fertilizer use survey conducted by the National Fertilizer Development Corporation and FAO, five major crops—wheat, cotton, sugar cane, rice, and maize—account for about 87 percent of fertilizer consumption. Wheat accounts for about 45 percent followed by cotton with a share of 23 percent. Sugarcane is the third crop; nutrient use per hectare (ha) is highest on this crop. The share of fruit and vegetables is 5.6 percent. The crop-wise per hectare use of fertilizer generally varies with the farm size, irrigation sources, educational level, land tenure, and cropping system. The use of site-specific recommendations by farmers is negligible.

Farmers apply fertilizers according to their financial resources, the availability of water, the types of fertilizers available, and expected financial returns.

26. Less than 2 percent of the farmers apply potash whereas 92 percent apply nitrogen and 83 percent apply phosphate. Half of the farmers apply farm yard manure. Almost five percent apply micronutrients. The use of green manures, crop residues, and bio-fertilizers is negligible. Almost all farmers with access to canal or tube-well irrigation water use fertilizers. In rain-fed areas, scarcely 50 percent of the farmers use fertilizers. About 92 percent of small-scale farmers (<five hectares) use fertilizers. Application rates decrease with an increase in farm size (rain-fed and irrigated). In rain-fed areas, the difference between application rates for small and large farms is very wide.

27. A comparison between fertilizer recommendations and actual use shows that the nitrogen application rate is close to 80 percent of the recommended amount, compared with about 40 percent or less (depending on the crop), for phosphate. Nitrogen application rates approach the recommended rates on irrigated wheat and cotton, but are well below the recommended rates for rain-fed wheat. Scarcely two percent of farmers apply potash, the small quantities used are applied mainly on sugarcane and vegetables and fruits. The N:P2O5:K2O ratio during the past three years has averaged 1:0.28:0.01.

Pesticides

28. Mahroof et al. (2011) note that pest attacks are a major factor in low levels of agriculture production in Pakistan. The beneficial effects of all other inputs may be wiped out within a couple of days if there is a pest outbreak. However, the use of pesticides in Pakistan is not as widespread as it should be. The need for increased use of pesticides has become greater as the use of fertilizers and improved seeds have increased. Pest attacks are generally more likely to occur in plants nurtured by fertilizer and cultivated from HYV seeds.

29. Imports of pesticides grew fast during 1952–53 to 1959–60. However, this growth rate was deceptive, because imports began to increase from a very low level. In fact, imports of pesticides began in 1972–73 (Mahroof, et al.). Yet the quantities imported fluctuated widely from year to year, as there was no organized system for plant protection in Pakistan. Further, farmers have often not been able to afford the expenditure required for the needed application of pesticides. Consequently, pesticide take off has varied widely in the country. Kang (2013) reports that the pattern of pesticide usage in Pakistan is different from crop to crop. The use of herbicides and fungicides is less heavy. The main use of pesticides in Pakistan is for cotton crops (60 percent), followed by paddy (7 percent), cereals (4 percent), sugar cane (2 percent), and other crops. Most farmers generally use pesticides without giving consideration to the infestation level and often spray the crop unnecessarily. The indiscriminate use of a wide range of pesticides is creating health and environmental hazards. There is a need for extension departments in the provinces to circulate required information regarding safe and correct methods of pesticide application.

30. Jabbar et al. (1994) reviewed the history of pesticide use in the country. The pesticide era in Pakistan can be divided into six distinct periods. Before 1980, pesticide import and distribution were the responsibility of the Plant Protection Department. At the time, the greatest imports were for locust control, malaria control, aerial spray of cotton and used on, sugarcane, rice, tobacco, etc. There were subsidies on pesticides and aerial spraying was free. Pesticides were shipped in large packages or containers; a number of accidents occurred during the transfer to smaller containers, handling, and storage of leftover toxicant (Ahmad 1988). Additionally, farmers had to purchase pesticides on a prepayment basis.

31. In 1980, the pesticide business was transferred to the private sector and there has been a steady increase in pesticide consumption and imports owing to the following factors: (i) pesticides are offered in small unit packs, (ii) they are available well before the start of the crop season, (iii) they are provided to farmers on a credit and deferred payment basis (this practice has been discontinued since 1988), and (iv) farmers are provided advisory services promotional campaigns about the time and mode of application. During the past four decades, pesticides have played a pivotal role in plant protection but side by side have generated problems of pesticide resistance in pests, persistence of toxicant in the ecosystem, and hazards to field applicators, food consumers, and dealers. Due to the lack of knowledge within the farming community and absence of appropriate regulatory agencies, pesticides in Pakistan are not used in ways likely to maximize benefits, except in (cash crop) cotton. The Central Cotton Research Institute in Multan, and the Nuclear Institute for Agriculture and Biology in Faisalabad, have played a key role in boosting cotton production.

32. Contrary to the experience in industrialized countries like the USA where herbicides make up 85 percent of total pesticides (USDA), recent data from Pakistan indicates that insecticides comprise 85 percent of the total pesticides consumed, and almost 65 percent of insecticides are used for cotton pest control. Better crop protection measures coupled with the introduction of high-yielding varieties has meant that production increased from 4.2 to 12.5 million bales from 1981 to 1992 (Economic Survey of Pakistan 1991–92). Experience supports that high yielding varieties perform better if the external inputs like fertilizers and pesticides are applied. Generally, the losses due to uncontrolled pests have been rated between 15–25 percent. The herbicide use share is increasing and is now 10 percent of all pesticides used. Imports of fungicides are more or less steady; however, their proportional share is decreasing.

Integrated Pest Management

33. Ali and Muhammad Sharif (2012) examine the integrated pest management (IPM) approach as an integrated approach to crop management to solve ecological problems when applied in agriculture. These methods are performed in three stages: prevention, observation, and intervention. The introduction of IPM approaches gained ground based on studies which estimated the environmental and social cost of pesticide use in Pakistan and place this cost at $206 million per year (UNDP 2001). The study indicated that over-use and misuse of pesticides had led to tremendous economic losses and hazards to human health (Azeem, 2000; Feenstra et al., 2000). IPM is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides while at the same time managing pest populations at an acceptable level. During the 1970s, research and development through IPM was initiated. Initial efforts to implement IPM in farms were reportedly unsuccessful; most impact studies at the time concentrated on measuring immediate impacts, notably the effects on pesticide use and yield, under the assumption that good IPM practices led to reduced spraying frequency and increased production. This may be due to the difficulties in quantifying and measuring other parameters, the lack of accepted methodologies by the broader scientific community, or the short time period within which many evaluation studies were conducted. A number of current studies, however, have attempted to capture a range of developmental impacts, including changes in the social and political domain.

34. Ali and Sharif (2012) maintain that most studies have not accounted for the econometric problems that arise in estimating program impact, when the placement of the program across villages and the selection of farmers for participation in the program is not done at random. This normally leads to biased estimates of program impact (Feder et al., 2003). These differences could arise from the non-random placement of the program or from the voluntary nature of participation in farmer field schools (FFS). For example, FFS villages might be chosen for their relative advantages

in land fertility or climate, or farmers who participate in FFS might be more productive, on average, than those who do not participate. Selective placement (through individual choice or purposive targeting) means that data on non-participants does not accurately reveal the likely achievements of participants in the program's absence. Unless non-random farmer and village selection is taken into account, the comparison of outcomes between FFS participants and non-participants will likely yield biased program impact estimates.

35. To deal with the selection bias, Ami and Sharif (2012) used propensity score-matching (PSM) methods to build a statistical comparison group of farmers comparable to FFS graduates. This allows us to ensure that bias in the impact estimate due to selection on observables is minimized. Any remaining bias in the matching estimator can thus be attributed to unobserved characteristics. Consequently, participants of FFS have more knowledge regarding insect pest management compared to non-participants. The participants of FFS were getting 30–40 kg/acre higher cotton yields as compared to non-participants. The policy implication of this finding can be that participation in FFS can help to increase household income which in turn can help to decrease household poverty. The demand for pesticides is also negative for participants as compared to non-participants, the policy implication of this finding can be that participation in FFS can help to reduce input cost. Similarly, less demand for pesticides has beneficial health impact for humans and animals and can also help improve the environment by decreasing environmental pollution. The knowledge level of participants regarding IPM practices was quite high as compared to non-participants. The policy implication of this finding can be that participants of FFS need to be trained in such a way that they can also train non-participants, which is important for the sustainability of the FFS program in Pakistan.

Farm Mechanization

36. Maroof, et al. (2011) point out that agricultural technologies have popularly been classified as mechanical technologies and biological technologies. Mechanical technologies are embodied in machines and appliances such as tractors, tube-wells, threshers, diggers, combines, etc. used in performing various farm operations, which typically help in expediting farm operations. Similarly, diffusion of these technologies results not only in a higher cropping intensity but also in quick planting and harvesting of crops, and the resultant handling of output. Although these technologies have a positive effect on cultivated area and cropping intensity, they do not necessarily increase crop yields.

37. Biochemical technologies, on the other hand, relate to new, more input responsive seed varieties, use of chemical fertilizer, and controlled application of irrigation water. Application of these technologies, in general, induces substitution of labor and industrial inputs for land, in addition to increasing crop yields (Mahroof, et al.). Biological technologies have also been regarded as the cause and effect of the green revolution that occurred during the 1960s and 1970s in different countries of the world. In Pakistan, the green revolution started during the early 1960s, although some of the modern inputs were introduced in the late 1960s. The main ingredients (inputs) of the green revolution witnessed in Pakistan were identified as HYVs, fertilizers, pesticides, tractors, and irrigation.

38. Mahroof, et al. (2011) examine the mechanization in the agriculture sector and conclude that the impact of mechanical technologies on agricultural growth and agrarian structures has been a controversial issue in Pakistan, particularly tractors. The argument encouraging the use of farm tractors posits their positive effect on cropping intensity, yields level, land preparation, and post-harvest operations. However, opinions differ widely on their positive effects, particularly on yield level and cropping intensity. Some economists also contend that large-scale tractor use in Pakistan

has resulted in labor displacement, tenant eviction, and expansion of already large landholdings (Malik, 1994; Khan, 2006). The government has provided incentives for the purchase of tractors by reducing import duties and taxes. These incentives are in addition to the low interest loans advanced by the Agricultural Development Bank of Pakistan. Tractors in operation increased at an average rate of over 14 percent during the 1970s, and 13 percent in the first half of the 1990s. The study argues that the mechanization of smaller farm holdings is not easy because almost all farm machines in Pakistan are basically designed to operate on large farm holdings. However, smaller tractors are gaining traction and the possibilities of their manufacturing locally are being explored. Despite the growth of tractors and tube-wells, the availability of farm power in Pakistan is estimated as being far below optimal levels, and many tasks on the majority of landholdings are still performed manually (Malik, 1994).

39. Iqbal, et al. (2015) review the situation and conclude that Pakistan has only experienced selective farm mechanization, as the concept has remained limited to the use of tractors only. Currently Pakistan's per hectare use of horsepower is 1.50 compared with India's 2.50, China's 3.88 and Japan's 7.0. A majority of farmers use tractor-drawn blades, ridgers to prepare seed beds, and cultivators. The other most common use is tractor-operated threshers, and haulage of inputs and produce from and to market. Tractor-drawn implements such as mold board plow, seed planters, fertilizer dusters, pesticide sprayers, and harvesters are in limited use. To encourage mechanization, the import duty on agricultural machinery is kept at the minimum (Mahroof, et al., 2011). Iqbal, et al. note that seed and seed-cum-fertilizer drills, planters, mechanical rice trans-planters, and vertical conveyor reapers are generally used by landlords and large farms only. In the recent past, zero-till drill and raised bed planters, laser land levelers, and turbo happy seeders are reportedly used by small farmers. Statistics are not available on the volume of production or its use. The use of solar technology is being introduced among growers across the country and solar-powered tube-wells and electricity generating panels are being used by a few progressive farmers. In recent years, mechanization has spread to small and medium-sized farmers which is being financed remittance incomes.

40. An assessment under the Agricultural Innovations Program (AIP) by SEP-CIMMYT (2015) studied the feasibility of the use of laser land levelling and two-wheel tractors in hilly areas, and compared it with traditional and modern techniques for tilling in both Azad Jammu and Kashmir (AJK) and Gilgit-Baltistan (GB). None of the respondents reported owning any such machinery, although 50.0 percent (AJK) and 51.2 percent (GB) said four-wheel tractors were available to them. Despite this access, 59.6 percent in AJK and 79.1 percent in GB still reported using bullocks to plough their land. The coefficient levels of the probit estimates from the SEP-CIMMYT (2015) report show only a very weak correlation between the willingness of farmers to adopt two-wheel tractors, or for land levelling technology and factors such as access to roads, ownership of bullocks, level of education, size of landholding etc. Consequently, no conclusion can be drawn as to any biases due to these factors. The benefits of the introduction of two-wheel tractors for tilling and of laser land levelling technology are yet to be determined, as are any potential constraints or barriers to its introduction since the AIP intervention is in its infancy at the time of writing.

41. The study discuses a long list of machines that are produced locally in Pakistan. They estimate that there are around 500 small- and medium-scale agricultural machinery units manufacturing farm implements, machines for land development, seedbed preparation, seeding, planting, inter-culture, reapers, wheat threshers, maize shellers, sprayers, farm trolleys, and tractors. There are a large number of local workshops that assist in servicing and repairing the equipment. As an incentive to their production, no sales tax is charged on their sale. The quality of locally produced farm

machines is generally poor due to the poor layout of workshops, lack of managerial, engineering and technical manpower; poor designs; improper manufacturing techniques; lack of availability of quality raw material components such as gears, sprockets, etc., and the lack of finance and marketing skills. The study makes a series of recommendations for promoting the production of these implements, in addition to encouraging their use by farmers.

42. The advent of the laser controlled land levelling equipment has marked one of the most significant advances in surface irrigation technology. The Punjab government has especially been promoting the technology, and reports that it is now considered a high priority among the country's farmers. Husnain et al. (2013) review the use of several innovative technologies in South Asia including the use of precision land levelling which reportedly significantly improves water use efficiency and land productivity, in addition to reducing waterlogging and salinity. They report that despite its various benefits, laser land levelling has yet to become popular across South Asia (RWC-IGP 2006). Punjab has made significant, albeit early-stage, progress in promoting this technology. The provincial government provided 2,700 laser units at a 50 percent subsidy to private sector individuals from 2005–2008, with the intent that a significant proportion of private cost recovery will come from renting machinery to others. Precision laser land levelling is now practiced on 1.6 million acres in the country (GoP, 2012), which represents about 7.0 percent of the total irrigated land in the country.

43. Mahroof et al. (2011) note that the most significant change that has occurred in the agrarian structure of Pakistan has been due to increased supply of irrigation water, particularly from private tube-wells especially in Punjab. Private tube-wells have not only provided additional water but have also provided it on demand. As a result, the cultivation of new irrigation-intensive crops is increasing with the rising fertilizer use positively impacting output and by extension, profitability for farmers (Acumen, 2008). In fact, it has been the improved availability of irrigation water that has facilitated rapid adoption of fertilizers and new seeds—particularly of wheat and rice—since approximately the mid-1960s (Kemper, 2003; Khan, 2006).

44. Encouraging the introduction of modern technology can also have some adverse long-term impacts. The subsidization in the use of tube-wells in Balochistan is one such example. Balochistan is dependent for its irrigation on the systems of flood irrigation, '*sailaba*', and rain-fed farming—'*khushkaba*'—which account for around 30 percent of the total irrigated area. For these lands, timely rains are essential to ensure a timely crop. To assist the province, the government introduced a subsidy for electricity to operate tube-wells in rural areas, where a farmer has to pay a maximum of Rs 48,000 as opposed to as much as Rs 600,000 without the subsidy. This policy resulted in a proliferation of tube-wells in the province which were irrigating 35 percent of the overall area in 2009. This in turn led to a massive decline in the water table that has resulted in major reductions in all water basins; another negative impact of this policy is that Balochistan's agriculture is now vulnerable to power outages (Management Systems International, 2012).

Water Saving and Efficiency Enhancing Technologies

45. The flow of the Indus River and its tributaries constitutes the main source of surface water for the country. The flow varies from year to year; the maximum was 186.79 million acre feet (MAF) in 1959–60 and the minimum was 100.31 MAF in 1974–75 (Hussein, 1998). In addition to the large (i.e. 65 percent) variation in the annual average flows, This presents a variation of over 65 percent in the annual average flows. Apart from this large annual fluctuation, there is a large seasonal variation in these flows as well. The Kharif inflows average 115.18 MAF while the flow in Rabi is 22.06 MAF. Thus 83.6 percent of the flow takes places during the five months of peak summer (Kharif) and only 16.4 percent is in the winter (Rabi) season (Afzal, 1999). To stagger the peak

summer flows, three surface reservoirs were constructed at Mangla (1967), Chashma (1971), and Tarbela (1974). The surface water is supplemented by the use of ground water. The groundwater storage capacity in Pakistan is estimated to be around 55 MAF (Hussein, 1999); hydrogeological conditions are mostly favorable for tube-wells. An estimated 15,504 large capacity public tube-wells and 469,546 private tube-wells of low capacity are currently installed in the country, resulting in the increase of ground water pumpage in the Indus basin from 3.34 MAF in 1959, to 48 MAF in 1996–97 (Bhutta, 1999). Groundwater quality is variable, with about 79 percent of the area in Punjab and 28 percent of the area in Sindh, suitable for irrigation. However, indiscriminate pumping without proper monitoring and the lack of knowledge about the chemistry and hydrodynamics of aquifers, has already contributed to their pollution and in many places, the salinity of tube-wells has increased (Chandio, 1999). Pakistan's groundwater resources are at the brink of exhaustion and there is a need to conserve this invaluable resource. In this context, several water conservation programs are being implemented in different parts of the country. In Balochistan, which relies almost exclusively on ground water, the water table has been decreasing by two to three feet annually.

46. Currently, 97 percent of the fresh water in the country is used in the agriculture sector and only 3 percent is available for domestic and industrial use. A review of growth trends shows that as the income of a country increases, the use of water by different sectors changes dramatically and the water needs of the industrial and domestic sector grow rapidly until in high income countries, water requirements are 47 percent of the water available. In the immediate future, Pakistan needs to review strategies for reallocation of water from irrigation to domestic and industrial use. For this purpose, it will need to consider market-based reallocation methods that are voluntary and yield economic benefits to both buyer and seller. The rate of return of a cubic meter of water used for agriculture is less than 10 percent of the return on municipal and industrial use. Conservation measures in agriculture can help in increasing the productivity of water.

47. The importance of water for Pakistan cannot be underestimated, particularly for irrigated agriculture. Irrigated agriculture covers 16.2 million hectares, 74 percent of the country's total cultivated area of 22.0 million hectares. The sustainability of irrigated agriculture is threatened because of the irrigation infrastructure's continuous deterioration. Additionally, the existing conveyance potential of the surface network is declining due to sediment deposits and deteriorating maintenance conditions. To augment the inadequate water supply for the agriculture sector, poor quality ground water is being used; indiscriminate use of this water will deteriorate physical and chemical properties of soils (Bhutta, 1999), resulting in poor yields.

48. A major paradigm shift is required in the agriculture sector in Pakistan. The cropping pattern is based on the premise of abundant water. Pakistan continues to produce water intensive crops like sugarcane despite water scarcity. The canal irrigation network was designed to support cropping intensities of 70–80 percent annually, with thinly spread supplies for the population. The fragmentation of landholding, low output of land, and increasing population pressure has forced high cropping intensities that have doubled with the help of extra supplies and ground water mining. Agricultural productivity is severely affected by the wide prevalence of water logging and salinity. Apart from the massive amount of sediment in the Indus, approximately 33 million tons of salt flow through its waters, with only eight million tons discharged into the sea. Consequently, today, water logging and salinity represent a serious threat to the country's agriculture. Crop yields of major crops like wheat, rice, and cotton in Pakistan are generally lower than other countries, like Egypt and Mexico.

49. The most significant development in irrigation has been the massive exploitation of groundwater, principally through private tube-wells. Groundwater usage has increased at an annual rate of 9.6

percent from 1960–1987. In the same period, canal supplies increased by 0.9 percent annually (Afzal, 1999). Surface water flows are being fully utilized in the irrigation systems up to their diversion capacities. Additional exploitation of surface water for irrigation or other purposes will depend upon Pakistan's ability to better regulate river flows through the construction of surface storage. Groundwater use has also reached a stage where further exploitation will be fraught with adverse consequences, exceeding the natural recharge rate.

50. Farmers employ practices which result in huge water losses at farmers' fields. The most widely used methods include flood irrigation, surface irrigation, and unleveled farm fields used for irrigation. In the wake of scarcity of water resources, demand has emerged to develop and adopt production methods and practices that can save water, reduce production costs, and improve production of agricultural crops at the same time. The water conservation technologies include land levelling, bed/ridge sowing, sprinkler irrigation, drip irrigation, zero tillage, etc. Although some of these technologies are too expensive to be adopted by small farmers, others can be adopted with little additional cost and effort. Bed/ridge sowing is one of the methods adding very little cost but it increases water productivity to a great extent. Many studies argue that resource conservation technologies increase farm productivity, conserve natural resources, and limit negative environmental impacts (Baksh at al., 2012)

51. In 2009, Baksh et al. (2012) conducted a study at the Institute of Agricultural and Resource Economics at the University of Agriculture in Faisalabad, identifying the factors affecting the adoption of water-saving practices, focusing on cotton crop. For this purpose, a data collection survey was conducted from two Punjab districts, i.e. Rahim Yar Khan and Mianwali, selecting 105 cotton growers. These growers were interviewed through a well-structured questionnaire. The results indicated that adopters of water conservation practices such as bed/ridge sowing had smaller land holdings (27 acres), compared to non-adopters (48 acres). Similarly, land fragments were relatively small for adopters (1.83 fragments), compared to non-adopters (2.67 fragments). Adopters applied a higher number of irrigations (7.08) to the cotton crop than non-adopters (4.72). The results of a Logit model indicated that ownership status, land fragmentation, farming experience, farm assets (especially sheep), and female workers played a significant part in the adoption of water conservation technologies in cotton production.

52. Rising water scarcity is one of the key factors limiting agricultural production in Pakistan. Surface water availability is deficient and unevenly distributed. Although the demand for irrigation water continues to increase, the supply of surface water is unlikely to increase due to the limited potential in surface water developments (Archer et al., 2010; Sharma et al., 2010; Laghari et al., 2012). As a result, farmers have started augmenting their irrigation water supplies through groundwater abstractions. Groundwater use now constitutes more than 50 percent of the total irrigation water supply (Qureshi et al., 2009). The use of groundwater has played a key role in propelling agricultural development in the country but massive groundwater abstraction has led to the rapid depletion of groundwater aquifers, with serious repercussions for the sustainability of irrigated agriculture (Qureshi et al., 2009). Within this context, pressure is increasing to improve rice productivity and irrigation water efficiency.

53. Watto and Mugera (2014) undertook a study with the objective of investigating the production and irrigation efficiency of rice farms and the factors that affect technical and irrigation water efficiency. They used a non-parametric approach to data envelopment analysis to estimate production and irrigation efficiencies using a cross-sectional dataset of 80 rice growers in Punjab. A second-stage truncated regression was used to identify the factors influencing technical and irrigation efficiencies. Besides investigating the production efficiencies of rice farms, the study attempted to measure irrigation efficiency among rice growers. Two methods, the DEA subvector

model and the slack-based model were used to measure irrigation water efficiency and to verify the robustness of the results. The empirical results show that on average, rice growers operate at fairly high levels of efficiency. Likewise, average estimates of scale efficiency show that scale inefficiencies are nearly absent among tube-well owners and water buyers. However, results on returns to scale suggest that farm efficiency can be improved by expanding the scale of operation. The cost and allocative efficiency estimates indicate that rice growers are not utilizing optimal quantities of inputs given their respective prices. The study finds that rice production could potentially be increased without increasing current input levels. Likewise, there is considerable scope for improving irrigation efficiency by using less water. A key finding of the study was that access to technology was not a major constraint in rice production in the study districts. However, the high cost of inputs does affect cost and allocative efficiency. The study recommended efforts to educate farmers and providing them with better credit opportunities and agricultural extension services.

54. Pressurized irrigation system technologies such as sprinkler and drip irrigation systems are a recent introduction. With the support of the World Bank, Pakistan initiated a national program on "Water Conservation and Productivity Enhancement using High Efficiency Irrigation Systems" during 2007–8. Sprinkler and drip systems have been installed on 25,000 acres, but due to the devolution of agricultural policy to provinces, the project has since been transferred to the provinces. A notable early success in Pakistan has been the active involvement of the private sector in the production and installation of pressurized irrigation systems (FODP, 2011). A major problem in the adoption of these modern irrigation systems is the high initial cost due to its capital intensity. The World Bank estimates that unless subsidized by at least 50 percent, these systems are beyond the reach of most farmers (World Bank, 2009). Quoting the use of the technology in Nepal, Husnain et al. (2013) note that while there was a high payback from vegetables, this may be less significant on fields cultivating lower value crops such as cereal grains. The Nepalese government made initial purchase subsidies available to ease the initial financial constraints of farmers, but more research is needed to determine where subsidies are appropriate, and where loans could be employed instead to ease the government's financial burden.

55. Quite distinct from the irrigated areas, the problem that besets rain-fed areas of the country requires a very different set of irrigation technologies such as water harvesting technologies. While water harvesting technologies have been promoted under several projects, the extent of their availability and use has not been documented. However, these technologies require the use of simple equipment generally available in the country. Baig et al. (2013) focuses on 25 percent of the cultivated, rain-fed area that is plagued by problems such as moisture stress, soil erosion and crusting, nutrient deficiency, and weed infestation, limiting the yield potential of these lands. To meet their food requirements, farmers bring all available pieces of lands, including steep slopes, under the plough. Farming on steep slopes, if not managed on scientific lines, results in severe erosion. The problems faced by farmers are due to the unsustainable practices they adopt to practice dry land agriculture, limiting the productive potential of these important ecosystems. Factors like dry climates and severe water deficits make dry land agriculture difficult to be adopted and practiced in these areas. Range management and livestock rearing businesses can be very successful on areas having limited scope for agriculture. Problems like extreme scarcity of water, overgrazing, deforestation, and water erosion are quite common in rain-fed areas and can be managed by adopting suitable rainwater harvesting techniques, employing scientific soil and water conservation methods, and using sustainable agricultural practices.

Tunnel Farming Technologies

56. Three types of tunnels are used in Punjab—low tunnels, walk-in-tunnels, and high tunnels. Crops grown in tunnels are chillies, bottle gourd, bitter gourd, tomatoes, cucumber, sweet pepper, and pepper (Khan, 2000). Tunnel farming is gaining popularity and is practiced in many areas of Punjab like Faisalabad, Gujranwala, Mamokanjan, Sahiwal, and Okara, though cultivation is not at any significant level. The Fruit and Vegetable Development Project (FVDP) was launched by the Government of Punjab in 12 districts for vegetable and fruit growers to enhance their production through the dissemination of modern production technologies, by using a FFS approach (Government of Punjab, 2012). Muhammad et al. (2014) undertook a study on the factors that influenced the adoption of the technology that was based on feedback from 120 participants of the farmer field schools in Faisalabad, operating under the FVDP. Of the factors reported as affecting adoption, the most significant were the lack of capital, the low education level of farmers, lack of awareness among farmers regarding the project, and the poor response of vegetable growers.

Precision Agriculture

57. Conventional farm management systems are based on the use of generalized recommendations across the whole field or all the fields within a farm (Bakhsh, 201). This increases the initial cost due to inefficient use of chemicals and raises environmental concerns, such as ground water quality (Corwin et al., 2003; McBratney et al., 2003). Before the revolution of agricultural mechanization in the world, farmers varied treatments by making small-sized fields. With intensive mechanization, the fields were enlarged in the developed world and it was difficult to take field variability into account without revolutionary development in technologies (Stafford, 2000). Ahmad et al. (2013) examine the potential for precision agriculture they describe as an information and technology-based farm management system. This aims to apply technologies and principles for identifying, analyzing, and managing spatial and temporal variability associated with all aspects of agricultural production within fields for near-optimal profitability, sustainability, crop performance, land resource protection, and environmental safeguards. It is a multi-disciplinary approach that covers a broad array of topics, such as characterizing variability in soil resources, soil tillage, irrigation, crop rotation, machinery performance, plant genetics, and crop physical, chemical, and biological inputs (Zhang et al., 2002). The development of new sensors, actuators, applicators, agricultural machinery, and other apparatus owes to the engineering discipline to a great extent. Precision agriculture also plays a role in determining engineering parameters related to soil and crops, such as predicting soil tillage and workability; determining irrigation requirements, soil strength, and compaction; and measuring draught force. In short, the concept of precision agriculture is to fine tune the agricultural production system by emergence and convergence of several technologies to enhance profit and reduce environmental risks (Whelan, 2007; Zhang et al., 2002). Adoption of precision agriculture is recognized as a new revolution in the agriculture sector, especially in America, Australia, and Europe, although the adoption is very slow (Mondal and Basu, 2009; Swinton and Lowenberg-DeBoer, 2001).

58. The adoption of precision agricultural technologies in the developed world has created a real challenge for developing countries to include some suitable modern technologies in their farming systems to meet the food requirements of their growing population. Accepting this challenge, some developing countries, such as Argentina, Brazil, China, India, and Malaysia have begun to adopt some components of precision agriculture, especially on research farms, but the adoption is still very limited. A few large, progressive farmers have adopted elements of this approach. Some researchers have stressed the suitability of this approach for Pakistan (Ghafoor et al., 2010), to handle within field variability for maximizing yield and profit given the small size of landholdings. It is also recommended due to the wide gap between the potential and actual yields in the country

(Bakhsh, 2011). Addressing the yield gap necessitates the promotion of precision agriculture to achieve the intended benefits. It has been postulated that despite small landholding and low income levels, precision technologies can make a significant difference in the livelihoods of equipment operators and farmers (Mondal and Basu, 2009; Srinivasan, 2001). Since precision agriculture is a rather new for the farming community of Pakistan, this paper provides an overview and examines the potentials, prospects, implications, issues, and relevance of precision agricultural applications in Pakistan.

59. Some experts have emphasized the need to initiate precision agriculture in Pakistan for quite some time and have guided farmers to use precision agriculture, such as tillage, water, and agro-chemicals for increasing the benefits of the farming community (Bakhsh, 2011), but not a single report of the use of precision technology has been presented so far (Tanveer at al., 2013). The only precision technology that has been used in Pakistan successfully for a few years is laser land levelling. This may also be termed as precision land levelling. This is topographic modification, grading, and smoothing of land to an even level with little or no slope, which improves irrigation application efficiency and increases the uniformity of water application with less chance of over and under irrigation (Kahlown et al., 2002). About 50 percent of total available water is lost in transit in tertiary level irrigation systems and at farms during crop application (Gill, 1994). A significant amount of irrigation water is wasted due to undulated fields and field ditches (Kahlown et al., 2002). Precision land levelling increases the crop yield by about 26 percent and reduces the mean time to irrigate an acre field from 2.12 hours to 1.13 hours (Johnson et al., 1977). Precision land levelling is a resource conservation technology to save irrigation and to gain more benefits. Despite useful benefits of precision levelling, there may be some environmental issues related with this technology, such as erosion and poor water holding capacity at filled spots (Kahlown et al., 2002).

60. In the last two decades, India has made significant advances in introducing precision agricultural technologies, such as micro-irrigation and protected cultivation (Tiwari and Jaga, 2012). This is attributed to government policies encouraging farmers to adopt precision technologies (Tanveer et al., 2013). In Pakistan, there is also a need to support this information-based agriculture by government agencies and researchers by conducting research on farmers' fields to demonstrate this type of agriculture. Unfortunately, Pakistan is lagging in the promotion of this technology which should be initiated with a comprehensive plan for increasing productivity. Though government agencies and researchers recognize that the introduction of any technology takes time and that the adoption of precision agriculture in the entire country is contingent on widespread acceptability, there are some relatively developed areas which can act as incubators for adoption of these technologies (Tanveer et al. 2013). This requires effective coordination among the public sector, private sector, and growers. Successful examples of this coordination include the United States Department of Agriculture (USDA) and the Agricultural Development and Advisory Service in the United Kingdom.

61. Most farmers in the country have small landholdings. It is true that most precision applications are not applicable in the small-scale farming culture, and searching for suitable technologies matching these conditions is a real challenge. However, some precision technologies can be used in small-scale farming systems as discussed by Cook et al. (2003). For example, application of Geographic Information Systems to small farms has been very successful in some developing countries, such as Korea, Japan, and China (Mondal and Basu, 2009). In the rice–wheat belt of the Punjab, combine harvesters are used for harvesting rice and wheat. Yield monitors can be successfully used on those combines for site-specific yield monitoring. This information can be linked to the determination of soil characteristics based on the yield of different locations in the field and for

making soil maps. Currently, not a single combine is equipped with a yield monitor in Pakistan (Personal Communication, 2012). Similarly, precision fertilizer applicators and spreaders can also be used in small-scale farming systems if soil variability maps are available. For in situ measurement of crop nitrogen status, portable chlorophyll meters are excellent diagnostic tools (Mondal and Basu, 2009). Potable pH meters can be used on the go for determining soil pH and developing maps. Tanveer et al. (2013) argue that excessive use of pesticides can be reduced by adding precision gadgets to spraying machines. If the benefits of new technologies are promoted to farmers in Pakistan and these technologies are offered to them at reasonable prices, they will embrace them. The prerequisite is that the technologies are reliable and don't inflate risks; if this can be achieved, these technologies can be recommended.

Conservation Agriculture

62. Considerable attention is being paid to conservation agriculture as this technique is increasingly being pursued in areas facing moisture and soil quality issues. Sheikh et al. (2002) set the stage for their study by outlining an important issue in the sector. In the 'rice–wheat' and the 'cotton–wheat' farming systems of Punjab, the late planting of wheat is a perennial problem due to often delayed harvesting of the previously planted and late maturing rice and cotton crops. This leaves very limited time for land preparation for 'on-time' planting of wheat. 'No-tillage' technologies reduce the turnaround time for wheat cultivation after rice and cotton have been developed, but their acceptability has not been as expected. This paper attempts to determine the farm and farmer characteristics and other socioeconomic factors that influence the adoption of 'no-tillage' technologies. Logit models were developed for the analysis undertaken. In the 'cotton–wheat' system, personal characteristics like education, tenancy status, attitude towards risks implied in the use of new technologies, and contact with extension agents are the main factors that affect adoption. As regards the 'rice–wheat' system, resource endowments such as farm size, access to a 'no-tillage' drill, clayey soils, and the area sown to the rice–wheat sequence, along with tenancy and contact with extension agents were dominant in explaining adoption.

63. Over the past decade, conservation agriculture (CA) has, arguably, become a "hegemonic paradigm in scientific and policy thinking about sustainable agricultural development. Andersson and D'Souza (2014) reviewed the experience with regards to CA adoption among smallholder farmers in southern Africa (Malawi, Zambia, and Zimbabwe), and analyzed the historical background of the upsurge in CA promotion, the various definitions of CA that have emerged since the 1990s, the barriers to its adoption, as well as uptake figures and adoption studies. First tested as soil and water conservation measures, large-scale promotion followed a reframing of CA as a production-enhancing set of practices. They specify that a commonly used, reductionist notion of CA adoption is the uptake of minimum tillage. They note that since CA uptake is often also incentivized by means of input support (fertilizers, seeds, and herbicides) provided by promotional projects, adoption claims have limited value. Current CA adoption studies are methodologically weak as they are biased by the promotional project context in which they are carried out, and build on farm-scale analyses of standard household surveys. A more thorough analysis of farming households and their resource allocation strategies is required to understand the farm-level adoption constraints that different types of farmers face. As contextual factors appear to be key influences on smallholders' farming practices, studies focusing on the wider market, institutional, and policy context are also needed if we are to understand (limited) CA adoption.

64. CA's prominence in recent debates on sustainable intensification, climate change, and as a form of climate smart agriculture, is further evidence of the paradigm's prominence in global agricultural development policy. At the same time, questions and controversies have emerged regarding the

CA's ability to achieve the many virtues that proponents assert it embodies. For instance, claims regarding the role of conservation agriculture in carbon sequestration have been questioned, as evidence is lacking or inconclusive. Simultaneously, the universal applicability of its three main principles—(i) minimal soil disturbance, (ii) permanent soil cover and, (ii) crop rotation (and crop diversification)—both individually and in combination, has come under scrutiny. Some scholars and practitioners favor more practical and context-specific approaches over the strict implementation of CA principles such as no-till. Others question the applicability of CA principles in the context of diverse, small holder farms and farming systems (Andersson and D'Souza, 2014). The diversity in what is considered 'conservation agriculture' complicates the assessment of CA uptake and the barriers to its adoption. While the literature has identified a number of adoption constraints at the farm level, contextual factors influencing CA (non) adoption have generally received less attention.

65. Andersson and D'Souza (2014) argue that current adoption studies are inadequate in defining exactly the extent of conservation agriculture uptake, and are biased. A heavy reliance on econometric analyses of standard farm household survey data limits the understanding of CA adoption. The interpretative framework of these CA adoption studies appears weak as the functioning of smallholder farming households and their production systems appears ill-understood. Consequently, these econometric analyses reveal general characteristics of CA (component) adopters, rather than revealing farmers' resource allocation strategies that underpin adoption and non-adoption decisions. Household economic analyses highlighting the viability and feasibility of CA for smallholders despite the higher capital investment needs of CA, appear equally limited in their understanding of the realities of smallholder farming in southern Africa. CA adoption studies may therefore benefit from adopting an empirically grounded systems perspective, and the use of a wider set of quantitative and qualitative research methods. Complementary analyses of wider socio-economic, institutional and policy factors are needed as farm-level practices are often constrained or enabled by forces beyond the farm.

Resource Conservation Technologies for Arid Areas

66. Pakistan is predominantly an arid country with 80 percent of its land area in the arid and semiarid regions and is considered among the most arid countries in the world, with an annual rainfall of under 250 mm. About 75 percent of the cropped area is irrigated and the rest is rain-fed. In Pakistan, dry land agriculture is synonymous with rain-fed (*barani*) conditions. In the past, resources were allocated for the development of irrigated areas (high potential), whereas less importance was given to agriculture on rain-fed areas (low potential) due to its intrinsic risks. However, rain-fed areas are vast natural resources that contribute a significant share to the national economy. It sustains 80 percent of the livestock population and contributes 12 percent of wheat, 27 percent of maize, 69 percent of sorghum, 21 percent of millet, 25 percent of rape and mustard, 77 percent of gram, 90 percent of groundnut, 53 percent of barley, and 85 percent of pulses (Zia et al ,1996).

67. The use of a range of conservation technologies has been highlighted given that Pakistan receives less than 250 mm of annual rainfall on average, and that around 25 percent of the cropped area is currently rain-fed. This has focused attention on resource conservation technologies and practices and the use of practices which can enhance the productivity of these arid lands. In these areas, farmers use obsolete methods of irrigation resulting in poor application and distribution efficiencies. In most of the area, the land is highly undulated and precision land levelling is not an economically justified option under the prevalent topographic conditions; gravity irrigation is also not possible in these areas. Highly efficient sprinkler and trickle irrigation techniques have been successfully introduced on a small-scale in Pakistan, and are particularly well suited to the water scarce rain-fed areas (Khan et al., 2012). Application efficiencies of these systems can be very high

(75 percent to 85 percent), thereby permitting almost complete use of the scarce water supplies. An additional advantage as compared with other methods of surface irrigation, is that efficient irrigation can be carried out even where topography is undulated and where the soil is of a light texture, as is the case in much of the rain-fed areas. Raingun sprinkler with mobile units and drip irrigation system components have been locally developed which are comparatively less expensive, and have proved successful and potentially promising.

68. Rashid et al. (2008) point to the addition of gypsum which has been able to successfully conserve soil moisture. In addition, gypsum application at the rate of 2.5 tons/ha was helpful in increasing wheat yield by 46 percent in low rainfall years. Their experiments in the rain-fed areas showed that such practices have the potential to mitigate the adverse effects of drought (Rashid et al., 2008). Khan et al. (2012) called for the adoption of integrated engineering, cultural, and biological measures for soil and water management practices. They also advised that ecologically suitable cropping systems be devised and applied in these areas. In addition to these, other innovative technologies include contouring, strip cropping, terracing, improved tillage practices, and construction of soil and water conservation structures. On gentle sloping lands, contouring reduces the velocity of overland flow. If ridge cultivation is practiced, the storage capacity of furrows is increased, permitting the storage of a large volume of water. It has been shown that contour cultivation of a good piece of land with grass at the beginning of the rainy season can reduce watershed runoff by 75–80 percent (Baig et al., 1999). Strip cropping consists of a series of alternate strips of various types of crops laid out so that all tillage and management practices are performed across the slope or on contours. Strip cropping is not a single practice but a combination of several good farming practices such as crop rotation, contour cultivation, proper tillage operations, stubble mulching, and cover cropping. Cover crops can also be highly effective for controlling erosion (Zia et al., 1996).

69. A key issue in efforts to keep food production rising is the lack of additional sources of fresh water for agricultural use. Partially in response to the water challenge, various resource conservation technologies (RCTs) are being developed and promoted, in particular for rice and wheat which together make up 90 percent of the country's total food grain production. Ahmad et al. (2014) examine the constraints and opportunities for water savings and increasing productivity through RCT in Pakistan. Increasing the productivity of rice–wheat cropping systems is critical for meeting food demand in rapidly growing South Asia. But this must be done with increasingly scarce water resources, bringing greater attention to RCTs such as zero tillage, laser land levelling, and furrow bed planting. While the impacts of RCTs on yields are easy to measure and explain, impacts on water savings are not well understood beyond the field scale because of the complex movement of water. This paper uses both physical measurements and farmer survey data from the rice–wheat cropping system of Punjab to explain the main drivers of RCT adoption and their impacts on land and water productivity and water savings across scales.

70. The primary drivers for RCT adoption (zero tillage wheat and laser land levelling) were reduced costs of production and labor requirements, reduced field scale irrigation water application, and higher yield. While the large proportion of farmers benefitting from RCTs explains the overall increases in RCT adoption, a considerable proportion (30 percent of zero tillage adopters for wheat cultivation) reported yield losses, highlighting the need for further technological refinement and enhancing farmers' ability to implement RCT. The study also indicates that the field scale reduction in irrigation application did not always translate into real water savings or reductions in water use in farms, cropping systems, and catchment scales, especially in areas where deep percolation from the root zone could be reused as groundwater irrigation. Finally, the evidence shows that medium- and large-scale farmers tended to use field scale irrigation savings to increase

their cropped area. This finding suggests that without regulations and policies to regulate the use of 'saved' water, adoption of RCTs can result in increased water use, with implications for the long-term sustainability of irrigated agriculture.

Other Specific Techniques

71. Awan et al. (2015) examined the sustainability of conventional flooded rice systems in Pakistan which they felt was threatened by diminishing resources, particularly land, water, and labor. Aerobic rice (AR) (i.e., growing rice by dry direct seeding in non-puddled, non-flooded fields under non-saturated (aerobic) soil conditions just like other upland crops such as wheat or maize) is one of the technologies showing great potential to improve resource use efficiencies in systems constrained by scarcity of resources. Aerobic varieties developed by crosses between traditional lowland and upland varieties combine some of the yield potential enhancing traits of lowland varieties with adaptation to aerobic soils (Atlin et al., 2006). The adoption of aerobic rice systems (ARS) could considerably increase resource use efficiencies. Information on farmer perceptions was vital to identify sociotechnological factors of adoption. The aim of the study was to understand and analyze farmer perceptions about ARS with regards to future adoption. The study was conducted in Punjab with three groups of farmers: (I) informant farmers in rice–wheat systems who trialed ARS in a participatory research trial (n = 70), (II) rice farmers in rice–wheat, mixed-cropping, and cotton–wheat system with no experience of ARS (n = 97), and (III) non-rice farmers in mixed-cropping and cotton–wheat system (n = 48).

72. Data was collected using a pretested semi-structured questionnaire and analyzed by using descriptive statistics and chi-square tests. More than half of the respondents in groups II and III had never heard of ARS, though 76 percent were open to experimenting. Across the three groups, farmers perceived ARS as a means of increasing resource-use efficiency particularly for labor, net profitability, and an option for crop diversification in the mixed-cropping system. Perceived threats were weeds, diseases, poor germination, spikelet sterility, low yields, and frequent irrigation requirement. Deciding factors for repeat ARS plantings by group I were ease of operation due to direct seeding, good income, and low input requirement. Deciding factors against repeat plantings were the unavailability of suitable fine grain basmati varieties, falling water tables, weed problems, and unsuitable soil types. The results suggest that aerobic rice is an interesting alternative to traditional rice production as evident from the willingness to plant again, by 73 percent of group I demonstration households. However, the unavailability of well-adapted basmati varieties hampers its expansion. Associated risks can be reduced by filling the identified knowledge or technological gaps through additional research and farmer awareness programs.

The Horticulture Sector

73. Pakistan enjoys an agro-ecological environment suitable for cultivation of almost 30 kinds of fruits with citrus, mango, dates, guava, apple, melons, and banana being the most prevalent (Sharif, et. al 2005). Although much literature exists on the topic of agricultural produce, it is important to note that fruits and vegetables are special crops and their production technologies, constraints, and problems are quite different than that of field crops (Muhammad Zafarullah Khan et al., 2012). Jawad (2015) reports that the production of fruits and vegetables in Pakistan is declining, while neighboring India is witnessing a significant rise in horticultural produce. Reforms such as improved technology and increased mechanization will enable horticulture exports to grow to their potential and earn a significant share of exports (Mirza, 2012). Issues highlighted in the literature include a lack of information, losses experienced both pre- and postharvest, and "harvesting at the incorrect maturity, under or over ripe fruit, poor grading, physical damage, high disease incidence, blemishes including sap burn, and poor packaging" (Mazhar et al., 2010). Pakistan

also has much lower yields per acre for many fruit crops and the yield of the mango crop at eight to nine tons/ha is less than half the world average yield of 25 tons per/ha (Sauco, 1993).

74. Pakistani exporters lack an awareness of global food safety standards (Mirza, 2012). According to Muhammad Aurungzaib Khan (2010), because horticultural produce is perishable, it is often subjected to high sanitary and phytosanitary standards that require technical expertise and strict quality control. Increasingly, distribution is dominated by large supermarket chains with exacting quality standards (UNIDO, 2010). Various studies such as those carried out by Masud and Akthar (1997), Parveen and Masud (2001), and Masud and Hasan (1992) revealed that fruits and vegetables bought from local markets in Pakistan often exceeded the maximum residue limits for organochlorine, organophosphate, and pyrethroid insecticides. "In 1995, 14 per cent of the samples were found to be above the permissible level of contamination set by FAO/WHO standards (Qazi, 2005). Complying with international standards is key to Pakistan becoming more competitive in the international market for horticultural produce (Khan, 2010).

75. Several technologies available for cereal crops are also available for use by the horticulture sector such as IPM. Irshad et al. (1978) identified several species of Scelio which act as parasites on Acrididae (species of grasshoppers). Similarly, Rehana and Mohyuddin (1981) argued for the introduction of the natural enemies of grasshoppers, some of which were brought in from other countries and proved to be a successful strategy. Another similar strategy relevant for the horticulture sector is that of using Entomopathogenic fungi (EPF) as biocontrol agents, as suggested by Qazi and Khachatourians (2010). EPFs are suited to both the country's environment and its climatic situation. EPFs infect pests and although this method has been used for over a century (Qazi, 2010), many new strains of the fungus are being studied with various levels of efficacy. However, Qazi's main argument is that these techniques for pest control eliminate the issue of contamination by pesticides. Such methods allow producers to circumvent the issue of their produce being destroyed by insects; if insecticides were used, their harvests would otherwise be deemed contaminated and not meet FAO/WHO standards. Passing international standards would make Pakistan's horticulture exports more competitive, and allow access to new markets.

76. There are some areas of Pakistan with very specific issues related to their peculiar location and geography such as the remote mountain areas of GB and AJK. These areas face additional challenges in the adoption of modern agriculture technologies and practices. The mountainous province of GB are quite unique in that only 2 percent of the land in the area is cultivable due to extreme terrain and climatic conditions, further exacerbated by the fact that only around half of the cultivable area is irrigated (Sendall, 2013). The area has an advantage in producing a large variety of horticulture products and farmers still prefer the use of traditional practices and do not use fertilizers or other purchased inputs (Khan, 2015). One of the main agricultural products of the area is apricots of which it produces 65 different varieties which are marketed both domestically and exported globally. Most of the literature about the area focuses on this crop. It is estimated that due to unavailability of good marketing, packaging, and value addition facilities almost 50 percent of the crop is wasted (Rehman, 2015). A few projects have initiated interventions to improve the processing and marketing of the crop. The Asian Development Bank's (ADB's) Agribusiness Support Fund introduced solar drying technologies (ADB website, 2014) but these technologies are quite basic. Nevertheless, this intervention helped to reduce losses and increase the demand for the processed fruit. A USAID project proposed the development of cold chains to facilitate linking producers to domestic markets and for international export (Bishop, 2013). The primary constraints identified in the implementation of the project were traditional practices and beliefs that cold chains cannot influence postharvest

losses, in addition to a lack of awareness about remedial measures (Bishop, 2013). A USAID funded agri-business project recommended improvements in storage and transport technologies (Sendall, 2013). A study by the Aga Khan Rural Support Program (AKRSP) reports that metaled roads were the highest priority for farmers in remote villages.

77. The mountain areas present a very important opportunity for the production of seed potato. Several projects and private sector players have tried to cultivate seed potatoes in GB and in certain valleys of Swat. Several international institutions have collaborated in this effort such as the International Potato Center, Swiss Potato Development Project, FAO, and GTZ. Tissue culture labs for mini tubers were established in the Northern Areas. However, despite having a combined potential of producing half a million mini tubers they are operating only at around 10 percent of their potential due to a lack of finance (Martin-Barros, 2013). In his report, Martin-Barros also highlights that farmers lack sufficient training on postharvest handling of tubers and the unavailability of cellars in which to store seed tubers, causing farmers to lose out on significant potential earnings from selling the seeds in Punjab.

78. One proven methodology for increasing productivity is effective microorganisms (EM), which consists of mixed cultures of beneficial and naturally occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plants (Higa and Parr, 1994). EMs have been tested extensively in both field and greenhouse environments in Pakistan since the 1990s and were found to have increased the levels of soluble sugars, fruit juice content, and the overall weight of two varieties of oranges by a considerable percentage. The study also quoted a paper by Waluyo (1993) reporting an increase in the weights of certain fruits.

79. The push towards adoption of improved technologies may be market led and may stem from a growing demand for improved quality of produce. Grace (2015) delves into this issue and finds that evidence on foodborne disease (FBD) in low and middle income countries (LMICs) is still limited, but important studies in recent years have broadened the scope. These suggest that developing country consumers are concerned about FBD; that most of the known burden of FBD disease comes from biological hazards; and that most foodborne diseases are as a result of the consumption of fresh, perishable foods sold in informal markets. FBD is likely to increase in LMICs as the result of massive increases in the consumption of risky foods (livestock, fish products, and produce), and lengthening and broadening value chains. Although intensification of agricultural production is a strong trend, so far agro-industrial production and modern retail have not demonstrated clear advantages in food safety and disease control. There is limited evidence on effective, sustainable, and scalable interventions to improve food safety in domestic markets. Training farmers on input use and good practices often benefits the farmers trained, but has not been scalable or sustainable, except where good practices are linked to eligibility for export. Training informal value chain actors who receive business benefits from being trained has been more successful. New technologies, growing public concern, and increased emphasis on food system governance can also improve food safety.

Post-Harvest Technologies

80. The use of poor harvesting and post harvesting technologies for handling agricultural production result in significant income losses in terms of quantity lost as well as reduction in value due to lower prices on account of poor quality. Post-harvest losses in fruits range from 12 to 40 percent (Iqbal and Ahmad, 2004). In most of the fruits, losses are high due to external and internal injuries occurred during harvest. The fruits are usually packed in jute sacks, used fertilizer bags, and in wooden crates. Due to extreme heat, high humidity, and improper packaging conditions, produce quality deteriorates rapidly, resulting in high losses. Most of the losses occur during transportation

and marketing, especially in the case of bananas, jujubes, and mangos. The absence of adequate cold storage facilities in wholesale markets is a major factor, resulting in high market level losses. Losses can be higher in the case of some fruits such as mangoes. In one study on the supply chain of the mango industry in Pakistan, Mazhar et al. (2010) found that only between a quarter to a third of acceptable quality produce—based on the variety of mangoes—actually made it to the market. Khan et al. (2008) reviewed the peach crop in the Swat district and found that a large part of the crop is lost postharvest. The study estimates a 23 percent loss on average, across all varieties, with a range being of 18–31 percent by variety. The most significant share of the total loss (77 percent) takes place at the peach picking stage, while 23 percent of the loss occurs during transportation. A substantial reduction in postharvest losses is possible through training of growers and others engaged in farming, picking, crop handling operations, etc. The net marketable produce can be further substantially increased by providing training and counseling to growers also in preharvest crop management. Most of the surveyed growers showed their willingness to adopt improved pre and postharvest practices.

81. The reduction of postharvest losses would bring about significant gains to export earnings and could potentially be very large. Aujla et al. (2007) identify several factors that influence the efficiency of fruit marketing including perishability, seasonality, quality, prices, and location of the products. Postharvest losses in fruits are estimated at Rs31 billion and in vegetables at Rs18 billion per annum (Ministry of Food and Agriculture, 2001). The value of the wasted quantities of just three fruits (mango, banana, and dates) amounts to over Rs4 billion per year. The shelf life and desired quality of horticultural crops must be improved to meet international standards and the preferences of international consumers, especially for potential export crops. While the country has some of the best citrus in its *kinno* strain, international consumers prefer seedless citrus (Aqbal and Ahmad, 2004). A combination of research efforts for evolving suitable varieties and developing improved harvesting, transporting, storage, and packaging technologies can save Pakistan a significant amount of otherwise lost agricultural income. The export of high quality fruits and vegetables needs to be supported by cold chain infrastructure and reefer containers which do not exist in the country on any significant scale.

82. According to Faruqee et al. (1999) the perishability of horticultural products requires an efficient processing and marketing infrastructure, which is largely lacking in Pakistan. Similarly, Abro and Sadaqat (2010) stress that the government must take on the initiative to launch technology missions to develop horticulture in an integrated manner, providing infrastructure support for horticultural development with an emphasis on postharvest management, strengthening agricultural marketing, mandatory crop loan insurance, and a seed bank scheme will lead to crop diversification and increase the production and productivity of crops and increase the income of farmers. There is also a push towards trying some new methods such as treatments for selected crops which can enhance demand. One of these, studied by Faheem et al. (2012), was hot water treatments of exportable mangoes which can effectively kill fruit flies, but can significantly deteriorate the fruit quality during the post-storage period. In the present study, the two mango varieties of *Sindhri* and *Chaunsa* were subjected to hot water treatments on recommended temperatures, i.e. 48°C for 60 minutes, and two proposed hot water treatments, i.e. 46°C for 60 minutes and 50°C for 60 minutes. All three hot water treatments killed all fruit fly eggs and larvae, in both varieties of mango. However, the treatment affected fruit quality during the nine-day post-storage period in terms of weight loss in *Sindhri* and stem end rot, brown rot, and physical injury in *Chaunsa*. Based on the findings, the authors recommend hot water treatment of *Sindhri* at 50°C for 60 minutes and of *Chaunsa* at 48°C for 60 minutes.

83. A lack of information regarding market prices tends to make producers and oftentimes contractors bear the risk, as they take on the responsibility for harvesting and transporting fruits to markets. Prices fluctuate and bidding for the produce is often done in secret, therefore producers and contractors are particularly vulnerable and forced to rely on commission agents to give them a fair deal (Khushk and Smith, 1996). Mujahid (2002) suggests that one way to ensure all individuals and institutions involved in the production process have improved access to information—not just about current market rates, but also about all information relevant to farmers, such as weather conditions, special reports, and information on canal water levels—is to use information technology to disseminate announcements regarding the latest technologies, the use of pesticides, warnings about current diseases, and other relevant information. The website (www.pakissan.com) has already been made functional and is providing all such information in both English and Urdu, helping farmers make decisions like what plants or fruits to cultivate, etc.

84. There are a number of ways information technology is supporting rural productivity through market information sharing via communication networks, helping farmers to make decisions about what crops to plant and how to plant them most effectively. The technology also provides information to rural stakeholders and farmers on timely weather forecasts, agriculture issues, government incentives and promotion measures, and information about advanced scientific knowledge on how to improve yields. The availability of this information and the related communication technologies has not been documented.

The Livestock Sector

85. Livestock is a key element in the mixed farming systems of smallholders and has a high potential for growth and poverty alleviation in Pakistan. It is a source of income, saving, and insurance; and it contributes to social functions and assets. The potential for food security and absorption of surplus labor and utilizing crop residue and grazing lands, makes it an attractive investment option for the smallholder. The livestock sector also has the potential to enhance incomes and empower women, and help them deal with issues of food security and household nutrition, and earn additional income. For many poor and marginal communities, livestock represents an invaluable element of identity, and owning livestock gives men and women a key asset. Women play an important role in activities dealing with livestock management, transformation and marketing. Identifying and supporting the roles, decision making and capabilities of women as livestock owners, processors, and users of livestock products are key aspects in promoting women's economic and social empowerment and consequently their ability to break the cycle of poverty. Sustainable livestock production systems enhance communities' capacities to diminish risk, manage uncertainties, and cope with difficulties (Rota and Sperandini, 2009).

86. The full potential for growth and development of the livestock sector is not being realized due to a host of factors which include low productivity due to nondescript breeds, poor feed and water intake, traditional management practices, limited capacity to provide balanced feed and mineral supplements, limited awareness of modern production practices, poor animal disease management, and limited access to quality health care. The lack of adequate and good quality vaccines and deworming medicines is one of the most critical constraints in ensuring protection of animals against disease. While the government has a policy to supply these at subsidized rates, in practice, it does not have the resources to procure the quality and quantity required. Productivity in the milk sector in Pakistan is one-third of the international average and meat production is half of the international average and is far below the productive potential of local livestock. In Punjab, AI coverage in cows is 13 percent and in buffaloes, it is only 7 percent (Director General, Livestock Development Department Punjab, 2011). The country has not capitalized on its stock of

high quality Sahiwal, Cholistani, and Red Sindhi breeds which have been exported to many countries as valuable breeding stock. The country's high animal mortality and morbidity is due to insufficient veterinary services and the lack of awareness among farmers, about animal disease management. Women who have the major responsibility for managing livestock in villages have limited access to government extension staff which lacks women extension agents. The capacity of the private sector is highly variable and uncertain. Similarly, the potential for growth of small ruminants is limited as a result of poor disease management practices, limited awareness about improved production practices and limited access to direct markets. Women are also hesitant to enhance their poultry flocks due to the high incidence of disease-induced mortality, despite the significant potential to earn a regular income from the sale of eggs and birds (IFAD, 2012).

87. The public sector extension services are weak and lack an overall vision and strategy for the development and growth of the sector. There do not appear to be any operational guidelines regarding vaccination policy, breed improvement policy, or any minimum thresholds established to eliminate some of the main animal diseases prevalent in the country. The government is not able to provide adequate animal health coverage, with its limited human and financial resources. Furthermore, the public sector does not deploy its human and financial resources on any rational or strategic basis. There are generally frequent transfers of staff in government agencies, further discouraging accountability or performance orientation. There are no incentives provided to staff and motivational levels are low. Supervision and monitoring systems are generally weak. The operations and maintenance funds provided to staff are inadequate; staff mobility is limited; equipment is mostly nonfunctional; supplies of vaccines and key medicines are insufficient and often of uncertain quality; and due to the breakdown of the cold chain, its reliability is questionable. The funds allocated for the livestock department are inadequate for its activities and the funds provided through District Account 4 are not punctual. There is no system of cost recovery for the services and medicines delivered, placing a huge recurring burden on the public exchequer, in addition to limiting the government's ability to provide adequate quantities for the quality of service required (IFAD, 2012).

88. Private livestock veterinary and production services are limited and have not developed in the same manner as the private service provision in the areas of education or human health care. Most graduates from the veterinary colleges in Pakistan prefer to join the public sector. A few of them also join the fledgling commercial dairy and meat companies which are being established in the country. There are very few private sector veterinarians providing veterinary services in rural areas. These service providers tend to focus on animal health and few have been trained on production extension. Some of the para-vets who have been trained by donor-funded projects or a host of other agencies are performing services for which they are not always properly qualified. Private sector providers generally deliver an uncertain quality of service at high costs and smallholders are not able to discern the quality of care provided by such para-vets. There is no formal regulatory or oversight mechanism for regulating the quality of services by private sector providers. Given the paucity of private sector provision and the dubious quality of care, it appears that the government will have to continue to provide livestock extension and production services in the short- to medium-term. For the long-term, there is a need to develop a strategy in which the growth and development of private veterinary and animal production services is properly guided and overseen by the public sector. In many isolated areas there is no presence of private sector providers and limited government presence. In these areas, there is a need to develop a cadre of community livestock extension workers (IFAD, 2012).

89. Smallholders face significant financial losses since livestock is a major store of value and asset for rural households. Farmers tend to diversify their risk by keeping a larger number of low

productivity animals, which has a detrimental impact on the natural resource base and further degrades the depleted resource base. There is a period of abundance of quality fodders in the spring and early summers, followed by a period of virtual starvation when the animals have to make do with poor quality crop residues. The animals seldom (if ever) receive quality concentrate, except some oilseed cakes. In other words, the overwhelming majority of milk-producing animals does not receive feed, according to their maintenance and production requirements. It is essential to improve the knowledge of farmers and livestock keepers, and the technology and skills required to enhance productivity. There is also significant loss in rural poultry due to the lack of knowledge about disease prevention and vaccination of poultry and limited attention paid to rural poultry by the Livestock and Dairy Development Department staff. The right kind of livestock services can make an important difference to poor livestock farmers struggling to manage their limited resources. These services include veterinary care, access to quality feed, reliable water sources, improved livestock infrastructure, breeding technologies, and access to a range of market services.

90. Pakistan has a high degree of variation in terms of agro-ecological zones, consisting of rain-fed desert, hilly areas, irrigated areas (both tube-well and canal) and a very large riverine area along the Indus and Jhelum Rivers. A major share of the land in Balochistan which consists of 43 percent of the country's land area comprises of deserts. Sindh and Punjab also comprise of large desert areas. In the desert areas, the soils are very porous with limited crop potential. Since a key source of animal feed is crop residue, the production and productivity of the livestock sector is integrally linked to the crop sector. The practice of free grazing of animals to economize on animal feed further limits the productivity of livestock and due to limited rangelands, reduces the marketable surplus. Water availability and quality are extremely important to animal health and productivity. However, there is highly variable access to water sources in the country. The irrigated and *katcha* areas have better access to water and have much better fodder availability, and smallholders are able to enhance their milk and meat production. Traditional feeding practices limit the water given to animals due to both water and labor scarcity and lack of knowledge of optimal water requirements (Hussein, 2012). Many of the villages are not connected to the national grid and even if they are, they suffer from electrical outages for extended periods of time and have few energy sources apart from fuel wood and cow dung. Investment in innovative energy solutions such as biogas and solar energy can help to use the abundant natural resources for increasing the local productive potential. In some cases, feeder roads are also required and could help to enhance the links of these areas to markets (IFAD 2012).

91. The smallholder farmer uses a combination of intensive and extensive management system for livestock production. In may parts of Pakistan, especially in the rain-fed and semi-desert areas and desert and mountain areas with a limited natural resource base, the animal population exceeds the carrying capacity of the land. In order to compensate for the low productivity and the risk inherent in livestock production, most smallholders keep more animals than they can feed to mitigate risk. This sets up a vicious cycle of low productivity and increased environmental degradation. The livestock sector is responsible for 18 percent of greenhouse gas emissions, more than the transportation sector worldwide. This is mainly due to deforestation and degradation of pasturelands, feed crop production, rumen fermentation, and livestock waste. If livestock practices are not properly managed, they could also cause other environmental concerns which contribute to climate change such as the loss of biodiversity, degradation and desertification of land, and pollution of water and air. Climate change could have far reaching consequences via impacts on grass and range productivity. Heat distress on animals reduces the rate of animal feed intake and causes poor performance growth (IFAD, 2012). The lack of water and the increased frequency of droughts and floods have already had disastrous consequences for livestock.

92. Quddus et al. (1997) reviewed the livestock sector in Pakistan. They contend that Pakistan's livestock subsector has been largely neglected over the past 30 years. During this period, the subsector has experienced an average growth rate of 2.9 percent per annum as compared to 4.0 percent for the crop subsector. They projected that population growth and improving living standards in Pakistan would increase the demand for livestock and livestock products in the future. However, they felt that under the existing production systems it was unlikely that this demand would be met. At the time, the National Commission on Agriculture had predicted a rapid growth in the demand for livestock products. If these projections were correct, Pakistan would have to spend substantial foreign exchange for imports of livestock and livestock products. An alternative to increased imports was to increase the productivity of the livestock sector. Guddues et al. (1997) used a linear programming sector model due to its strength in explicitly recognizing interdependencies of various subsectors. They felt that policy or technology changes designed to enhance the livestock subsector would be reflected in changes in the crop subsector. Likewise, changes in the cropping pattern would have impacts on the livestock subsector. Few, if any, studies had taken this linkage into specific account for Pakistan. They reviewed 1990–1995 issues of the *Pakistan Development Review* and identified articles focusing on issues of livestock and crops and irrigation, and found that none of the articles considered interactions between the livestock and crop subsectors. Therefore, the purpose of their paper is to use a linear programming sector model to examine the crop and livestock linkages in the country's agricultural sector.

93. The Quddus paper briefly reviews the linear programming sector analysis literature, and describes the Pakistan Agricultural Sector Model (PASM) [Davies et al., 1991] in general terms. It then contrasts the feedstuff based livestock component in the original PASM, with a nutrient-based livestock component (Model 1) developed by Quddus (1993), and uses the latter specification to show implications of several livestock component enhancements. The overall picture drawn in this paper has several implications for the agricultural sector in Pakistan. First, fodder area will quite likely increase with the added livestock production needed to meet the greater demand as per capita income grows in Pakistan, partly because of the limited ability of livestock to consume low energy roughages because of stomach capacity limitations, but more importantly because of the need to provide green fodder that is constrained by season. The second point is that if the traditional livestock ownership structure remains, there may be a greater herd size than warranted, and excessive land, water, and fertilizer resources would be diverted to livestock maintenance. By maintaining fewer cows in a modern, feedlot-based subsector, more concentrate could be fed to the smaller herd, and land could be released for the production of other crops. Cotton and wheat are the main crops that would expand with this change. The paper has endeavored to demonstrate the importance of livestock in the overall performance of Pakistan's agricultural sector and to indicate the usefulness of sector modelling. The explicit incorporation of livestock and crop sectors has been a unique feature of these simulations, in which extensive substitute and complementary relationships between various crops and livestock were found. The impacts of a modern livestock feeding industry and increased cotton and rice exports are just two of the analyses possible with the PASM.

94. Iqbal et al. (1999) point out that Pakistan is fortunate to be the home tract of some of the finest breeds of livestock, as compared with other regional countries. There are two buffalo breeds, namely, Kundi and Nili-Ravi and eight discrete breeds of cattle. There are about 28 breeds of sheep and more than 20 breeds of goats recognized in Pakistan [Hasnain (1985)]. Breed improvement work in Pakistan has mainly revolved around AI programs (Usmani and Shah,1986; Khan, 1994). Though the government has a huge infrastructure for the AI service in the country, the actual coverage of AI services to adult buffalos and female cattle could not be increased by

more than 3 percent. Efforts should be made to increase the AI coverage, both in buffalo and cattle for the upgrading of the genetic stock. Iqbal et al. conclude that for rapid and continuous development of the livestock sector, the economically viable technologies developed at research stations are to be transferred to the farmer's field. Technologies developed in nutrition, vaccination, and AI are readily available for the extension system.

95. To inform agricultural extension programs, Cain, et al. (2007) assessed the critical factors affecting the viability of small-scale dairy farms in Punjab. They found that productivity is constrained by a slow uptake of new technology such as fertilizers and new plant varieties, and poor livestock management, which leads to extended calving intervals, and a lack of available capital. This study used LP models, constructed with original local data on milk and crop production activities, to investigate the effect on profitability of alleviating the main constraints. The results demonstrate the powerful effect of using better, well managed dairy livestock, of increasing the uptake of simple technological improvements, and of widening access to credit. They also show the synergy between these elements, for example, the importance of finance as part of any intervention strategy. The results should enable agricultural development policymakers to rank the changes and devise better targeted programs to deliver the changes at farms.

96. Chaudhry et al. (1999) pointed out that the contribution of livestock in agriculture GDP rose from 27.3 percent in 1969–70 to 36.2 percent in 1997–98. The study examines trends in livestock growth in the 25 years between 1972–73 to 1997–98 and concludes that the growth can be explained in the light of contributions of various factors of production such as land, labor, capital and technological process. The study cautions that because of complementarities of inputs and embodiment of technological change, precise calculation of the input contribution is not possible (Nadiri, 1970). What is intended is to look at the contributions made by the number of animals, inputs such as feeds, fodder and roughages, and the progress of technology (inherently reflected in the estimates of total or aggregate factor productivity). Nearly 57 percent of the total increase in livestock production is attributable to increasing the number of animals over time. The quantitative improvements in roughages, fodder and animal feeds, in aggregate accounted for another 21 percent of the total increase in livestock production. This leaves an unexplained residual of 22 percent which can be assumed to be a contribution of technological progress to Pakistan's livestock subsector.

97. A closer examination shows that the growth of technological change peaked at 3 percent during 1989–90 to 1994–95. With the exception of this period, the contribution of technological progress in livestock production was either negative or hardly exceeded 1 percent per annum. In spite of the low contribution of technological progress to production in the livestock subsector relative to the crop production subsector, the former sector witnessed higher growth rates than the latter sector. The underlying reason seems to be the relative price situation in the two subsectors. The producer prices in the case of major agricultural commodities were controlled by the government to protect consumers. On the other hand, the government has followed a policy of indiscriminate increases in the prices of key agricultural inputs, attempting to eliminate all kinds of input subsidies under World Bank sponsored reforms. As a result, the profitability of major agricultural crops has consistently been on the decline (Ahmad and Chaudhry, 1987; Afzal et al., 1992). Given this situation, farmers have responded only half-heartedly resulting in staggered output increases. By contrast, the livestock sector was not controlled by the government (Chaudhery et al., 1999).

98. Progress in the livestock subsector has been mainly as a result of a growing number of animals, rather than rising productivity per animal. The analysis of the paper underlines the importance of

technology in the livestock subsector, especially in the use of AI. For this purpose all necessary infrastructure especially refrigeration must be placed at the disposal of insemination centers which need to be widely spread throughout the countryside. Secondly, livestock holders must be provided with adequate incentives by ensuring a fair share in consumer prices not only to induce them to adopt the latest technologies but also to reward their efforts. Livestock extension services can be particularly helpful in convincing the farmers to adopt modern husbandry practices. By way of ensuring fair prices to farmers, animal sales, on a live weight basis, as in the case of poultry, should be encouraged in livestock markets. Thirdly, most of the livestock feed markets are still in their infancy and suffer from inadequate competition. They are typically characterized by monopoly positions of one kind or another and lack any quality control. There may thus be the need to ensure an adequate supply of quality and balanced animal feed through imposition of penalties for illicit trade practices. Finally, the low productivity of animals can also be attributed to widespread incidence of animal diseases and lack of animal husbandry services apart from poor feed quality (Iqbal, 1994; Iqbal and Ahmad, 1999). They recommend the widespread provision of services in the country.

99. Iqbal et al. (1999) describe the livestock sector and report that about two-thirds of the farming community in Pakistan consists of small farmers who are characterized by small land holdings (less than five hectares) and by several factors that influence their productive potential and income generating capacity. Livestock farming is an integral part of rural smallholders and has a vast untapped potential for productivity increase and income generation. Livestock holdings by small farmers constitute a significant portion of farm incomes. Small farmers and landless livestock producers derive around 10–25 percent of their incomes from this subsector. Livestock raising is closely integrated with crop production system, partly because fodder production is a part of the crop rotation cycle and also because crop byproducts and waste are utilized by the livestock sector. In other words, all ruminant production systems depend heavily on crop residues, fodder grown on the farm and/or rangelands, wastelands, and fallow lands. A rapidly growing economy, higher per capita incomes and rising population are the determinants of increase in the demand for livestock products (Byerlee and Iqbal, 1987) which exerts a continuous pressure on the country's livestock resource base. In Pakistan, the increase in animal products has mainly been the result of an increase in animal numbers, not productivity per animal. However, improved animal efficiency will be an imperative necessity for future increase in food production (Dahlin, 1998).

100. There is a large yield gap in livestock production. Productivity or yield gap is defined as the differential between the actual yield being obtained from an animal of a breed and the maximum possible potential yield of the breed that can be obtained by adopting different production strategies and management practices. Iqbal et al. (1999) explore the constraints in the sector. One popular hypothesis often discussed is that the national livestock herd consists of a substantial number of unproductive and low productive animals that claim their share in feeding and management leaving less for the more productive stock. This, in turn, decreases national averages of milk and meat production. Secondly, the composition of the national herd is also not economical and appropriate in several ways. This means that the national herd with its present level of per animal productivity is unable to meet the rising demand for livestock products. Livestock production experts assert that the national livestock herd is undernourished to the extent of 30–40 percent, which is presented as a reason for low per animal productivity. The above analysis implies considering culling the less or nonproductive stock. This would release huge amounts of feed and management resources for the more productive stock, leading to substantial yield increases.

101. There are several explanations given for the yield gap. Livestock professionals assert that better nutrition, selection of quality breeds, culling of unproductive animals, and adoption of proper management regimes are needed to exploit the available genetic potential. Iqbal (1994) summarized the major constraints to improve the livestock productivity in Pakistan and argued that they can be grouped into three categories, namely: nutritional constraints (feed gap), inadequate support services, and market and policy constraints.

102. In discussing the nutritional constraints, Iqbal et al. (1999) found that of the total livestock feed resources available in the country, the crop sector contributes about 60 percent of total digestible nutrients (TDN) and rangelands provide 11 percent of total TDN. Other grasses which includes river banks, wastelands, road sides, fallow and forested grass lands make an important contribution to feed resources, with 27 percent of total dry matter (DM). The current feed gap is huge and warrants immediate attention. To narrow the feed gap, various research institutions have evolved nutritional technologies that have proved economical and biologically viable. Unfortunately, the delivery system (livestock extension system) is not efficient to disseminate the technologies to bring a breakthrough in the national situation of feed scarcity. It is therefore, a requirement that these technologies are tested on the farms under the farming system perspective and outreach research programs.

103. Some of the literature documents the experience regarding livestock projects and it is assessed that projects often fail to deliver tangible products to the beneficiaries and seldom trigger variables that can lead to long term growth (Amir, undated). An ADB review (ADB, 1990) found deficiencies in many Bank-financed projects at each stage of the project cycle for a host of reasons. Where new technologies are being introduced, testing, refining, and tailoring them to meet farmer's needs is an important stage (Zandstra, 1985). Some livestock projects assume that commercially available techniques are equally applicable under smallholder conditions and often this assumption leads to the failure of many livestock projects. For example, imported exotic breeds seldom perform as expected under smallholder management conditions. Preliminary testing using Farming Systems Research (FSR) methods assist in ensuring that new technologies are appropriate, and it may be advantageous to establish on-farm evaluation units within projects.

104. The ADB's experience indicates that there is considerable scope for modifying the approach to livestock development projects. A prerequisite is to obtain accurate and relevant information, especially at the farm level, on which to plan projects. Equally important is to ensure the direct participation of the beneficiaries in the planning process. The planning, implementation, and monitoring of the proposed activities requires multidisciplinary teams experienced in describing the existing situation, identifying constraints and the designing, testing, evaluating, and extension of the appropriate technology. In some cases, technologies practiced by progressive farmers, when properly extended, may find greater acceptance than imported technology that is unfamiliar under village situations. On-farm testing and evaluation can help ensure that inappropriate technologies are not introduced by projects. An example of such inappropriate technologies is found in the introduction of Holstein-Friesian cows in Indonesia (Amir, undated). A lack of milking machines, high feed requirements, and disease susceptibility made these cows a liability to many farmers who had bought them by taking out loans. Projects that focus on animal distribution programs, especially of exotic stock, should be aware of the limitations of such an approach to small farm development.

105. The historic approach to livestock development involved upgrading government livestock farms, development of infrastructure, provision of village level veterinary support, animal distribution, provision of processing units (Amir, undated). Such projects were usually coordinated by the Ministry of Agriculture, under their respective livestock departments. The experience with these

projects has been mixed. They normally depend on existing overburdened staff and limited resources. Without direct private sector participation, these projects are unlikely to have real impact. All too often these projects generate additional government jobs, help certain interest groups but rarely serve the target beneficiaries, especially where the beneficiaries are smallholders. Furthermore, this approach is rarely sustainable once disbursement is completed and no institutional structures are left behind to ensure continuity.

106. Chander and Bardhan (2013) focused on livestock technologies in India. Their study was motivated by how, in the context of the diffusion of livestock innovations, little research efforts are visible, in spite of the economic, social and environmental implications of livestock technologies. They note that productivity of livestock in India is very low and even lower than that of the world averages, mainly due to low adoption of improved technologies. Only 5.1 percent farmer households in India access any new information on animal husbandry against 40.4 percent of the Indian households accessing information on modern technology for crop farming (Government of India, 2005). There is a considerable gap in the technologies developed and available at research institutions and technologies actually being adopted or used by farmers. The livestock technologies developed with high expectations of the researchers and considered very promising like urea treatment of straw, deworming, vaccinations, AI and crossbreeding, fodder chaffing, feed supplements, etc. have huge regional variations in terms of their adoption by the livestock farmers. For instance, urea treatment of straw is considered one high potential technology by animal nutritionists, but it is rarely used by farmers in many parts of the country. Yet there could be areas where it has shown good acceptance with reasons for this high acceptance. There is often a significant interval between the time an innovation is converted or developed as a technology and available in the market, and the time it is widely used by producers. As such, adoption and diffusion are the processes governing the utilization of innovations.

107. Studies of adoption behavior emphasize factors that affect if and when a particular individual will begin using an innovation. Measures of adoption may indicate both the timing and extent of new technology utilization by individuals. Adoption behavior may be depicted by more than one variable. It may be depicted by a discrete choice, whether or not to utilize an innovation, or by a continuous variable that indicates to what extent a divisible innovation is used. For example, one measure of the adoption of high-yielding cattle by a farmer is a discrete variable denoting if this breed is being used by a farmer at a certain time; another measure is what percent of the farmer's herd is occupied with this breed. There is a general consensus that the application of new technologies and practices is largely based on the desire of farmers to maximize economic returns (Birkhaeser et al., 1991; Black, 2000; Huffman and Evenson, 2006), while there is considerable debate regarding the processes that lead to adoption. Under normal circumstances, new technologies and farming practices are adopted within particular environmental contexts to increase productivity, reduce costs, or both (Leeuwis and Van den Ban, 2004).

108. Chander and Bardhan (2013) note that significant technological advances have been made in breed improvement. However, their adoption in the field has been limited and regionally concentrated. Animal vaccinations, AI, deworming, fodder chaffing, and crossbreeding shows differential adoption across the country. For example, chaff cutters are very well accepted, even by the resource poor dairy farmers, in some states of India. For instance, crossbreeding technology in India despite better performance in select pockets, its widespread adoption is constrained for various reasons. Technology is the key to the growth in any sector including livestock. Over the years, many livestock technologies in the field of animal health and production have been developed by various institutions for different livestock/animal species, resulting in lots of promising technologies available at the level of research stations. The technologies offered by the livestock sector have

yet to gain wider acceptance. These technologies are at various stages of diffusion adoption process in different agro-ecological zones of the country. There is need to assess the technological gaps, actual adoption of these technologies, constraints faced by farmers in adoption of these technologies, and the way forward for these selected technologies. There is a need to document the field experiences with respect to many technologies, so as to have a comprehensive picture based on empirical evidences collected through systematic efforts. Moreover, these technologies alone are not enough to bring about widespread change in livestock systems. In order to make the difference in production and productivity in livestock systems through these technologies, and the diffusion and adoption theories need to be put into practice in the right perspectives.

109. The literature also covers the poultry sector in Pakistan to come extent. A study by Jamali et al. (2011) investigates the problems faced by the poultry industry in Pakistan. Data was collected from 1,000 respondents by using simple random techniques. A structured questionnaire was developed for the reliability and validity of data. The study found that the parent stock layer is increasing at a rate of 120 percent every year and by as much as 200 percent in a few years. On the contrary, a consistent growth rate of 135 percent is seen in the case of broiler parent stock. The average growth rate in the case of layer day-old chicks per week is 140 percent except in a few years. The paper reported that there was a lack of poultry training institutions and a general lack of skilled manpower in the poultry sector. A study on poultry development from AJK (Choan, 2007) noted that the poultry sector entailed high production costs due to the use of expensive inputs and vulnerability of broiler chickens, i.e. those produced for commercial sale on an industrial scale. The study recommended ensuring availability of requisite medicines and vaccines on affordable rates, large-scale commercial hatcheries established by the government to reduce the costs of inputs (day-old chicks), and the motivation of private investors to establish feed mills in certain areas. The main barrier to the establishment of these facilities was a lack of financing and access to credit to poultry farmers in AJK.

Livestock Extension Services

110. The support services in the livestock sector consist of the livestock departments in the four provinces which give overwhelming importance to adequate provision of animal health services. These services include diagnosis and treatment of diseases, vaccination programmes and production of biological vaccines. The most important diseases of livestock are foot and mouth disease (FMD), hemorrhagic septicemia, black quarter, rinderpest in cattle and buffaloes, and sheep pox, anthrax, and enterotoxaemia in sheep and goats. These diseases cause heavy economic losses particularly in buffalo and cattle. In poultry, major diseases are Newcastle disease, mycoplasmosis, salmonellosis, Merek's disease, leucosis, Gumboro disease, and fowl pox. These diseases in poultry cause mortality to the extent of 7 percent in broiler and 15 percent in layer farms. The animals actually vaccinated every year may not be more than 10 percent of the livestock population. Vaccines are produced in the public sector while all other drugs are produced by the private sector which are purchased by the public sector to be distributed to all veterinary hospitals and dispensaries. Financial assistance to the livestock sector is very low as compared to the crop sector. The budgetary allocations cover a very small part of the costs of the necessary drugs.

111. The public sector extension services are weak and lack an overall vision and strategy for the development and growth of the sector. There do not appear to be any operational guidelines regarding vaccination policy, breed improvement policy, or any minimum thresholds established to eliminate some of the main animal diseases prevalent in the country. The government is not able to provide adequate animal health coverage with its limited human and financial resources. Furthermore, the public sector does not deploy its human and financial resources on any rational

or strategic basis. There are generally frequent transfers and posting of staff in government agencies. This short tenure further discourages accountability or performance orientation. There are no incentives provided to staff and motivational levels are low. Supervision and monitoring systems are generally weak. The operations and maintenance funds provided to the departments are inadequate, staff mobility is limited, equipment is mostly nonfunctional, and supplies of vaccines and key medicines are insufficient, often of uncertain quality, and due to the breakdown of the cold chain its reliability is questionable. The funds allocated for the Livestock Department are inadequate for its activities and even the funds provided through District Account 4 are generally not provided on time. There is no system of cost recovery for the services and medicines delivered, thus placing a huge recurring burden on the public exchequer on one hand and limiting government's ability to provide adequate quantities or the quality of service required (Hussein, 2012).

112. There is a need to rationalize the human resources deployed by the Livestock Department. In many areas, especially in the most isolated areas, sanctioned posts are not filled. The allocation of sanctioned posts per district is generally not on the basis of animal population, geographical spread, or workload. International standards suggest that the allocation of staff should be based on the animal population in each area rather than on artificially drawn administrative boundaries. An analysis of four districts in Punjab showed that the present staff to animal ratio is 167,367 animals per veterinary officer and 25,843 animals per veterinary assistant and 24,000 breeding animals per one AI technician (Hussein, 2012). There is considerable variation in these ratios among the four districts. These numbers reveal that it is clearly beyond current Government capacity to provide services to the existing animal population. Government is cognizant of these gaps and under three phases of the Support Services for Livestock Farmers (SSLF) Project, has substantially enhanced the deployed staff numbers on the basis of one veterinary officer, one veterinary assistant and an AI technician per Union Council in 24 districts of Punjab. Among project districts, only Layyah has been covered under the SSLF. All provincial governments need to develop a more rational allocation of staff based on the animal population and a more strategic assessment of the workload of their extension staff. There is generally no women extension staff in the Livestock Department, which is a critical constraint given that it is women who are primarily responsible for livestock in the homestead.

113. Private livestock veterinary and production services are limited and have not developed in the same manner as the private service provision in the areas of education or human health care. Most graduates from the veterinary colleges in Pakistan prefer to join the public sector. A few of them also join the fledgling commercial dairy and meat companies which are being established in the country. There are very few private sector veterinarians providing veterinary services in rural areas. These service providers tend to tend to focus on animal health and a few have been trained on production extension. Some of the para-vets who have been trained by donor-funded projects or a host of other agencies, are performing services for which they are not always properly qualified. Private sector providers generally deliver an uncertain quality of service at a high cost and smallholders are not able to discern the quality of care provided by such para-vets. There is no formal regulatory or oversight mechanism to regulate the quality of services by private sector providers. Given the paucity of private sector provision and the dubious quality of care, it appears that the government will have to continue providing livestock extension and production services in the short- to medium-term. For the long-term, a strategy needs to be developed in which the growth and development of private veterinary and animal production services are properly guided and overseen by the public sector. In many isolated areas, there are no private sector providers and the presence of the government is limited. In these areas, there is a need to develop a cadre of community livestock extension workers (IFAD, 2012.)

114. The problems that confront the smallholder are not just restricted to the production function but also relate to marketing. The marketing system is highly skewed in favor of the middlemen and against the smallholder who often gets around half the final retail price. The system of price controls imposed by the government on the two major livestock products, milk and meat is ineffective and works to the disadvantage of the small producers. While milk can yield a regular source of cash for the households, income from it is small due to its limited options for sale, the perishable nature of the product, lack of technology which can help reduce wastage, lack of mechanisms for collection, and the collective bargaining due to the fragmented nature of production and marketing by a large number of small and dispersed producers. The seasonality of milk production and consumption, the availability of close substitutes like milk powder and the lack of sensitivity of consumers to quality products and lack of regulation of products such as dairy liquids further exacerbates the marketing problems for the small producer. In terms of the meat market, the smallholder is also at a disadvantage. The smallholder often sells their live animals in the village to the local *Beopari* or middleman because of a cash emergency, their limited access and understanding of livestock markets—an exploitative system run by contractors and the lack of facilities in these markets limit their potential for direct marketing. The smallholder also has a limited knowledge and understanding of market demand and current prices.

Gender Roles and Livestock Management

115. Projects financed by the Pakistani government and donor agencies have been an important source of provision of enhanced awareness and training to women in improved agriculture production and animal husbandry practices. An analysis of various projects working with women was undertaken by Hussain (2012). The Prime Minister's Special Livestock Initiative was launched with the objective of enhancing livestock productivity through the provision of livestock production, extension and veterinary services. This program was implemented in all four provinces. The key intervention of the project was the creation of a trained cadre of 7,250 community livestock extension workers (CLEWs) to provide sustainable animal health services to the target rural community. This included vaccination, deworming, first aid, and awareness raising on animal health and productivity. The project provided training, kits, and supervision by a doctor of veterinary medicine, in addition to subsidized medicines.

116. Overall, smallholder farmers valued CLEW services with 90 percent finding vaccination most beneficial and for reducing disease and mortality, and 65 percent of the farmers identified deworming as most beneficial for animal health. Much fewer identified animal nutrition (27 percent), awareness (22 percent), and treatment (17 percent) as beneficial services. The spending behavior of the poor on animal healthcare varied depending on whether farmers were engaged in subsistence farming or involved in commercial production, disease prevalence etc. and this affected the income CLEWs were able to earn. There was some evidence that the services benefited participating households but as the sample was very small, these findings can only be taken as indicative. In terms of income, on average, the household income of the treatment groups was 25 percent higher than the control groups, and in terms of asset creation, there was a 10–15 percent difference, with the most significant difference in sheep and poultry. Overall, the beneficiaries reported stable or better economic conditions; 32 per cent of the treatment respondents have reported significant improvement in economic conditions while only 17 percent of the control group respondents have reported the same.

117. The "Program for Rehabilitation of Agricultural Livelihoods of Women in Marginal Post-Conflict Areas of Afghanistan and Pakistan," a collaborative research initiated in 2006, funded by IFAD, had a strong gender and poverty focus. Small ruminants were selected as these are preferred by poorer farmers and women traditionally have more control over them. The aim of the program

was to rehabilitate the livelihoods of rural women in post conflict and marginal areas of the two countries through access to and use of improved knowledge about raising dairy-goat and include the improving of the skills and knowledge of rural women in marginal and post-conflict areas to cope with shocks and risks through: 1) access to and adoption of improved technological, institutional and policy options in goat production; 2) better use of the natural resource base, and 3) enhancing processing and marketing of surplus products; and (b) strengthening skills and knowledge of research and development organizations so as to conduct gender-sensitive research and development more effectively and institutionalize such approaches within these institutions. In this project, women were trained exclusively as animal health workers for vaccination and treatment of diseases and functioned successfully. The intervention showed that with supplemental feed and improved healthcare, in the Punjab, the milk yield was tripled and profit from selling goats for meat doubled.

118. In 2010, PLAN Pakistan initiated a European Union-funded project, the PLAN Milk Value Chain Project, in Southern Punjab's Vehari district to enhance the livelihoods of subsistence livestock farmers (Peerzada, undated). In this project, the role of women in the management of livestock was recognized and women were included in the farmers' cooperative, with goats also distributed to women. The goat intervention for women was evaluated as not being successful due to high mortality rates of goats and the involvement of women in the rest of the project was assessed in very general terms as not being as equitable as it should have been. The report recommends that older goats should have been bought and it will be preferable to give women poultry. There is a general recommendation that women should be more equitably involved. However, the gender analysis in the final assessment report for the project is very weak and it is difficult to draw any meaningful conclusions or lessons learned from the documentation available. As far as the impact on participating households was concerned, an increase of productivity by 15–20 percent was reported. As the price of milk increased by 50–100 percent, profitability increased with a spillover effect in nearby villages. However, poorer women's access to milk was adversely affected and the study noted that the project had not paid sufficient attention to the impact of higher prices on the intake of milk for children.

119. Community Empowerment thought Livestock Development and Credit, a UNDP funded $3.8 million project was implemented in Punjab, in partnership with Nestle, from 2006–2009 (UNDP, 2009). The project's mission was to improve the health and production of livestock through women's empowerment to ensure better economic opportunities for them in terms of income and employment generation for rural women, through livestock healthcare skills development. After certification, the women were inducted as livestock health and extension workers, milk collection agents or small business entrepreneurs (for sale of animal feed). They were given Rs1,000 as stipend and kits, and facilitated in setting up their business. They were also linked to private milk collection centers, veterinary pharmaceuticals, animal feed suppliers and the government's livestock department. They were registered with the Livestock and Dairy Development of Punjab. The project trained 3,225 lady livestock workers in 1,530 villages in 12 districts of Punjab; 65 percent of them were working as independent entrepreneurs; 1,595 were trained as animal healthcare workers, 117 village milk collection agents, and 1,486 as small business entrepreneurs. At the end of the project, 65 percent of the women trained were engaged commercially and 35 percent were utilizing the training domestically to look after their own livestock. The final assessment report highlighted the following achievements as a result of the training of this cadre: 80,000 healthcare treatments were delivered monthly, animal health, and livelihoods from livestock improved as did the status of women who participated.

120. The Pakistan Livestock Dairy Development Board initiated a program for "Enhancing Milk Production in the Punjab" under which 4,000 women and men were to be trained as livestock extension workers in several districts of the Punjab. In each target district, 200 men and 200 women were to be trained. Men received a three-month training in AI, while the women are given a two-week training in basic nutrition and animal health. The men received motorbikes on credit and a Rs7,000 stipend, while the women received Rs25,000 worth of feed on loan and a monthly stipend of Rs3,000. The women were to purchase and sell feed and good quality seed for growing fodder to farmers. Most importantly, they were to refer insemination cases to the AI technician (AIT). The criteria for women's inclusion as extension agents was that they should have at least attended middle school and be between 18–35 years of age and belong to the target village. Some women were chosen as cluster heads so they could gather orders and place collective orders with private suppliers. The project staff felt that it was important to give stipends, otherwise there could be no close supervision and those trained would look for other jobs rather than focusing on their current task as it took time to gain the confidence of the community. The project staff maintained that 40 per cent of referrals were through the women livestock extension workers.

121. The Dairy Project (2011–2014) was a joint effort of USAID and the Dairy and Rural Development Foundation to foster sustainable increase in dairy and livestock productivity through adoption of best farming practices, breed improvement, availability of timely extension services, and promotion of livestock businesses. It was implemented in all four provinces with a major focus on Punjab. The four components were built on the premise that effective training and awareness building can quickly align the local dairy sector with the modern best practices; thereby improving sector's productivity. Under the program, 9,000 farmers and 100 farm managers were to be trained in best farm practices, improved feeding and animal nutrition, basic level animal health management, farm equipment management, shed management, and the importance of improved breeds. Participants would be given a support kit to improve farm management practices for increased milk yield and earnings, and training and support for artificial insemination technicians; and 2,000 AITs were to be trained and established as small entrepreneurs. All participants were provided with a support kit to jumpstart their businesses and improve incomes. The program trained 5,000 women livestock extension workers of which 2,000 were to specialize as livestock health workers and 3,000 as livestock business entrepreneurs.

Marketing of Livestock Products

122. The livestock sector is characterized by widening shortages in production to meet the growing demand for dairy and meat products in Pakistan. Pakistan is the fourth largest producer of milk and the sector spans eight million farming households that together produce around 35 billion liters of milk annually. The demand for milk is increasing by 15 percent annually and supply is rising by just 2 percent a year in Pakistan (Pakistan Dairy Development Company, 2012). The potential of the dairy industry is huge but is hampered by its largely fragmented, small-scale, and subsistence oriented milk production structure. About 95 per cent of the country's milk output is consumed in villages and/or sold in cities through intermediaries called '*gawallas*', in unhygienic conditions and without any quality standards in place, and the absence of proper storage facilities result in significant losses. The meat demand for the country's domestic market is growing at a rate of 2.8 percent for beef, 2.9 percent for mutton and 6.1 percent for poultry. The supply and demand gap of meat is increasing by 4.1 percent per annum. The domestic demand is growing due to population growth, migration of population from rural to urban areas, and improving consumption patterns, in addition to a rise in per capita incomes. Pakistan's goat meat consumption of 779,000 tons in 2011–12 ranks it among the top three meat consumption markets in the world. The rising trend is estimated to reach a gap in supply of 2.3 million metric tons (MT) from 0.16 million MT in 2003 for beef, and 1.47 million MT and 1.47 million MT from 0.1 million MT for mutton. In

addition to the growing gap in the domestic demand, there is immense potential to export live animals and meat to regional countries (IFAD, 2012).

123. Small ruminants are considered an important asset that contributes significantly to food security and income generation of many rural households, to fulfill the increasing national and export demand for mutton and goat meat. Pakistan is the second largest goat meat producing country, after China. Sheep and goat farming for mutton production is mainly a small-scale rural activity that forms an integral part of an age old system of mixed farming. Mutton production is secondary farm enterprise and its potential has not yet been fully exploited. The present methods of sheep and goat farming, slaughtering, processing and marketing result in low carcass yield, heavy losses of byproducts and the supply of poor quality meat to consumers. It is claimed that sheep and goat fattening gives better profit margins compared to other ruminants. Small ruminant producers often sell their animals in the village to the local *beopari* because of the limited access and understanding of livestock markets, an exploitative system run by the contractors, and the lack of facilities in livestock markets for farmers to engage in direct marketing, to eliminate the role of middlemen (IFAD 2012). The smallholder also has a limited knowledge and understanding of market demand and current prices. The lack of access to credit hampers individuals or groups of villagers to enhance their capacity to fatten a larger number of animals for Eid ul Adha (the annual obligatory sacrifice by Muslims), therefore missing the one-year opportunity of generating a significant revenue for the household's economy. The lack of breeding management coupled with low livestock husbandry practices (poor health, feeding, and housing conditions) results in low productivity and animals sold at a lower market price to butchers. There are also significant problems in marketing of meat. Out of a total production of 2.96 million tons of meat production (data from 2009–10), 80 percent of the slaughtering is done outside the slaughter houses (Afzal, undated). A significant share of the butchering is done in shops. While local governments own and operate some slaughterhouses, they are generally rated as unhygienic. Bradfield and Ismail (2012) highlight that small-scale butchers or processors simply do not have the means to acquire animal handling facilities.

124. The private sector has made major investments in milk and meat sectors, aimed at both domestic and export markets. However, due to the fragmentary nature of production, their links with the producers entail a high transactions cost. Wherever farmers are able to provide a large volume of milk or live animals for sale, the private sector is willing to enter and procure these products. Discussions with the private sector revealed that they were very interested in collaborating with the project to help them secure direct contacts with the producers (IFAD, 2012). There are many example in Punjab where the corporate sector has rushed in to forge mutually beneficial relationships with smallholders. Small and medium sized companies like Gourmet, Millac, Haleeb, etc. have all formed direct contractual arrangements with smallholders in Punjab. Some of these companies are also working in Sindh but there are few in other parts of the country.

125. The tehsil municipal administration (TMA), the local government institution responsible for livestock markets, is oriented towards revenue generation, rather than a service orientation to protect the interests of the smallholder or provide for the welfare of animals. The TMAs contract the livestock markets to large private sector contractors, who do not provide any supportive facilities. There is generally no shade, feeding, or watering facilities and no ramps or any type of weighing equipment or personnel who can examine the animal. The animals brought here undergo extreme stress and there is little regard for animal welfare. This discourages the small farmer from engaging in direct marketing at these locations and they are often in a hurry to complete the transaction and leave. The TMAs responsible for establishing and managing these markets have

limited experience or knowledge about managing them and have no concept of the type of services that they or contractors should provide.

126. The market and policy constraints identified by Iqbal et al. (1999) center around the existing milk marketing system for commercial dairies not being capable of adjusting to seasonal fluctuations in the supply and demand for milk. In summer, when urban demand for milk is higher, the supply is relatively inelastic, due to the limited capacity of milk vendors. Conversely, when supply increases in winter, the demand is relatively inelastic. This is due to reduced consumer demand for processed milk. The most limiting factor in expanding the milk marketing system is the lack of infrastructure in rural areas. The entire ultra-high temperature industry is using only less than 2 percent of the total milk produced in the country.

127. Milk production in Pakistan is in the hands of millions of small landholders or landless people. Farmers, whose principal occupation is agriculture, keep a few dairy animals for milk production either for home consumption or as a supplementary source of income. There is a large yield gap in the production of milk; an analysis of the yield gap in milk production has been made under two scenarios. Firstly, if the production potential achievable at research stations for each breed is extrapolated for all in-milk animals of the breed, the resultant gap is equivalent to about 50 percent of the present milk production. The second scenario is developed with a hypothesis that the maximum milk production potential based on the production of elite herds usually maintained at research stations or at private livestock farms. This shows that the milk production in the country can easily be doubled. Iqbal et al. (1999) caution, that there is large gaps in the data set and that where data exists, it is based on estimates. The paucity of data on key parameters like breed-wise production coefficients, production potential estimates, particularly under varying feeding and management regimes were noted. Relatively marginal variations in the values of key parameters can produce significant changes in results. Such data problems are widely recognized.

128. A major portion (about 70–80 percent) of this milk is converted into milk products (e.g., ghee) due to transport difficulties in shipping fluid milk from villages to distant urban markets. There are thousands of traders collecting small quantities of milk from producers in the area. These traders belong usually to the poorer segment of the society. The existing marketing has been functioning without much attention by the policy-makers and planners. If it is required that the dairy industry should survive, the milk marketing system will have to be improved. The milk collection units need to be established more densely which collect, chill and market the available milk. Currently, all of milk plants are operating at under capacity resulting in higher per unit cost.

129. Burki and Khan (2012) provide empirical evidence on the impact on technical inefficiency of smallholder dairy producers when they formally participate in a milk supply chain. Here the stochastic production frontier and technical inefficiency effects model are estimated based on the data gathered from 800 smallholder dairy farms in Pakistan. The results suggest that the technical inefficiency of the participating farms is significantly reduced. A strong impact of the supply chain is also detected in reducing technical inefficiency of farms that are located in remote areas and on those that have larger herd-size. Experienced farmers up to the age of 36 years have the advantage of reducing technical inefficiency. The remaining differences in relative inefficiency of dairy farms are accounted for by severe long-term depressive disorders.

Agricultural Credit and Modern Financing Arrangements

Agriculture Credit

130. The actual or perceived lack of access to credit has led to considerable literature on the subject. Mahroof et al. (2011) discuss the importance of farm credit as a major source of acquiring new technology for efficient and profitable agriculture, and the key determinant of the level of production. They argue that the growing popularity of "HYV agriculture" has enhanced the importance of rural credit significantly. Farmers now need credit in ever-increasing amounts to finance timely purchases of modern inputs and farm implements. Credit helps not only in removing financial constraints but also provides incentives to growers for adopting new technology and practices with new aspirations and horizons, provided it is properly delivered (Rao & Khan, 1991; Malik, 1991). However, the clientele of the rural credit markets are often small farmers who often find it difficult to fulfil the collateral requirements of the lending institutions. In order to facilitate the adoption of HYV technology amongst small farmers, the government has disbursed large amounts of credit often at highly subsidized rates. In Pakistan the peak expansion rate of credit was observed during the 1970s. The rural credit expansion rate was estimated at 42 percent per year during 1969–70 and 1976–77. Such a surge in rural credit during this period was due to the nationalization of the commercial banks (Qureshi, et al., 1992; Bastin, 2008). Nationalization of banks aside, overall agricultural credit has tended to increase at an annual average rate of 25 percent over the period from 1965–66 to 2006–07 which has been higher than the average growth rates of all the other agricultural inputs.

131. A study by Ahmad et al. (2015) attempts to analyze the impact of credit on wheat productivity in District Jhang in Punjab. The study explores the purpose of farmers for acquiring loans and major sources of credit in the district. It is based on primary data collected from 160 farmers in 2013 from eight villages in the district and it used the Cobb Douglas Production Function to analyze the data. The results of the study indicate that credit has positive effects on wheat productivity. Analysis shows that only 30 percent of credit users are utilizing loan for the purchase of seed and fertilizers while 70 percent are utilizing loan for other purposes such as marriages, other ceremonies, purchase of agriculture land and tractors, etc. About 80 percent of credit users were borrowing from Zarai Tarqiati Bank Limited. The study concludes by suggesting that financial institution should expand the credit facilities to the farmers and stipulate that these should be utilized exclusively for agricultural purposes.

132. Khan et al. (2014) undertook a research with the main objective to examine the relationship between agricultural financing, regulatory framework of State Bank and economic growth. For this purpose data were collected from existing agriculture clients of Allied Bank Limited in the Sargodha Region of Punjab in March 2014. The study used multiple regression analysis for the empirical analysis. Results show that agriculture financing and regulatory framework is significant and has a positive relationship with economic growth. A majority of farmers complained about the high mark-up rate, extra burden of crop loan insurance, untimed availability of finance and very long documentation procedure and the mismatch between repayment schedules and harvesting seasons. In light of these results the study recommends a decrease in the mark-up rate, making crop loan insurance optional, resetting the capitalization mark-up frequency, and simplifying the process for obtaining the agriculture finance.

133. Pervaiz et al. (2011) based their study on primary data collected and collated in June–August 2007 for disbursement of agricultural loans and factors constraining its availability to farmers. The universe of the study consisted of the whole of Khyber Pukhtunkhwa. Multi-stage sampling method was used to select the sample. Four districts were randomly selected and 291

respondents were interviewed. The selected respondents were grouped into three categories namely small (146), medium (81) and large (64). They concluded that majority of the small farmers were deprived of loans, because almost all the financial institutions extend loans on the basis of grantees and capacity to repay. The larger the farm size the greater the chances of access to loans. Access to loans by small farmers was hampered by lack of grantees, high rate of interest, complicated procedures, and religious reasons etc. The study suggested that making credit available and ensuring its productive use should form the basic plank of any credit policy to foster agricultural productivity. The authors recommended the use of "one-window operation" to encourage and educate small farmers in the proper utilization of loans. The study also suggested that the rate of interest for farming activities should be minimized and for the purchase of new agricultural technology interest free agricultural loans should be provided. The study also recommended that loaning procedure should be simplified for the benefit of farmers.

134. Hafiz et al. (2014) examined the impact of improved management practices on the technical efficiency of dairy farms using the stochastic production frontier approach. The study used data from 120 daily farms in Punjab to show that better management practices were significantly contributing in increasing milk production. The results of the study demonstrated that credit availability had the highest impact in reducing inefficiency. Farmers having better financial resources first adopt the innovations introduced at the farm level. Credit availability strengthens the financial position of a farmer which motivates him to take the risk of adopting new technology or management practices. The study concluded that the role of financial institutions needs to be reformulated and they should tie up the credit availability with adopting better management practices by the dairy farmers.

Value Chain Financing

135. The State Bank of Pakistan (SBP) has been very proactive in the promotion of a range of innovative financial services for the country and issuing guidelines for adoption by commercial banks and micro-finance banks. Small farmers with up to five acres land holding constitute 65 percent or 5.4 million as against 8.3 million farm households in the country. Therefore, SBP, in line with government's efforts to promote access to finance to small farmers, is working on a number of initiatives that include value chain financing, credit guarantee scheme for small and marginalized farmers, crop and livestock insurance and warehouse receipt financing. These guidelines are headway into SBP's consistent efforts to improve small farmers' access to finance to achieve the broader goal of financial inclusion. SBP has advised banks to use the guidelines for developing their own products for providing credit to contract farmers particularly to those who lack collateral to offer to the bank. Successful adoption of the guidelines will improve depth and spectrum of agri-financing to escalate rural household incomes and economic growth of the country.

136. In October 2014, the State Bank of Pakistan issued guidelines on value chain contract farmer financing to encourage banks to extend credit to small and marginalized farmers by leveraging on the strengths of inter-relationships that exist in the agriculture value chain. These guidelines will serve as a basis for banks to develop mutually beneficial relationship between the banks, farmers and the value-chain agent. Contract Farming assumes an extensive number of arrangements along the value chain linking small-scale farmers to markets by either formal or informal contracts. Value Chain Contract Farmer Financing schemes are broadly defined as binding arrangements between banks and agri. value chain actors including producers, processors, aggregators, traders through which a farmer or group of farmers ensures supply of agricultural products to individual firms. It replaces the traditional collateral requirements with trade agreements by facilitating coordinated commercial relations between value chain actors.

137. The introduction of value chain contract farmer financing scheme will enable farmers to avail financing from banks backed by processor's guarantee and in return buyers/processors may get assurance of getting required quantity and quality of agricultural produce. The guidelines have introduced five instruments including Trader Credit, Input Supplier Credit, Marketing Company Credit, Lead Firm Credit and Arthi or Intermediary, besides identifying roles and responsibilities of stakeholders, financing mechanism, eligibility criteria, types of financing, loan limits, security and collateral, insurance and loan monitoring mechanisms. It is expected that the guideline would benefit farmers in terms of enhanced productivity in a variety of ways such as availing quality input facilities, adopting new technologies, insurance coverage for crop/non-crop activities and most importantly assurance of buyer in advance. The processors, traders, exporters and Artis gains ensured supply of desired quantity of quality produce and bankers are at ease with assured loan settlement by the VC agents.

138. After the launch of agricultural value chain financing, banks have begun using this tool to boost their risk-mitigated lending to the agriculture sector. Currently, the bulk of value chain financing (VCF) is concentrated in crop growing and animal farming, as it is easier for banks to identify and classify value chain partners and commodity or input suppliers who act as guarantors for the farmers. Under the VCF, banks lend to value chain partners or companies that buy the growers' produce and also to commodity traders and input suppliers, instead of directly lending to farmers. And although banks are encouraged to make long-term loans, they are currently focused on making short-term loans. Such loans get repaid in instalments as and when the growers sell their crops or when dairy farmers complete their supplying of milk to milk-processing companies. Bankers say these two things are making the VCF attractive for them and this is why commercial and microfinance banks are using it actively. Bankers say they are using value-chain financing in lending operations such as trader credit, input supplier credit, marketing company credit and lead firm credit. It is difficult to quantify agricultural loans being offered under the VCF, but bankers boast of a good start in the very first year since the launch of the scheme. And according to the SBP, the VCF was one of several factors that led to a phenomenal 38 percent year-over-year growth in gross agricultural lending in Financial Year 2015 (Dawn, August 24, 2015).

Warehouse Receipt Financing

139. The SBP assessment (2014) showed that Pakistan's agriculture commodity sector suffers from a lack of both infrastructure and market structure. The resulting inefficiencies impact all market participants and keep the sector from becoming competitive. On the infrastructure side, there is a lack of warehousing and storage facilities. In the market, there is a lack of standardization, independent verification, collateral management, commodity financing, and transaction data. The result is an opaque and illiquid market where there is a lack of financing, trading opportunity and significant wastage. At the base of the value chain, farmers are most harmed by wastage, price fluctuations, and an inability to access finance. In order to address the issue, SBP conducted a study funded by USAID in collaboration with international consultants and Competitive Support Fund. The objective of the study was to review the existing system of commodity warehousing in Pakistan, the international best practices, legal framework in warehousing and feasibility for development of storage, marketing and post-harvest financing system. The study concluded that the development of a warehouse receipt (WHR) financing system is feasible and would be beneficial in Pakistan.

140. As a result of its findings, the SBP introduced a concessional refinance scheme to encourage construction of silos, warehouses, and cold storages, etc. Within the State Bank, a working group has been formed for the development and implementation of the system. The SBP has conducted a survey on banks' awareness and interest in WHR financing system. It has brought in an

international company called ACE Global Depository which provides a comprehensive range of risk management solutions across the entire commodity value chain. The SBP expects to implement a WHR system in Pakistan which will include a regulatory authority and framework for the supervision of warehouses, cold storages and silos. In addition, it will introduce a regulatory framework for the acceptance of WHR by banks as collateral, accreditation of warehouses with collateral management company, adoption of system development of a centralized database of borrowers and farmers to act as an information bureau, real time inventory monitoring and management. In a framework issued on the subject, the State Bank (2014) encourages all banks, insurance companies and warehouse owners to participate in this new venture. It alerts them that they may require banks to build products, and build capacity of their staff, etc.

Modern Agriculture Insurance Services

141. There is growing literature on crop insurance as a means of mitigating the risks inherent in the agriculture sector. In Pakistan, the insurance penetration accounts for only 0.7 per cent of the GDP, one of the lowest in the world, and there has been no growth in it during the past 10 years (Ali, 2013). The initiatives taken by various governments to promote agricultural insurance in the country have had limited success. The introduction of crop insurance in Pakistan has been under consideration since independence with renewed focus in the late 1980s. (State Bank of Pakistan). A number of committees constituted by the government deliberated and reported on the subject starting from 1986 onwards. The focus of all these schemes was on crop insurance and very little attention was paid to any type of insurance for the livestock sector. These schemes, with the exception of the earliest ADBP schemes had the characteristics of pilot projects with limited risks; insurance for specified crops and specified areas; Government subsidies in sharing of premiums or through reinsurance for the programs and high premium rates. State Bank refers to the views of independent experts who contended that crop insurance would serve as a powerful instrument in promoting and adopting modern techniques in agriculture especially by small farmers. However, despite doing exhaustive exercises spanning nearly three decades, our economic and agricultural experts are still looking for a model Crop Insurance Scheme for Pakistan, while India and Sri Lanka had actually been insuring the crops of their farmers for decades.

142. The SBP has been working closely with financial institutions to develop a market driven rural finance market. In 2006, SBP formed a task force to come up with a comprehensive crop loan insurance framework. This was comprised of representatives from banks, insurance companies, farmer organizations, central bank, and the government. There were interminable debates amongst the task force members as it involved making some tough decisions in the strategic interest of the rural finance market. It was a long drawn process, taking almost two years to come up with a market driven conceptual framework and implement the first ever crop loan insurance scheme in Pakistan. An important initiative in this regard was the introduction of a market-based crop loan insurance scheme in 2008. There were many challenges involved in coming up with a feasible crop loan insurance framework. Cost of insurance, premium collection mechanism, claim trigger, role of government, reinsurance treaties, willingness of farmers to pay for insurance, perils to be covered, and lack of recorded historical data to evaluate probability of calamities, etc.

143. Thanvi (2013) reported on the experience of the crop insurance efforts in Pakistan. In his article he notes that it has been more than four years since crop loan insurance was first implemented and it has gradually been strengthened by the active participation of banks, insurance companies, and farmers along with targeted government support. He notes the salient features of the available crop loan insurance scheme which made the crop loan insurance mandatory for farmers requesting a loan from a financial institution for any of the five major crops: wheat, rice, sugar cane, cotton, and maize. Banks were required to collect the insurance premium on behalf of the

insurance company. Aggregate liability of the insurance companies was limited to 300 percent of collected premiums. Calamity declaration by the Revenue Department, is expected to be the trigger point for payment of claims, followed by overall and specific farm surveys by the insurance company. In case there is a loss of more than 50 percent in terms of area yield outcome, the insurance trigger is activated. Amount of insurance cover is limited to the loan amount. The multi-peril insurance covers excessive rains, floods, draught, hailstorm, frost, crop related viral and bacterial attacks, and damage by locusts. The framework also defines a maximum ceiling on the rate of premium to be charged from a farmer.

144. Thanvi notes that between 2009 and 2011, approximately $20 million was collected in premiums. Claims paid by the insurance companies amounted to approximately $10 million. During this period 38 calamity notifications were issued (2009–2011) affecting 98 districts across Pakistan. This includes the worst ever flooding of 2010 where sizeable losses were incurred across the country. However, the future challenges in the design and implementation of insurance products for the agriculture sector include lack of awareness amongst rural clients, cost of the premium, premium collection and claim trigger points and lack of historical data among other factors. However, despite this the banks have not shied away from entering this market. With crop loan insurance gaining momentum banks are classifying their business model as one which has shifted from 'poverty lending' to 'financial services'.

145. Ali (2013) studies farmer's willingness to pay for index based crop insurance given that agriculture is vulnerable to multiple risks, especially in the rain-fed areas of Pakistan. He quotes other studies which report that livelihood in agriculture is threatened by frequent crop failures and price volatility. Agriculture in the rain-fed areas is of subsistence nature characterized by low land- as well as labor-productivity, and high yield gap (GoP, 2009). The vulnerability of rain-fed agriculture to extreme weather conditions results in substantial income loss to farm households. The farm households have little support from the government in the form of insurance cover or subsidy to face the disaster (Khan et al., 2004). In the rain-fed areas of Pakistan, there is an urgent need for the effective risk management measures. The study by Ali (2013) assessed farmers' willingness to pay for insurance in the rain-fed areas of Pakistan by conducting a survey of 531 farmers in the Soon valley and Talagang areas of Punjab. The farmers' willingness to pay for the index based crop insurance was studied by employing different econometric models. He found that farmers consider indexed based insurance to be an important risk management strategy. The empirical results indicated that farmers' economic status, household assets and membership of community organization were the important determinants of their willingness to pay a higher insurance premium. He concluded that the provision of direct risk relief to farmers will enable them to alter their production strategies towards maximizing output, rather than diversifying risk, and to shift their demand for credit from consumption loans to investment loans. The study suggested making agricultural insurance schemes more successful, the government should provide subsidy which will help in increasing the area under food and cash crops and ensure food security in the region.

Livestock Insurance

146. At the end of 2013, the SBP, in collaboration with the Securities and Exchange Commission of Pakistan, banks, insurance companies and provincial livestock and dairy departments developed a framework for livestock insurance for borrowers. The scheme is aimed at improving access to finance for the livestock and dairy sector by mitigating risk of livestock loss due to disease, natural calamities and accidents. The State Bank initiative was a response to the low level of credit which is invested in the sector by the commercial banks. The SBP noted that the financing from the commercial banking sector to livestock, dairy and meat industry was only Rs 56 billion, constituting 17 percent of total agriculture lending of Rs 336 billion in 2012-13. One of the major

reasons for the modest credit off-take was limited availability of appropriate insurance products or other risk mitigation tools. According to the SBP, the livestock insurance scheme will provide an essential risk mitigating tool to encourage banks to enhance flow of credit to this highly potential and underserved sector. The scheme is expected to safeguard the interest of farmers, who borrow from banks, in case of livestock mortality death due to disease, accident, flood, heavy rains and storms. Under the scheme, banks will obtain insurance of all livestock loans up to Rs 5 million for the purchase of animals. The SBP has asked banks to implement the scheme according to given parameters and enter into agreements with reputable insurance companies for underwriting livestock insurance for their borrowers. Banks may also negotiate with insurance companies for best terms relating to insurance coverage for disability and theft of animal, premium rate, etc. The SBP said it would ask the government to bear the cost of insurance premium for small farmers through budgetary support as was done under the government's mandatory crop loan insurance scheme for five major crops. The central bank classifies farmers having up to 20 cows or buffaloes and 50 fattening cattle as small farmers. Several Insurance companies such as Admajee, Jubilee General and United Insurance companies have initiated livestock insurance products.

Some Key Questions in the Adoption of Modern Agriculture Technologies and Practices

What Role the Agriculture Extension Services Played in the Dissemination and Adoption of Modern Technologies and Practices?

147. Abbas, et al. (2003) examine the existing role of farmer-extension interaction in the dissemination of recommended sugar cane production technologies. They selected 180 sugar cane growers as study respondents through stratified random sampling technique. It was found that extension agents communicated sugar cane production technologies to 100 percent large farmers and a large majority of them adopted some of the technologies. However, in many developing countries including Pakistan, wide adoptions of research results remains quite limited. The present paper assesses the farmer extension interaction and the dissemination of recommended sugar cane production technologies in the central Punjab. The finings report that the average distance of the offices of agriculture officers from villages was found to be 10.22 Km in the study area. Agriculture extension agents (AEAs) paid 1.25 visits per month to large farmers. However, they visited small and medium farmers off and on. More medium farmers (24.3 percent) paid visits to the offices of agricultural officers (AOs) than large farmers (18.5 percent). A significant proportion of medium farmers (88.9 percent) paid visits occasionally to the offices of AOs, which was higher than large (75.0 percent) and small farmers (60.0 percent). A significant proportion of large farmers (61.9 percent) had no time to contact AEAs; whereas, 22.0 percent farmers of the study area were not interested to consult AEAs. A large proportion (above 70 percent) of small and medium farmers reported farmer's meetings as extension method used by AEAs, which was higher than large farmers. A notable proportion of small and medium farmers (above 50 percent) perceived farmer's meetings the best among other extension methods, which was higher than large farmers. AEAs communicated sugar cane production technologies i.e., varieties, sowing methods, fertilizer application, plant protection, eradication of weeds and irrigation methods to all large farmers which was high among small and medium farmers (76.5 and 78.6 percent, respectively). Above 70 percent of large farmers adopted the sugar cane production technologies i.e. varieties and sowing methods. However, the adoption of technologies like fertilizer application, plant protection, eradication of weeds and irrigation methods was relatively low.

148. Abdullah (2013) studies the factors that impact farmers' use of agriculture technology in Malaysia. The paper outlines the factors affecting technology usage. Based on the findings, the author

concludes that farmers' perceptions and levels of education, as well as extension workers' knowledge, the management of the extension program, and the physical conditions of the area, are all factors that affect technology adoption among farmers. Factors such as the knowledge level of extension workers, methods of organization and management of extension programs, and local conditions are also highlighted as the drivers for technology adoption. The author quotes a study by Truong (2008) which identifies many obstacles to running a successful technology strategy. The main reasons for non-adoption of technology are weak perceptions of technology and low education of farmers, low teaching capacities, limited knowledge among extension workers, disorganization, geographical conditions, and inadequate resources and funds. Furthermore, farmers need to have a certain level of education and be very familiar with the crop they are farming in order to be motivated to learn new technology. Truong's (2008) study suggests that for the rice crop which was being examined, technology adoption demands a great deal of land preparation, a high rate of seed germination, proper seed soaking and incubation, and maintenance of water after sowing. Technology usage must be in line with the financial capacities of farmers, and farmers with limited financial ability will have little chances to adopt the technology. In addition, not all farmers are able to adopt technology due to the small number of extension workers, and the fact that it comprises many measures that require a high level of knowledge from farmers. Furthermore, farmers are afraid of low price production and technology adaptation also depends on the ecosystem (irrigation sources, fresh or saline water areas, inland fields, etc.

149. In a paper on understanding the Extension Services role in diffusion of agricultural Innovations. Ali et, (undated) report that income and education have a significant correlation and played a significant role in adoption of agricultural innovations. He notes that farmers were not particularly interested in field day visits by the agriculture extension department. Land and irrigation system were not found to play a role in changing knowledge, attitude and practices. The female role in farming was reported not to be effective in changing behavior of farmers, in adopting agricultural innovations. Communication technologies regarding agricultural innovations played an important role along with extension services, other media and local persons such as agricultural experts, agricultural agents, relatives, friends and co-farmers. It appeared that among media variables, television was perceived as the most effective medium in diffusion of agricultural innovations in rural areas where newspapers and magazines received very low responses. The role of interpersonal communication- agricultural experts, agricultural experts, relatives, friends and interaction with other farmers was also explored. Interaction with neighbors regarding agricultural innovations was observed to be significant.

Does Farm Size Matter in the Adoption of Modern Technologies and Practices in the Agriculture Sector?

150. Mahroof et al (2011) explore this issue and conclude that there is impressive empirical evidence on the inverse relationship between the farm size and its productivity in agriculture. Empirical evidence in Pakistan also lends support to the inverse relationship between farm size and agricultural productivity. The paper maintains that the gross productivity of the small farms has been consistently higher than that of the large ones between 1965–66 and 2004–05 in Pakistan. They dispute the claims of some that the large farms overtook the small farms in farm productivity under the green revolution. The differences in the adoption rates of various modern technologies between the two groups have narrowed with the passage of time. It is argued that the major difference in farm investments of larger and small farmers lies in their ownership of tube-wells and tractors. According to the 1980's Census of Agriculture, large farmers owned nearly 59 percent of the tractors and about 39 percent of the tube-wells. By contrast, the small farmers owned only 16 percent of the tractors and 35 percent of the tube-wells (GoP, 1985). However, the small farmers depend more on increased access to custom sales of tube-well water and tractor services.

Accounting for this fact, shows that nearly 35 of the small farmers were users of tractors and 32 percent for tube-well services.

151. As far as the adoption of bio-chemical technologies is concerned, both the large and small farms used HYVs with almost the same proportion by the early seventies (Chaudhry, 1996). It may be interesting to note that the HYVs of wheat accounted for 68 percent of wheat acreage in 1980, on both the small and large farms. By contrast, the small farms devoted nearly 54 percent of their rice area to HYVs of rice compared to 44 percent on large farms (GoP, 1983). Whatever differences in the rates of application of fertilizer on large and small farms existed in the Sixties, they were greatly reduced by the early 1980s (Naqvi, Khan and Chaudhry, 1994). One of the most probable reasons for a somewhat lesser use of the modern inputs on the small farms relative to the large ones is that they are compelled by their resource endowments to prefer to make a more intensive use of some of the traditional inputs. For example, although tractors may enable the large farms to undertake tillage operations with precision, small farms can do the same in better ways with greater inputs of human labor and animal power in addition to their access to hiring of tractors.

152. According to available evidence, the labor input per unit of land for the small farms is, at least, twice as much as that for the large farms (Chaudhry, 1989). Similarly, the bullock-power input of the small farmers was 4 times that of the large farmers. Although the small farmers have a somewhat limited access to tube-well water, their proportionate irrigated area has historically exceeded that of the large farmers, probably because they tend to use water more efficiently. This would be particularly true if the small farmers had only a limited access to surface and ground water supplies. According to the 1990's Agricultural Census, the proportionate irrigated area of the small farmers was close to 81 percent as against 73 percent of that of the large farmers. A somewhat lesser use of chemical fertilizer on the small farms is perhaps more than offset by their higher application of manure which they use twice as much per acre as is done by large farmers (Chaudhry, 1982). As farmyard manure is rich in plant nutrients, its greater use would be instrumental in enabling the small farmers to secure a higher and better soil-nutrient balance than is obtained by large farmers, who solely depend on chemical fertilizers.

153. Salam (1976) examined factor inputs use and farm productivity on different farm categories in Punjab for the time period 1976 by using multiple regression models. The major finding was that small farmers used higher amounts of factor inputs. The farmers operating small farms obtained lower crop yields. This trend was more pronounced in case of MexiPak wheat. Owner-operated farms generally obtained higher per acre yields than the tenant-operated farms. Azhar (1991) found that education coupled with new technology results in greater production, than education combined with traditional methods of production technical change in agriculture. Mukhtar and Mukhtar (1988) examined the inputs used and productivity across farm size and undertook a comparison of Punjab of Pakistan and Punjab of India, by using multiple regression models. The results reveal that inputs play an important role in increasing agricultural output so, gains confined to that class which has better access to such inputs. Indian Punjab is better equipped than Pakistani Punjab with respect to land distributed owner operation of farms and infrastructure provision. In Pakistan's Punjab the small farms are deprived of a lot of facilities.

Do Farmer Attributes Matter as a Determinant of Adoption of Modern Inputs and Practices?

154. Many of the studies have focused on the characteristics of the farmers as determining the adoption of a particular technology or input use. Much of the published empirical work has estimated and explained technical efficiency based on: (i) socioeconomic characteristics such as

farm size, age, education, farming experience, land tenure status, family size and off-farm income; (ii) institutional factors such as extension services and farm organization membership; or (iii) input use characteristics such as soil and seed type. Khan et al. (2010) find that experience is positively related to efficiency while Coelli et al. (2002) find a negative relationship. Many studies confirm a priori expectations about the impact of education on efficiency levels (Villano and Fleming, 2006; Tan et al., 2010). Nonetheless, numerous studies do not find a significant relationship between education and efficiency (Rahman and Rahman, 2009; Gedara et al., 2012). Some studies even suggest a negative relationship between education and efficiency, presumably because formal education does not focus on rice farming practices (Tian and Wan, 2000; Coelli et al., 2002; Rahman, 2003). There are also mixed results in regard to the impact of different institutional factors such as extension services and participation in farmer organizations on rice production efficiency (Rahman, 2003; Rahman and Hasan, 2008; Gedara et al., 2012). Among the different socioeconomic characteristics, various studies show a positive and significant relationship between farm size and technical efficiency (Wadud and White, 2000; Coelli et al., 2002; Balcombe et al., 2008; Rahman and Rahman, 2009) while others find a negative relationship (Rahman et al., 2009). The age of the head of the household is one of the most influential characteristics in many studies. Older farmers are found to be more technically efficient than younger farmers (Villano and Fleming, 2006; Khan et al., 2010; Rahman, 2010; Tan et al., 2010). Results on the impact of farming experience on rice growers' efficiency level are mixed and inconclusive (Mariano et al.)

155. Sajida Taj et al. (2013) present the determinants of adoption of raised bed planting of wheat in irrigated areas of Punjab as a method of water saving. The study was planned and conducted by the Social Sciences Research Institute in Faisalabad in 2011-12. The study reported the results of the research which was based on interviews with 63 farmers at three sites of the districts of Faisalabad and Toba Tek Singh. The results of Probit regression analysis regarding raised bed technology indicate that young and educated farmers are more likely to adopt this technology as compared to old age farmers. The study revealed that adopters typically have a more favorable resource base and tend to variously out-perform non-adopters. The research findings revealed that the adopters owned relatively more agricultural land (20 acres) as compared to non-adopters (15). The land holding coefficient is positive and highly significant at 1 percent level of significance. She argues that as land holding is an indicator of household wealth so it can be concluded that mostly wealthy household have adopted raised bed technology. She concludes that more access to education and other social indicators increases the chances of adoption of new technologies in the farming community.

156. Muhammad et al. (2014) undertook a study intended to identify the adoption gap in livestock production practices and in particular, to examine the gender role regarding livestock care and management. For this purpose, district Jhang (Tehsil Bhowana) and district Pakpatan (Tehsil Arifwala) were selected as the study area. From each area, 10 villages were randomly selected. Furthermore, 15 farm families per village were selected at random and one woman from each farm family was randomly selected making a total sample size of 300 respondents. The data were collected through a pre-tested and validated interview schedule and analyzed with the Statistical Package for Social Sciences (SPSS). The results revealed that a large majority of the respondents (53 percent) were illiterate. About half the respondents had awareness about different vaccines like FMD (55 percent) and HS (53 percent), but adoption trend was meager. Regarding housing conditions, more than seventy percent were aware about recommended housing conditions but few of them had adopted it. The authors of the study felt there was a dire need to motivate and guide women regarding improved livestock production practices through extension and training programs. It also reported that their access to capital inputs and services need improvement.

157. Jalauddin (2009) examined how small farmers are dealing with socioeconomic problems in adopting new farm technology. For this purpose, 60 respondents were randomly selected in three villages, i.e., Babeni, Fatma and Muliano Kale in district Mardan. The data for this study was collected through face to face interviews. This study revealed that a majority of the respondents were illiterate. Moreover, most of them had meager means of purchasing agricultural inputs, fertilizers, sprays and storage facilities. Most of the households belonged to low monthly income group and large families. This study further revealed that lack of proper extension services of the agriculture department was another obstacle in improving the productivity of small farmers in the study areas. These studies showed that majority of the respondents were tenants and owner cum tenants and therefore were not prone to take any risk. This study also revealed that lack of latest information as well as non-availability of credit facilities was main problems of the small farmers of the study area.

158. Pravan (undated) reviews the literature with respect to the factors that impact adoption of new technologies. These explanatory indicators vary from study to study based on their contextual applicability, but traditionally include: (i) farm size, (ii) risk exposure and capacity to bear risk, (iii) human capital, (iv) labor availability, (v) credit constraints, (vi) tenure, and (vii) access to commodity markets. In delineating these particular factors, the literature points out that the categories are not discrete or exclusive and that boundaries may blur and overlap due to the interdependent relationship between indicators. For example, inadequate rural financial systems decrease the availability of affordable credit; a lack of credit increases aversion to risky undertakings such as new technology adoption; higher levels of risk aversion — or decreased ability to mitigate and bear risk — are correlated with higher levels of poverty and vulnerability to shocks; higher poverty levels are themselves associated with smaller farm sizes, lower levels of education and less allocative ability to manage change. Many studies have shown that each of these indicators significantly influences the agricultural technology adoption process; trying to separate each characteristic from the others is difficult and may even be unnecessary. The objective of the paper was to show how each variable affects adoption, allowing implementing actors to refine their strategies based on a wide body of empirical and qualitative results.

159. The literature review revealed that although literacy rates in Kashmir were relatively higher than other areas of Pakistan, as exemplified by Chohan and Ahmad (2008) in their study of tomato production in AJK, the vast majority of tend to use traditional farming practices, such as the use of livestock for land ploughing. "Lacking modern yield increasing technology, the increasing population has brought more hillside land under cultivation, causing degradation of the environment. While a number of government institutions provide agricultural credit, farmers in AJK have tended not to take advantage of these programs," (The World Bank, 1984 p. 11). A more recent study by Jamil et al. (2015) conducted in Bhimber valley found that of 150 farmers that participated in their study, around 91 percent felt that demonstration of results was the most effective extension method for transferring information. They also reported findings similar to those for GB; a correlation between literacy levels, size of landholdings, supplementary income etc. and the farmers access and openness to new methods or technology.

What are the Most Effective Tools and Mechanisms for Dissemination of Modern Agriculture Technologies and Practices?

160. Just as there are different types of technologies, there are different kinds of adoption. Feder, Just, and Zilberman make three distinctions in types of adop-tion: (i) individual vs. aggregate adoption, (ii) singular vs. packets of technologies available for adoption, and (iii) divisible vs. non-divisible technologies. The first option is between final adoption at the individual level, which involves an internal deliberative process but is ultimately manifested as a dichotomous decision, and the

aggregate adoption behavior observed as the diffusion of a technology, and its corresponding adoption, throughout a discrete space. Individual adoption can measure the degree of use in the long run, but it is ultimately a binary observa-tion. Aggregate adoption, on the other hand, is measured as the aggregate level of use of a particular technology among one specific group of farmers or within one particular area. These farmers, whether observed individually or collectively, can choose to adopt in different ways. In some instances, farmers are presented with a single choice: the adoption of one discrete technology such as a new HYV seed, or some other single input. But in most cases, as with MERET, agricultural technologies are introduced in bundles, and these bundles are often complementary. A HYV seed is introduced along with the fertilizer and corresponding land preparation practices needed to make the HYV work as designed.

161. Feder et al. (1982) note that different theoretical models of adoption show that observed diffusion patterns depend critically on complicated and sometimes unobservable relationships between different elements such as the risks associated with various technologies, the nature of farmers' attitudes, the existence of fixed production costs (either actual or imputed) and the availability of cash resources. Similar innovations may therefore experience different adoption patterns in different areas and by different groups of farmers. Specifically, the relationship between farm size and adoption can take different shapes due to a host of factors. The empirical studies reviewed in the survey reinforce most of the conclusions emerging from theoretical models. Innovations involving higher fixed costs are adopted at a higher rate by larger farmers. Innovations which are neutral to scale are eventually adopted by all classes of farmers, but large farmers are typically among the early adopters. There is also evidence that the "intensity of adoption (e.g., proportion of area under new variety, quantity of fertilizer per acre) may be higher on smaller farms, under certain conditions, while in other cases the opposite is observed. The conflicting evidence in the literature stems from the fact that farm size is a surrogate for a number of factors, some of which have contradicting effects.

162. Tenancy status is hypothesized by a number of authors to have an impact on adoption of innovations. But empirical evidence to substantiate this hypothesis is not conclusive, and in a number of studies no significant differences are found between owners and tenants. These results may be due to measurement problems (need to distinguish between owners-tenants and pure-tenants) or to underlying relationships between tenancy and other factors (access to credit, inputs and information). The review points out a number of problems faced when empirical analysis of adoption patterns is applied. A common weakness is the tendency to consider innovation adoption in dichotomous terms (adoption/non-adoption), even though the actual decisions made by farmers are defined over a continuous range (e.g., quality of fertilizers used). Another aspect which enters the analysis is due to the simultaneous nature of many of the decisions on adoption when a package of new practices is promoted. Such a situation requires appropriate econometric tools. The diversity of experiences with different innovations in different geographical and social-cultural environments suggest that studies of adoption patterns should provide detailed information on attributes of the institutional, social and cultural settings and their interactions with economic factors. These may be an important element in explaining conflicting findings (Feder et al., 1982).

163. Studies which tried to empirically establish the role of perceived risk and risk aversion in explaining adoption of innovations have usually been afflicted by measurement problems. In some cases, proxies, which measure the access to access to information (e.g., contact with extension) or ability to decipher information (education, literacy) are used in order to infer on the role of uncertainty, with obvious difficulties in interpretation. labor supply problems may sometimes inhibit adoption of innovations, if these are labor intensive. However, labor replacing innovations

were adopted quite rapidly in other areas, where labor availability depended on seasonal and uncertain supply. The literature shows that credit supply is not necessarily an obstacle to adoption. However, evidence on this matter is mixed.

164. The conventional wisdom is that constraints to the rapid adoption of innovations involves factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, in-sufficient human capital, absence of equipment to relive labor shortage (thus preventing timeliness of operations), chaotic supply of complementary inputs (such as seed, chemical, and water) and inappropriate transportation infrastructure. Many development projects have sought to remove some of these constraints by introducing facilities to provide credit, information, orderly supply of necessary and complementary inputs, infrastructure investments, marketing network, etc. Removal of these constraints was expected to result not only in adoption of the improved practices but also in a change in crop composition which was thought to further increase average farm incomes. Expectations, however, have been realized only partially. Past experience shows, uneven adoption of innovations in agriculture. In most cases, adoption behaviors differ across socioeconomic groups. While some innovations have been well received other improvements have been adopted only by a very small group of farmers (Feder at al., 1982).

165. Extension techniques such as demonstration plots and field days have been proven to be successful means for introducing the results of modern research in agricultural practices and hence increasing production (Afzal, 1995). In Chitral District, AKRSP has reported that when new technologies were demonstrated to be successful, adoption rates were very high; for instance, once survey showed that use of modern machinery by farmers rose from 43 percent to 90 percent from the results of one survey (Khan, 2009).

166. Waqaz et al (2015) examined the effectiveness of information sources regarding livestock production in Punjab. Their study was conducted in Tehsil Bahawalpur during 2012 to assess the effectiveness of information sources on the adoption of improved livestock production practices. Multistage random sampling technique was used for the selection of study respondents. Data were collected through interview schedule from the 120 respondents from the research area and were analyzed with the help of SPSS. Pearson product moment correlation and chi-squares test was also used for in-depth analysis. Results indicated that family farmers and neighbor farmers were the most effective information sources while extension field services and animal festivals got the lowest rank. Regarding constraints, lack of technical skills was ranked as the first followed by finance shortage which led to lack of purchase of the recommended ingredients i.e. ration, nutrients, supplements etc. for their animals. Results of correlation show that there is a positive significant relationship between age, education, and effectiveness of information sources while chi-square analysis opposed the rejection of hypothesis. On the basis of results it is suggested that Extension field staff need training so they should be trained regarding latest livestock techniques by the Punjab Agriculture Department through refresher courses and training workshops. Public sector should launch some micro credit schemes or interest free loan to reduce the finance shortage problem.

167. Shahzad et al (2011) examined the effectiveness of agricultural publications as a tool to disseminate agricultural information among the farming community. The universe of the study was district Faisalabad with a sample size of 52 subscribers of five selected agricultural publications drawn from the study area. A pretested and validated mail questionnaire was used for data collection. The result of the study reveals that the response of young farmers was in favor of agricultural publications as compared to old farmers regarding usefulness in crop productivity, information authenticity, and practicability of information. The study concluded that young farmers

should be the focus and target beneficiaries of the agencies publishing content regarding agricultural technologies. The study concluded that subscription of the agriculture publications should be increased for maximum coverage of farming community. The study concluded that the articles should meet the requirements of the diversified farming community.

168. Shaukat and Shah (2013) evaluated farmer's readiness towards implementation of mobile information and trade systems in Pakistan. They attempted to assess key factors that affect farmer's decision and readiness to use mobile based agriculture services expected to provide important market information to the farmers and traders about agriculture such as better price, better quality of seed, weather conditions, better time for cultivation, better pesticides and fertilizers, etc. The study was based on interviews with farmers from four cities in Punjab. The study reported that farmers seem to be ready for the technology but like to have less complex devices and feel discomfort with extra functions.

169. Muhammad et al contend (2004) that nothing seems more important in agricultural development than the dissemination of latest agricultural technologies among the farmers. Agricultural extension organizations are entrusted with this primary task for which they use a variety of extension teaching methods and the media. Television is one of the media being used for this purpose both by public and private sectors. The present paper aims to assess the role of television in agricultural technology transfer. A majority (53 percent) of the respondents watched agricultural telecasts rarely. A reasonable number were occasional viewers and only 5.6 percent respondents were found to be regular viewers. The vast majority claimed they got only up to 25 percent agricultural information through agricultural telecasts.

170. In Pakistan, yield maximization—a new concept—has gained popularity over the past few years (Amir, undated). Essentially, research results that demonstrate high probability of success (best bet) are brought to the farmer's field. Inputs are subsidized, demonstration trials conducted and the local administration fully involved to create a dramatic impact over a short time period. All forms of media (print, TV, and radio) are used in these campaigns and the private sector is involved in input supply, marketing and processing. The hope is that once a group of farmers is convinced with the technology's superiority, than widespread adoption will follow. Recent work by the University of Faisalabad, Punjab, has shown that farmers responded well to molasses/urea multi-nutrient blocks and new fodder varieties and a significant impact can be achieved in a short period (Majid at al., 1989). However, the approach is dependent on trained manpower and is costly in terms of input subsidies.

171. Pilot projects often take a single component, for example, feeding concentrate or multi-nutrient blocks and test these ideas through limited farmer participation with the hope of extending such components on a wider scale. The impact of such activities is limited, although, such projects are helpful in addressing single issues. FSR tools that focus on "before and after" effects and "with and without treatment" effects are helpful to measure the benefit of new technologies. A detailed discussion on various on-farm methods that can be used to assist livestock projects can be found in Amir and Knipscheer (1989). The principle concern of these methods is not to provide very sophisticated technologies that are unlikely to be beneficial to the majority of small farmers but to concentrate on proven practices that can be verified under farmer conditions with his direct participation (Hart and George, 1983). The final decision maker is the farmer and he should be the principle judge of the technology.

172. There is also increasing information on the use of new modes of information technology. The Government has established several portals to further develop and support the agricultural sector

Shafique (2008) reports on these portals. However, there is insufficient data available on the extent to which the IT services are used at the producer, processer and marketing/export levels.

a. TelMedPak's Agricultural Page (http.//www.telmedpak. com/agriculture.asp). It provides information on agricultural business and engineering, crops, fertilizers, new agricultural technologies, pesticides and weather updates. It provides news in Urdu and Sindhi, with features on agricultural machinery, trade and the agro-ecological zones of Pakistan. Online polls, a calendar of national and international agricultural events, related links, a members' area, discussion forums and questions to be asked from experts are also available online, together with relevant contact information

b. NationalPak (http.//www.nationalpak.com). It provides a unique opportunity to access agricultural information and facilitates electronic access to farming techniques for the public. It also aims to increase the use of information technology at agricultural institutions in Pakistan. The site provides detailed information about all major food or cash crops of Pakistan and provides complete guidelines for sowing, cropping and harvesting. The site provides fresh updates in Urdu, an agricultural directory and links to various agricultural research and educational institutions. Central Cotton Research Institute (http.//www.ccri. org.pk/). The Institute was established in 1970 by the Pakistan Central Cotton Committee under the Ministry of Food, Agriculture and Livestock, and charged with the task to carry out research and development on various aspects of cotton production. The site has interesting links to plants pathology and physiology, breeding, genetics, cyto-genetics, etc. It also carries statistical data on crop production.

Have Modern Technologies Tended to Focus on Some Areas and Neglected Others?

173. Renkow (1993) examined the differential technology adoption and income distribution in Pakistan and its implications for research and resource allocation. He explained that Pakistan contains two distinct production environments, a highly productive irrigated sector and a more marginal rain-fed zone. Historically, most wheat research has focused on the irrigated sector, and the rapid technology adoption and yield increases characterizing the green revolution of the 1960s were largely confined to those areas. High yielding varieties (HYVs) better suited to rain-fed conditions were developed and released in the mid-1970s. In some rain-fed areas, yield increases associated with this second-generation of HYVs were substantial, but still much smaller those in irrigated areas. Rain-fed areas continue to lag behind the irrigated areas, in terms of both adoption and yield. He summarizes the results of past investment in wheat research in Pakistan which had achieved a higher rate of return compared with returns on alternative public and private expenditures within Pakistan and compared to agriculture research in other developing countries. Their data indicate that wheat research accounts for about 16 percent of total agricultural research expenditures. The magnitude of public resources devoted to wheat research and the historically rapid adoption of new wheat technologies underscores the importance of how those research resources are spent. This paper has investigated the potential impacts on income distribution of currently available wheat technologies in Pakistan. A multi-market model of technological change was used to simulate the income effects of different regional patterns of diffusion of these technologies. The results indicated that the traditional allocation of the bulk of wheat research to improving the productivity of Pakistan's irrigated sector continues to be a reasonable strategy. A dramatic reallocation of research aimed at rain-fed areas would be inferior in terms of promoting overall income growth, and at the same time cannot be justified on equity grounds. This finding is important in that it directly speaks to the question of whether or not there is a conflict between the goals of improving agricultural productivity and enhancing income

distributional equity. Given the technologies currently available in Pakistan it appears that such a conflict does not exist.

Is the Shortage of Energy Likely to Have an Impact on the Adoption of Modern Agriculture Technologies and Practices?

174. Energy demand has been increasing in Pakistan, hence there is a pressing need to evaluate and analyze the agricultural technology and energy consumption nexus and to find out the inter relationship. In their paper Zaman et al. (2012) undertake analysis to find a statistical relationship between agricultural technology and energy demand in Pakistan using secondary data from 1975–2010. A large number of studies have been carried out to show how technology affect energy demand or energy demand affects agricultural technology. The relationship between energy consumption and agricultural technology is well documented in the literature; however, the direction of causation of this relation-ship remains contentious. That is, whether agricultural technology leads to energy consumption or that energy consumption leads to the agricultural technology. The direction of causality has significant policy implications.

175. The results of the study reveal that gas consumption has bidirectional causality with agricultural growth, however, there is no causal relationship found for petroleum and electricity with agricultural growth. The results of the regression indicate that there is a very strong relationship between energy demand and agricultural technology. The results of their various models show that energy consumption and agricultural technology i.e., tractors, high technology exports, livestock production and subsidies have positive relationship between them, however, this relationship is less than one to one i.e., less elastic. On the other hand, energy consumption and technological factors i.e., cereals production, irrigated agricultural land and agricultural value added have positive and more elastic relationship. In contrast, there is a negative relationship between total primary energy consumption and industrial share of value added. In their second model, however, neither fertilizers; cereals; high technology exports and subsidies nor electricity consumption per capita affects each other. They conclude that incentive-based supports such as per hectare fuel subsidy might be a good policy for increasing the use of energy level in agriculture and a combination of energy-efficient technologies and diverse energy source would set the stage for better economic development.

ANNEX 2: REFERENCES

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