Developing Sustainable Agriculture in Pakistan

Iqrar Ahmad Khan
Muhammad Sarwar Khan
Developing Sustainable Agriculture in Pakistan
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Preface

The history of agriculture is the history of humans breeding seeds and animals to produce traits they desire in their crops and livestock. Agriculture plays a pivotal role in the economy and development of Pakistan. It contributes to about 21% of the total GDP and employs nearly 46% of the labor force of Pakistan. However, agriculture production is compromised due to fixed cropping patterns, reliance on a few major crops, narrow genetic pools, and the changing climate. This demands a holistic approach to develop agriculture and to improve the livelihood of the rural populace. This book provides critical analyses of present trends, inadequacies in agriculture, strategic planning, and ways forward to improve programs and policies keeping in view the natural resources, agriculture (crops and animals) production technologies, input supplies, population planning, migration and poverty, and balanced policies on finance, credit, marketing, and trade.

*Developing Sustainable Agriculture in Pakistan* consists of 38 chapters subdivided into four sections. The flow of chapters in the book is strategically organized to allow for easy reading. It begins with Chapter 1 “Planning for Sustainable Agriculture in Pakistan” in which Drs. Iqrar Ahmad Khan and Muhammad Sarwar Khan comprehensively provide an overview of the latest approaches which could be used to develop sustainable agriculture. Section I (Natural Resources and Input Supplies) begins with Chapter 2, in which Drs. Tahir and Khalid explain precisely how production factors can be exploited to improve agriculture. In Chapters 3 and 4, Dr. Allah Bukhsh and his team stress upon the necessity of developing water reservoirs to meet ever-increasing requirements for irrigation while exploring the potential of renewable energy sources. In Chapter 5, Drs. Rashid and Nasir discuss environmental degradation and its remedial measures. Dr. Zahir and his colleagues, in Chapter 6, have proposed a number of remedies against factors which cause depletion of soil fertility and decrease productivity. In Chapter 7, Drs. Arshad and Ahmad discuss facts concerning the irrigation system of Pakistan, whereas Dr. Cheema and colleagues, in Chapter 8, describe ICT-based precision agriculture for increased farm productivity and decreased adverse environmental impacts. In Chapters 9–12, Drs. Ali, Khan, Akhtar, Arif, and their colleagues describe the current status and provision of services to farmers for increasing agricultural productivity and improving their livelihood.

Section II (Crop Production Technologies) consists of ten chapters (i.e., Chapters 13 through 22). In Chapter 13, Drs. Ahmad and Husain provide a comprehensive account of climate change and its effects on agriculture. Dr. Murtaza and his colleagues discuss the treatment and management options of low quality waters in Chapter 14, and suggest that changes be brought about in policies for significant improvement and sustainability of crop husbandry. In Chapter 15, Dr. Khalid and his colleagues discuss production trends, constraints in productivity, and have suggested a way forward for crops of economic significance. In Chapter 16, Dr. Basra and his colleagues stress upon the use of crop rotation and diversification and also suggest introducing new crops in the cropping pattern. In Chapter 17, Dr. Ahmad and his colleagues propose growing high-value horticultural plants including wild-type medicinal plants to improve the pharmaceutical industry. Dr. Siddiqui and his colleagues, in Chapter 18, propose strategies to improve productivity on a sustainable basis while discussing forests and rangeland management issues. In Chapter 19, Drs. Khan and Joyia elaborate on how biotechnology plays a pivotal role in developing GM plants, which are designed to address emerging problems of insects, pests, and diseases under changing climatic conditions. In Chapters 20–22, three teams of authors discuss devastating diseases, insects, and the different uses of methods to combat them.

Section III (Animal Production and Health) is comprised of five chapters (i.e., Chapters 23 through 27). In Chapter 23, Dr. Khan and his colleagues give an insight into problems and solutions related to livestock production, public and private ownership of commodities, and markets. In Chapter 24, Dr. Akhtar and colleagues discuss problems related to the poultry industry. Drs. Javed and Abbas discuss in Chapter 25 how capacity building and integration of new techniques are important for
sustainable aquaculture and fisheries in Pakistan. In Chapter 26, Dr. Javed and his colleagues offer a lengthy discussion on the developments and issues related to the livestock and poultry industry and propose suggestions for improvement and value addition to the products of both industries. In Chapter 27, Dr. Sharif and colleagues highlight the problems of malnutrition in children and—considering the severity of the issue—suggest various strategies to alleviate the problem such as school health, nutrition programs, diet diversification, targeted food fortification, nutrition education, and a “one health” approach.

Section IV (Agricultural Incentives for Farmers) consists of eleven chapters. Chapter 28, by Dr. Anjum et al., illustrates the need for gender equality and women’s empowerment in different agricultural sectors and classifies the means for improving the economic impact of women’s work in agriculture, as well as for enhancing food security and sustenance. In Chapter 29, Dr. Maan and colleagues give a SWOT analysis of the five years population plans and suggest improvements to the quality of schools—through improved curricula and staffing with competent teachers—to reduce the dropout rates of female students. In Chapter 30, Dr. Akhtar and colleagues suggest that reducing the reliance upon foreign debts may result in poverty alleviation in Pakistan. Dr. Farah et al. examine in Chapter 31 the rural–urban migration in Pakistan and suggest effective steps to manage and curb the increasing trend of internal migration. In Chapter 32, Dr. Ali and his team present a critical review of various rural development programs carried out in Pakistan while discussing the highlights of the success story of rural development in South Korea. In Chapter 33, Dr. Ahmad and colleagues describe various challenges confronting the outreach and agricultural extension system in Pakistan. They also refer to social mobilization while emphasizing various opportunities for improvements. In Chapter 34, Dr. Sadaf and her colleagues discuss the future perspectives for Pakistani agricultural price policies in the light of regional and international policies, whereas Drs. Mushtaq and Bashir present the pros and cons of agricultural credit and agricultural cooperatives in Chapter 35 and suggest changes for traditional cooperatives—keeping in view the global economic situation. In Chapter 36, Dr. Ghafoor and colleagues suggest how different initiatives could improve the agricultural marketing system in Pakistan. In Chapter 37, Dr. Ahmad and colleagues, while examining the bilateral trade relations of Pakistan in the region, comment on the fact that value addition in agricultural products is the limiting factor of trade with other countries. In the last chapter, Dr. Khan and colleagues stress upon the need for increasing the production of value-added products through improved supply-chain management, production of innovative nutrient dense foods, and improved storage conditions.

Agriculture is an interdisciplinary endeavor; therefore, it is difficult to cover all aspects of this subject in a single book. The editors of this book are conscious of the fact that there is considerable scope for increasing agricultural productivity by incorporating modern technologies. This is only possible if the farmers have the means necessary and access to credit and free markets. The development of markets where farmers can sell their commodities will directly improve their lives. In this book, we have tried our best to provide a critical overview of the latest trends and future perspectives in agriculture. We hope this book will be a worthwhile resource of up-to-date information for different stakeholders, including policy makers. We also welcome your suggestions, which may help us improve the next edition.

Iqrar Ahmad Khan, PhD
Muhammad Sarwar Khan, PhD
Editors

**Iqrar Ahmad Khan** has had a long career in education and agriculture and earned his PhD from the University of California, Riverside. He is currently serving as vice chancellor of the University of Agriculture, Faisalabad, Pakistan (since 2008). Dr. Khan has supervised more than 100 graduate students and researchers. Dr. Khan has established a center of agricultural biotechnology and has co-founded a DAAD-sponsored “International Center for Decent Work and Development” (ICDD). He has also helped in establishing a USAID-funded Center of Advanced Studies in Agriculture and Food Security, as well as a French Learning Center and the Chinese Confucius Institute. He has organized numerous international conferences and established academic linkages across continents. Dr. Kahn has also released a potato variety (PARS-70), pioneered research on breeding seedless Kinnow, and discovered new botanical varieties of wheat. Dr. Khan has initiated an internationally acclaimed program to solve the devastating problem of Witches’ Broom Disease of lime in Oman. He is currently leading international projects to combat citrus greening disease and mango sudden death. He has published more than 270 articles, five books, and several book chapters.

Dr. Khan has the diplomatic skills to attract international partnerships and establish academic linkages in such countries as Afghanistan, Australia, South Korea, China, Germany, France, Malaysia, Indonesia, Turkey, Iran, India, Oman, Canada, the United Kingdom, and the United States. He has managed collaborative research projects sponsored by national and international agencies. Dr. Khan is a fellow of the Pakistan Academy of Sciences and a member of several professional societies and associations. He has been the recipient of a civil award, Sitara-e-Imtiaz, from the government of Pakistan in recognition for his outstanding contributions to the areas of agriculture and food security. Recently, he has also been awarded the *Ordre des Palmes Académiques* (with the grade of Officer) by the French government for his exceptional role as educator.

**Muhammad Sarwar Khan** has a vibrant career in agriculture, education, and biotechnology and has earned his PhD from the University of Cambridge, UK. The Rockefeller Foundation awarded him a prestigious fellowship under the Rice Biotechnology Program for Developing Countries to carry out research at the Waksman Institute of Microbiology, Rutgers, at the State University of New Jersey. His findings—a research of first-of-its-kind—was published in Nature Biotechnology. Dr. Khan was appointed as national coordinator to train “A” and “FSc” level students by holding training camps across Pakistan to compete for medals in the International Biology Olympiads. He served as the founding head of Biotech Interdisciplinary Division at NIBGE, and is currently serving as the director of the Center of Agricultural Biochemistry and Biotechnology (CABB), University of Agriculture, Faisalabad, Pakistan.

Dr. Khan has supervised more than 100 PhD candidates, MPhil students, and researchers who are now serving at national and international levels in various research institutes and universities. He has vastly published in high impact journals, including *Nature* and *Nature Biotechnology*, and is the author of a number of book chapters and books. Dr. Khan has made significant contributions in the field of agricultural biotechnology. He has developed transgenic sugarcane resistant to top borers and tolerant to herbicides, which was approved by the National Biosafety Committee (NBC) for field trials in 2006–2007. This was the first proposal of endogenously developed GM plants...
approved by the NBC in Pakistan. Dr. Khan has also pioneered plastid transformation in rice and sugarcane, recalcitrant plant species. He has also knocked out a number of genes from the chloroplast genome of higher plants to assign functions. His current research interests include development of edible-marker-carrying transgenics and cost-effective therapeutics and edible vaccines for animals. Dr. Khan has received prestigious awards, including the President’s Medal for Technology, a Gold Medal in Agriculture from the Pakistan Academy of Sciences, a Performance Gold Medal by NIBGE, the Biotechnologist of the Year Award by the National Commission of Biotechnology, and the Best University Teacher Award by the Higher Education Commission of Pakistan. He is also a fellow of the Cambridge Commonwealth society, the Cambridge Philosophical Society, the Rockefeller Foundation, the Pakistan Botanical Society, and the International Association for Plant Biotechnology.

In addition to contributing to innovations in the field of agricultural science, Dr. Khan has served in different senior positions of the Social Safety Net Program of the Government of Pakistan—supported by international donors, including the World Bank—to contribute towards poverty alleviation. During his service there, a number of social protection special initiatives were undertaken to help underprivileged people in Pakistan, especially women for their empowerment.
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# Planning for Sustainable Agriculture in Pakistan

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1.1 INTRODUCTION

Sustainable development refers to development which meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The report has left strong imprints on future development policies by considering development and environment inseparable, while focusing on intergenerational equity. The UN Millennium Summit in 2000 passed the following 8 Millennium Development Goals (MDGs), including target dates to achieve these:

1. To eradicate extreme poverty and hunger
2. To achieve universal primary education
3. To promote gender equality and empower women
4. To reduce child mortality
5. To improve maternal health
6. To combat HIV/AIDS, malaria, and other diseases
7. To ensure environmental sustainability
8. To develop a global partnership for development

Although all member countries at that time were committed to achieve the goals by 2015, there was mixed progress where some countries were able to achieve all the goals while others (including Pakistan) remained largely off-track.

In 2015, the United Nations adopted the 2030 agenda for sustainable development. As a responsible nation, we are committed to the UN Sustainable Development Goals (SDGs), once more. Of the 17 indicators/goals, at least 12 are directly dependent on sustainable agriculture and its outcome. The National Assembly of Pakistan has adopted the UN SDGs. The Planning Commission of Pakistan and the Provincial Planning and Development Departments are mandated to ensure that all development spending is targeted towards achieving the SDGs by 2030. Hence, agricultural planning and policy formulation must conform with the SDGs.

Achieving the SDGs means transition to higher productivity and strengthening of rural livelihood. This requires conservation of natural resources (the ecosystem) and building resilience towards climate change. Adoption of emerging technologies (biotechnology and site-specific precision agriculture) and decision-support systems offer new solutions to old problems. The desired transition to sustainable agriculture can only happen under a revamped policy and governance structure which can promote public and private investment in this sector.

Agriculture in Pakistan consists of a vast spread of crops, livestock, fisheries, rangelands, and forestry supported by irrigation network and markets. It ensures food security in the country and contributes 19.8% of the GDP, employs 44% of the workforce, and it provides a livelihood to 66% of the population (>5 million households). The industrial output in the country is dependent on the raw materials and consumption capacity of agriculture-led activities. Exports are also largely dependent on agriculture (65% agro-based).

Characteristically, agriculture in Pakistan is dominated by small farmers growing mainly five crops, and a large population (>70 million each of large and small ruminants) of underperforming livestock. The yields of crops and livestock heads are stagnant. Water scarcity has become evident. Despite stagnation, we have an excess of essential commodities and our farmers are losing money. Furthermore, the surplus of commodities has failed to provide nutritional security for the vulnerable, as a large segment of the population is suffering from nutritional deficiency. We have high costs of production, which makes us uncompetitive in export markets. Our current food imports are worth over $5.3 billion. Sustaining agricultural growth remains an important policy and governance challenge, which would, in turn, determine our ability to comply with the UN’s SDGs.

Overcoming stagnation requires continuous development and delivery of technology. Achieving economies of scale and value addition are the other options to make agriculture profitable. Among technologies GMOs, precision focused mechanization, and use of ICTs offer current solutions/
applications. The technology development requires long-term commitment (policy) and investment in agricultural research. We have a large infrastructure and diversified human resource competencies to undertake research challenges, provided we set our priorities right. It also requires international networking, linkages, and a liberal knowledge environment to promote critical thinking and enquiry.

The Federal Government announced a 341 billion Pakistan rupees package for the farmers in 2015 before the onset of Rabi season. This had yielded significant results. The Chief Minister of Punjab addressed the Punjab Agriculture Conference held on the 19th of March, 2016, and announced a 100 billion development package for the farming sector. He also declared the creation of an Agriculture Commission which he planned to chair himself. Lately, the World Bank has stepped in with a new $500 million project called SMART Agriculture (Strengthening Markets for Agriculture and Rural Transformation) in Punjab. There are many other provincial and federal programs for the promotion of agriculture in the country deserving critical analyses to promote sustainability.

There are several pertinent points to ponder including aggressive growth agenda, enhancement of rural economy, global trends in commodity prices, stagnant yields, coupling agricultural growth with research and technology transfer, increasing input use efficiency, market connectivity, backward and forward value chain linkages, land records management, and international linkages (Spielman et al., 2016). It could only happen with a strategic plan for sustainable land and water use.

The Punjab government’s agriculture commission created a policy committee, which launched a multipronged review and consultation process. A series of consultative meetings were organized at the farmer’s level as a bottom up exercise. This book includes contributions based on the messages gathered during this consultation process. Similar exercises are being carried out in the other provinces of Pakistan, led by the FAO. The FAO is also working with the provincial governments to redefine Agro Ecological Zones (AEZs).

While the world prepares to feed 9 billion people by 2050, we may be expected to feed twice the number of people we have today. The review and consultation exercise has revealed there is no shortage of information but a serious lack of implementation. An analysis of the Agriculture Commission report of Sartaj Aziz (1988) indicated that most of the proposals made then are still valid today but failed to produce results due to inconsistent implementation (GOP, 1988). Hence, it is high time we undertake a SWOT (strength, weakness, opportunity and threat) analysis of our agriculture sector and develop a strategic plan to guide public policy for sustainable agriculture. This book is an attempt to define a framework for sustainable agriculture and food systems. In addition to discussing natural resource and technology aspects, it also delves into the larger human development picture (poverty, gender, and malnutrition) in the country where the rural economy is being drained of skilled manpower and capital. There cannot be a sustainable agriculture without rural development.

### 1.1.1 Sustainable Agriculture

Agriculture has always evolved through complex interactions between weathering processes of geological material (upper surface of earth or soil, alluvial deposits, mixing organic matter), adaptations to climate, domestication of plants and animals, and anthropological phenomenon. Markets and technological revolutions have become driving forces, which include cultural factors. Intensive agriculture has its toll. The deteriorating soil conditions—as well as the environmental implications of technology and human expectations—demand we examine the challenges and forecast the sustainability of our current agricultural production systems.

The world economic community looks at sustainability as a challenge of global competitiveness which includes productivity of our agricultural and industrial outputs and markets. The global trade of agricultural produce directly affects the income of our farm households, hence their human development index. Our standing on various sustainability indictors is currently dismal (Table 1.1). High population growth and intensive farming has exerted tremendous pressure on land and other natural resources. Injudicious use of chemical fertilizers and pesticides/herbicides has aggravated the
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problem and has degraded land and aquifers. The sustainability of natural resources is essential to sustain agricultural activities. Foreseeing similar challenges, Rothamsted (https://www.rothamsted.ac.uk/long-term-experiments) was established in 1843 to investigate the sustainability of agricultural production systems. The long-term experiments conducted there have revealed trends and dangers associated with different agronomic systems of farming. Since then, more than 14 long-term research experiments have been conducted in other parts of the world (Table 1.2), but nothing in this subcontinent. We have been practicing cropping systems and patterns which are bound to decline, that is, wheat-cotton and wheat-rice. Another example is the potato/corn belt, where an extremely exhaustive cropping system is used, lacking a restoration process. Groundwater exploitation has a limit, which is being ignored. Overgrazing in the range lands have created space for intrusive growth.

| TABLE 1.1 |
| Important Indices for Pakistan Related to Sustainability |
| Index | Rank | Source and Data |
| Global innovation index | 113 | 127 countries data |
| Global competitiveness index | 122 | 138 countries surveyed (WEF, 2016) |
| Gender gap index | 143 | 144 countries surveyed (WEF, 2016) |
| Human capital index | 118 | 130 countries surveyed (WEF, 2016) |
| Human development index | 147 | 188 countries/territories surveyed (UNDP, 2015) |
| Enabling trade index | 122 | 136 countries surveyed (WEF, 2016) |
| Networked readiness index | 110 | 130 countries surveyed (WEF, 2016) |

| TABLE 1.2 |
| Long-Term Research Experiments (LTRE) in the World |
| LTRE Name | Year Started | Focus | Site/Location |
| Russel Ranch | 1990 | Wheat-tomato | UC Davis |
| The Morrow Plots | 1876 | Continuous corn cultivation | Urbana Campaign University of Illinois |
| Sanborn Field | 1888 | Rotation Field | Columbia University of Missouri Stillwater, Oklahoma State University |
| Magruder Plots | 1892 | Winter wheat | |
| Callars Rotation | 1911 | Cotton | Auburn University, Alabama |
| Permanent Topdressing Experiment | 1912 | Superphosphate | Rutherglen Center, Victoria, Australia |
| Crop Residue Management | 1931 | Crop residue management | Pendleton Oregon State University |
| LTR-KSU | 1961 | N, P, and K in irrigated continuous corn | Tribune Kansas State University |
| No Tillage Plots | 1962 | No tillage with corn Soybean Oats | Wooster Ohio State University |
| Belvin Long Term Tillage Trial | 1970 | No-tillage and moldboard plowing compared | University of Kentucky |
| INTA Experiment Station | 1975 | No-till soybean following wheat Corn-soybean-wheat-rotation with different cropping system | Marcos Jaures Argentina Michigan State University |
of weeds, leaving nothing to graze while long-term planning and experimentation are nonexistent. Lack of profitability is also a persistent threat to the sustainability of agriculture systems, forcing migration and brain drain from rural economies. The key to sustainable agriculture lies in focusing on productivity without letting the natural resources decline.

1.1.2 Global competitiveness and innovation

It is resolved that innovation is the key to achieving global competitiveness through enhancement of productivity and is a way forward to meeting the SDGs without compromising environmental integrity. At UAF, we wrote Vision 2030 in 2014 where opportunities in agriculture were described as our targets for 2030, a year before the SDGs of 2015 (Khan, 2014). In the year 2016, UAF launched the first innovation catalogue (Khan et al., 2016). Because, we knew that innovations have been the instruments of success during human history.

Innovations are at the heart of sustainable development. Humanity has progressed in overcoming hunger and premature death due to innovations in agriculture and other sectors (advancement in plows, irrigation, fertilizers, green revolution, cotton ginning, vaccines, mechanization, genomics, etc.). Fogel (2004) has developed a history map of innovations in agriculture followed by the industrial revolution (Figure 1.1).

Based upon the review of different indicators and relative positions, sustainable development is only possible in the presence of the right institutions and legal frameworks for incentivizing agricultural innovation through promotion of human capital (required skills, education), agricultural entrepreneurship, infrastructure (research, physical infrastructure), and a mechanism for diffusion of the agricultural innovations along the agricultural value chain. The policies to transform the agriculture sector into an innovation-driven sector (with reliance on smart technologies) can help achieve the goal of sustainable food production and distribution (for an ever-increasing population) and provide foreign exchange (to boost other sectors).

1.2 Agricultural issues and analysis

There can be many ways to look at sustainability challenges. We have undertaken a SWOT (Strength, Weakness, Opportunity and Threat) analysis to narrow down issues facing the sustainability and competitiveness of agriculture in the country. A seven-point agenda has emerged (Figure 1.2). Strategic planning and policy measures would emerge to guide the public decision-making process. At the end of the day, a framework for indigenous solutions through investment in research and development, skill development, and outreach is being envisaged.
1.2.1 Land and Water Productivity/Sustainability

1.2.1.1 Land and Water Use Policy

It is our major strength that the diversity of topographic features, land textures, climatic variations, technologies, and markets has created a range of agro-ecological divisions/zones. We are also endowed with human resources and indigenous knowledge suited for making agriculture a profitable business, which provides us an opportunity to grow a full range of commodities. The weakness includes subsistence-oriented farming practices, uneven distribution of ownership rights, and fragmentation, which all obstruct optimal land and water use. Land resources are also faced with degradation due to salinity, water logging, soil erosion, soil compaction, desertification, urbanization, and infrastructure projects (the threats) (Khan et al., 2011). High cropping intensity and use of unfit subsoil water are affecting soil health and organic matter content, and therefore sustainability of the system. At present, we have four persons per acre (50 million acres for >200 million people) to feed and clothe, which could increase to 8 per acre by the year 2050. Migration and urbanization have consequences for land use. While we do have more cultivable land, we do not have extra water to expand agricultural activity without reducing our current water use.

The productivity of agricultural lands can be enhanced by precise interventions at the micro zones and commodity clusters (at agro-ecological) level by introducing soil and water analysis and plant residue management. The climate change necessitates that we revisit our traditional definition of agro-ecological zones.

There is a need for schemes for wetlands, rainwater harvesting, flood canals, river dredging, river lakes/locks, canal water storage, on-farm storage, and ground water recharge wells. Restriction on groundwater pumping will have to be imposed, sooner or later. Irrigation water should be priced (according to depth of water table) and cultivation of low delta crops should be incentivized for
restricting area under rice and sugarcane. It is important to understand the crop share of irrigation water (Table 1.3).

While rice and sugarcane are high delta crops (not to be defended), we use more water for wheat and cotton due to large acreages. Any water savings from wheat and cotton would contribute more in quantities saved. Our average irrigated wheat acreage takes five irrigations per season. This could be reduced to three with better genetics and precision planning, which would translate into saving more water than the entire storage in Tarbela and Mangla dams put together. High Efficiency Irrigation Systems HEIS programs should be reviewed and rewritten after an independent monitoring of the sites developed during the past 5 years. In Punjab, the amount of wastewater disposed after treatment is only 22.11 million cubic feet per day out of 552.23 million cubic feet produced. The lack of watershed management strategies, deforestation, and erosion are sending excessive silt into the rivers, which are silting up our storage dams. The country should have land and water use policies to address these sustainability challenges.

1.2.1.2 Water Governance and Political Challenges

Pakistan’s agricultural growth is closely linked with availability of surface water. The surface water supply is stagnant/declining because of the inability to build new water reservoirs and the silting up of existing storage. Moreover, the industrial and municipality water demand is surging, thereby further cutting into the surface water available for the agriculture sector. This leaves the country with the only option to increase water productivity through the use of High Efficiency Irrigation Systems (HEIS), improved irrigation practices and to shift to low delta crops through diversification and promote the development of water efficient crop varieties. Additionally, canals and water courses should be lined, and water should be priced for its rational use. Currently, five crops are major consumers of water and there is an urgent need to rationalize water use during their production.

Due to the concentration of rainfall and glacial melt in river water during the summer months, Pakistan’s irrigated agriculture faces water shortages both in time and space. The water shortage is compensated by 50MAF pumped up from the groundwater to meet 104 MAF requirements at the farm gate (Table 1.4). Pakistan’s groundwater economy is currently under threat because of discharge rates consistently exceeding recharge rates, and due to climate change related rainfall frequency and intensity uncertainties. Groundwater extraction occurring in the Indian Punjab is also a cause of concern, which was not a factor at the time of signing of Indus Water Treaty.

Table 1.4 shows high water losses at all stages, right from the origin of river flow to the Arabian sea. In order to maintain sustainable use of water resources, losses should be minimized and net groundwater abstraction should be near to neutrality in the long run. One of the reasons for a chaotic water economy is the lack of volumetric pricing mechanism, absence of groundwater rights, and skewed entitlements. In absence of any legal rights, the fuel prices are mistaken as the balancing force for groundwater abstraction. The cheaper energy sources (solar, biogas) and fuel subsidies will further hurt the groundwater economy. Currently, there is lack of proper data about the aquifers and their boundaries. Aquifers should be mapped so that the confined and unconfined aquifers transcending administrative boundaries can be protected through legal rights and water policies.

### Table 1.3

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water Consumption (MAF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>39</td>
</tr>
<tr>
<td>Cotton</td>
<td>29</td>
</tr>
<tr>
<td>Rice</td>
<td>26</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>23</td>
</tr>
<tr>
<td>Maize</td>
<td>5</td>
</tr>
</tbody>
</table>
Developing Sustainable Agriculture in Pakistan

The irrigation system in the country was an outstanding gravity-driven design at the time of its creation, which was developed as a supply model, that is, “warabandi” arrangement. The canal water flows into the farm at fixed time slots per acre on a weekly basis without any need assessment and storage arrangements at the farm level (receiving end). The intensification of cropping systems further increased the demand for water. However, the corresponding investments in water storage (both at source and farm levels) were not made, resulting in groundwater overabstraction. The political realities led to the freezing of water charges and deregulation of groundwater abstraction. Water thefts and distorted allocations are common. There is a clear need to revisit water laws and regulatory mechanisms at the farm level (Cheema, 2012).

Water resource management is further complicated by unresolved transboundary issues with India (Indus Water Treaty) and emerging challenges (no treaty) from Afghanistan. Pakistan, being a lower riparian country, has disadvantages. There also are interprovincial water disputes on the provincial shares, storages and allowable flow in the Indus river down Koteri Barrage, the last diversion before draining (~35 MAF) in to the Arabian Sea. It is alarming to note that we have only a 30 days storage capacity against a 900 and 90 days capacity in the United States and India, respectively. Within provinces, there are significant disparities in irrigation water allocations between and within different canal divisions.

There is a case for developing water stewardship to be socially equitable, environmentally sustainable, and economically beneficial. There could be a value chain approach and/or a community/participatory approach. Water education can play a significant role in conservation and prevention of water pollution. Since the monsoon season is a narrow time bracket, rainwater harvesting is a low hanging fruit to prevent floods and to enhance water availability during droughts. Promotion of on farm storage and separation of rainwater flow from sewerage drains are important challenges. This analysis indicates that treating water is a central issue to sustainability and is a community challenge.

The water-energy-food nexus is strongly linked with climate change. Glacier melt contribute >70% of our freshwater supply. Accelerated melting of snow, due to global warming, may cause more floods and enhanced river flow in the near future as well as drying up of rivers in the coming decades.

**TABLE 1.4**
The Water Budget of the Indus Basin Irrigation System (Values in MAF)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Mean annual rivers flow</td>
<td>140</td>
</tr>
<tr>
<td>B. Flow to Arabian sea</td>
<td>27</td>
</tr>
<tr>
<td>C. River system losses</td>
<td>10</td>
</tr>
<tr>
<td>D. Canal losses</td>
<td>26</td>
</tr>
<tr>
<td>E. Water course losses</td>
<td>23</td>
</tr>
<tr>
<td>F. Water losses till farm gate (B + C + D + E)</td>
<td>49</td>
</tr>
<tr>
<td>G. Canal supplies at farm gate (A − F)</td>
<td>54</td>
</tr>
<tr>
<td>H. Groundwater contribution</td>
<td>50</td>
</tr>
<tr>
<td>I. Irrigation water at farm gate (G + H)</td>
<td>104</td>
</tr>
<tr>
<td>J. Field channel losses</td>
<td>10</td>
</tr>
<tr>
<td>K. Field application losses</td>
<td>24</td>
</tr>
<tr>
<td>L. Total field losses (J + K)</td>
<td>34</td>
</tr>
<tr>
<td>M. Irrigation water for consumptive use (I − L)</td>
<td>70</td>
</tr>
<tr>
<td>N. Rainfall contribution</td>
<td>13</td>
</tr>
<tr>
<td>O. Total water availability for crop consumptive use (M + J)</td>
<td>83</td>
</tr>
</tbody>
</table>

1.2.2 CLIMATE CHANGE

Climate change is a continuous process which has created our warm world since the ice ages. The process has been accelerated by man-made interventions. Revolutionary measures are needed to arrest/mitigate these trends and to adapt to the changes. Pakistan is situated in a region regarded as highly vulnerable to adverse impacts of climate change, and this calls for disaster preparedness. Erratic rains, floods, and melting of glaciers in the Himalayan ranges pose threat to our perennial supply of fresh water.

There should be a specific focus on developing monitoring techniques to detect the effects of climate change with an emphasis on productivity (crops, livestock, fishery, and forestry). A decision support mechanism must evolve through prediction models. Education and extension frameworks need to be revamped to disseminate knowledge to communities regarding adapting/mitigating impacts of climate change and preparedness for disaster management. There is a need and opportunity to develop genetics for heat, drought tolerance, and agronomic interventions. Wheat, cotton, and rural poultry should be our near future targets to prepare against the vagaries of climate change.

Small ruminants and camels are uniquely adapted to extreme weather conditions. Our cattle and buffalo breeds are pastoral animals, which are genetically robust and resilient to inclement weather. However, lack of systematic breeding programs has caused genetic deterioration of our milk animals, which deserves urgent attention. We are producing less milk from 70 million heads than 9 million heads in The United States.

The methane produced by livestock and poultry should be converted into valuable options of bioenergy and biofertilizers, while providing an opportunity to claim carbon credits. Puddled rice is a double jeopardy. It is water intensive (inefficient) while producing unwanted methane. The new rice production agronomy is emerging fast and combines direct sowing and AWD (alternate wet and drying) irrigation schemes. It will not only save water but also optimize the plant population, which is the major cause of low productivity of puddled rice.

Breeding efforts to develop heat tolerant germplasm of crops and exploitation of heat adapted animal genetics are making significant progress. Genetic engineering opportunities are also emerging fast. CRISPR/Cas9 is a current technology to edit/tailor the genomes for adaptations and for incorporation of superior characteristics.

An indigenous chicken breed has been developed with 30% less feather load, demonstrating has better heat adaptation as backyard poultry. The naked neck chicken, when crossed with feathered chickens, produces a progeny that has a middle phenotype. The breeding process has been further refined to develop a superior poultry strain for harsh rural environments.

Agro Ecological Zoning (AEZ) was carried out in the 1980s when most of the present day analytical tools and data were unavailable. Today, we have better access to software and data gathering devices (GIS). It is high time AEZs are redefined to develop decision support systems and to enable precision applications. This will also help the government in policy formulation and long-term strategic planning.

1.2.3 PRODUCTIVITY GAPS AND STAGNANT YIELDS

1.2.3.1 Productivity Gap in Crop Sector

Before the advent of settled agriculture, during the times of the hunter-gatherers, the optimum yield was based on the criteria of how much energy is collected per unit of energy consumed. However, with the shift to settled agriculture, the definition of yield became the ratio between number of grains sown and harvested, or as an input/output ratio. As settled agriculture faced land, water, and nutrient scarcity, the yield became defined in terms of spatial boundaries, plant genetic potential, agronomic practices, technology, nutrients, water, and climatic and other agro-ecological parameters.

The agriculture sector of Pakistan is facing severe stagnation in productivity and declining growth. The farmers are leaving their profession. Yield gaps for wheat, rice, maize, cotton, and
sugarcane between progressive growers and the national average stand at 43.5%, 45.6%, 58.55%, 30.85% and 61.6%, respectively. Similarly, there are enormous yield gaps when compared with other countries and regions of the world. Major reasons for this difference are unavailability of quality seed, inappropriate sowing (methods and time), weeds, lack of balanced fertilizers, partial mechanization, and excessive use of unfit irrigation water. There are many major pest and disease challenges currently restricting our output (Figure 1.3).

There are different methods to calculate yields depending on which definition of yield is under consideration, namely, theoretical yields, potential yields, water limited yields, attainable yields, and actual yields (FAO, 2015). The yield gaps can be further broken into research and science gaps when the national average yield is compared with research station and global average yields, respectively and extension gaps when actual yields are compared with progressive farmers’ yield (Iqbal and Ahmad, 2005).

However, these measures have different sets of data requirement and calculation of yield gaps is always a compromise between the level of analysis and the availability of data for yield and related inputs.

The stagnation is partly due to small farmer’s inability to invest and adopt technology. That means >60% of cultivated land is underperforming. Other reasons for stagnation are lack of updated technology and repeat market failures and imperfections. Weed control and plant protection measures provide another opportunity to enhance productivity and bridge the yield gaps. Conventional weed control methods have limited success and research is now moving towards herbicide resistant crop cultivars. An analysis of sugar beet yield in three U.S. states showed higher production with the introduction of Roundup Ready sugar beet cultivars (Figure 1.4). Herbicide tolerant and borer-resistant sugarcane lines have been developed at the Centre of Agricultural Biochemistry and Biotechnology (CABB), University of Agriculture, Faisalabad.

![Productivity gaps in agriculture.](image-url)

11 Planning for Sustainable Agriculture in Pakistan

Adoption of GMOs can combat biotic and abiotic stresses. Further, introduction of heat tolerance in cotton allowed late sowing (after wheat) and created a new cropping system/pattern.

1.2.3.2 Productivity Gap in Livestock

Our livestock wealth is massive in terms of numbers and very poor in terms of productivity. While we pride ourselves in our livestock breeds, we must recognize the lack of potential within the pastoral genetics which has evolved to spend energy on fetching water and grass. The milk and meat breeds bred for modern dairy and fattening operations are high converters of energy. A balance must be struck between retaining the native genetics while introducing high performing breeds.

About 51% of the dairying households owned 1–4 animals, 28% households owned 5–10 animals, 14% of dairying households had 11–50 animals, and 7% of the dairying farms in Pakistan had more than 50 animals (Table 1.5). As majority of the dairying households have very small herds and the scope for breed improvement and transfer of technology for productivity enhancements becomes difficult. Only large dairying households (herd sizes more than 50 animals) raising cattle and buffalo can afford to adopt advanced technologies and increase herd productivity. Again, in Pakistan most of such herd sizes are held by the pastoral and nomadic owners in Cholistan and other rangelands, which are highly unlikely to be converted into high yield animals.

The subsistence livestock farmers with small herd sizes face low yields and profitability due to poor breeds, lack of proper milk chain, seasonality in production due to heavy dependence on green fodder available only certain months (mainly Jan-April), seasonality in milk consumption (usage is normally low in winter months), lack of cold chain to use surplus milk and market in summer months, high cost of production, and relatively stagnant milk prices (Zia, 2009). An important emerging challenge is how to feed the livestock well. There is a clear case for a scientific management process for rangelands, development of fodder (silage and hey), and animal feed industries.

As such, there are two separate strategic issues to overcome stagnation, that is, to narrow the unachieved gap and to break the barriers in potentials. The narrowing of gap could be achieved by enablement and market incentives. That is a case of optimization of current input/technology uses and practices. The new potentials could be created through research and innovation. That includes investment in human resource, genetics, and precision tools.
Biotechnology, Environments, and Risk Perception

The adoption of biotechnology applications is very broad. The genetically engineered/modified crops (GM) are a scientifically appropriate tool. The global spread of GM crops is on the rise because of economic (higher yields and lower cost of production) and environmental (less pesticide and less fuel) advantages (Table 1.6). Globally, the biotech crops have shown enormous benefits as the cross-country data shows that there is 33%–77% reduction in use of insecticides in different countries, 37% increase in yield in India, and 470% increase in profit in China due to cultivation of Bt cotton.

The debate on its risk perceptions has been continuing and the world is divided. However, the empirical evidence shows that with the advent of biotechnology the related global environmental effects have been positive, as evidenced in the following 15 years data.

- 443 million kg less pesticide active ingredients used (9.1% reduction)
- 642 liters fuel used
- 17 billion kg reduction in greenhouse gas emission, equivalent to taking 8.6 million cars off the road
- 17.9% reduction in overall environmental impact

(Source: Brookes and Barfoot, 2012)

Moreover, meta-analysis of published studies based on primary data shows that cultivation of GM crops resulted in a 21.6% increase in yield and 68.2% increase in profitability (Figure 1.5). The pesticide cost decreased by 39.2% due to 36.9% reduction in pesticides use (Klumper and Qaim, 2014).

We have failed to fully exploit the opportunities offered by the GM crops. That is partly due to the dysfunctional regulatory framework. It is the combination of GM crops and precision in agriculture that can make our agriculture globally competitive. The future lies in investing in biotechnology development and applications (Malik, 2014).

1.3.1 FIVE CROPS AND DIVERSIFICATION

There exist more than 20 cropping patterns in the country as defined by the various agro-ecological zones (Figure 1.6). Yet, our agriculture is characterized by the dominance of five crops, that is, wheat, cotton, rice, maize, and sugarcane. Excepting maize, the other four have an element of promotion by the political economy. The subsistence mentality of the farmer is another big impediment. The small farmer is more concerned about food security and cares less for profitability. There is also a case of lack of technology (seed in particular), skill deficit, and market forces, which keep the farmers hooked to the five crops for which seed and skill are not limiting and which can sell easily. The diversity of our climate and land features is suited to expand the cropping mix through technology adoptions and incentives. We are a net importer of essential commodities, which could be otherwise grown successfully, that is, edible oilseed crops, pulses, high value vegetables, and spices. Soybean is a crop generally rotated with maize, which restores the soil (being a legume) and provides raw material for high value food and feed ingredients. We grow/overproduce maize but not soybean. We import soybean and its products while allowing soil degradation due to lack of crop rotation.

FIGURE 1.5 Average percentage differences between GM and non-GM crops are shown. Results refer to all GM crops, including herbicide-tolerant and insect-resistant traits. The number of observations varies by outcome variable: yield: 451; pesticide quantity: 121; pesticide cost: 193; total production cost: 115; farmer profit: 136. *** indicates statistical significance at the 1% level. (Klümper, W. and Qaim, M. 2014. PLOS ONE 9(11), e111629. https://doi.org/10.1371/journal.pone.0111629.)
Diversification can be accelerated by incentivizing minor crops with emphasis on fodder, vegetables, fruits, pulses, and oilseed crops. The maize acreage has increased beyond its existing demand. It is high time to promote maize consumption to improve the quality of food and to maintain its demand. Maize farmers should be incentivized to rotate with soybean.

Fruit orchards have remained an isolated activity for the few. A better marketing framework and a value addition pull are required to incentivize fruits farming. Again, there is a scarcity of certified planting material (nurseries), which must be addressed.

Fodder production has suffered or has been compromised due to lack of attention and competition with other crops, while the livestock population has continued to grow. As a result, we have underfed animals which is the major cause of their low productivity. We have a success story in the poultry feed industry which has not been replicated for the ruminants.

The declining farm size is directly affecting the farmer’s ability to adopt technology or to achieve an economic threshold required for optimum yields, and thus reduces their ability to accept newer options of diversification. The land holding in Pakistan is characterized on one end by a majority of marginal landholders who own farms less than 5 acres in size (64.7% of total farms comprise only 20% of the agricultural land in the country), and on the other end by a small number of very large farms of more than 150 acres (0.2% of the farms covering 13% of the area). High population growth (almost unaffected by land reforms efforts) has changed the land ownership structure over time. The change of land distribution structure offers interesting information for development planning. Although the proportion of large farms among all farms (bigger than 50 acres) was 3.8% in 1960 and 1.2% in 2010, this class continues to accommodate a disproportionately large share of farm area of 27.5% and 24% in 1960 and 2010, respectively. On the other hand the proportion and area of small farms has increased from 19% and 3%, respectively in 1960 to 64.7% and 20%, respectively in 2010. The proportion of farms of small and medium size (i.e., 5–12.5 acres and 12.5–25 acres) has
also decreased. The average farm size of marginal and small category was 2.2 acres and 7.7 acres in 1990 and 2010, respectively. The fragmentation of land is continuing to drag down farm sizes to uneconomic levels. The disproportionally high number of farms of less than 5 acres poses a serious challenge for sustainability (Table 1.7).

This variation in land ownership structure demands provision of different packages of technological intervention for different clients. There is a need to develop hi-tech machinery models to cater to the needs of different land classes. Similarly, the value chain and marketing system needs to be modeled according to the adaptation capacity of different farming classes. Any policy ignoring this important aspect of farming will not be feasible, both economically and politically.

An important indicator for choosing a crop should be its global/regional competitiveness in terms of cost of production and productivity. Our costs of major crops are high and productivity is low. Obviously, diversification has a future and requires a multipronged strategy of delivering competitive technology packages to ensure fair returns through marketing incentives.

### 1.3.2 Postharvest Losses and Agricultural Marketing

Globally, food losses and waste accounts for one third of the total food produced for human consumption (FAO, 2011). Food loss is defined as “decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption,” whereas “food waste” refers to discarding food that is appropriate for human consumption, and “food wastage” as food lost by waste or by deterioration (FAO, 2013). Food wastage has food security and climate change implication and avoiding it can help meet food requirements and reduce the food related carbon footprint. By this definition, if food wastage is considered as a country then it stands at 3rd position in terms of total greenhouse gas (GHG) emissions excluding “land use” change related emissions. Avoidance of food wastage also has significant implications for blue water footprint and biodiversity. In developed countries, there are more losses downstream of the supply chain (i.e., consumption and distribution level) while the developing countries incur more losses during upstream phases (i.e., production, postharvesting). The losses also depend on the commodity under consideration and the cultural and technological context (FAO, 2011). Depending on the crop—and different stages along the value chain, there are variations in losses. Ultimately, the losses at all levels (Table 1.8) drain the competitiveness and profitability of the agriculture sector.

Conservative estimates indicate 16% losses in grains during harvesting and storage due to lack of drying and proper storage structures. The horticultural commodities suffer losses because of faulty harvesting practices and due to lack of cold chains. The bulky nature of fruits and vegetables and

### TABLE 1.7

**Agricultural Land Distribution**

<table>
<thead>
<tr>
<th>Category</th>
<th>Operational Holding (acres)</th>
<th>1960</th>
<th>1990</th>
<th>2010</th>
<th>Farm Area Out of Total Area (%)</th>
<th>1960</th>
<th>1990</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal</td>
<td>&lt;5</td>
<td>19</td>
<td>47.5</td>
<td>64.7</td>
<td></td>
<td>3.0</td>
<td>11.3</td>
<td>20</td>
</tr>
<tr>
<td>Small</td>
<td>5–&lt;12.5</td>
<td>44.3</td>
<td>33.4</td>
<td>24.8</td>
<td></td>
<td>23.6</td>
<td>27.5</td>
<td>26</td>
</tr>
<tr>
<td>Medium</td>
<td>12.5–&lt;25</td>
<td>23.8</td>
<td>12.2</td>
<td>6.8</td>
<td></td>
<td>27.0</td>
<td>21.5</td>
<td>18</td>
</tr>
<tr>
<td>Large</td>
<td>25–&lt;50</td>
<td>9.0</td>
<td>4.7</td>
<td>2.6</td>
<td></td>
<td>19.0</td>
<td>15.8</td>
<td>13</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt;50</td>
<td>3.8</td>
<td>1.8</td>
<td>1.2</td>
<td></td>
<td>27.5</td>
<td>24.0</td>
<td>24</td>
</tr>
</tbody>
</table>

Source: Agriculture Census (1960, 1990, 2010).
glut during harvest seasons requires cold storage and processing to avoid losses due to short shelf life. The losses of fresh produce can vary from 25% to 90%, with an average accepted losses of 40%. There are no technological solutions to increase the production of grains by 16% and fresh produce by 40% in a year; however, the prevention/reduction of such losses by investment in postharvest technology, infrastructure, or value addition through processing are possible.

The dairy and meat industries are also victims of market imperfections. The short life of milk and lack of processing facilities are further aggravated due to a very large spread of milk animals across the rural landscape (Riaz, 2008). About 70 million milk animals are owned by small farmers and collection of milk is an insurmountable task. As a result, malpractices are rife to enhance the shelf life of milk. The story of meat marketing is equally complex and its practices obsolete (Jalil et al., 2013). The traditional butchers dominate the meat supply and the need for modern abattoirs and processing plants is evident. The cattle marketing system is full of exploitation. Recently, the Punjab Government has taken a bold step to revamp cattle marketing, the effect of which needs to be watched.

The public procurement of wheat is an important measure, which keeps balance in favor of a plentiful supply of staple food. The economic rational of this intervention is questionable. We offer a support price, which is higher than the international price, but we lack storage facilities resulting in huge losses and quality deterioration of the grain. The market situation is further compounded by the fact that Indian farmers are heavily subsidized and 28 of their commodities are offered support prices. That creates unhealthy competition in the regional trade, which works against the interest of our farmers. The strategic question of support price and public procurement remains a politically sensitive issue. While it is ideal to let the market forces work, it is equally important for the government to ensure that market distortions are not against the farmer and consumer. The markets must be transparent, competitive, and convenient before one expects the market forces to determine the flow of commodities fairly.

The biggest cause of marketing disadvantage to the farmer is his inability to hold the commodity, generally because of lack of storage or because of seasonal debts. Warehousing, trading platforms, and future markets offer some solutions. Other options include investing into value addition along the value chains. This proposition has a unique requirement for every given commodity. The cluster approach can work to support the farmers during the production cycle followed by warehousing/storage and marketing. Heavy losses of produce also occur due to poor transportation, inadequate grading, very heavy spread in price between consumer and farmer, and tough competition with imported goods. The Punjab Government’s rural roads program and revamped cattle markets are good examples of corrective measures.

### TABLE 1.8
The Food Losses along the Value Chain

<table>
<thead>
<tr>
<th>Value Chain Stages</th>
<th>Production</th>
<th>Postproduction</th>
<th>Processing</th>
<th>Distribution</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Preharvest</td>
<td>Handling</td>
<td>Canning</td>
<td>Retail</td>
<td>Preparation</td>
</tr>
<tr>
<td>Breeding</td>
<td>Harvest</td>
<td>Storage</td>
<td>Packaging</td>
<td>Transport</td>
<td>Table</td>
</tr>
<tr>
<td>Damage/spillage</td>
<td>Breeding</td>
<td>Transport</td>
<td>Transformation</td>
<td>Discard</td>
<td>Discard</td>
</tr>
<tr>
<td>Left behind in fields</td>
<td>Left behind in fields</td>
<td>Degradation</td>
<td>Bargain</td>
<td>Degradation</td>
<td>Discard</td>
</tr>
<tr>
<td>Pests/diseases</td>
<td></td>
<td>Degradation</td>
<td>Discard</td>
<td>Discard</td>
<td>Excess preparation</td>
</tr>
<tr>
<td>Weather</td>
<td></td>
<td>Premature animal death</td>
<td>Spillage</td>
<td>Spillage</td>
<td>Spoilage</td>
</tr>
<tr>
<td>Wrong inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Our lack of competitiveness in the international market is our biggest challenge, due in part to the high costs of production and because of our inability to meet compliance requirements. An increase in our competitiveness would also require narrowing of yield gaps, that is, productivity enhancement. Our regional trade has three major (India, Iran, and China) and several adjoining partners. The current value of trade with India is estimated at $3 billion. The trade with Iran, China and regions along the China-Pakistan Economic Corridor (CPEC) connected by a “one road one belt” has a brighter future. We have to prepare the system to be able to respond to the emerging market access in the near future. This could mean developing new products and skills. Grades, standards, traceability, and SPSS requirements along with international trade barriers (tariff and nontariff) need to be understood as WTO requirements.

Only a small percentage of produce is processed. Food fortification and food safety is also made difficult in part due to the small and informal nature of food processing and distribution. These issues require a deeper understanding of the dynamics of overall food systems, and associated regulatory lapses. Processing and wholesale firms (private or cooperative) could be encouraged to use contracts to directly produce safe and nutritious food supplies. These could support small farmers, kitchen gardening, and small-scale vegetable farming at times.

1.3.3 Social Disparity, Poverty, and Gender Mainstreaming

There are four indicators of global gender gap index: economic participation and opportunity, educational attainment, health and survival, and political empowerment. Pakistan ranks second last in a list of 144 surveyed countries. This relative position shows a dismal situation compared with other countries since 2006, a significant decline over the past 10 years (Table 1.9). In Pakistan, rural women are the largest group at a disadvantage.

Agricultural growth reduces poverty on a much larger scale than growth in other segments of the economy, as studies have shown (Johnston and Mellor, 1961). The growth in agriculture cascades through the economic activity of rural industries and businesses, in turn providing jobs closer to home (suited for women), halting migration from rural areas, and improving livelihoods on a larger scale.

The contribution of rural women to this economy largely goes unacknowledged. Farm household income is usually a mix of on- and off farm engagements. The migration from rural to urban centers has been a continuous process, which has led to the erosion of skills and a transfer of resources from rural to urban areas. The partial migration of family members has benefitted agriculture by allowing some resource transfer back to farming at critical times of the year. Overseas migration from rural areas is an additional debate. The critical issue is how to retain a healthy and skilled workforce in the farming sector while promoting investment available from the income of off farm employment.

Infrastructure and services in rural areas are grossly insufficient and substantial improvements are needed. These include physical infrastructure, education, health facilities, safe drinking water, and sanitation. Above all, the deterioration of social institutions and the disappearance of conflict resolution mechanisms promote out-migration.

The women’s contribution to agriculture has been estimated at 43%–80%, a labor force unrecognized and underpaid. In crops like cotton and rice, women contribute directly in the field operations. In family farms, they take part in the whole value chain. The small landless livestock holders involve women in the daily rotes. The critical role of gender equality and women empowerment in agriculture is an integral part of ensuring food security and improved nutrition.

In Pakistan, gender roles differ across the provinces and regions, but generally the traditional role of women is that of caretaker, with the major responsibility of tending to the families’ domestic needs, including cooking. Along with domestic activities, rural women also play an important role in routine agricultural activities including cleaning seed, cultivating land, harvesting crops, and tending to livestock. Despite their participation in the labor force, women are far less likely to own income-generating assets such as land and livestock or to have a say in household economic decisions.
Studies on Pakistan show that women spend more efficiently on food consumption, families eat more nongrain food items and consume better calories from fruits and vegetables when women have a decision-making power in households.

Despite significant economic growth and potential poverty reduction, many people in Pakistan still do not have economic access to adequate food. The Benazir Income Support Program (BISP) is the largest social protection program with 5.3 million beneficiaries, and it is expanding. BISP has been successful in constructing a National Socioeconomic Registry and a Poverty Scorecard for targeting those in need, and has been a significant step towards achieving the SDGs of eradicating extreme poverty, zero hunger, and the empowerment of women. The BISP in its present framework can work in the shorter term and must evolve into a social protection system.

The youth in rural Pakistan are desperate. Education and skill development opportunities have failed to materialize there. Agriculture there is not envisioned as a career. Rapid urbanization attracts the migrating youth in a search for better future. This also accentuates the erosion of residual skills from rural regions and produces a constant resource transfer to the urban centers. There is a need to provide them with skills and hope by promoting alternate income generation options and entrepreneurship. This can only happen within the broader framework of rural development as a simultaneous process with agricultural growth.

### 1.3.4 Malnutrition

Micronutrient deficiency, known as hidden hunger, is widespread in Pakistan and well characterized among rural areas. The National Nutrition Survey (GOP, 2011) revealed that 43.7% of children are stunted while 15.1% are wasted and 31.5% are underweight. The survey data showed that stunting and wasting in 2011 had increased over the past decade. These problems are higher in rural areas and periurban slums compared to urban centers. Suffering is higher among women and children, that is, anemia (61.9%), iron deficiency (43.8%), zinc deficiency (39.2%), vitamin A deficiency (54%), and vitamin D insufficiency (40%). This situation demands nutritional interventions to combat the threat of hidden hunger. There is a need to launch a School Nutrition Program. The domestic food...
consumption trend is shifting (positively) from cereal consumption to high-value commodities (Figure 1.7). These trends have implications for agricultural planning and policy.

1.3.4.1 Global Food Security
The global food security index covers food affordability, availability, quality, and safety. The index was calculated for 113 countries based on regional diversity, economic importance, population size (to ensure the inclusion of the maximum number of people in the sample). The index results reflect the poor performance of South Asian countries including Pakistan. The results of selected South Asian countries in the calculation of the Global Food Security Index for year 2016 are as in Table 1.10.

1.3.4.2 Global Hunger Index (GHI)
Global Hunger Index (GHI) and Global Food Security index are well known measures related to food security on a global scale. GHI combines undernourishment (proportion of undernourished population), child wasting (proportion of children under 5 who suffer from wasting, i.e., below normal weight to height reflecting undernutrition), child stunting (proportion of children suffering from stunting i.e., low height compared to their age), and child mortality (mortality rate of children below age of 5 reflecting inadequate nutrition and unhealthy conditions). The results of GHI show Pakistan’s dismal situation as it is ranked at the 107th position and has made poor progress compared to other selected South Asian countries in the survey. The data of South Asian countries included in the survey of GHI calculations out of the surveyed 118 countries for 1992 and 2016 are as in Table 1.11.

TABLE 1.10
Food Security Index of Selected South Asian Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Rank</th>
<th>Overall Score</th>
<th>Affordability</th>
<th>Availability</th>
<th>Quality and Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>95</td>
<td>36.8</td>
<td>28.9</td>
<td>46.5</td>
<td>29.7</td>
</tr>
<tr>
<td>India</td>
<td>75</td>
<td>49.4</td>
<td>42.0</td>
<td>57.1</td>
<td>46.7</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>65</td>
<td>54.8</td>
<td>51.9</td>
<td>60.1</td>
<td>47.4</td>
</tr>
<tr>
<td>Nepal</td>
<td>82</td>
<td>42.9</td>
<td>36.4</td>
<td>47.0</td>
<td>47.9</td>
</tr>
<tr>
<td>Pakistan</td>
<td>78</td>
<td>47.8</td>
<td>46.3</td>
<td>50.4</td>
<td>44.5</td>
</tr>
</tbody>
</table>

Developing Sustainable Agriculture in Pakistan

The national nutrition survey (GOP, 2011) also revealed poor maternal knowledge about micronutrients. Nutrition education and behavior change initiatives are needed. Families, schools, community leaders, and other stakeholders need to be involved. Avenues for diffusion include social interactive frameworks, such as self-help groups, informal gatherings, and associated activities facilitated by the government and nongovernmental sector. Adolescence is the stage when lifelong nutrition patterns are formed. Viewing this from a life cycle approach to nutrition, it is essential to provide adolescent girls with nutrition education. The horizontal integration of nutrition programs, supported by community mobilization, is suggested to ensure that all marginalized segments of the population are reached. The creation of dedicated nutrition positions in outreach programs and the hiring of qualified nutrition experts in schools are essential. To achieve this, long-term human resource development initiatives are needed, that is, college/university education in nutrition and dietetics as a compliment to public health initiatives.

Our agricultural development scenario of food security needs attention since we are surplus in producing major food commodities (wheat, rice, sugarcane), yet more than half of the population is nutrient deficient. There are two important issues, which are (1) the lack of diversity in diets, and (2) the price/affordability for the consumer. The inclusion of vitamin- and mineral-rich produce and dairy products is needed. The cost of production has to be reduced and market distortions minimized to make these diverse foods affordable. The UN SDG “Zero Hunger” is a complex target which requires a multipronged strategy combining agricultural productivity with access to a full package of nutrition.

### TABLE 1.11
Global Hunger Index of Selected South Asian Countries for 1992/2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Rank</th>
<th>GHI Score 1992</th>
<th>GHI Score 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sri Lanka</td>
<td>84</td>
<td>31.8</td>
<td>25.5</td>
</tr>
<tr>
<td>Nepal</td>
<td>72</td>
<td>43.1</td>
<td>21.9</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>90</td>
<td>52.4</td>
<td>27.1</td>
</tr>
<tr>
<td>India</td>
<td>97</td>
<td>46.4</td>
<td>28.5</td>
</tr>
<tr>
<td>Pakistan</td>
<td>107</td>
<td>43.4</td>
<td>33.4</td>
</tr>
</tbody>
</table>


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### 1.4 STRATEGIC VISION AND OBJECTIVES

Governments in developing countries prefer policies to appease urban consumers: like overvalued exchange rates discouraging agricultural exports; low domestic prices for agricultural commodities; indirect and implicit taxation; poor financial services and credit for agriculture; and low public investments in rural physical and human capital. This urban biased macroeconomic twist has resulted in an underdeveloped and slow growing agriculture sector. A policy shift is needed to make agriculture competitive, profitable, and sustainable through enablement, efficiency, and value addition for food/nutrition security and socioeconomic development. We have to reform the agriculture sector into a profitable industry by promoting investments in infrastructure, research, outreach, skills, value chains, agroindustry, and rural development. The productivity gap could be narrowed by focusing on land being cultivated by small farmers. The application of ICTs should become integral to the value chain management (Smart Agriculture). The distortion of the terms of trade against agriculture and the rural economy must be stopped. The agriculture-led growth of the economy shall bring prosperity for the masses.
1.4.1 Technology/Precision

- To ensure sustainable use of natural resources (land, water, and air)
- To increase productivity through delivery of quality inputs, credit, and services
- To minimize harvest and postharvest losses from farm to fork
- To promote nontraditional farming segments, practices, and crops/livestock.

1.4.2 Institutional Reforms

- To strengthen the regulatory framework and enabling legislations
- To ensure sustained investment in research/knowledge systems and outreach
- To promote productive employment of rural women and youth through skill development and off farm activities by promoting rural development and alternate incomes.

1.4.3 Infrastructure

- To revamp/invest in marketing systems in order to make them transparent, just, and equitable
- To accelerate interprovincial and regional/CPEC integration of the agriculture sector.

1.5 Short-Term Strategies

Priority 1: The low hanging fruit is to narrow the yield gap between the average and progressive farms. This will require working with the small landholders for the timely provision of inputs, services, and credit along with guaranteed irrigation. The costs of production must be constrained initially by input subsidies and followed by productivity enhancement. The farmer will also respond to the market signals, that is, support price and public procurement initiatives. The current yield gaps and stagnation must be treated separately. The yield gaps can be addressed by the delivery/adoption of available technology while the current stagnation cannot be broken without investment in research to develop new precision tools as well as biological and genetic interventions. Reducing the yield gap by a half is an achievable target for wheat, rice, and cotton by simply optimizing plant populations, enough to accelerate the GDP growth to >4%. This will spare about 2 million Ha of land for crop diversification in Punjab alone. This would require quality seed and precision drilling equipment. The seed industry is currently a victim of incompetent laws and a poor regulatory framework. The breeders have developed a range of varieties which have failed to benefit the farmer due to the faulty seed value chain. It is a distant dream to replace traditional varieties of fruit trees like mango, citrus, and dates due to the lack of a nursery certification system in the country. But, the seed industry would be an easy option to put right. We cannot replace the low yielding livestock in the short term, but we can add high performing cattle to our inventory. Fodder production, silage-making, and markets must be developed to ensure enough animal feed and fodder. We have sufficient mechanical power in the form of tractors but very little as tractor-mounted equipment.

Priority 2: Crop diversification is a challenge. The complication arises from the political economy of food security. We can broaden our choices by focusing on two crops, that is, wheat for food security and cotton for cash. The productivity enhancement of two crops can easily spare land for oil seeds, edible legumes, soybean, fodder, vegetables, coarse grains, and orchards. There are good reasons to deemphasize rice and sugarcane due to water costs to the public. The fifth crop, corn, in its present rotation system is also unsustainable. It must be rotated with a legume, preferably soybean for sustainability. The farmer’s uptake of new crops will depend on market signals or a public procurement policy. The government has to offer guaranteed minimum returns for alternate crops. The diversification can also be promoted by crop zoning based on agro-ecological or agro-economic advantages and offering incentives for commodities/products most suited to the zone. A part of the wheat procurement budget should be diverted to minor crops. An alternative to support
price/public procurement and subsidies lies in increasing efficiency and precision to reduce the unit cost of production. Livestock breeding and health initiatives must be made into commercially viable propositions to attract the private sector into the business of service providers.

**Priority 3:** Climate change has provoked new challenges to sustain agricultural productivity. There has to be an elaborate plan to mitigate and adapt to these. The immediate option is to redefine crop zones on the basis of long-term climate trends, soil and water analyses, available technologies, available skills, and current markets and industrial demands. The country could be divided into more than 30 different crop zones and subzones, which would allow a precise decision mechanism for technology transfer and incentive packages.

**Priority 4:** There should be an emergency plan to curtail postharvest losses by half. This will require an investment in the training programs promoting value addition through product development and for market preparations along the value chain. Home science groups should be incorporated in rural development and extension programs. Investments are also required for transportation and storage infrastructures. The marketing system needs a long-term improvement plan for new markets, legislation, and governance reforms. The Punjab rural roads program must be amplified and the example of cattle markets should be replicated to create a new structure of grain and produce markets. CPEC routes should be marked for the establishment of new agro-processing zones and markets for exports to regional markets. The French government has introduced a new law to mandate the distribution of unsold produce and food at the retail level and in the restaurants for the needy; otherwise, it requires the return of such items to farmers for use as bioenergy or organic matter in soil.

### 1.6 LONG TERM STRATEGIES

If implemented, the short-term strategies can raise the agriculture sector growth above 4% for the near future. However, for long-term sustainability of the system, as well as agricultural growth and poverty alleviation, the following sections detail the proposed areas of public policy interventions.

#### 1.6.1 FOOD SECURITY, NUTRITION, AND HUNGER

The food security paradigm must shift from a supply side excess of staple items to an integrated nutritional package where diversified dietary needs are met (zero hunger of SDGs). Food safety issues like pesticide and antibiotic residues in food, mycotoxins, and malpractices associated with food handling must be addressed. All food secure countries in the world have less emphasis on wheat and rice and more on corn, potato, soybean, vegetables, fruits, dates, dairy, and poultry. We need to work on diversification of food supply and consumer habits.

It is pertinent to include food and nutrition subjects in school curricula, coupled with media awareness campaigns and counseling. Legislation for mandatory wheat flour fortification with iron should be introduced/implemented. Breeding programs for genetic fortification of food crops for nutritional enrichment and fertilizer use efficiency are long-term solutions. The greater good could only come from a social and behavioral change towards food through participatory actions. Rural poverty alleviation programs must be focused on the landless and women’s enterprises.

#### 1.6.2 LEGAL FRAMEWORK AND INSTITUTIONAL REFORMS

Performance of agriculture is linked with the performance of many public and private sector institutions. This requires legislative and administrative measures, political will, and social movements. There are federal and provincial legal frameworks. With the 18th amendment of Pakistan’s constitution, much confusion has arisen which have diminished the role of already underperforming federal institutions. The Irrigation Act, Seed Act, the Plant Breeders Act, the Pesticide Act, the Fertilizer Order, the Cooperatives Act, the Market Act, the Food Act, National Biosafety Committee, and so on are obsolete instruments. The Punjab Government has an Agriculture Commission, which has embarked upon the review of laws and policies impacting...
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agriculture. Similar actions are required to be taken on by the other provincial governments. The Council of Common Interest (CCI) should have an agenda to provide a fresh look at federal laws and policies affecting agriculture and rural development. The CCI could also ask for uniformity among the provinces and all federating units.

1.6.3 Research System and Budgets

The national agricultural research system (NARS) and international agricultural research system (IARS) must compliment each other for a better agriculture (crops, livestock, irrigation, forest, and fisheries). Unfortunately, our NARS is underperforming, full of overlaps, and segmented (research, education, and extension). There are federal institutions, provincial institutions, and universities that have huge investment and strengths. The outcome has been very impressive over a long period of time, however, the current stagnation reflects serious recent malfunctions. There are institutions that have lost their relevance after 18th amendment which include the Pakistan Forest College in Peshawar, the FSC&RD, and to some extent the PARC. Mechanisms are needed for funding research well above the current level of 0.18% of agricultural share in the GDP. Autonomous commodity boards are an option to levy a research tax on value-added agricultural products.

A worldwide recognized system of integrated research, teaching, and extension is that of the United States, called as land grant colleges. It is a tripartite arrangement created through a series of enactments by the U.S. congress (Figure 1.8). However, we have not following this model and have kept research, education, and extension in different domains without any practicable mechanism for integrated effort for agricultural growth. This needs to be aligned to successful land grants college models to improve the efficiency of our public agriculture services.

We also need to create mechanisms to prioritize agricultural research and introduce funding of commissioned research programs. The research should be internationally compatible (scholarship) on the one end, and farmer focused on the other end, with innovations a high priority. At present, investment in commissioned research in the following priority areas is considered essential:

a. Seed production and technology
b. Development of stress-tolerant germplasm for crops and livestock genetics
c. Promotion of new and nontraditional crops
d. Special programs on dates, rangelands, and orchards

FIGURE 1.8 The structure of land grant university: A success model.
e. Pest management strategies for fruit flies, ticks, pink boll worm, white fly, and vector borne diseases  
f. Control of tree dieback (mango and sheeshamin in particular) and citrus greening  
g. Ensuring and improving the health and nutritional value of food  
h. Mechanization of farm operations (land development to postharvest) including technological adaptation to the Pakistan farm setting and precision farming  
i. Increasing viability of horticulture enterprises through zoning and cool chains owned by the marketing cooperatives  
j. Use of Information and Communication Technology (ICT) in the transfer of agriculture and food systems knowledge and technology (Smart Agriculture)  
k. Policy research and commodity analyses as a regular feature.

1.6.4 Fiscal Policy

The taxation of the agricultural sector and the overall growth rate of the economy are strongly correlated (Krueger et al., 1988; Schiff and Valdés, 1992). The economic growth of a country is strongly linked with growth in its agriculture sector (Johnston and Mellor, 1961) as its growth generates a large multiplier effect (Block and Timmer, 1994). Despite empirical evidence, the agriculture sector has remained subject to heavy taxes (implicit). It is assumed that the agricultural exports earn high profits due to country quota and should be taxed. An explanation for agricultural taxation is given by the fact that the sector is not making proportionate contributions in tax revenue compared to its share in national GDP. Such arguments fail to consider the fact that the agricultural sector provides raw materials and markets which helps the growth of other sectors. Some of the key devices proposed for agriculture taxation include selective commodities taxation, export quota taxation, agricultural income tax, and general sales tax on inputs. It is important to compute all implicit taxes if the goal of the government is to generate tax revenues from agriculture sector, which are commensurate to its share in the GDP. The selective commodity taxation cannot be recommended as it alters resource allocation (the taxed commodity gives incentive to shift to a different commodity). The risk of intersectoral resource allocation can make matters worse for an already dwindling agriculture sector.

Fiscal policies and taxation regimes are important determinants of regional trade and commerce. With the passage of time, support prices of various commodities have been withdrawn except for wheat. Higher general sales tax rates on fertilizer and petroleum products and other taxes on inputs contribute to the escalating costs of production. In order to improve the profitability of various commodities, there is a need to move back to the support price system (selectively) and the provision of inputs at subsidized rates (targeted). The ultimate aim should be progressive liberalization and deregulation to let the market forces work. A rational fiscal policy proposition would be to first provide enabling conditions for agriculture growth and then impose taxes once it progresses at a decent pace.

1.6.5 Credit and Cooperatives

Agriculture is a business and every business requires investment. The farmer is always cash strapped and at the mercy of “rent seekers.” He needs credit. Looking at agriculture’s share in GDP and corresponding formal credit availability, it is evident that there is a situation of huge underinvestment. The rural areas remain deprived of vast coverage of financial services mainly due to remoteness, high transaction costs, lack of traditional collateral, low literacy to understand procedures, and perverted instruments. The issue is aggravated due to inflexibility on the part of lending agencies. The formal credit services can be made sustainable in rural areas through innovative policies to screen reliable borrowers, monitoring techniques for effective use of loans, and erecting a regulatory environment to encourage sustainable rural financial services (Norton, 2004).
The formal/institutional credit for agriculture is an insignificant component in the entire investment portfolio of agriculture. The vacuum created by the lack of a formal financial stream is being filled by the nonformal sector at exorbitant costs to the farmer. Cooperatives used to play a significant role in the supply of credit and services. In Punjab, there are 136 branches of the Punjab Cooperative Bank, which is dysfunctional. We need to create Marketing and Services Cooperatives (default corporatization) to revive the supply of credit through these branches. This will require market reforms, investment in the improvement of supply chains, promotion of clusters, and enablement for value addition. Revival of cooperatives can boost the productivity of small farmers in many ways. The development of CPEC offers an opportunity of SEZs (Special Economic Zones), which could be agro-focused centers for value addition. This can support credit for entrepreneurship, SMEs, and local employment opportunities. A credit task force of composed of bankers should be constituted to look after these needs.

1.6.6 Input Supply

Seed, fertilizer, agrochemicals, and energy/machinery are the major inputs. The farmers who can better manage these elements are called progressive and can usually harvest optimal yields. The progressive farmers are not necessarily the large owners. They can be landless contractors or small farmers. Generally, large farming operations end up with a better mix of input supplies, and hence produce better yields. The state has a role to play in ensuring timely supply and accessibility of inputs (unadulterated) to the farmers regardless of their ability to pay up front. Now, with ICTs becoming easily accessible, the state must enable the farmer with a “decision support strategy.” Use of ICTs for research and development, dissemination of knowledge, and crop/commodity advisories must be fully capitalized. Credit delivery and monitoring should be linked with the ICT services. Precision agriculture has emerged as a tool for efficiency. The ICT strengths in Punjab are enough to take advantage of precision agriculture technologies (Figure 1.9).

1.6.7 Service Provider

Agriculture has now become a high-tech sector in developed countries and the role of agricultural technology is rapidly increasing. In order to remain in the business and be competitive in the world
at large, technological adoption is an essential condition. There are always risks involved with new technologies but it is proven that the restrictive approach of trade in technology is riskier than the liberal policy of importing technologies (Gisselquist and Grether, 2000). The service providers can be a useful conduct to transform the agriculture sector into a high-tech sector. This is an option to narrow the technology gap and for the small holders to achieve significant savings. This model has been successful in different parts of the world. The idea is to create a range of crop-specific or region-specific entrepreneurial setups with farm machinery and input supplies. These could be matched with credit availability when required. Incentivized farmer’s cooperatives could be another option. Entrepreneurs are given loans and incentives to start their businesses (corporatization). The goal should be to elevate the productivity of underperforming small farms and to improve the gains of progressive farmers. Use of agricultural drones is a hot topic of research. Crop monitoring, yield mapping, and agrochemical spraying can be performed by manned and unmanned aerial vehicles.

1.6.8 RURAL DEVELOPMENT

Agriculture and rural development go together. Rural infrastructure development (roads, school, health) and skill development need massive investments. There is room for social mobilization for collective action and dispute resolutions through community-based organizations. Population welfare, gender mainstreaming, and youth programs must be targeted for rural communities to raise their aspiration and increase their love for agriculture. The agriculture and veterinary universities should be mandated to prefer students’ intake from the rural schools. These universities should be mandated to create pre-agriculture programs to promote the attendance of rural youth. Rural poverty needs multidimensional strategies of enablement and job creation along with alternate income generation activities.

1.6.9 WAY FORWARD/STRATEGIC PLANNING

In the short term, sustainability planning should include education and dissemination of knowledge and skill for enhancing the participation of farming/rural communities. In the medium and long term, the role and effectiveness and relevance of agricultural research and extension, credit services, and marketing are needed to build resilience. Investment in decision support systems would be critical:

1. Analyze public investment and subsidies in the agriculture sector, particularly after the 18th amendment and institutionalize public investment priorities in agricultural infrastructure and marketing with a clear commitment of finances perpetually.
2. Irrigation systems needs improvements from the dam up to the farm level. Real time discharge data should be made public. The tail end farmers must be looked after. Groundwater pumping should be regulated and water should be priced. Promote low delta crops and ban rice cultivation before the onset of rains.
3. Revamp the marketing system on the along the lines of cattle markets to get rid of “Market Administrators” and cartels. That should be aimed at creating a transparent (market information and intelligence), competitive, and efficient marketing structure.
4. Phase out of public procurement of wheat by creating a PPP model for storage (buffer) and distribution. Incentivize warehousing of major commodities and create a commodity exchange. Minimize postharvest losses: Fix targets for reducing overall postharvest losses to the level of 25% for fresh produce and 8% for grains (a half of the present).
5. Incentivize crop diversification by providing a better marketing option or support price for the minor crops/oilseeds/pulses and nontraditional crops. Launch special programs for periurban agriculture to avoid contaminated produce.
6. Create a regional trade policy forum like NAFTA, EU, APAP with a special focus on CPEC. A CPEC think tank on agriculture must work on developing long-term strategies.

7. Seed sector reforms include facilitation for the private sector in seed multiplication and trade. Enforcement of biosafety rules is required to pave the way for the introduction of GM crops. The universities must launch seed science and technology programs. A liberal regime for international partnerships is needed.

8. Balanced use of fertilizer is an utmost need to improve the productivity and to protect our environments. That will also reduce the cost of production. The urea economy of fertilizer industry must be revisited. The attention on P and K has already proved to be a wise step. The crop residue management and micronutrient would be other essential items. Soluble fertilizer formulations are now demanded to promote fertigation.

9. Mechanization and reverse engineering of farm machinery is an opportunity for the small and medium sized enterprises (SME) sector. This includes all tractor mounted equipment from ploughing to postharvest handling and processing. Establishment of service centers/Rural Business Hubs (RBH) is an option for small rural towns where mechanization and input needs could be met under one roof.

10. Climate change adaptations and mitigation framework needs to be formalized as an essential part of Smart Agriculture; it can be called Climate Smart Agriculture.

11. Invest in skills for value addition and for promotion of SMEs. The rural youth needs to be trained for SME and service delivery options to create alternate income streams for their families (rural nonfarm sector). Value addition training is the low hanging fruit to promote aspirations and create opportunities. Link microfinance and youth loans with skills and entrepreneurship.

12. Gender mainstreaming by extending benefits of women development programs to the rural areas will address inequality by developing women markets and investment in startups. Promotion of bikes for rural girls after matriculation and nutrition awareness of girls are needed. Skill development for women labor forces and awareness about their rights are also important. Future mothers and school lunch programs and curricula are needed. Targeted food fortification and blending options deserve to be tried.

13. Extension and outreach should promote entrepreneurship and aspirations in the agriculture sector. Venture capital and training for future farmers in high-value crops, fruits, and commodities should work. Launch residue management programs and educate farmers on the responsible use of chemicals. Launch crop packages for diversification (alfalfa, oilseeds, pulses, soybean, sorghum, millet, and vegetables) on the basis of agro-ecological zones. ICT enabled centers with the provision of extension and training of farmers (particularly women and youth) are currently being tried. Special programs for lead farmers and theme leaders (champions of change) should be created.

14. Investments should be made in skill development to reduce postharvest losses and to add value. The quality standards and WTO requirements as well as regional opportunities offered by the CPEC must be addressed to become globally competitive. Comprehensive market reforms program are needed.

15. The investment in research and development should be linked with institutional reforms for the integration of education, research, and extension. Commodity research boards should be institutionalized. Long-term research experiments should be launched to model sustainability of cropping systems.

16. Rural development must include infrastructures for farm to markets at a much larger scale than presently available. Rural life must be made attractive to reduce migration by introducing women and youth development programs along with alternate income propositions (at Markaz level or the small town centers/the new Mandi Towns).
1.7 CONCLUSION

This book is a farmer centric document to be treated as a baseline to establish a continuous review for policies and planning processes. There should be a 1–3 years plan written as a departmental operations manual, which includes investment strategies and implementation targets. Food security must include nutritional security. The political economy of food security must not compromise the profitability of the farmer and transfer resources from rural to urban economies (terms of trade). The immediate targets should be addressing the small farmers’ productivity challenges by ensuring quality seed (plant population), machinery, balanced fertilizer, insect pest management (IPM), and weed management. The public procurement of wheat should be phased out and available resources should be used to incentivize crop diversification. The HEIS must be evaluated and redesigned. Medium to long-term plans should be devised for land and water resource management (fragmentation, on-farm water storage, rain water harvesting, water pricing). Grain and produce markets are insufficient and imperfect. Infrastructure and legal frameworks are needed to enhance capacity and to promote the transparency and competitiveness of business systems, which should be free of exploitation by middlemen.

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