DIAGNOSTIC ASSESSMENT OF THE PUNJAB

AGRICULTURAL AND LIVESTOCK INNOVATION SYSTEM: ACHIEVEMENTS, CONSTRAINTS, AND WAYS FORWARD

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ABSTRACT

To suggest a framework for reforms at the request of the provincial government, a World Bank Review Team conducted a diagnostic assessment of the agricultural (crop) and livestock innovation system (AIS) in Punjab Province, Pakistan. The Team found that over time the system has expanded to cover almost all agricultural commodities, ecoregions, and disciplines. It has generated new varieties of major crops, developed vaccines and diagnostic kits for major animal diseases, produced information and knowledge, devised mechanisms to disseminate some of its outputs, and developed infrastructure for training. Yet the system's supply-driven, top-down, and bureaucratic orientation has often forestalled engagement with stakeholders to identify and resolve problems along agricultural value chains, including engagement at the farm level and with the private sector. Financial resources—flowing entirely from the provincial government—are insufficient and unreliable, and unsustainable. Lacking incentives for innovation and for maintaining the quality of science and services, and gender imbalance in its staffing have gradually turned the system less relevant for stakeholders and less efficient in its operations. As a result, it has largely failed in recent years to increase agricultural productivity, to make Punjab's agricultural and livestock products more competitive in national and international markets, and to improve food security for the people of Pakistan. These deficiencies cost the country billions of dollars of forgone revenue. To improve the performance of the AIS and meet the demand for "knowledge-based" agricultural growth, Punjab must introduce a stronger, scientifically-based, and gender balanced AIS that is efficient, relevant, responsive, and fosters interactions among all of the system's elements—universities, research, extension, producers, and other value-chain stakeholders in the public as well as the private sector. This report suggests: (1) three high-profile initiatives—one to upgrade PARB, another to develop a broad Capacity Building Strategy, and a third to pilot a state-of-the-art research institute in high-value agriculture; (2) eight steps to improve the research system, making the Ayub Agricultural Research Institute (AARI) an autonomous research body, including empowering the commodity boards, improving the sustainability of public AIS funding, empowering research and extension directors, strengthening the quality of science, consolidating and rationalizing research into strategic projects and programs, reforming the service rules, and strengthening the regulatory framework for

private research and development; (3) four approaches to improve the extension system, including expanded use of modern technologies in communication, bringing public extension closer to the grassroots level, moving toward specialized rather than general extension, and promoting private sector extension; (4) several structural reforms for research and extension, including shifting several institutes and combining directorates to improve coherence and avoid duplication; and (5) three strategies for enhancing coordination between agricultural research, education, and extension: better administrative coordination at the micro and macro level, structural coordination, and institutional coordination. In proposing these strategies, the report cites international good practice relevant for Punjab. With these strategies in hand and agreed upon, a detailed implementation plan with timelines should be prepared and a monitoring mechanism must be developed.

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ACRONYMS AND ABBREVIATIONS

AARI	Ayub Agricultural Research Institute
AdR	Adaptive Research
ADU	Agriculture Delivery Unit (of DoAg)
AE&AR	Agricultural Extension and Adaptive Research (Directorate General of DoAg)
AE&M	Agricultural Economics and Marketing (Wing of DoAg)
AF	Agriculture (Field) (Directorate General of DoAg)
AIS	Agricultural innovation system
AMRI	Agricultural Mechanization Research Institute
AR	Agricultural Research (Directorate General of DoAg)
ASTI	Agricultural Science and Technology Indicators (IFPRI)
AVRDC	Asian Vegetable Research and Development Centre (World Vegetable Center)
Bt	*Bacillus thuringiensis*
CEMB	Centre of Excellence for Molecular Biology
CEO	Chief Executive Officer
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize & Wheat Improvement Center
CPI	Consumer Price Index
CV	Coefficient of variation
DG	Directorate General
DH	Directorate of Horticulture of DG(AE&AR)
DoAg	Department of Agriculture
DoL&DD	Department of Livestock and Dairy Development
Embrapa	Brazilian Agricultural Research Corporation
FA	Farmers' association
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Statistics Unit/Statistical Webpage of FAO
FBOs	Farmer-based organizations
FFS	Farmer Field Schools
FMDRC	Foot and Mouth Disease Research Center
FTE	Full-time equivalent
FY	Fiscal year (July 1-June 30)
GDP	Gross domestic product
GIS	Geographic information system
GoP	Government of Pakistan
GoPunjab	Government of Punjab
HEIS	High-efficiency irrigation system
IATI	In-service Agricultural Training Institute
ICARDA	International Center for Agricultural Research in the Dry Areas
ICTs	Information and communication technologies
INCAGRO	Peru's competitive grant scheme for R&E
IFPRI	International Food Policy Research Institute
IPM	Integrated pest management
IRRI	International Rice Research Institute
ISI	International Scientific Index (Elsevier)
ISNAR	International Service for National Agricultural Research
IWMI	International Water Management Institute
KPI	Key Performance Indicator
KPK	Khyber Pakhtoonkhwa Province
LS	Livestock (farms of the Directorate of Livestock Extension)
LSE	Livestock Extension (Directorate)
LSR	Livestock Research (Directorate)
M&E	Monitoring and evaluation
MANAGE	National Institute of Agricultural Extension Management (India)
MNSUAM	Muhammad Nawaz Shareef University of Agriculture Multan
NARC	National Agricultural Research Centre
NGO	Non-governmental organization
NIAB	Nuclear Institute of Agriculture and Biology
NIBGE	National Institute of Biology and Genetic Engineering
NPR	Nominal protection rate
OFWM	On-Farm Water Management (Directorate of DoA)
OIE	World Animal Health Organization
PAC	Pakistan Agriculture Coalition
PAH	Punjab Agricultural Hotline

PARB	Punjab Agricultural Research Board
PARC	Pakistan Agriculture Research Council
PARCB	Punjab Agriculture Research Coordination Board
PARMP	Punjab Agriculture Research Master Plan
PC	Plant Clinic
PCCC	Pakistan Central Cotton Committee
PCRWR	Pakistan Center of Research for Water Resources
PERI	Punjab Economic Research Institute
PHR&DC	Punjab Horticulture Research and Development Corporation of GoPunjab
PMAS-AAU	Pir Mehr Ali Shah Arid Agriculture University (formerly Barani Agricultural University)
PPRI	Punjab Poultry Research Institute, Rawalpindi
PW&PQC	Pest Warning and Pesticide Quality Control
R&D	Research and development
R&E	Research and extension
RCA	Revealed comparative advantage
RRI	Rice Research Institute
SMART	Strengthening Markets for Agriculture and Rural Transformation
SOP	Standard operating procedures
T&V	Training and visit (extension)
TAC	Technical Advisory Committee
TAIPAN	A USAID project in KPK
TEVTA	Technical Education and Vocational Training Authority
TFP	Total factor productivity
TTS	Tenure Track Scientist
UAF	University of Agriculture Faisalabad
USAID	United States Agency for International Development
USDA-ERS	United States Department of Agriculture Economic Research Service
UVAS	University of Veterinary and Animal Sciences
VRI	Veterinary Research Institute

CHAPTER 1
INTRODUCTION

Punjab is Pakistan's most important agricultural province, yet growth has been lagging (Box 1). The Government of Punjab (GoPunjab) has embarked on an ambitious program to accelerate agricultural growth, enhance water use efficiency, diversify production to meet changing market demands, and increase the competitiveness of its agricultural sector in world markets. The Go Punjab recognizes that a large part of future growth and improvement in competitiveness, as well as quality enhancement and diversification, will depend on how successfully new scientific knowledge is developed and applied,[3] on institutional change that favors innovation, and on stronger information and educational systems at the farm and industry levels. Under the SMART (Strengthening Markets for Agriculture and Rural Transformation) program, supported by the World Bank, the GoPunjab plans to double investment in research and development (R&D) by 2022. At the same time, the government and other major stakeholders in the agricultural sector know that increased R&D investment will not achieve the desired results unless it is accompanied by major efforts to improve the performance of the entire Agricultural and Livestock Innovation System (AIS).[4]

In light of those considerations, this report, requested by the GoPunjab and commissioned under SMART, presents the major findings of a review of the provincial AIS for agriculture and livestock. The Review Team[5] started by assessing the structure and evolution of the system and proceeded to diagnose its major strengths and weaknesses, quantify its impacts on stakeholders, and identify options to enhance performance, including opportunities for reform and investment. The structure of this report reflects that process.

The analysis that follows regards technology generation as only one part of the AIS and broadens the view to include the whole spectrum of knowledge that sparks innovation in agriculture: the mechanisms for creating knowledge (universities), applying

[3] Rajalahti, Janssen, and Pehu (2008).

[4] The term "agriculture" or "agricultural" is used for the crop sector throughout this report to distinguish it from the livestock sector, but the term "AIS" encompasses the innovation system for both the crop and livestock sectors.

[5] The Team consisted of Mubarik Ali, Jock Anderson, Derek Byerlee, and Hans Jansen.

BOX 1. THE LACKLUSTER PERFORMANCE OF AGRICULTURE IN PUNJAB

Agriculture is a key contributor to the economy in Pakistan in general and Punjab in particular, yet agricultural growth is languishing. Nationally, agriculture accounts for 21% of GDP, employs 44% of the labor force, and directly and indirectly delivers nearly 80% of the total value of Pakistan's exports. Sector growth fell from 3.3% over the last decade to nearly zero in fiscal year (FY)2015–16, before recovering in FY2016–17. Crop and livestock productivity are lower than in other Asian countries. Except for maize, crop yields have barely risen in decades. In Punjab, where agriculture contributes 26% of GDP and provides 40% of employment, growth in agriculture has been similarly low and highly erratic as well. This is despite that the vast fertile lands of Punjab, consisting of about 27 million acres of irrigated area, are endowed with diverse natural resources and climatic conditions, which are highly suitable for diversified and productive agriculture. Yet 90% of cultivated land is under five major crops: wheat, rice, cotton, sugarcane, and maize, leaving only about 10% for horticulture and other high value crops. Punjab encompasses 72.6% of national cropped area and 77.7% of national irrigated area. Approximately 60% of the cultivated area lies within the Indus Basin Water System. The province provides large shares of the country's primary crops: maize (78%), wheat (77%), cotton (73%), sugarcane (63%), and rice (52%).

The lack of progress of Punjab agriculture has numerous causes but primarily reflects low farm-level productivity growth, resulting in high unit production costs and lack of competitiveness; distorted cropping patterns with limited diversification to high value crops; and large herds of low-producing animals. Large gaps exist between average yields, the progressive farmer yields, Punjab's potential and the world's best averages. Agricultural growth is held back by include poor adoption of modern technologies, poor service delivery, and poorly functioning agricultural markets. Punjab could restore its agricultural competitiveness through innovations that renew growth in on-farm productivity and improve efficiency and quality throughout the post-harvest value chain. At 0.18% of agricultural gross domestic product (AgGDP), Pakistan's public expenditures on agricultural research are the lowest in a region that is already lagging behind others. Most agricultural research expenditures still go to food grains, sugarcane and cotton, rather than to high-value crops and livestock products. Few resources are dedicated to post-harvest management, including value addition, quality, food safety, and nutrition. A high pay-off could be gained by redirecting public expenditures and associated policies toward the best potential investments for outcomes, with a focus on reforms in wheat, irrigation, subsidies, and marketing, and concomitant investments to improve service delivery, agricultural research and development, and insurance.

knowledge to create technologies (research), and adapting (adaptive research) and disseminating (extension) knowledge and technology. It examines how these mechanisms, in both the public and private sectors, are linked with each other at each level of application (that is, among farmers and other stakeholders along the value chain).[6] Unlike earlier reviews, this review evaluates the performance of the system against a set of indicators that include *relevancy*, *efficiency*, *effectiveness*, *quality*, *incentives*, and *private sector regulations*. The main purpose is to suggest a reform framework to improve the system's delivery and application mechanisms in both the agricultural (crops) and livestock sectors.

The Team interviewed (in a non-structured manner) dozens of stakeholders in the AIS, both individually and in groups (Annexure 1), reviewed a large number of recent reports, conducted a survey of scientists, collected data on human and financial resources from official files of the GoPunjab, and analyzed standard metrics of publication output as a measure of science quality. This draft report is intended to be used as an input into further consultations in early 2018 with stakeholders on the options for enhancing performance of the AIS, which will form the basis for finalizing recommendations.

The Team recognizes the limitations of the evidence collected and analysis undertaken within the relatively short period of 10 weeks allocated to the task. The Team relied largely on qualitative evidence, given the lack of evidence from rigorous field-based evaluations. Meetings held with groups of farmers and leaders of producer and industry associations cannot substitute for a systematic survey to elicit feedback from millions of potential clients of the AIS—farmers, processors, input suppliers, traders, and consumers. Nonetheless, the Team, which collectively has

[6] The definition of AIS adopted for this review is derived from Rajalahti, Janssen, and Pehu (2008), who describe an AIS as "a network of organizations, enterprises, and individuals that focuses on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance." In other words, the AIS includes education, research, and extension institutions in the public and private sector, non-governmental organizations (NGOs), and stakeholders along the value chains of agricultural commodities, such as farmers, processors, service providers, traders, consumers, and others as knowledge generators, innovators, knowledge and technology transmitters, financiers, and adopters of new technologies.

decades of experience of working with the Punjab innovation system, sees a more widespread commitment to change than before, both at the grassroots level within the system and among the top GoPunjab leadership, which provides grounds for optimism that many of the needed changes can be implemented. The Team hopes that the planned series of stakeholder workshops built around the menu of options presented in this draft will help to fine-tune recommendations and build shared ownership as they are implemented.

The next chapter opens the discussion by describing how the Punjab AIS has arrived at its current structure and providing fresh estimates of the human and financial resources currently invested in the system. Chapter 3 briefly describes some of the system's major achievements in terms of results on the ground, albeit very incompletely, given the lack of good impact assessment studies. To gain at least some perspective on the system's impacts, negative and positive, Chapter 4 quantifies its impacts based on various welfare parameters. Chapter 5 diagnoses the major weaknesses that lead the system to perform well below its potential, or even at a level that is sufficient for the needs of Punjab Province. Chapter 6 outlines ways to improve performance, as a basis for discussion to build consensus on a series of actionable recommendations.

CHAPTER 2
OVERVIEW OF THE AIS IN PUNJAB PROVINCE

2.1. HISTORICAL EVOLUTION

2.1.1. PUBLIC RESEARCH AND EXTENSION INSTITUTIONS

Punjab Province of Pakistan has developed an extensive research and extension (R&E) system spanning federal ministries, provincial departments, agriculture-related universities and colleges, and the private sector (Annexure 2). The system is one of the oldest in the subcontinent. The Veterinary School was established in Lahore in 1886 and the Punjab Agriculture College and Research Institute in Faisalabad in 1906. Research stations established before independence include the Cotton Research Station in Multan (1902), Fodder Research Sub-station in Sargodha (1924), Rice Research Station in Kala Shah Kaku (1926), Beekeeping Research Station in Murree (1936), and Fodder Research Station, also in Murree (1937).[7]

On the recommendation of National Commissions on Food and Education, the Punjab Agriculture College and Research Institute was scaled up to become the University of Agriculture, Faisalabad (UAF) in 1962, and its research and education components were bifurcated. Its research component, Ayub Agricultural Research Institute (AARI), flourished with the introduction of Green Revolution technologies in the mid-1960s. The technologies—new high-yielding varieties—had huge potential for raising productivity, if Pakistan could bridge the large gap in knowledge of how to manage them under local conditions. To do so, AARI was upgraded to a Directorate General (DG) Agriculture Research (AR), and simultaneously a Directorate General Agriculture Extension DG(AE) was created, both under the Secretary of the Department of Agriculture (DoAg) of the GoPunjab. The DG(AR) was separately established in AARI in Faisalabad, while the DG(AE) was established on Davis Road near the government seat in Lahore. Adaptive Research (AdR) farms to test and adapt new

[7] Discussions with the respective Directors of these centers.

technologies in the ecoregional context were established under the DoAg and later merged with the DG(AE) and renamed the DG(AE&AR).

The developing R&E system for the livestock sector proceeded in parallel but independently of R&E for agriculture. While the DG(AR) and DG(AE) remained largely focused on crops, a separate Department of Livestock and Dairy Development (DoL&DD) was created in 1977, in recognition that animals were a major source of livelihood for farmers. At the same time, the Forestry and Fisheries Departments were created. All of these departments established their own R&E wings. The DoL&DD established its own Directorate General of Livestock Research (LSR) in the Veterinary Research Institute (VRI) and Directorate General of Livestock Extension (LSE), both in Lahore. Similarly, the Punjab Forestry Research Institute was established in Faisalabad in 1982 and the Punjab Fisheries Research Institute in Lahore around the same time.

University education related to agriculture and livestock also evolved. The only Veterinary School in the province became the Punjab Veterinary College in 1942 and remained under Punjab University. In 1971, the Punjab Veterinary College affiliated with UAF (which already had a Faculty of Animal Sciences) was upgraded into an independent University of Veterinary and Animal Sciences (UVAS) that same year. Similarly, Barani Agriculture University was established in 1995 in Rawalpindi and later renamed the Pir Mehr Ali Shah Arid Agriculture University (PMAS-AAU). All of these universities now have several sub-campuses in various regions of Punjab. In addition, the Muhammad Nawaz Shareef University of Agriculture Multan (MNSUAM) was established in Multan in 2015. General universities such as the University of Sargodha in Sargodha, Bahaudin Zikria University in Multan, and Islamia University in Bahawalpur also have agriculture and/or animal husbandry faculties/colleges. Each of these universities contributes to supplying trained human resources, and they also undertake some research. The province's oldest general university (Punjab University) also has the Institute of Agricultural Sciences and the Centre of Excellence for Molecular Biology (CEMB). A private university—Forman Christian College—recently established an agriculture biotechnology laboratory.

2.1.2. FEDERAL INSTITUTIONS

Federal institutes contribute significantly to research output and outcomes of the agricultural sector in Punjab Province. The federal research establishments are supposed to be involved mostly in basic and strategic research, with provincial research institutes focusing on applied and adaptive research, and agricultural universities working across the research spectrum from basic to adaptive. The most important federal institute is the Pakistan Agricultural Research Council (PARC), with its three regional centers in Multan, Bahawalpur, and Faisalabad. PARC was established in 1981 to coordinate research at the national level and provide upstream research through its National Agricultural Research Centre (NARC) located in Islamabad. In addition, PARC is currently also managing six other research centers, two of which are focused on commodities (sugarcane and tea), and four of which have a regional focus. PARC resorts under the Ministry of National Food Security and Research. An independent third-party review of PARC carried out in 2012 with assistance of the International Food Policy Research Institute (IFPRI) recommended PARC to review its mandate and partnership with the provincial agricultural research system in the context of 18th constitutional amendment with the objective to build effective partnerships and plan its work program together to meet future needs of the national agricultural research system. It concluded that currently PARC does not effectively exercise its mandate to coordinate federal and provincial research and help setting research priorities at the provincial level that are consistent with national agricultural policies. Currently, the Provinces are represented in the Interprovincial Agricultural Research Coordination Committee (IPARCC), but not per se in PARC's Board of Governors. Also, research carried out at PARC is often of the more visible applied type rather than of the strategic kind. And PARC hardly promotes a culture of demand-driven research through collaboration with the provincial agricultural universities, private sector, NGOs and farmers. Based on the IFPRI review, a five-year Business Plan for PARC was developed with the help of the Food and Agriculture Organization of the United Nations (FAO) in 2013 that, inter alia, laid out the foundations to turn PARC into a research planning, coordination and promotion body with actual research implementation largely left to provincial institutes; promote a greater role for the private sector, NGOS, farmers' organizations and

academia; and increasingly rely on competitive research grants. However, most key recommendations this Business Plan have not been implemented. In particular PARC (through NARC in Islamabad and a few national research institutes located in Punjab) remains involved in agricultural research implementation. Coordination of research efforts between the federal and provincial research institutions remains weak. On the other hand, other longstanding federal institutes, namely the Pakistan Atomic Energy Commission (with its two research centers in Faisalabad) and the Ministry of Textile Industry (with its Pakistan Central Cotton Research Institute in Multan and the Textile College in Faisalabad) make important contributions to the Punjab AIS. Other federal ministries that conduct agriculture-related research are the Ministries of Science and Technology, Education, Commerce, Water and Power, and Environment (Annexure 2).

2.1.3. INSTITUTIONS FOR COORDINATION OF RESEARCH

Coordination mechanisms and organizations can play an important role in establishing networks when the market is not sufficiently developed to provide incentives to do so.[8] Coordination of the R&E system in Punjab became an issue with its expansion under various provincial departments, federal ministries, and autonomous universities. To coordinate the research system in the province, the Punjab Agriculture Research Coordination Board (PARCB) was established under UAF in 1978 through an ordinance. The board's role was mainly advisory. Control of the board by UAF diminished its overarching role as coordinator, and because it could provide only limited financial and technical support, it soon became irrelevant to GoPunjab scientists. The PARCB was recreated as the Punjab Agricultural Research Board (PARB) through an Act of the Provincial Assembly in 1997 to plan, coordinate, evaluate, and fund research in the province, but after only two years it was moribund, stricken by structural and legal problems and disinterest across provincial departments. Revamped again in 2007 by the international recruitment of a Chief Executive Officer (CEO) (Annexure 3), PARB now provides competitive multi-institutional and multi-disciplinary grants for R&D, as well as small grants for travel to participate in international conferences and publication.

2.1.4. INSTITUTIONS TO BUILD THE CAPACITY OF FARMERS AND EXTENSIONISTS

Each department of the provincial government has long realized the importance of training (beyond extension) and capacity building for their own staff, farmers, and the general public. A number of training institutes/centers were created over time. For example, under its Directorate of Training the DG(AE&AR) has four training institutes. All have linkages to UAF, which provides technical backstopping. These institutes offer three-year diploma courses to the general public, which are validated after every three to four years by UAF. The institutes also offer short-term training courses for farmers. Every crop season, the Directorate of Adaptive Research (AdR) of the DG(AE&AR) holds one-day discussions with extension staff on major crop issues and conducts field days for farmers to see new technologies on the AdR farms, experiment stations, and farmers' fields. The extension staff makes farmers aware of technologies and practices emerging from the AdR farms.

Similarly, the DoL&DD has a number of training institutes and mechanisms to support farmers and extensionists. Recently it has been upgrading its training facilities in a newly created Directorate of Training under the DG(LSE), while establishing five new training centers (bringing the total to seven). All of these centers are linked with UVAS for technical backstopping and offer two-year diploma courses to the general public. The Veterinary Officer of the DoL&DD stationed at the district level has recently begun to provide 20 days of training to one male and one female Community Facilitator from each of the 25,000 villages in the province. Community Facilitators are trained to lead specialized extension or development campaigns to promote (for example) a balanced diet for livestock, artificial insemination, and other practices. Recently, the DoL&DD set up nine mobile training schools (one for each division of the province) for farmers, particularly women. The training bus visits a village and invites 20–25 women for a session of two to three hours with a female veterinarian covering various topics, using videos. The Punjab Poultry Research Institute (PPRI) also provides training to poultry stakeholders, including backyard and commercial producers.

[8] Rajalahti, Janssen, and Pehu (2008).

Almost all DGs of both departments claim to have training activities. For example, the DG of Pest Warning and Pesticide Quality Control DG(PW&PQC) conducts training on integrated pest management (IPM), On-Farm Water Management (OFWM) provides training on high-efficiency irrigation systems (HEIS), and Floriculture offers training on home gardening. Each agricultural university in the province also offers short courses for farmers and other stakeholders (women farmers, processors, and so on). The UVAS provides in-service training and new staff training for DG(LSE). For various groups of personnel, the completion of one to five months of in-service training has become mandatory for promotion. The UVAS provided the Team with a list of 69 specialized short-term courses offered to a variety of researchers in the university as well as to the staff of the DG(LSR). Similarly, all agriculture-related universities, especially UAF and PMAS-AAU, provide short courses that range from one to several days for farmers as well as the general public; the courses cover a variety of agricultural, agribusiness, and post-harvest topics.

2.1.5. PRIVATE SECTOR RESEARCH AND EXTENSION

The greatest degree of development in private R&E has occurred in the seed industry, especially after permission to establish private seed companies was granted in 1991. Some 608 registered seed companies have been established so far in the province.[9] Only recently, however, following approval of the Plant Breeders' Rights Act (2017) and amendment of the Seed Act (1976), have several companies started to invest in their own research laboratories, farms, and marketing networks, engage with the public sector in product evaluation, and hire professional staff.

Private sector extension has taken off to a greater extent but in specialized areas.[10] The most common form of private extension is for input dealers to provide very specific advice, often biased toward sales of their products (such as insecticides and fertilizers),[11] which also creates a bias toward the large farmers who can buy their products.[12] Other private firms are developing new micronutrient products, bio-fertilizers and compost manure, and plant growth promoters, or offering soil testing services (Annexure 2).

A second type of private extension consists of commodity-specific advice provided by processors and wholesalers, often as part of contract farming arrangements. Examples include Rafhan Maize Co for hybrid maize, Tareen Farms for sugarcane, and the Pakistan Agriculture Coalition (PAC) for chili peppers and basmati rice. The PAC enlists both the public and private sectors in its activities; the public sector defines grades and trains farmers to implement them, and the private sector builds collection centers, identifies international quality markets, and provides loans and contracts to farmers. In rice, cotton, mango, citrus, and dairy value chains, producer or exporter associations can play an important role in coordinating and upgrading the value chain, especially if the public sector takes responsibility for bringing different players together or bearing the transaction costs. In the livestock sector, Nestlé and Engro Foods contribute significantly by linking farmers through milk collection centers, supplying extension services to them through those centers, and providing semen of exotic bulls. The private sector is also becoming active in introducing mechanized poultry sheds and equipment to make silage.

In reality, this growth in private extension activity may mean little for the large number of farmers who need unbiased and comprehensive advice. During the brief period available for data collection and interaction, the Team found no private suppliers that depended solely on selling advice in Punjab. It concludes that the public system remains the major potential source of extension advice for most farmers and that private investment in R&E is still relatively small.

2.2. STRUCTURE OF RESEARCH AND EXTENSION IN THE PUNJAB GOVERNMENT DEPARTMENTS

The main concentration of agricultural research in Punjab, AARI, consists of 25 institutes and 141 stations spread throughout the province. Of the 25 institutes, 11 are located at headquarters and the remaining 14 are outside

[9] Rana, Spielman, and Zaidi (2016).

[10] Riaz (2010); Gómez, Mueller, and Wheeler (2016).

[11] Davidson (2005).

[12] Mengal, Mirani, and Magsi (2014).

the headquarters. Thirteen of the institutes are commodity based, six are disciplinary based, and another six are regionally based. Two research sections are also located at headquarters (Annexure 2). In addition, the Agricultural Mechanization Research Institute (AMRI) falls under the DG Agriculture (Field)—DG(AF), the Punjab Institute of Agriculture Marketing under the DG Agriculture (Economics and Marketing)—DG(AE&M), and floriculture research under the Director of Floriculture (Research and Training). AARI covers a wide range of disciplines (including breeding, soil science, plant protection, biotechnology, and agronomy), commodities, and eco-regions (including irrigated, *barani*,[13] and arid zones). The Team noted limited capacity for policy analysis, however, except for some capacity in UAF, PMAS-AAU, and University of Sargodha. Outside the main agricultural universities or colleges, the Lahore University of Management Sciences, Lahore School of Economics, the Center for Economic Research of Pakistan, Innovative Development Strategies (a private consulting firm), and several think tanks have developed reasonably good infrastructure for policy research.

Many of these institutes also engage in, and sometimes focus on, development-type activities. For example, the Soil and Water Conservation Research Institute mainly builds small and mini dams, whereas the Salinity Research Institute has become a development arm for distributing inputs to reclaim salt-affected soils. The Floriculture and Landscaping Research Institute mostly distributes nurseries. Similarly, the VRI mostly produces vaccines. Sometimes the directorates of both the agriculture and livestock departments are drawn into relief and emergency campaigns, such as dengue control or the distribution of seed and animal feed in areas affected by flooding, possibly at the cost of conducting their research.

In the crop sector, public sector extension, adaptive research, and training are the responsibility of the DG(AE&AR), which is under the administrative control of DoAg. The Director Extension (Headquarters) is the biggest directorate, with 9 regional offices administratively controlling 36 district offices. The district offices have extension staff at the union council level for undertaking field extension activities. The main extension-related functions of the DG(AE&AR) are the transfer of improved production technologies (including varieties, IPM, and management practices), adapting these technologies to the conditions of each ecoregion, and providing training to its own staff as well as to farmers. Extension personnel also monitor input supply and quality and have some regulatory power to implement laws. The DG(AE&AR), however, is not responsible for extension related to agricultural machinery, floriculture, agricultural marketing, and value-chain development.

For research to address different ecological conditions and farmers' problems, AdR farms were created in five ecological conditions of Punjab (later extended to eight ecological zones) under the Training and Visit (T&V) program in 1978, but surprisingly they were put under the control of the DG(AE&AR). These farms were supposed to adopt the farming systems research approach—identifying farmers' problems, finding technology solutions in consultation with them, testing the technology on AdR farms, and then setting up experiments in farmers' fields in collaboration with farmers. A multi-disciplinary team (including an agronomist, plant protectionist, agricultural engineer, and economist) was created at each AdR farm to analyze different aspects of the technology to be tested, and subject matter specialists were recruited for each district to identify the issues and set up experiments on farmers' fields. The philosophy was not only to demonstrate technology at AdR farms but to train or provide knowledge to farmers and get their feedback on new technology. Zonal Coordination Committees of university and AARI researchers and farmers' representatives were formed to discuss the AdR program in the *kharif* and *rabi* seasons.[14]

In response to the Punjab Agriculture Sector Plan 2015, the Extension Services 2.0 program was introduced to transform the entire institutional base of the DoAg and change how government interacts with farmers.[15] Extension Services 2.0 is based on the idea that improved public awareness of certain soil and environmental conditions can greatly help to improve crop production, and that public awareness can be expanded through recent information

[13] Rainfed.

[14] *Kharif* is the hot season from May to October, and *rabi* is the winter season from November to March.

[15] The Punjab Agriculture Sector Plan, 2015 (p. 43).

technology innovations and common tools such as mobile phones and GIS. The program plans to register four farms from each village and expand regularly to reach the majority of farms within five years. It will adopt the latest extension approaches and tools for regular interaction and field visits with registered and other farmers aimed at addressing agricultural technology and input management issues through inbound/outbound calls, a helpline/complaint line with interactive voice response capabilities, an outbound survey call facility, and short message service and multimedia message service query and broadcasting capabilities. Aside from delivering relevant information to farmers, the program will establish Plant Clinics (PCs) and offer training to farmers.

In response to the increasing importance of fruits and vegetables in farming systems, the DoAg has appointed an Additional Director General (Horticulture) in the DG(AE&AR). The main objectives pursued through this new arrangement include enhancing farmers' capacity, improving production quality, extending the period during which horticultural crops are available in markets, popularizing the latest production technologies, and promoting true-type nursery plants, biological control, and value addition in high-value crops. This initiative is too little in terms of providing human and financial resources to deliver the prodigious assigned tasks, however, and it is also too late compared to the response (in neighboring India, for instance) to the expanding opportunities for horticultural crops in international markets. Thus, the Directorate of Horticulture D(H) under the DG (AE&AR) continues its routine training activities for farmers through 48 Farmer Field Schools (FFSs) in citrus, 48 in mango, and 81 in vegetables in 4 major fruit and 21 vegetable growing districts.[16] The coverage of this training remains limited to farm field issues, and its effect is further constrained by the poor capacity of the extension staff to conduct training and the scarcity of resources for the staff to reach farmers' fields.

The DG(AE&AR) has dramatically changed its earlier farmer outreach methodologies, which are succinctly reviewed on its website (http://ext.agripunjab.gov.pk/background). The T&V system has been replaced by a modified form of T&V, complemented by other approaches such FFSs and PCs. By 2015, the Directorate of Plant Protection of DG(AE&AR) had established 478 PCs in 31 districts (to be increased to 545 clinics), staffed by more than 1,000 "plant doctors" (plant protectionists). The DG(AE&AR) starts crop maximization campaigns for major crops every year, trying to reach each village. For example, in 2016–17 for wheat alone, the directorate organized 369 extension teams to reach over 10,000 of the province's 26,000 villages (about 1 million of the province's 5.5 million farmers).[17] The campaign distributed over 160,000 printed materials, and the Directorate of Information conducted a campaign through electronic media, hotlines, telephone messages, and other communication outlets.

The DoL&DD has two major DGs in Lahore: The DG(LSR) and DG(LSE). The former has three research institutes: VRI, Foot and Mouth Disease Research Centre (FMDRC), and PPRI. The other four institutes labelled as research institutes are placed under the DG(LSE) in recognition that in practice they conduct little or no research and largely focus on extension. The DoL&DD also has 21 livestock experiment stations or livestock (LS) farms.

The DG(LSE) mainly delivers veterinary services rather than livestock extension in its true sense. Its rather effective system consists of 300 mobile veterinary dispensaries serving 22,000 villages through monthly visits. The remaining 4,000 villages have static veterinary dispensaries. The DoL&DD also runs 574 district/division-level veterinary hospitals, 1,605 dispensaries, 161 artificial insemination centers, and 602 subcenters. The DG(LSE) of DoL&DD traditionally focused on treating disease but has reoriented its approach to focus on preventing major animal diseases through universal vaccination, which might be most usefully thought of as farm risk management interventions. Field veterinary officers occasionally hold meetings with livestock farmers, after being briefed on LS farms, to extend advice on methods to improve livestock productivity beyond the interventions that they

[16] The information was downloaded from the DG(AE&AR) website, http://www.ext.agripunjab.gov.pk/ffs.

[17] Presentation of the Director General (AE&AR) to the Team.

typically emphasize, such as deworming treatments, vaccines, artificial insemination, and castration.

2.3. RESOURCES INVESTED IN RESEARCH AND EXTENSION

The most comprehensive data on investments in research are provided by the International Food Policy Research Institute's (IFPRI's) Agricultural Science and Technology Indicators (ASTI) for Pakistan, developed in collaboration with PARC. The most recent ASTI survey and latest updates are not available, however, and unless otherwise specified, for this review the Team updated ASTI data where possible using data from official GoPunjab files.

2.3.1. HUMAN RESOURCES

The Team estimated human resources data for research separately from extension for DoAg, DoL&DD, and agricultural universities. According to the data provided by the GoPunjab and agricultural universities, over 32,700 employees are working in R&E in Punjab, of which only 14% are professional staff, 70% are support staff, and the remaining 16% are administrative staff. Each scientist in agriculture and livestock research is supported by an average of about 3.6 non-professional staff. The ratio is 11.0 in agricultural extension and 6.4 in livestock extension (Table 1).

Out of the total human resources engaged in R&E in the agricultural and livestock sectors in Punjab, extension for livestock and agriculture each have about a 35% share. Agricultural research accounts for 23% share of human resources, and livestock research has a 7% share—in other words, the human resources dedicated to research on agriculture are more than three times the human resources dedicated to research on livestock. Overall, agricultural extension has more than twice the human resources than in research, while this ratio is five to one for livestock. Very few scientists and extension workers are female, although a large proportion of students in agriculture universities are women.

Although the number of scientific staff in universities almost equals or exceeds the number in the research system, most university scientists spend little time on research, and the teaching burden limits professors' capacity to provide quality guidance to student research. The Team used ASTI estimates of the share of university scientists' time

TABLE 1. HUMAN RESOURCES IN RESEARCH AND EXTENSION FOR AGRICULTURE AND LIVESTOCK, PUNJAB PROVINCE, 2017–18 (EXCLUDING FEDERAL RESOURCES)

Head[†]	Professional staff	Support staff	Administrative staff	Total staff
GoPunjab agricultural research	1,332	3,810	1,397	6,539
GoPunjab agricultural extension	918	9,563	551	11,032
Universities[‡]	266	643	205	1,115
Total agricultural research	**1,598**	**4,453**	**1,602**	**7,654**
Total agricultural sector	**2,516**	**14,016**	**2,153**	**18,686**
GoPunjab livestock research	403	1,084	385	1,872
GoPunjab livestock extension	1,588	7523	2,708	11,819
Universities[††]	80	126	142	348
Total livestock research	**483**	**1,210**	**527**	**2,220**
Total livestock sector	**2,071**	**8,733**	**3,235**	**14,039**
Grand total	**4,587**	**22,750**	**5,388**	**32,725**

[†]The human resources from service delivery wings of agriculture departments such as OFWM are not included.
[‡]Only 15% of the resources in agriculture and livestock universities are considered as doing some research.
[††]All human resources of the UVAS and 30% of the UAF human resources are included in the livestock sector.
Source: Authors' collection of data from DoAg and DoL&DD.

devoted to research to compute Full Time Equivalent (FTE) staff allocated to research in the universities. Based on that calculation, universities contribute less than 5% of the total human resources engaged in agricultural and livestock research.

The number of agricultural researchers specializing in the crop management (agronomy, plant protection, and horticulture, for instance) is overshadowed by the number specializing in plant breeding and soil science (Figure 1). Social scientists such as economists, statisticians, policy planners, and agribusiness specialists are mostly absent, underlining the system's poor capacity for policy, prioritization, and impact analyses. Human resources in horticulture management also seem low relative to the potential of the horticultural sector.

According to an earlier estimate in 2012 by ASTI, over half of the professional resources of the GoPunjab are working in the agricultural sector, while the livestock sector engages less than one-fourth of the total. Research on natural resources such as soil, water, and the environment engage 12.6% of FTEs, while all other research activities (mainly in the agricultural sector), such as economics, mechanization, and others, consume 8.8%. The forestry and fisheries sectors have relatively low shares (Table 2).

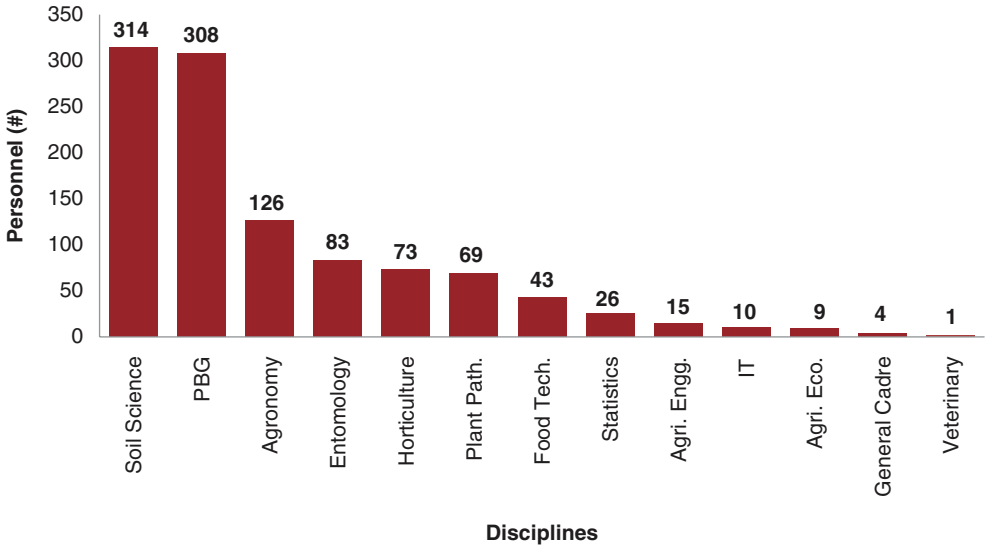
2.3.2. FINANCIAL RESOURCES

The total investment in R&E by DoAg, DoL&DD, and agricultural universities increased by 100% in the 10 years between 2007 and 2016–17, largely because of a substantially higher investment in livestock R&E in 2017. Specifically, total R&E investment (in 2016–17 rupees) grew from Rs 8.8 billion in 2007 to around Rs 17.7 billion during 2016–17. Investment in the livestock sector rose from Rs 5.9 billion in 2016 to Rs 13.3 billion in 2017, although during that year spending on agriculture also increased by 17%. The phenomenal increase in livestock sector spending enhanced the sector's share in total R&E from 55% in 2008 to 76% in 2017 (Table 3).

The share of the crop and livestock R&E expenditure in the respective GDP of the sectors also increased during the last year, from less than 0.25% to around 0.40% (Figure 2), mainly due to the increased expenditure on livestock, particularly for extension. The crop sector's share remains at around 0.20%. The increase in expenditure on livestock extension comes from a special Chief Minister's program, the sustainability of which is not assured.

All of the funding for research, extension, and universities comes from one funding source—the GoPunjab. The university share of investment in agriculture has gradually picked up from 9% during 2007–08 to 18%

FIGURE 1. DISTRIBUTION OF SCIENTIFIC SPECIALISTS IN THE AGRICULTURAL RESEARCH INSTITUTES OF PUNJAB, 2016–17



Note: PB&G is plant breeding and genetics; DVM is Doctor of Veterinary Medicine.
Source: Authors' collection of data from AARI.

TABLE 2. ALLOCATION OF GOPUNJAB RESEARCH INSTITUTE AND UNIVERSITY PERSONNEL BY COMMODITY, 2012

	Full Time Equivalent scientists	Percentage of total
Crops		
Wheat	139	10.0
Rice	71	5.1
Maize	54	3.9
Other cereals	43	3.1
Sugarcane	43	3.0
Pulses	54	3.9
Oilseeds	37	2.7
Vegetables	91	6.5
Fruits	70	5.0
Cotton	78	5.6
Other crops	43	3.1
Livestock		
Buffalo/cattle	143	10.3
Small ruminants	33	2.4
Poultry	122	8.8
Forages	32	2.3
Other livestock	27	1.9
Fish and forests		
Fisheries	23.6	1.7
Forestry	1.9	0.1
Other		
Agricultural engineering	175	12.6
Post-harvest	34	2.4
Soil and water	33	2.4
Socioeconomics	45	3.3
Total crops	**723**	**51.8**
Total livestock	**358**	**25.7**
Total fish, forests	**26**	**1.8**
Total other	**288**	**20.6**
Grand total	**1,394**	**100.0**

Source: Data provided by G. Stads (pers. comm.), ASTI-IFPRI.

during 2016–17. In agriculture, most expenditure goes to research, although it varies widely over time. In livestock most funding goes to extension and only 10–20% is allocated for agriculture research (Table 4). This variation in annual allocations and availability of funds is a major constraint to planning, conducting, and continuing R&E on a sustainable basis. In research in particular, unexpected reductions in funding halt programs until funding is resumed at a later stage. Almost complete dependence on GoPunjab funding significantly increases the possibility that funding will be unreliable. The high expenditure share of livestock extension needs careful analysis and justification.

The ASTI data for 2000–12 indicate that Pakistan's research investment in agriculture and livestock as a percentage of agricultural GDP is far lower than in neighboring countries (Figure 3). Agricultural research expenditure as a percentage of agricultural GDP in Pakistan has stagnated at around 0.2%, while it has dramatically increased in China to 0.6% (2012 figure). In most other countries, although research expenditures as a percentage of agricultural GDP have been relatively stagnant, they have still remained higher than in Pakistan. The Team's extended analysis for 2007–16 confirms this conclusion, except for 2016.

2.4. CONCLUSION

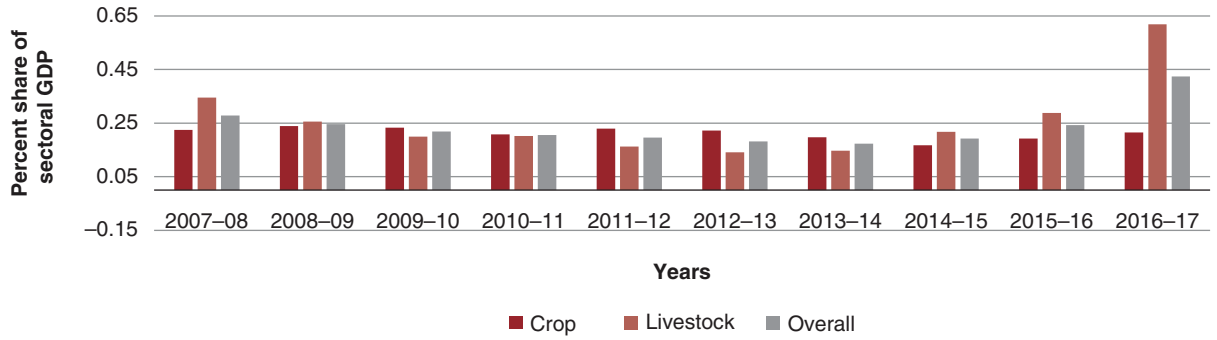
The public sector AIS has expanded to cover a large number of commodities, ecoregions, and emerging disciplines such as biotechnology and post-harvest management. This expansion continued until very recently with the opening of new research institutes, extension directorates, and universities. The financial and human resources of the public AIS grew accordingly, yet they did not account for a larger share of agricultural GDP, remained lower than the desired level of one percent of agricultural GDP, and are also lower than resource levels of most other countries in the region. Moreover, the public AIS remains highly dependent on unpredictable public funding. During the past 50 years, the public sector has pursued new collaborative approaches, tested new extension methods, and applied new research methods such as genetic modification using the tools of biotechnology. The federal research system continues to contribute to agricultural R&D in Punjab. The private sector fulfills its role of promoting modern inputs and related practices, and it has recently embarked on agricultural research on a limited scale. The next two chapters will examine what this expansion has achieved.

TABLE 3. REAL EXPENDITURE ON RESEARCH AND EXTENSION IN CROPS AND LIVESTOCK, PUNJAB, 2007–16

Year	R&E spending (million 2016–17 Rs)†			Percentage share in spending	
	Crops	Livestock	Total	Crops	Livestock
2007–08	3,921	4,885	8,806	45	55
2008–09	4,616	3,552	8,169	57	43
2009–10	4,426	3,005	7,431	60	40
2010–11	4,965	3,311	8,278	60	40
2011–12	4,202	2,944	7,147	59	41
2012–13	4,221	2,661	6,882	61	39
2013–14	4,106	2,716	6,822	60	40
2014–15	3,429	4,430	7,859	44	56
2015–16	3,687	5,973	9,660	38	62
2016–17	4,316	13,378	17,694	24	76

†The nominal values were deflated by the CPI with the base value of 2016–17 = 100.
Source: Authors' collection of data from DoAg and DoL&DD.

FIGURE 2. INVESTMENT IN RESEARCH AND EXTENSION IN PUNJAB AS A PERCENTAGE OF GDP FOR THE CROP AND LIVESTOCK SECTORS, SEPARATELY AND COMBINED, 2007–17



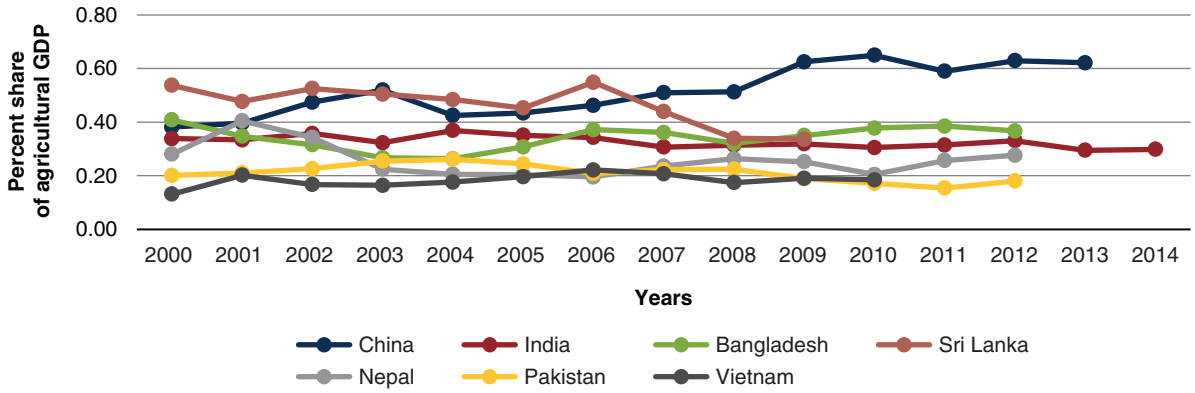
Source: Authors' calculation from the data collected from DoAg and DoL&DD.

TABLE 4. SHARE (%) OF RESEARCH, EXTENSION, AND UNIVERSITIES IN TOTAL RESEARCH AND EXTENSION SPENDING IN PUNJAB, 2007–16

Year	Crop sector (% share)			Livestock sector (% share)		
	Research	Universities	Extension	Research	Universities	Extension
2007–08	52	9	39	17	5	78
2008–09	41	8	51	15	7	77
2009–10	42	9	50	13	8	79
2010–11	40	8	52	16	8	76
2011–12	50	9	40	20	8	72
2012–13	58	11	31	18	11	70
2013–14	57	11	32	21	12	67
2014–15	72	18	10	20	10	70
2015–16	73	19	9	18	9	73
2016–17	46	18	36	10	5	85

Source: Authors' calculation from the data collected from DoAg and DoL&DD.

FIGURE 3. TREND IN RESEARCH EXPENDITURES IN SELECTED ASIAN COUNTRIES, 2000–12



Source: ASTI 2013.

CHAPTER 3
MAJOR ACHIEVEMENTS OF THE AIS

What have been the signature achievements of the AIS in Punjab over the past decade or so? The list of achievements highlighted in this chapter is unavoidably incomplete, in part because little effort has been devoted to evaluating the outcomes and impacts of agricultural R&E in Punjab. The system has been quite good at reporting outputs, such as the number of varieties released (65 released by AARI alone since 2011) or number of vaccines produced (13 in total). Yet outputs cannot be defined as achievements in the absence of evidence on outcomes (such as adoption and use levels) and on impacts (cast in terms of economic, social, and environmental benefits). Even when impact evaluations are conducted, such as the recent studies of the economic benefits of crop varieties produced at AARI, the results are not communicated well. With these considerations in mind, this chapter describes notable outputs of the R&E system in recent years (specific technologies developed and extended) in relation to outcome indicators commonly used to measure the impacts of R&E.

3.1. CROP VARIETIES

Undoubtedly the major strength of the AIS lies in the development, release, and uptake of improved varieties of major crops, mainly through breeding programs under AARI. About 70% of all crop varieties released in Punjab (Table 5) and 40% released in Pakistan[18] are from AARI. Since the Green Revolution period, wheat research in particular has a long history of regular release and adoption of improved varieties, although many analysts noted that those varieties seemed to be adopted slowly—the average age of varieties grown by farmers was about 11 years.[19] More recent evidence suggests that adoption is proceeding more quickly, however, with an average age of seven years, faster than for wheat in Haryana but much slower than the three-year turnover period in Mexico.[20] The adoption of several generations of new varieties

[18] Rana, Spielman, and Zaidi (2016).

[19] Heisey and Ahmad (1990).

[20] Spielman and Smale (2017).

TABLE 5. NUMBER OF VARIETIES RELEASED IN PUNJAB BY AARI, OTHER INSTITUTES, AND THE PRIVATE SECTOR, 1963–2010 AND 2011–17

Crop	AARI		Other institutes		Private sector		Total
	1963–2010	2011–17	1963–2010	2011–17	1963–2010	2011–17	
Wheat	49	7	5	5	0	0	66
Barley	3	0	0	0	0	0	3
Cotton	28	7	31	18	8	8	100
Rice	11	3	4	2	0	0	20
Sugarcane	11	5	0	0	1	0	17
Maize	7	7	0	0	2	0	16
Pulses	26	5	12	2	0	0	45
Fodder	14	3	0	1	1	0	19
Millet and sorghum	8	4	0	0	1	0	13
Oilseeds	16	5	6	0	5	0	32
Vegetables	34	6	0	0	0	0	40
Fruits	0	10	0	0	0	0	10
Flowers	0	3	0	0	0	0	3
Total	**207**	**65**	**58**	**28**	**18**	**8**	**384**

Source: FSCRD 2016.

of wheat has contributed 0.5–1.0% to annual growth of wheat yields.[21] Notably, the continuous release of varieties with new sources of resistance to the wheat rusts has prevented a widespread outbreak of that disease since the late 1970s—a major but hidden achievement of research, given the devastating losses to rust that once occurred in Punjab.

The benefits of public sector crop breeding have undoubtedly been very large. It is estimated that a 1.0% increase in the research expenditure in the crop sector leads to an increase of 0.13% in the Total Factor Productivity (TFP) index in Punjab. Different studies have estimated the rate of return on research to be 36–88%.[22]

Releases of improved varieties of other major crops have been more sporadic, but their adoption has nonetheless contributed to yield gains and other benefits. Outstanding examples include rice (such as the super basmati released in 1996), sugarcane (HSF-240 released in 2006 and SPF-234 in 2004), and cotton (MNH-886 released in 2012), all varieties from AARI. The high-yielding, yellow mosaic virus resistant, and short-duration mung bean variety, NM92, developed by the Nuclear Institute of Agriculture and Biology (NIAB) in collaboration with the World Vegetable Center[23] revolutionized mung bean cultivation in southern Punjab in the 1990s.[24] Recently AARI varieties such as Azri Mung 2006 have replaced NM92 and are sustaining yield improvements. Over half of the area planted to gram is under AARI varieties.[25] The private sector introduced Bt[26] technology in cotton production in 2004. There is very limited evidence on the adoption of varieties of other crops, such as pulses (other than mung bean), oilseeds, and horticultural crops.

Another major achievement, largely by the private sector, has been the adoption of hybrid maize seed and a shift to spring maize production since 2000. While the regulatory framework for the private sector is still a work in progress, regulations permitting the importation and release of maize varieties developed by the private sector helped Punjab to spearhead a maize revolution in which produc-

[21] Fischer, Byerlee, and Edmeades (2014).

[22] High rates of return are also suggestive of low investment in research; see Kiani, Iqbal, and Javed (2008).

[23] Formerly the Asian Vegetable Research and Development Center (AVRDC).

[24] Ali et al. (1997).

[25] Personal communication with DG AARI.

[26] *Bacillus thuringiensis*.

tion has increased four-fold since 2003. Since 2011, the private sector has released 8 cotton varieties, compared to 7 from AARI. The private sector is also very active in importing varieties of fodder and vegetable crops.

3.2. DEVELOPMENT OF LIVESTOCK VACCINES AND DIAGNOSTIC TESTS

The VRI concentrates on producing vaccines but has also had notable success in adapting vaccines to local pathogen strains and conditions and developing diagnostic tests. A major achievement attained through local vaccine adaptation was the elimination of rinderpest disease in 2007, adding Pakistan to the successful effort to eliminate rinderpest globally. Pakistan has also been declared free of avian influenza subtype H5N1, and progress on other subtypes has been significant. The VRI's work on a vaccine for peste des petits ruminants to allow the efficient production of 19 million doses promises similarly important impacts, as does the vaccine developed for Newcastle disease. In another case, the VRI and UVAS demonstrated effective vaccination for foot and mouth disease with one dose instead of the four doses previously prescribed as well as successful prevention of hemorrhagic septicemia with the same vaccine, thus dramatically reducing the operational costs of vaccination. Overall, the VRI has adapted and developed efficient production processes for 13 vaccines. The VRI has also contributed to the development of 6 diagnostic tests which include the Mallein test for detection of glanders in horses and for detecting tuberculosis and Brucella antigens. Most recently, the VRI has employed molecular techniques for rapid testing for a number of animal diseases. The UVAS has also developed a kit for testing milk adulteration that provides results on the spot.

3.3. INTRODUCTION OF NEW CROPS AND ANIMAL BREEDS

Although diversification of production has been a long-standing objective of the innovation system for agriculture and livestock, examples of successful diversification are few. Recently the provincial and federal governments, in collaboration with the Government of Italy, attempted to introduce olive cultivation in the Pothwar region of northern Punjab and Khyber Pakhtoonkhwa (KPK). Through PARC-funded projects, the GoPunjab and Italian government undertook to import and screen 34 olive varieties, develop management practices to adapt them to local conditions, and provide incentives for olive cultivation. Yield targets were fixed, based on an assessment of the economic viability of olive cultivation. PARB funded a project to establish standard operating procedures for nursery management, train nursery staff, and develop processed products from olive oil. Pakistan has imported processing machines from Italy, which PARC is redesigning for local conditions. This collaboration is a unique attempt to identify and address the issues involved in developing a value chain for a new commodity, to link various stakeholders in resolving those issues, and to properly sequence the various R&D activities. It is too early to evaluate the impact of the effort, although the project has achieved its initial milestone of bringing 5,000 ha under olive cultivation, with a target of achieving 40,000 ha in 10 years.

The DoL&DD conducts little research on developing and introducing new animal breeds and thus has little success to report. In contrast, the private sector is increasingly effective in promoting exotic cattle breeds through sales of high-quality insemination materials. Two famous Beetal goat breeds, namely Makichini (with small black spots on the body) and white Nagrai (with pink eyes), were developed and introduced by unidentified farmers through selection. The UAF has successfully introduced a new breed of backyard naked-neck poultry on the university farms, but they have not reached many Punjab villages. The PPRI is further improving its breed.

3.4. MANAGEMENT TECHNOLOGIES, PROCESSES, AND MACHINERY

The DG(OFWM) of the DoAg has promoted water conservation practices and technologies since the 1980s. Lately it has partnered with the private sector in a highly

focused effort to adapt, test, and roll out three on-farm water management technologies: downstream canal and watercourse lining, laser leveling, and HEIS (such as drip irrigation) for high-value agriculture. The first two technologies already cover the greater part of the irrigated Punjab. Some progress has been made in indigenizing the HEIS technology and making it more cost-effective and robust for wider adoption. The technology remains very expensive for small farmers, however, especially when low water prices offer little incentive for saving water. The lack of corresponding R&E means that farmers who adopt HEIS must adjust their crop management practices to the new irrigation system on their own. The DG(OFWM) estimates that about 13,000 ha have been brought under HEIS so far, although the sustainability of the technology is being questioned because of its high cost. A more sustainable practice spread through the private sector is laser leveling, which is reaching about 1.27 million ha per year (and the potential area where this technology could be used is much larger). In addition, an average of 20% of the length of 50,000 of the province's roughly 60,000 water courses have been lined,[27] which according to a third-party evaluation brings great savings in irrigation water as well as enhanced crop productivity, improved profitability, and more equitable distribution of water.[28]

To bring marginal land under cultivation, the DG(AF) provides land-leveling services at subsidized rates. Mainly through these services (and some private operations), about 0.5 million ha of marginal land has been brought under cultivation, although the economic viability of the public sector land-leveling services can be challenged.

Various organizations have promoted direct seeding in rice fields, such as the Rice Research Institute (RRI), Kala Shah Kaku, and International Maize and Wheat Improvement Center (CIMMYT) through its Agricultural Innovation Project. The emergence of weeds in direct-seeded fields was considered the main constraint to adoption of the technology; it was overcome by importing a post-emergence weedicide. The RRI demonstrated direct seeding extensively on farmers' fields throughout the rice-growing region, and its adoption reached about 15,000 ha within five years.[29]

The AMRI has developed about 40 machines in collaboration with private sector processors. Five of the machines have been commercialized to the extent that 1,000–7,000 units have been manufactured and adopted by farmers.

A good example of work in a value chain comes from the post-harvest department of UAF, which has developed protocols for using controlled atmosphere technology in shipping mangos. The protocols have now been communicated to and adopted by shipping agencies and are used to move Sindri mangos from Sind to Europe.

The private sector is popularizing silage technologies for livestock, while the public livestock extension division is extending simple management practices such as keeping animals freely constrained rather than tethered and encouraging greater consumption of better-quality water. Through a PARB project, the Buffalo Research Institute has developed a balanced diet, which is being commercialized through the private sector at a subsidized rate. The impact of these public sector efforts is unknown, however. The UVAS and livestock extension have developed model animal and poultry sheds, but little research underlies those models, and they are not widely accepted by farmers. On the other hand, automated poultry sheds, mainly developed and promoted by the private sector, are becoming quite popular among commercial poultry farmers.

3.5. GENERATION AND DISSEMINATION OF INFORMATION

Public R&E has played a significant role in generating and sharing relevant knowledge and information for various stakeholders, especially information related to the quality of resources engaged in agricultural production and data on the market prices of agricultural commodities.

[27] Personal communication with the Director OFWM on November 23 and 24, 2017.

[28] Government of Pakistan (GoP), 2011.

[29] Personal communication with the Director RRI, Kala Shah Kaku, on November 23, 2017.

The Rapid Soil & Fertility Survey & Soil Testing Institute, which provides soil and water testing services to farmers, has maintained the records of test results and thus has become a major source of historical information (from the 1970s) on soil and water quality in Punjab. Recently, under the Extension 2.0 Program, the institute finished mapping the water quality of all tubewells in the province. In addition, it has developed a province-wide grid of one million soil samples, which will ultimately increase to 2.8 million samples within the next two years. This soil grid will provide information on 34 parameters of average soil quality of the land at the individual ownership level for all farmers in the province.[30] These data bases are designed to facilitate extension recommendations but also have much potential in research when overlaid with other data, such as information from household surveys and data on crop yields and production practices from crop cutting surveys. The Team is not aware of a comparable comprehensive data base of this type orchestrated by the public sector anywhere else.

The DG(PW&PQC) provides weekly information on the pest situation, which is collated at the district level and published in monthly reports that can be used to devise timely strategies to control any anticipated pest outbreak. The DG(AE&M) of the DoAg has been keeping records of market arrivals and average prices of a large number of horticultural commodities. Initially these data were not widely available to stakeholders, but in 2010 the DG(AE&M) established an Agricultural Market Information Service portal that provides daily market prices of different grades of a large number of agricultural commodities and their arrival quantities. The portal contains links to other agriculture-related information, such as district-level area, production, and yields of all crops grown in the province, and international production and prices of agricultural commodities. It also communicates daily prices of agricultural commodities in various markets to about a million stakeholders. With easy access to market information, farmers and market agents should be able to increase their participation in various agricultural markets in Pakistan and reduce marketing margins, to the ultimate benefit of farmers and consumers. Evidence of such impacts is still lacking, however.

The DoL&DD has linked the veterinary services delivery system with Android mobile devices, which not only helps to monitor service delivery but provides data on the history of animal infections. Because the service has registered all animals in the province by type, a more accurate animal count is available. Now that the DoL&DD has completed a mineral map of land throughout all five ecological zones of Punjab, the data can be used to develop balanced animal feeds based on soil nutrient deficiencies in each region and the associated nutrient deficiency in fodder. The department's list of breeding (supposedly healthy) bulls in every village is expected to improve the health of young stock and help to identify the progeny.

3.6. REACHING OUT TO STAKEHOLDERS FOR EXTENSION

Public agricultural extension services were devolved in 2001 with the objective of reaching more stakeholders and involving them in decisions related to public R&D. Devolution was envisioned as a big step toward bringing extension closer to farmers, but empirical studies on devolution show that it brought mixed results.[31] Although a majority of the extension staff perceived the devolved system to be better than the old system, a majority of farmers perceived no change. There is evidence that district administrators (the District Coordination Officer, Nazim, and so on), rather than farmers, were making major operational decisions. Political intervention was pervasive, and the use of staff for political and non-extension purposes was common. The DGs of Extension for both crops and livestock also reduced the technical support that district extension staff used to receive from provincial headquarters. The abrupt merger of several functions sowed much confusion.

It is premature to evaluate the effectiveness of the GoPunjab's massive new Extension 2.0 effort, initiated

[30] Personal communication with the Director of Rapid Soil & Fertility Survey & Soil Testing Institute, Mr. Shahzad Munawar Mehdi, on January 27, 2018. The Director indicated that all of this data would be available on the internet in the near future.

[31] Saeed et al. (2006).

in 2016. The Team believes that the development of a soil attributes database, with the corresponding GIS mapping, will succeed and strengthen existing capacity. On the other hand, little progress has been seen so far regarding service delivery software, adoption of the latest extension approaches and tools, and establishing helplines.

Before the Extension 2.0 program, the "yield maximization" programs of the DG(AE&AR) in major crops (wheat, rice, and cotton) reached a large number of farmers every year to "transfer modern production technologies." The Directorate in its presentation to the Team claimed that its major post-T&V training program for wheat alone "reaches" more than one million farmers in some 21,000 Punjab villages through 784 teams, while "providing" more than 345,000 printed materials each year. In cotton, the program reaches about one million farmers in over 10,000 villages through 369 teams. [32] The Team observed some visits and saw literally truckloads of glossy printed materials being dispatched.

Some evidence suggests the kinds of impacts produced by these programs to promote simple, standardized Green Revolution technologies related to seed and fertilizer, especially in wheat production. For example, most wheat farmers in the province know the best performing variety,[33] and they generally use the optimal seed rate[34] and fertilizer doses.[35] Farmers' access to extension services has been shown to significantly improve wheat productivity[36] and reduce inefficiency in wheat[37] and rice[38] production in Punjab. Direct access to extension also appears to improve farmers' ability to adopt all three climate change adaptation practices studied in Pakistan, thereby enhancing their food security and reducing rural poverty.[39] In fruit, vegetable, pulse, oilseed, and livestock production, however, the impacts of extension contacts are visibly unimpressive. For all crops, including major crops, the impacts of direct extension contacts are not well documented.

In fact, farmers still have relatively limited direct access to extension services. For example, one study reports that 14% of farmers in Punjab have direct access to extension; another study reports that across Pakistan 26% of farmers have direct access to extension.[40] Limited access to extension services forces farmers to rely more on *informal* sources for agricultural advisory services than public or private *formal* sources.[41]

The PCs established by the Plant Protection Directorate of DG(AE&AR) currently reach about 45,000 farmers, and they are rapidly expanding to reach more. The data they collect on disease incidence and diagnosis are recorded by CABI.[42] An independent evaluation of the PC program suggests that, despite some governance issues, it is effective, efficient, and relevant to farmers' needs.[43]

The large-scale vaccination program operated by the veterinary services in Punjab does not fall within the parameters of this review, because it is not an extension program, strictly speaking.[44] Nonetheless, the delivery of vaccines should be listed here under achievements, partly because it demonstrates something of the capacity of the DoL&DD and partly because vaccine delivery involves a field presence that could become the basis for a wider extension effort.

In deviating from its traditional focus on supplying curative services through archaic veterinary hospitals, livestock "extension" has taken a revolutionary leap. Without ignoring the curative services, it has focused on delivering animal disease prevention services to farmers' doorsteps. Throughout Punjab, the DoL&DD has started its mobile veterinary services; mounted a 100% deworming campaign for all large and small animals (including equines and camels) as well as a tick/Congo virus control campaign;

[32] Presentation by the DG(AE&AR) to the Team on September 4, 2017.

[33] Javaid (2017).

[34] Battese, Nazli, and Smale (2017).

[35] Ali et al. (2016).

[36] Elahi et al. (2018).

[37] Battese, Nazli, and Smale (2017).

[38] Fatima et al., (2018).

[39] Ali and Erenstein (2016).

[40] Battese, Nazli, and Smale (2017) for extension contact in Punjab; Ali and Erenstein (2016) for all of Pakistan.

[41] Elahi et al. (2018).

[42] Personal communication with Dr. Aamir Humayun Malik, Deputy Director Development, CABI on November 23, 2017.

[43] See Williams, Alawy, and Danielsen (2015). The governance issues are highlighted in CEIL PEAKS and DAI (2015).

[44] The standard definition of extension or advisory services used by the Team is *those services that provide information to farmers and other clients and build their capacity to seek out and utilize information best suited to their meeting their goals and addressing their resource constraints* (Byerlee 1988).

and provided comprehensive carpet vaccination against contagious/infectious animal diseases. Mobile Veterinary Dispensaries have been established in all tehsil[45] headquarters hospitals, and all veterinary officers and their assistants have been equipped with motorbikes. With an ample supply of medicines, the mobile dispensaries cover all villages within a tehsil on a scheduled tour program. The dispensary staff has extensive training in identifying and treating disease and especially in administering vaccines. The field activities of mobile veterinary officers are geotagged through their Android mobile sets, which also gather service delivery data for monitoring by district and provincial headquarters. Aside from facilitating quick and easy communication between producers, doctor/service providers, and other stakeholders, this effective, state-of-the-art virtual system provides accurate data on all animals in the province.

It is a truly impressive achievement to deliver a comprehensive preventive program to all animals in the province. Because the treatment is free, however, farmers may not even know if their animals have been treated and may not be confident about the quality of services. The DoL&DD needs to build farmers' trust in the effectiveness of these services so that ultimately farmers will be willing to help pay for them. The outcomes of these efforts in terms of increased yields of livestock products or reduced mortality of animals are not yet clearly visible or documented. A third-party independent evaluation should be an integral component of the program.

3.7. CAPACITY BUILDING

A range of GoPunjab institutions and agricultural and livestock universities offer opportunities to build capacity. Four In-service Agricultural Training Institutes (IATIs) offer three-year diploma courses on agricultural production for about 300 high school candidates every year. The graduates of these courses join the DoAg as field assistants, run their own farms, or pursue graduate studies at a university. In addition, the DoAg plans to provide three-day training events through the IATIs to all technical in-service staff and about 500 new entrant staff of DG(AE&AR) during 2017. Short-term training for extension staff normally features guest instructors from universities and research institutes. The IATIs also provide some training to farmers on specific issues on a need basis.[46] The Directorate (AdR) also "trains" (through discussion sessions) almost all extensionists two to three times a year, who then brief farmers. The AdR also plans to hold 250 field days at farmers' demonstration fields and 50 field days at AdR farms during this year.

The seven training institutes of the Training Directorate of the DG(LSE) offer a two-year diploma course to about 350 trainees every year. Under its 9211 program, the DoL&DD has prepared 50,000 community facilitators who can be mobilized in any extension campaign. In 2016, the UVAS provided in-service training to about 700 staff promoted to a higher grade and to new entrants. The PPRI has three types of training activities: (1) short training events, consisting of a one-week course for about 350 poultry farmers and a single-day question-and-answer session in every district that reaches about 5,000 poultry farmers every year; (2) internship training for students, new staff, and in-service staff, producing about 300 qualified trainees every year; and (3) a six-month kill-development training course based on the priority needs of the industry. The six-month course prepares about 200 workers for the industry each year and currently consists of training in poultry housing management, poultry hatchery management, laboratory technicians for the poultry industry, and laboratory techniques for testing poultry feeds and water. Stakeholders such as commercial poultry farmers help to design and evaluate the skill-development courses. This training program is being linked with national programs such as the Technical Educational and Vocational Training Authority (TEVTA).

A unique development is the collaborative agricultural business program of the UAF and Institute of Business Administration Sukhur to meet the needs of agribusiness in the province. The UVAS provided a list to the Team of 70 modules of short-term courses for in-service and new researchers, vaccine producers, and (to a limited extent) extension staff.

[45] Sub-district.

[46] Personal communication with Mr. Muhammed Zikrya, Director Agricultural Training Institutes, Karor Laleason, District Layyah.

3.8. PRIVATE SECTOR RESEARCH AND DEVELOPMENT

The private sector is playing a useful role within the AIS by organizing farmers around a few output collection centers in confined areas, such as centers for milk, maize, sugarcane, chili peppers, carrots, and rice. Private firms are also reaching out in a major way to farmers through their input supply systems, especially for pesticides, seed, fertilizer, and animal semen and feed, although as noted earlier, information is usually biased toward each firm's own products[47] and to wealthier farmers.[48] However, the quality of private sources of advice was reported to be better than public sources[49] due to its easy availability and processing.[50] The spectacular success of the private sector in introducing and promoting hybrid maize has been noted.[51] Other private programs (Nestlé and Engro, for example) have had only a limited impact, however, in disseminating artificial insemination of elite breeds, disease control practices, and silage machines (mostly imported).

In livestock, the private sector's major success has undoubtedly occurred in the poultry industry, which has expanded spectacularly since the first poultry farm was established in 1962 with imported broilers (PIA Shaver) by Pakistan International Airlines. The industry now consists of some 25,000 commercial poultry farms, providing jobs to 1.5 million people, and its annual turnover has reached Rs 564 billion. This phenomenal growth is largely attributed to private importation of breeds and promotion of state-of-the-art poultry sheds, poultry feeds, and associated management practices. The GoPunjab has supported this development through disease surveillance, a regulatory framework, and capacity building.

[47] Davidson (2005).

[48] Mengal, Mirani, and Magsi (2014).

[49] Davidson (2005).

[50] Elahi et al. (2018).

[51] Due to the introduction of hybrids in maize production by the private sector, the maize yield more than tripled from 1.9 t/ha in 2002 to 6.0 t/ha in 2015 (GoP, various issues).

3.9. REGULATORY FRAMEWORK

An appropriate regulatory framework is important to induce private sector investment and inclusive growth. Conceptualizing that framework requires significant social sciences research, however, especially on economic and political aspects of the economy. Several earlier studies have highlighted the importance of regulatory reforms in seed and output markets,[52] as well as the fertilizer[53] and livestock[54] sectors. Some of that research led to successful legislation to carry out reforms, such as the Amendments to the Seed Act 1976 (2015) and the Plant Breeders Right Act (2017). The Ministry of Food Security and Research has also notified the regulation under the reformed Seed Act (2015), although the GoPunjab has several reservations on the amended Seed Act (2016) and regulation notified under the act.

Similarly, in the livestock sector, the GoPunjab has notified a Livestock Breeding Policy (2012), followed by a Livestock Breeding Act (2014) and a Livestock Breeding Services Authority (2015). The Animal Feed Stuff and Compound Feed Act (2016) and the Punjab Poultry Production Act (2016) have been approved, and regulations under those acts have been notified. Enactment of the Punjab Food Authority Act (2011) and subsequent establishment of the Punjab Food Quality Control Authority will go a long way toward improving food quality in the province and pressure all value-chain players, including farmers, to meet food quality standards.

Standards for poultry feeds and all poultry products have been defined and circulated to stakeholders, and all poultry-related industries (poultry farms, feed mills, hatcheries, processing units, rendering plants, poultry

[52] Ali and Byerlee (2004) highlighted the need for reforms in seed and output markets of Punjab and delineate the basic parameters of those reforms. Ali (2015) also showed how improved market laws in India and the USA transformed their marketing systems. Rana, Spielman, and Zaidi (2016) pointed out how the outdated regulatory framework has held the cotton sector back in Pakistan and emphasized the need for reforms to bring growth in the cotton sector.

[53] Ali et al. (2016).

[54] World Animal Health Organization (OIE) (2016).

labs, and so on) have registered at PPRI through a simple mechanism. The regulations also define protocols for the movement of birds and poultry products, especially in the event of disease outbreaks. Poultry Officers in each district are responsible for implementing these rules and regulations. Implementation mechanisms in dairy and meat products remain relatively weak.

Regulatory reform is a continuous and evolving process to address developments in technology and changes in input and output markets, as well as to meet international obligations. The recently improved regulatory framework is expected to improve the food quality and safety situation in the province for the benefit of the whole livestock sector, although it is too early to judge its impact.

3.10. CONCLUSION

The outstanding outputs of the public sector AIS at the individual technology level include varieties of major crops, vaccines and diagnostic kits for animal health, the generation and dissemination of an array of information and knowledge, and the development of extension mechanisms to reach stakeholders. The turnover in wheat varieties is faster in the Punjab of Pakistan than the Punjab of India, and the capacity of the Punjab AIS to reach all of the province's livestock farmers through a specially developed Android network may be unique in the entire world. Under the improved regulatory framework, the private sector is becoming active, especially in developing and releasing hybrids of Bt cotton, maize, rice, sorghum, tomatoes, and cucumbers, poultry breeds and feeds, semen of exotic animal breeds, and new goat breeds.

Despite success in lining water channels and promoting laser leveling of fields, the public R&E system generally seems insufficiently capable of generating and disseminating advanced crop management techniques and expanding mechanization. The need for public sector outputs is highest where the private sector has contributed little. Success is limited to promoting high efficiency irrigation and protected vegetable cultivation; the latter is linked to hybrid seed imported by the private sector. In a few cases, however, the private sector is playing a larger role in promoting advanced management practices and mechanization, especially in the poultry sector, including mechanized poultry sheds and balanced poultry feeds.

Although the achievements identified in this chapter are remarkable in many respects, a more exacting assessment of the innovation system's performance follows in the next chapter, based on indicators related to welfare, productivity, sustainability, and competitiveness, among others.

CHAPTER 4
INDICATORS OF SYSTEM-LEVEL OUTCOMES

This chapter measures the quantitative outcomes of the entire Punjab AIS based on various indicators of the system's performance. It makes no attempt to disaggregate outcomes between research and extension, which would require detailed field surveys that lie beyond the scope of this review.

4.1. SLOW YIELD GROWTH IN THE PAST DECADE

Yield growth, considered a crude indicator of innovation system performance, has been unimpressive over the period between 1995 and 2015 (Table 6). Even in wheat, Punjab's major crop, yield growth has been lower than the population growth rate of more than 2%, especially during 2006–15. Although yield growth has been satisfactory in maize, sugarcane, mung beans, and potatoes, the crops that are important for diversifying Punjab's cropping systems—including vegetables, fruits, pulses, edible oils, tomatoes, minor crops, and fodder—experienced negative or insignificant yield growth during 1995–2005. This performance is even more worrisome because growth in yields of major crops like wheat, rice, and cotton continued to decline during 2006–15. The high growth in maize yield, especially during 2006–15, was driven by the private sector's introduction of hybrids, as discussed. Growth in mung bean yields was driven by high-yielding varieties resistant to yellow mosaic virus, developed by NIAB and AARI, and growth in sugarcane and potato yields was driven by high output prices that induced farmers to use more inputs.

4.2. LOWER YIELDS THAN IN COMPETING COUNTRIES

Farmers in Punjab achieve lower crop yields than those achieved elsewhere in the region under similar conditions (Table 7). Milk yields may be stagnating for a number of reasons (Figure 4), but poor progress in fodder and feed systems for improved nutrition, poor genetic potential of animals, and heavy productivity losses due to various

TABLE 6. AVERAGE LEVELS AND GROWTH RATES IN YIELDS OF CROPS GROUPED BY PERFORMANCE, 1995–2015

Crop groups	Average yield (t/ha)			Growth rate (% per annum)		
	1995–2005	2006–15	1995–2015	1995–2005	2006–15	1995–2015
Better-performing crops (overall period)						
Sugarcane	45.0	53.0	49.0	1.5	2.3	1.8
Maize	2.0	5.2	3.6	13.5	3.7	9.7
Potatoes	16.1	20.2	18.1	3.3	3.8	3.6
Mung beans	0.64	0.56	0.64	2.6	5.2	3.0
Poorly performing crops (in the 2nd period)						
Wheat	2.4	2.7	2.6	2.5	1.0	1.4
Rice (paddy)	2.4	2.9	2.6	2.9	1.0	2.1
Cotton (phutty)	1.8	2.1	1.9	2.5	0.7^{ns}	1.8
Poorly performing crops (overall period)						
Vegetables (excluding potatoes and tomatoes)	2.1	2.6	2.3	−0.2	−1.0	−0.6
Tomatoes	15.6	14.7	15.2	−1.6	0.5	−0.7
Fruits	13.7	12.8	13.3	0.7	0.2^{ns}	0.7
All pulses	10.2	11.1	10.7	1.3^{ns}	−2.8^{ns}	−1.1
Edible oilseeds	0.6	0.5	0.6	2.2^{ns}	0.6^{ns}	1.6^{ns}
Fodders	1.1	1.3	1.2	0.2^{ns}	−0.5	−0.2
Minor crops	22.3	21.7	22.0	0.2^{ns}	−0.1^{ns}	0.1

Source: Data on yield per hectare were taken from the Agriculture Statistics of Pakistan (Pakistan Bureau of Statistics, various years), and growth rates were estimated as the log-linear trends of the respective yield series; ^{ns} implies not statistically significant at the 10% level.

TABLE 7. CROP YIELDS (t/ha) IN PUNJAB AND SELECTED ASIAN COUNTRIES DURING 2014

Crop	Punjab, Pakistan	India	China	Vietnam
Wheat	2.8	3.1	5.2	–
Rice (paddy)	2.4	3.6	6.8	5.8
Maize	4.3	2.6	5.8	4.4
Sugarcane	55.1	70.2	71.3	65.0
Pulses (lentil)	0.4	0.6	2.0	0.8
Potatoes	18.1	22.9	16.9	14.1
Tomatoes	9.5	21.2	52.6	–

Source: FAOSTAT.

infections are likely to be the major reasons. If Pakistan could bring its yields just to the level of world average yields, its agriculture could earn US$ 10 billion in additional gross revenue.[55]

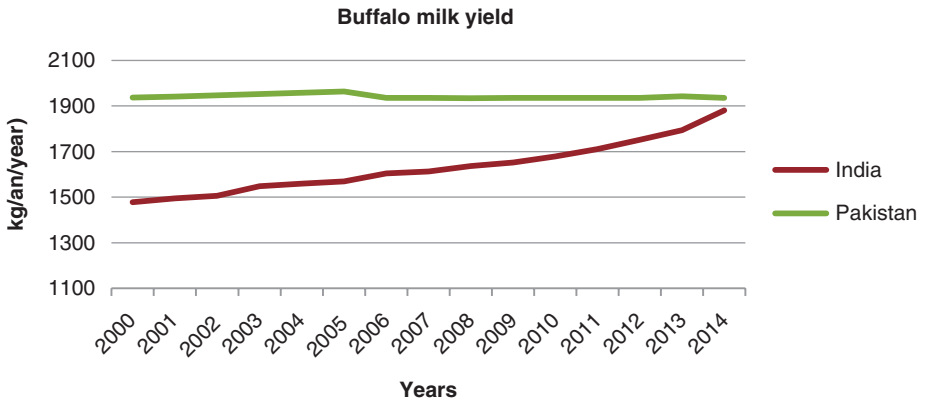
4.3. LARGE YIELD GAPS

The large gaps in average crop and animal yields shown in Figure 5 indicate that the productivity gains generated through research are not exploited through an efficient extension system. Some yield gap is inevitable, since farmers will never maximize yields due to loss of profits and higher risks.[56] Earlier studies, especially in rice in the 1990s, suggested that variation in the quality of farmers' natural resources base could cause part of the yield gap (saline or waterlogged land, for example, or poor quality

[55] Ali (2017).

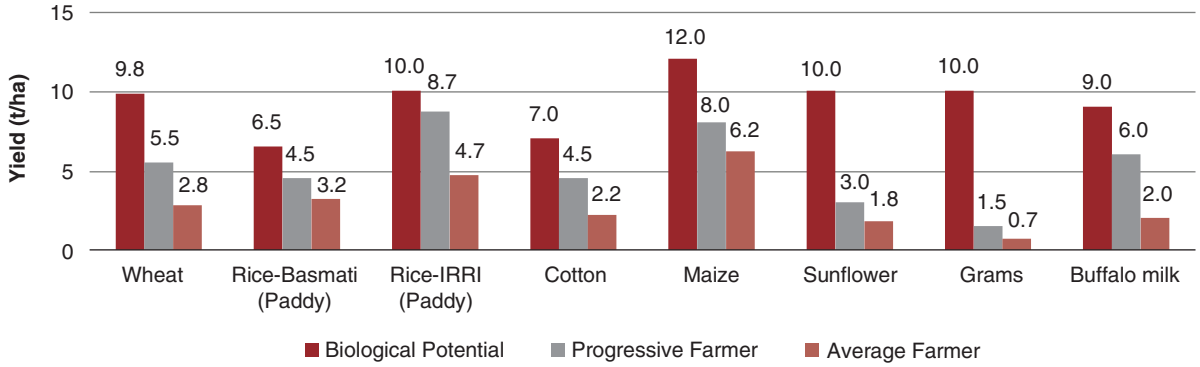
[56] Fischer, Byerlee, and Edmeades (2014).

FIGURE 4. TRENDS IN BUFFALO MILK YIELD IN PAKISTAN AND INDIA DURING 2000–14



Source: FAOSTAT.

FIGURE 5. GAPS IN YIELDS OF MAJOR CROPS (t/ha) AND MILK (t/ANIMAL/ANNUM), PAKISTAN



Source: Punjab Agriculture Sector Plan, 2015.

water and substandard feeds), but a significant portion can be attributed to poor management practices, indicating weaknesses in access to institutions such as information and input-supply markets.[57] Substantial scope exists to enhance productivity and close those gaps by investing to improve the quality and efficiency of extension services.

4.4. STABILIZATION OF YIELDS

Farmers are widely assumed to invest more intensively in a crop if they perceive yields to be more stable,[58] and yield stability has long been an important objective in crop-improvement.[59] For this review,[60] the extent of variation in crop yields is measured by the coefficient of variation (CV) around linear trend values for seven major crops and computed separately for three periods: prior to the Green Revolution (1948–70), the Green Revolution period (1971–93), and the post-Green Revolution period (1994–2015). Results are reported in Table 8.

The results suggest that the variability in yields of wheat, rice, and sugarcane—the crops where most research resources are invested—has significantly declined since the pre-Green Revolution period. Potato and mung bean yields largely remained stable across all three periods. In all crops except rice, maize, and mung beans, the variation in the second period is lower than or similar to the variation in the first period. This achievement of the AIS is important. It indicates that research has enabled Punjab's farmers to cope with the effects of climate change, which is widely expected to contribute to increased yield variation.[61]

[57] See Ali and Flinn (1989); Ali (1995).

[58] Hardaker et al. (2015).

[59] Eberhart and Russell (1966); Flinn and Garrity (1989); Simmonds (1991).

[60] Following Anderson and Hazell (1989).

[61] Rosenzweig et al. (2013).

TABLE 8. COEFFICIENT OF VARIATION (IN %) IN CROP YIELDS AROUND THE TREND VALUE

Crop	Period		
	Pre-Green Revolution (1948–70)	**Green Revolution (1971–93)**	**Post-Green Revolution (1994–2015)**
Wheat	15.1	7.0	5.2
Rice	14.3	5.3	9.0
Cotton	8.1	26.8	9.8
Sugarcane	13.6	5.5	5.2
Maize	9.0	4.0	7.7
Potatoes	13.2	12.3	12.6
Mung beans	9.1	5.6	9.7

Source: CV calculations based on yield data obtained from Agricultural Marketing Information Service (AMIS), GoPunjab website.

4.5. RECURRING PRODUCTION CRISES

Although the AIS has reduced yield variability in some crops and shielded Pakistan from major epidemics of plant and animal diseases such as leaf rust in wheat, avian influenza, and foot and mouth disease, recurring crises reflect gaps in the research, extension, and seed regulatory systems. In recent years crises have occurred in cotton (2015–16, reducing national GDP by 0.5%), mango (2011–13), rice (2013–14), and gram (2012–14).[62] Outbreaks of foot and mouth disease and other diseases in large ruminants, although never reaching epidemic proportions, have caused heavy direct losses to farmers through high animal mortality, reduced milk yield, and animal weight loss. They have also caused indirect losses by restricting meat exports to high-end markets.[63]

4.6. REDUCED SEASONALITY

Extending the production period of perishable agricultural commodities to expand their availability during the off-season is an important goal of R&D for horticultural crops.[64] During the past decade or so, the agricultural extension wing of the DoAg incentivized protected vegetable cultivation and encouraged IPM practices through training. The private sector also imported hybrids of several vegetable crops and sought to adapt them to local conditions. As a result of these efforts, and probably in conjunction with the opening of trade with India, certain vegetables became significantly more available during the off-season. This increased availability is reflected in dramatic reductions in seasonal fluctuations in prices of tomatoes and cucumbers during 2014–16 compared to 2008–10 (Figure 6).

4.7. SLOW PRODUCTIVITY GROWTH

Productivity growth, measured as total factor productivity (TFP), is often used as a quantifiable measure of innovation in a firm, sector or country.[65] Very slow growth in TFP since 2001—a sharp deceleration from the 1980s and 1990s (Figure 7)—is another indication of the poor outcomes of the agricultural R&E system in Punjab. Although the data used in the calculation are for Pakistan as a whole, the fact that Punjab accounts for over half of national agricultural production means that the same trends likely apply to Punjab. Indeed, Pakistan (and probably Punjab) had the slowest rate of gain in TFP of any country in Asia over 2001–14 (Figure 8). These results are consistent with results of earlier studies conducted for Punjab[66] as well as for the whole country.[67] The data in Figure 8 also suggest that yield increases are not only slower in Pakistan than in neighboring countries but that most of the yield growth in Pakistan derives from higher levels of input use rather than growth in total factor productivity. Another factor explaining very low TFP growth may be deterioration in the quality of the natural resource base.[68]

[62] GoP (various year).

[63] Ashfaq et al. (2015).

[64] Ali (2000).

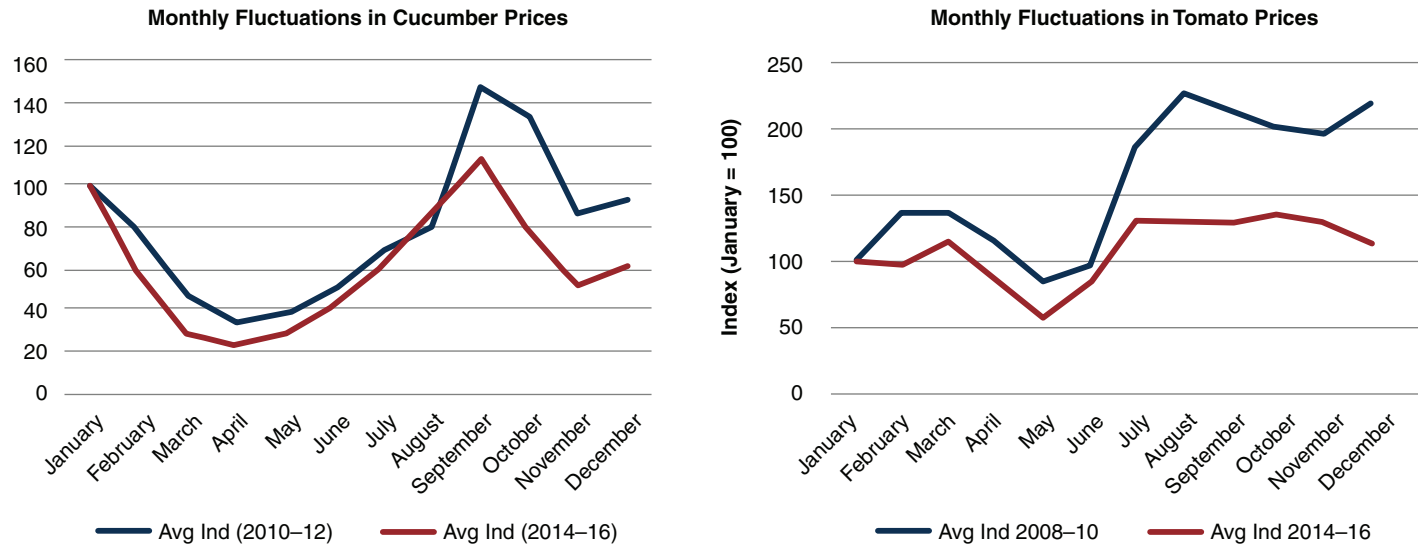
[65] However, innovation can help pursue objectives other than productivity growth, in particular in terms of product quality, diversity and safety, sustainability, etc. (OECD 2011). TFP as a measure of productivity growth may be regarded cautiously, as it may reflect the effects of resource mining. (see Ali and Byerlee 2002).

[66] Ali and Byerlee (2004); Amer and Gautam (2013).

[67] Malik et al. (2016).

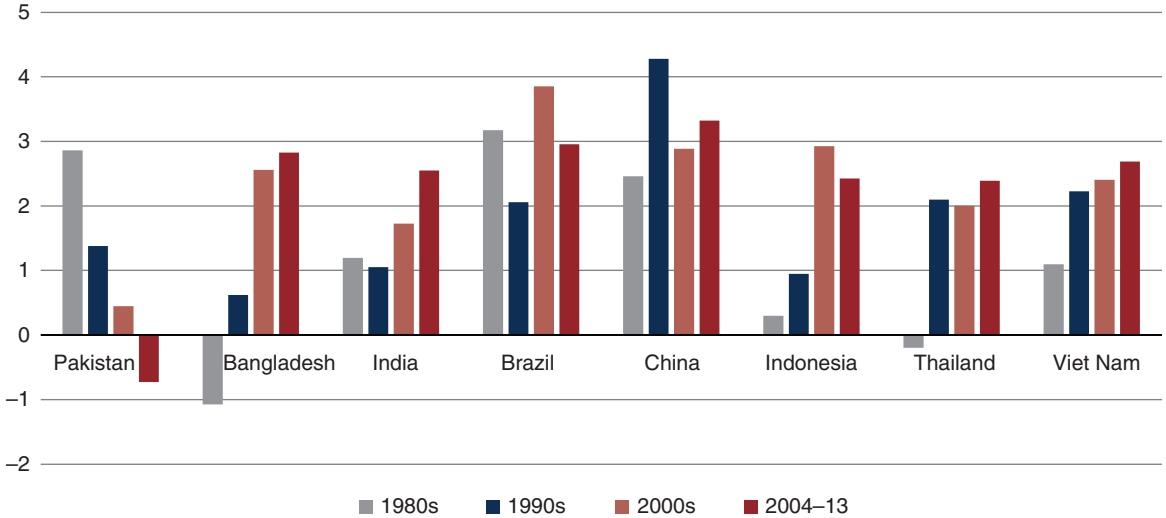
[68] Ali and Byerlee (2004).

FIGURE 6. SEASONAL FLUCTUATION IN MONTHLY PRICES OF TOMATOES AND CUCUMBERS



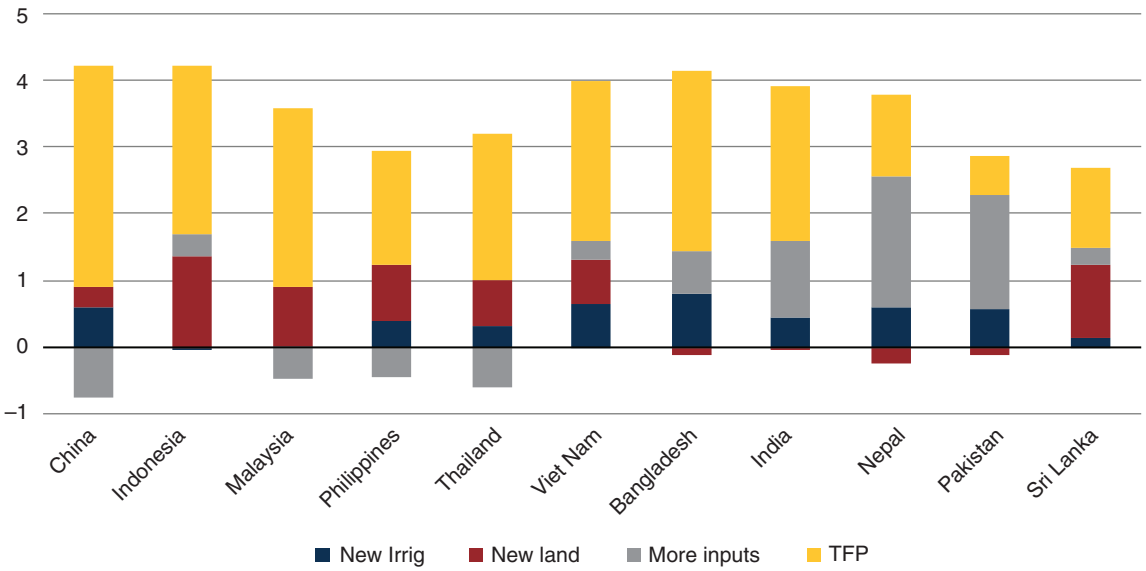
Source: The monthly price index for every year was developed from the monthly nominal price data obtained from the *Pakistan Economic Survey* (GoP, various issues) and then converted into a monthly average three-year index.

FIGURE 7. PERCENTAGE ANNUAL GROWTH IN TOTAL AGRICULTURAL FACTOR PRODUCTIVITY (TFP) IN SELECTED COUNTRIES IN FOUR PERIODS SINCE THE 1980s[1]



[1]Growth in TFP is measured as changes in an index of all agricultural output (both crop and livestock) in relation to an index of changes in all inputs.
Source: Technical Assessment conducted in 2017 for SMART Punjab (based on USDA-ERS data).

FIGURE 8. DECOMPOSITION OF AGRICULTURAL OUTPUT GROWTH BY SOURCE FOR MAJOR COUNTRIES IN ASIA (%/YEAR), 2001–14



Source: "International Agricultural Productivity," TFP growth indices from USDA-ERS, available at https://www.ers.usda.gov/data-products/international-agricultural-productivity/ (accessed December 2017).

4.8. DEVELOPMENT OF SUSTAINABLE TECHNOLOGIES

Another objective of agricultural research should be to develop sustainable technologies to protect the agricultural resource base and environment. Some of the recent technologies used in Punjab are especially important for environmental protection, such as the introduction of Bt technologies in cotton production. This innovation is based on the Monsanto gene MON 531 incorporated initially by the private sector into its own varieties but later by the public sector into public sector varieties. Because Bt cotton varieties are sprayed for pests significantly less often, pesticide costs are about 17% lower than on non-Bt plots. Reductions in chemical pesticide use confer significant health advantages in the form of fewer cases of acute pesticide poisoning, and the environmental advantages include greater biodiversity on farm land and lower soil and groundwater contamination, adding up to a gross margin of US$ 283 per acre, or US$ 1.8 billion for the total Bt cotton area in Pakistan.[69] Cotton yields are also significantly higher on Bt than on non-Bt plots, despite lower use of pesticides on Bt varieties. The Bt varieties yield better because bollworm is effectively controlled and does less damage,[70] and not because Bt varieties have higher genetic yield potential. Largely because of the higher yields to be harvested from Bt cotton fields, Bt cotton adoption has increased the use of hired labor; the additional employment is worth US$ 211 million per season. This additional income from agricultural employment is especially important for the landless rural households that are often the poorest of the poor. The largest increase in demand for hired labor occurs for female laborers, as farmers predominantly hire disadvantaged women workers.[71]

Apart from cotton, however, efforts to introduce sustainable production practices in crop and animal production have met with little success. High pesticide residues on fruits and vegetables[72] and high heavy metal content and bacterial loads on livestock products[73] continue to be reported in various studies. Fertilizer use efficiency has continuously declined,[74] and water use efficiency remains

[69] Kouser and Qaim (2013).

[70] Kouser and Qaim (2014); Abedullah, Kouser, and Qaim (2015).

[71] Kouser, Abedullah, and Qaim (2017).

[72] Ahmad et al. (2012).

[73] Ahmad (2016); Imran, Hamid, and Amjad (2015); Iqbal and Asi (2013).

[74] Ali et al. (2016).

TABLE 9. UNIT COSTS (RS/T) OF PRODUCING MAJOR CROPS IN PUNJAB, 1995, 2005, AND 2016

Crop	Nominal			Actual (deflated by CPI) (1995 = 100)		
	1995–96	2005–06	2016–17	1995–96	2005–06	2016–17
Wheat	4,625	6,125	23,025	4,625	3,375	4,625
Basmati rice	4,800	9,150	34,975	4,800	5,050	7,000
Cotton (seed cotton)	8,400	14,725	35,000	8,400	8,125	7,025
Sugarcane	450	750	3,500	450	425	700

Source: The nominal unit costs (Rs/40 kg) were taken from Punjab Economic Research Institute (PERI) reports for the respective years, deflated using the CPI from the Economic Survey of Pakistan, and converted to the 1995 = 100 base.

low compared to other countries.[75] Despite several companies which produce organic fertilizer in Punjab (Annexure 2), and World Bank-supported efforts for its promotion,[76] its use has never picked up significantly.

4.9. DECLINING COMPETITIVENESS OF PAKISTAN'S AGRICULTURE

Although competitiveness can cover any aspect of market performance (such as product quality, ability to innovate, capacity to adjust rapidly to consumer needs, and so on), competitiveness can also be narrowly interpreted based on relative costs and prices.[77] Competitiveness can be measured at various levels using different methodologies at each level. In this study, two measures are used to estimate the competitiveness at the farmgate level. First, the trends in real unit production costs (after accounting for inflation) of different commodities are a proxy for competitiveness. Second, the dynamism in relative farmgate prices in Pakistan versus in the international market reflects trends in real costs of production at the farm level. Similarly, two measures for competitiveness are used at the export level. First, the revealed comparative advantage (RCA) is applied to analyze the changing export competitiveness of Pakistan's agricultural sector. Second, the relative export prices of Pakistani products versus international export prices of these products are used to analyze the quality competitiveness of the value chain of Pakistani products.

4.9.1. RISING REAL COST OF PRODUCTION

It is obvious that if the relative unit cost of products is high, the ability to compete internationally is compromised.[78] To consider changing cost as an indicator of altering competitiveness, the effect of inflation is factored out in this study by deflating the nominal costs with the consumer price index (CPI). For major crops, the real per unit production costs (after deflating with CPI) declined or remained constant from 1995–96 to 2005–06 but then increased sharply for two of the four major crops from 2005–06 to 2016–17 (Table 9). Rising production costs indicate that yield increases in these crops (due to introduction of innovations in production practices), if any, did not match the increasing input costs during the later period, revealing reduced input-cost efficiencies. The higher cost of producing food and fiber has serious consequences for food security as well as for international competitiveness, discussed in the later sections.

4.9.2. INCREASED RELATIVE PRICES OF AGRICULTURAL COMMODITIES

Increasing real production costs are reflected in increasing commodity prices. If the increase in the domestic price of a commodity is higher than the increase of the corresponding international price, the competitiveness of that commodity deteriorates or is lost. However, nominal prices include the effects of border subsidies and tariffs or

[75] Qureshi (2011).

[76] See 'Lahore Composting project' of the WB, project code P106652.

[77] Turner and Van't dack (1993).

[78] Turner and Van't dack (1993).

TABLE 10. AVERAGE ADJUSTED FARMGATE AGRICULTURAL COMMODITY PRICES IN PAKISTAN AND WORLD MARKETS AFTER ACCOUNTING FOR THE NOMINAL PROTECTION RATE (NPR) DURING 2006 AND 2013

Crop	2006		2013		Difference (%)		Competitiveness: increase (+), decrease (−)
	World	Pakistan	World	Pakistan	2006	2013	
Wheat	130	160	262	327	−23	−25	−2
Rice	187	235	291	429	−26	−47	−22
Cotton	589	347	1,309	925	41	29	−12
Maize	146	140	243	257	4	−6	−10
Milk	292	184	415	180	37	57	20
Poultry meat	1,780	1,430	1,827	2,297	20	−26	−45
Mango	576	366	875	503	36	43	6

Source: Estimated by the authors.

Note: Adjusted farmgate prices are estimated using the procedure explained in Footnote 80. Only those commodities are considered here for which NPRs are available for the years 2006 and 2013.

monopolies and camouflage real competitiveness. In this study, the "true domestic price" is estimated by taking out the effects of these protection at the border[79] on farmgate prices[80] both at domestic and international levels.

Pakistan's agricultural sector is gradually becoming uncompetitive, as reflected in the higher increase in adjusted farmgate prices than in international farmgate prices of most agricultural commodities, except for milk and mango. This gradual loss of competitiveness must be attributed at least in part to slow progress in improving TFP compared to impressive TFP growth in competing countries due to an inefficient and unresponsive AIS.

4.9.3. DECREASING REVEALED COMPARATIVE ADVANTAGE

At the export point, changing export competitiveness of all individual agricultural commodities traded in international markets as well as for the whole agriculture sector is estimated for the years 2001 and 2013 using the RCA approach.[81] The results suggest that the RCA of all major agricultural commodities except citrus, and potato, have deteriorated over the period, while the RCA of livestock commodities, except milk, has improved (Table 11). The RCA for the whole agricultural sector has significantly deteriorated over the period, however, which not only indicates that the AIS is performing poorly but generates grave concern for policy makers in the country.

4.9.4. WEAK VALUE CHAIN DEVELOPMENT

Another measure of competitiveness at the export point is the average export prices of Pakistan's commodities

[79] The effects of border interventions such as tariffs and subsidies are measured in terms of nominal protection rate (NPR) in percentage. The NPRs on agricultural commodities are taken from http://www.ag-incentives.org/indicator/nominal-rate-protection. To take out the effects of border protections on commodity prices and estimate the real prices reported in Table 10, each commodity farmgate price, at the national and international level, is inflated to the extent NPR is positive, or deflated to the extent NPR is negative. This procedure of adjusting the nominal prices still does not remove the effects of public controls and monopolies on prices. However, it is assumed here that these effects do not change within the short period studied (seven years) and thus do not affect the relative competitiveness measured here.

[80] The farmgate agricultural commodities prices are estimated from FAOSTAT data by dividing the farmgate value with the respective quantity produced of each commodity separately for Pakistan and the world.

[81] The RCA approach to estimate export competitiveness was first suggested by Balassa (1965), and adopted by Riaz and Jansen (2012) to compare Pakistan's regional export competitiveness. As suggested by Balassa, the RCA is measured as$(X_{ji}/X_{jw})/(X_i/X_w)$ where X_{ji} is exports of product j from country i, X_{jw} is the world exports of the product j, X_i is exports of country i, X_w is world exports. The RCA value of less than 1 means that the product has no export comparative advantage, while a value above 1 indicates that the product has a "revealed" comparative advantage.

TABLE 11. REVEALED COMPARATIVE ADVANTAGE (RCA) INDICES OF MAJOR AGRICULTURAL COMMODITIES AND THE AGRICULTURAL SECTOR DURING 2001 AND 2006

Commodity	RCA Indices	
	2001	2013
Wheat	1.09	0.22
Rice	29.69	23.86
Cotton	3.31	3.19
Potato	1.68	7.72
Mango	15.99	9.21
Citrus	0.12	15.19
Beef (cattle)	0.074	3.54
Milk (whole condensed)	0.556	0.05
Meat (goat)	13.64	16.4
Weighted average RCA for the agricultural sector†	23.67	14.19

Source: Estimated by the authors applying the Blassa (1965) specification on FAOSTAT export data.

†Estimated from RCAs of all individual commodities being exported by multiplying these RCAs with the respective shares of those commodities in total agricultural sector exports from Pakistan.

in comparison with the world average export prices of the respective commodities. In commodities in which Pakistan remains competitive (such as citrus, mangos, rice, and beef), the export prices of those commodities are lower than average international export prices, suggesting that the quality of Pakistani products is lower than the average quality of such products in international markets and that the value chains for those products are not well developed. In the milk value chain, for example, unhygienic management practices, low processing, and lack of proper regulations make Pakistan uncompetitive in international markets.[82] In the meat industry of Pakistan, widespread breeding of inferior animals, poor feeding practices, unhealthy animal management practices, unhygienic product handling practices, and lack of quality standards are the major constraints.[83] Fruits and vegetables produced in Pakistan struggle to compete internationally because producers cannot obtain high-yielding hybrids adapted to local conditions, the seedling industry for fruits and vegetables remains in its infancy, post-harvest losses are high, and processing and certification facilities are lacking.[84] One estimate suggests that if Pakistan can improve the quality of the agricultural commodity value chain to the world average level, it could earn over US$ 9 billion additional gross revenue from the sales at higher prices in national and international markets.[85] Aproperly functioning AIS can prevent many of the losses due to poor quality thus helps to improve the competitiveness.

TABLE 12. AVERAGE INTERNATIONAL AND PAKISTAN EXPORT PRICES (US$/t) OF AGRICULTURAL COMMODITIES, 2014–15

Commodity	International	Pakistan
Mangos	1,025	579
Citrus	798	426
Rice	648	553
Beef	5,310	3,035

Source: FAOSTAT

4.10. IMPACT OF LOSING COMPETITIVENESS

The consequence of the agricultural sector's loss of competitiveness in domestic and international markets, as productivity and input-use efficiency are kept at low levels and value chain development remains limited, is the ballooning trade deficit in agricultural commodities (Figure 9). The widening trade deficit is an additional signal that the agricultural sector is increasingly uncompetitive and that the innovation system is not aligned with emerging trends in national and international markets. Yet with its good land, water, and labor resources, Pakistan should be able to become internationally competitive in at least most high-value products—if the AIS is efficient, relevant, and responsive.

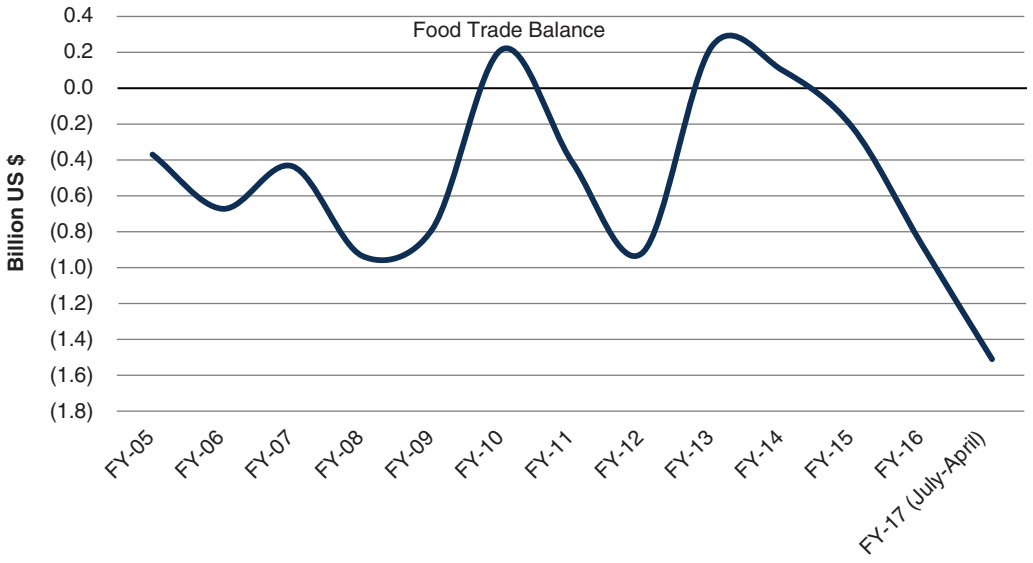
[82] Godfrey et al. (2013).

[83] Bradfield and Ismail (2012).

[84] Zahoor ul Haq (2012).

[85] Ali (2017).

FIGURE 9. FOOD TRADE BALANCE OF AGRICULTURAL COMMODITIES IN PAKISTAN, 2005–16



Source: Pakistan Economic Survey (GoP, various issues).

4.11. WORSENING FOOD SECURITY

Food prices in Pakistan have increased from 2007 onward (Figure 10). The increase in food prices is higher than the increase in the general CPI, suggesting higher demand pressure in the food market than in the general economy. Because it erodes purchasing power, food price inflation adversely affects health and nutrition, especially among poor small-scale producers and landless households.[86] Food price inflation also produces other undesirable socioeconomic consequences, such as removing children from school and sending them to work. It is likely that the food price hike has had a relatively worse impact on the education of girls than on boys.[87] The consistent increase in food prices could have been halted by effectively developing and promoting high-yielding varieties and cost-effective technologies in food production and marketing.

Micronutrient deficiencies have not only persisted in diets in Punjab but have grown worse over time. An analysis of nutrient consumption from the household dietary survey data of the Federal Bureau of Statistics suggests that serious deficiencies of iron, vitamin A, and calcium are on the rise in Punjab (Table 13). The focus of research and policy on major crops has increased the field concentration of those crops (although their consumption has not increased greatly) while reducing space for micronutrient-rich crops and animal products in the farming system.

4.12. CONCLUSIONS

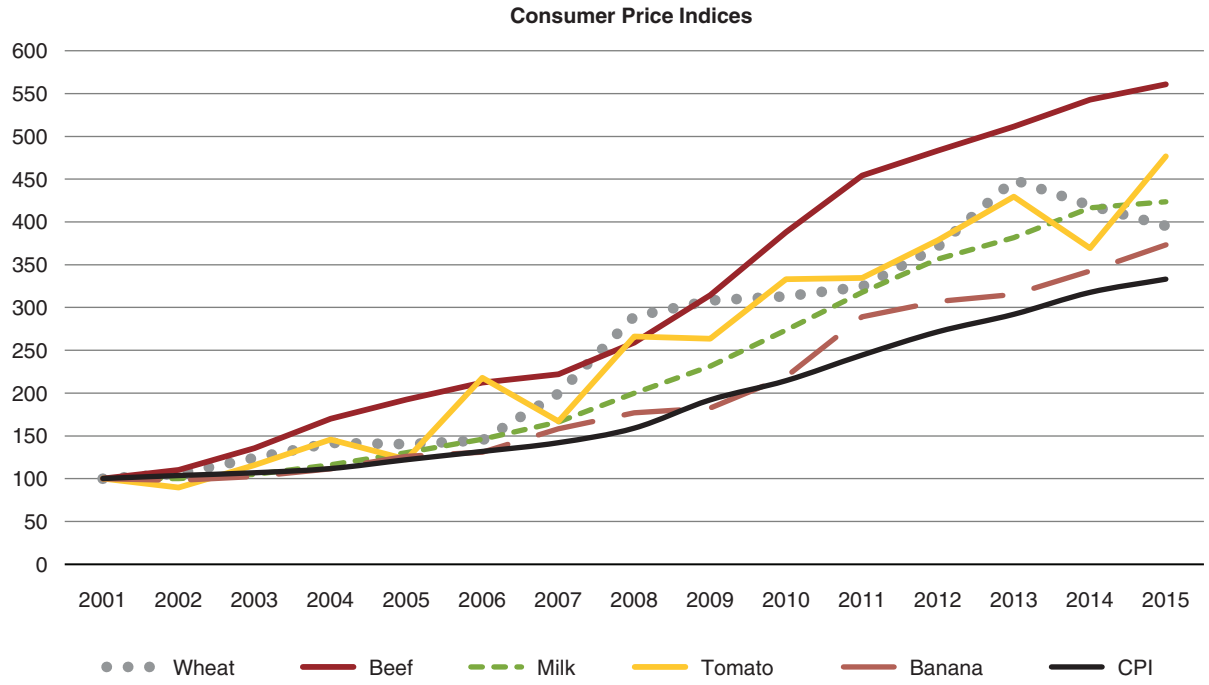
Strong crop breeding programs have stabilized yields of major crops. Improvements in protected cultivation have helped to reduced seasonality in certain vegetable crops. Developments in biotechnology have contributed to environmental protection through reduced pesticide use. These outcomes are positive, but the fact remains that the AIS has not produced growth in crop and animal yields at rates equal to or higher than neighboring countries, with serious consequences. More worrisome is that, growth in total factor productivity, the best measure of an effective innovation system, has been very slow.

As a result of these productivity trends, food prices have increased faster than the general CPI. Higher prices

[86] UN (2008).

[87] Hussain (2010).

FIGURE 10. TRENDS IN NOMINAL WHOLESALE PRICES OF MAJOR FOOD ITEMS AND CPI DURING 2000–15



Source: Pakistan Economic Survey (GoP, 2015–16).

in turn have eroded the competitiveness of Pakistan's agriculture in domestic and international markets, with serious effects on food security and nutrition. Reflecting the AIS's scant attention to value-chain issues, food imports have grown, exports have declined, and the negative trade balance has ballooned. Food production systems have not become sufficiently diversified to meet the nutritional requirements of the population, and an already large deficiency of micronutrients in the diet has increased over time. In Chapter 5, the Team delves into the weaknesses of the innovation system that have led to this overall poor performance in agriculture.

TABLE 13. NUTRIENT DEFICIENCIES IN PUNJAB, PAKISTAN, 1992 AND 2012

Nutrient	Recommended Dietary Allowance	1992	2012	Deficiency in 2012 (%)
Energy (kcal)	2,200	2,292	2,097	4.9
Protein (mg)	50	60.2	51.7	−3.3
Calcium (mg)	968.3	596.4	579.8	67
Iron (mg)	12.2	6.9	6	103.3
Vitamin A (µg)	4,758	1,783	1,326	259
Vitamin B2 (mg)	1.3	1.6	0.8	62.5
Niacin (mg)	14.9	12.1	10.5	41.9

Source: Ejaz et al. (2016).

CHAPTER 5
DIAGNOSIS OF THE INNOVATION SYSTEM

5.1. REVIEW OF REFORM EFFORTS: A HALF-CENTURY UNFINISHED AGENDA

The Team is mindful that this review follows on the heels of previous efforts to promote reforms in agricultural R&E in Pakistan generally and Punjab specifically. However, those previous efforts appear to have had little effect, as shown in the following sections.

5.1.1. AGRICULTURAL RESEARCH

The fact that Punjab research has performed below its potential has been widely recognized for many decades, both within the system and by external reviews. Perhaps the first major review was carried out by a Pakistani-American high-level team in 1968[88] following an agreement reached in Washington, DC over dinner between Presidents Ayub Khan and Lyndon Johnson to support Pakistan in developing its science and technology capacity. The 1968 review noted "(a) the low status of agricultural scientists and specialists in the governmental hierarchy, (b) the lack of incentives to scientists due to failure to reward merit in selection, promotion and salary, (c) failure to delegate authority at all levels, and (d) time-consuming procedures." It pointed out the lack of cooperation between universities and research institutes and between research agencies at a given location or within a region, inadequate linkages with international research programs, and the lack of effective liaison with agricultural extension and development agencies. The team proposed basic changes through the development of semi-autonomous research organizations that could use more flexible procedures than government. This recommendation was applied a decade later in the creation of PARC and NARC at the federal level but not at the provincial level. A national review in the 1980s arrived at similar conclusions.[89]

Punjab Province attempted a major reform of the research system in the second phase of the World Bank Agricultural Research Project, 1991–98. The project recommended

[88] GoP (1968).

[89] Pakistan National Commission on Agriculture (1988).

giving autonomy to AARI, creating a semi-autonomous Punjab Agricultural Research Board (PARB) with its own rules to manage competitive grants, and developing a detailed Punjab Agriculture Research Master Plan (PARMP) through wide consultation with stakeholders. The PARB was created through an Act of Assembly in 1998. It funded a few projects in selected disciplinary areas—horticulture, livestock, pest management, soils, and social science—but all were halted as soon as funding from the World Bank stopped. The PARB became inactive as all professional staff taken on deputation returned to their home departments, and non-professional staff assumed the professional duties (Annexure 3). None of the other PARMP reforms were implemented (most notably changes in service rules for AARI scientists), and the World Bank project was rated "unsatisfactory."

In the early 2000s, there was another flurry of activity to reform the provincial research system. The Asian Development Bank took up the challenge, and part of its Agricultural Sector Program II included a condition to carry out studies to reorganize and strengthen the delivery and coordination of agricultural research, extension, and higher education services. Accordingly, the Government of Pakistan through FAO commissioned a review of the national agricultural research system (including Punjab), *Rationalization of Agricultural Research: A Proposed Agenda for Action*, which resulted in a roundtable event in Islamabad. The review reinforced the findings of earlier reviews in calling for major reforms to orient the research system to emerging market challenges and resource scarcity, provide incentives to motivate scientists, and expand flexibility to engage in partnerships with the private sector and other agents in technology delivery. There was little follow-up, however.

In 2004, the World Bank as part of its Punjab Economic Policy Review included a chapter on the "Punjab Agricultural Innovation System" (including extension), which echoed the recommendation for AARI to become an autonomous research organization with the power to set its own rules on human resources and funding conducive to good science. The review reiterated the need for a strong PARB with significant resources to allocate competitively for high-priority research. The following year, Asian Development Bank conducted its own more in-depth review, "Restructuring of Agricultural Research in Punjab," through a highly respected local scientist. Following both reviews in about 2005, a senior adviser to the Chief Minister in Lahore commissioned a workshop to work out the details of building a state-of-the-art research institute for one commodity (tentatively wheat) as a first step in modernizing the system.

This renewed push in the 2000s eventually produced some action. Most notably, PARB was revamped in 2007 with an internationally recruited CEO and allocated significant funding for competitive grants. Also in 2007, the GoPunjab established on paper six Research and Development Corporations for major crops (cotton, wheat, rice, sugarcane, mangos, and citrus) under the company law (Section 42), which would provide the requisite financial and human resource and rules conducive to good science. The corporations were abandoned before they could be implemented, following a change in leadership in the DoAg and opposition from scientific staff to the change.

5.1.2. AGRICULTURAL EXTENSION

The history of agricultural extension in Punjab (and much of Pakistan) is well told by several reviewers[90] who chart a checkered experience. From Partition to 1962, Pakistan had no formal public extension system. Apart from a number of community-development-type programs noted below, the country relied on teaching staff of the Agricultural College, Lyallpur (now UAF), to provide extension services. Responsibility for extension formally shifted to the DoAg in 1962.

The early programs in Punjab started with (1) the 1952 Village Agricultural and Industrial Development (V-AID) Program, followed by diverse initiatives that included (2) the Basic Democracy System, (3) the Rural Works Program, (4) the Integrated Rural Development Program, (5) the People's Works Program, and (6) the Barani Area Development Program. These were followed in 1962 by the traditional agricultural extension system operated by the DoAg until the early 1980s, when the T&V approach,[91] largely funded by the World Bank, was introduced. The

[90] Including Abbas et al. (2009) and Yaseen et al. (2015).

[91] Anderson, Feder, and Ganguly (2006).

T&V program was formally abandoned in 1999 and replaced with a modified T&V program. The many problems experienced with the T&V system in Punjab (and elsewhere in Pakistan) included its high and unsustainable cost and its emphasis on communicating messages rather than helping farmers understand those messages and improve their technical and managerial skills.[92]

In the 2000s agricultural extension in Punjab experimented with various innovations, such as FAO's much-promoted FFSs and PCs. The contemporary public system provides advisory services largely through Extension Field Schools, which are village-level farming training programs that follow a monthly schedule developed by the Agriculture Officer. This "new modified" model is little different from the antecedent T&V, which was a top-down, supply-driven, and seldom "participatory" or farmer-empowering approach. Both T&V and FFSs focused on crop production and largely excluded livestock and value-chain development from their activities. The real difference between today's extension and earlier incarnations is the rising significance of private agricultural advisory services.

During 2001–15, agricultural extension in Punjab (and throughout Pakistan) went through a dramatic change as administrative control of the system devolved to the local level. In the new setup, each district administration managed its agricultural extension activities. The functions of all sister organizations (water management, fisheries, livestock, soil conservation, forestry, and so on) were placed under one local manager called the Executive District Officer of Agriculture. That official reports to the District Coordination Officer, who answers to the elected District Nazim (administrator), while the line departments provide technical backstopping and monitor cross-district agricultural development projects. The devolution of extension services was an attempt to replace the supply-oriented delivery system with a more demand-oriented system by ensuring active participation of local people in planning, monitoring, and evaluation—bringing the entire process down to the grassroots level,[93] reducing bureaucratic impediments, and giving people better access to public services.

[92] Abbas et al. (2009); see also Byerlee (1988).

[93] Saeed et al. (2006); Memon, Khusk, and Mallah (2015).

5.1.3. LIVESTOCK SECTOR

Reform in the livestock sector has typically been linked with reform in the agricultural sector. The exception was a separate Performance of Veterinary Services evaluation by the World Animal Health Organization (OIE). The evaluation, conducted in December 2014, was exclusive to the livestock sector and covered all of Pakistan, including Punjab. The report was submitted to the government in 2016. The main findings were discussed in a meeting of all Livestock Departments, including Punjab. The evaluation pointed out a large number of deficiencies, including a lack of specialist training in specific areas, few training opportunities, poor coordination across relevant organizations, small operational budget, poor quality assurance system and accreditation for diagnostic and vaccine production laboratories, lack of animal quarantine facilities at any of the borders, no surveillance system for most animal diseases, lack of an animal identification and traceability program, absence of any control of veterinary medicines and biologicals, lack of compliance with veterinary legislation (including OIE standards for poultry and the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures), incomplete notifications to the OIE on the national animal health situation, and lack of communication and information exchange with neighboring countries. Some of these constraints have been effectively addressed in the meantime by the DoL&DD.

5.1.4. CONCLUSIONS ON PAST REVIEWS

This "review of reviews" shows that several attempts were made to identify the problems besetting different components of the AIS and suggest reforms in their own timeframes. This review differs from earlier efforts in several ways, however. First, earlier reviews focused separately on research or extension, whereas this review considers the performance of each component of the AIS in conjunction with the others, and it takes on the whole spectrum of technology at the system level. Second, unlike earlier efforts, this review goes beyond the farm level in evaluating the performance of the AIS and considers the whole value chain of agricultural commodities as the sphere for impact. Third, this review considers the interconnectivity of the agricultural and livestock sectors and analyzes how the deep separation between the two

affects overall performance of the AIS. Finally, earlier reviews placed little emphasis on the private sector, which was natural considering that it was not a very strong element of the AIS at the time. In contrast, this review considers the private sector in its technology creation, dissemination, and application roles to be an important component of the AIS.

5.2. A FRESH REVIEW OF WEAKNESSES: A FRAMEWORK APPROACH

The Team uses a framework of six column metrics—*relevance*, *efficiency*, *effectiveness*, *quality*, *incentives*, and *private sector regulations*—to subjectively analyze weaknesses in the system and reveal how each one is related to different aspects of the system's performance. The following sections define the framework and then use it to diagnose weaknesses in the performance of research and extension separately, although in some cases the weaknesses are common.

5.2.1. FRAMEWORK FOR ANALYSIS

The six metrics in the analytical framework are defined as follows:

- ***Relevance*.** Relevance is the extent to which the priorities selected for R&E reflect the needs of the ultimate users of products of the system—farmers, input and service suppliers, processors, exporters, and consumers—as well as policy goals such as growth, poverty reduction, and environmental sustainability. Relevance is not a static concept, and research must be nimble in responding to changing market contexts and policy priorities, such as climate change and nutrition.
- ***Efficiency*.** Research and extension activities must be cost-effective in developing and delivering their products, taking into account the comparative advantage of the system in relation to alternative suppliers.
- ***Quality of science and extension activities*.** All modern R&E organizations now use standard metrics to assess the quality of science and the delivery of information based on peer review of their activities; such metrics may include publications, training courses, patents, methods of communication with stakeholders, literature to be distributed, and others. Today's R&E organizations and often programs within or across organizations are also subject to periodic external reviews by peer review panels.
- ***Incentives*.** Quality of science in turn relates to recruitment standards, opportunities for on-the-job training, and above all incentives in terms of well-defined performance criteria for promotion and setting salaries.
- ***Effectiveness*.** The R&E system is useful only when its products (technologies, patents, messages, and so on) reach their intended users and are adopted by them. Common measures of the effectiveness of applied research are adoption and economic impacts. Sometimes rigorous analysis is conducted before and after an intervention to measure adoption. The impacts of R&E are intimately linked and difficult to separate, although some measures are designed to separate them.
- ***Private sector regulations*.** An important measure of the success of an R&E system is whether appropriate regulations are in place to promote the private sector, such as regulations related to the registration of agriculture-related companies and their products, protection of those products by law, and access of the private sector to public goods and services created by the public sector AIS.

5.2.2. RESEARCH

Issues and constraints affecting the performance of the research system are summarized in Table 14 and discussed more fully in the following sections.

5.2.2.1. Relevance

One measure of relevance is how research resources are distributed across commodities. As noted, most of the human resources for research in Punjab Province go to the major crops, even taking into account the research resources of federal bodies, which also focus mostly on the major crops. Livestock research may account for less

TABLE 14. SUMMARY OF THE MAJOR WEAKNESSES OF THE PUNJAB RESEARCH SYSTEM

Relevance	Efficiency	Quality of science	Incentives	Effectiveness	Regulation
No systematic process to identify emerging researchable issues and set priorities taking account of markets, policy goals, and comparative advantage. No regards for socio-economic, political, and demographic situations in developing new technologies	Budgets for research operating costs vs. salaries under-funded (although recently increased). Inflexibility in moving budgets among specific expenditure categories. Poor linkages between research needs and budget allocations. Lack of mobility for researchers to interact with farmers and extension workers.	Low output of peer-reviewed publications in certified standard journals. Many articles published in journals with low standards.	Very limited career growth opportunities, even for highly qualified researchers.	Lack of a "results culture," since incentives do not reward outcomes and impacts.	No rules in place to implement plant breeders' rights.
Low participation of private sector, growers, and value chain agents in setting research agenda (although Commodity Research Boards recently established).	Overlapping and duplication of research and few efforts to build complementary research, because partnerships are lacking within and across institutes in the country and abroad.	Insufficient number of PhD quality trained staff. Lack of on-the-job training for researchers and research managers.	Research managers appointed by seniority.	Lack of effective coordination and collaboration between researchers and public and private delivery agencies at the field level (although coordination exists at a macro level).	There is no established mechanism to license public sector varieties to the private sector.
Lack of participatory on-farm and value-chain R&D.	High ratio of support staff to scientific staff and high overheads due to large research station infrastructure. Bureaucratic rules govern the release and use of funds.	Opportunities for attending international workshops and similar events are not given or are lost through lengthy, bureaucratic approval process.		AdR and LS farms have limited capacity to fine-tune wide-ranging research products for stakeholders' needs.	

Source: Team's review of previous reviews in Section 5.1 and interviews with stakeholders, September 2017.

than one-third of the total, which is low in relation to the livestock sector's overall importance. The large allocation to poultry research seems anomalous, given that Punjab's large and growing commercial poultry industry relies mostly on private R&D from abroad. Research resources are distributed across the most important crop groups, although the allocation to fodder research appears low. The standard tools based on the importance of a commodity and likely research payoffs[94] do not seem to be applied to analyze the optimal allocation of resources across commodities. Research on socioeconomic aspects, especially the role of gender in agriculture, is almost completely lacking. This makes agriculture research and technology development rather 'gender insensitive', although studies have shown a significant role of women in Punjab's agriculture.[95]

Within commodities, the strong focus on crop and livestock breeding means that important gaps persist in research on

[94] Alston, Norton, and Pardey (1995).

[95] Batool and Nosheen (2015).

input efficiency, IPM, livestock management, and sustainable management of soil and water resources. Priorities for the development and delivery of livestock vaccines could be sharpened by a rigorous assessment of disease losses, together with a cost-benefit analysis among alternatives. The separation of crop and livestock research across different departments also means that priority research on livestock nutrition is not addressed in a holistic manner.

Another way of assessing relevance is to review how priorities are set. The Team's assessment is that priorities in the system are mostly supply driven, being determined largely by scientists' interests and their perceptions of what is important. For that reason, the system has been slow to respond to new markets and opportunities, notably in high-value crops and livestock. The research system is especially weak in addressing post-harvest and other issues within a value-chain context, despite the increasing share of agricultural output that undergoes further processing for urban markets.

Within the province, there is no analytical capacity to provide strategic direction to the research system, although this is an objective of PARB. Capacity in economics and policy research is especially weak. In the absence of foresight analysis and a clear articulation of comparative advantage, research priorities reflect "business as usual." For example, in the wake of rapid adoption of hybrid maize, led by the private sector employing proprietary hybrids, Punjab continues to employ over 50 scientists in public sector maize research. The objective of developing domestic hybrids that can increase competition and reduce seed prices paid by farmers is worthy, but policy makers need to set a target date for success and then gradually phase out the public hybrid breeding program, which has now been operating for 60 years.

A further weakness in developing relevant research is the lack of close partnerships with the major users of the research system's products—notably farmers, processors, and other private actors. The Team found no good examples of on-farm participatory research involving farmers, and that finding also applies to the so-called adaptive research activities currently under extension. It found only a few examples of good public-private partnerships. The AMRI has had modest success in turning over machinery prototypes to the private sector, and post-harvest research also provides its "recipes" to fruit and vegetable processors. But neither of these research programs starts with the demands of the market and then works jointly with private firms to respond to those demands.

The GoPunjab recognizes the challenges inherent in moving toward a more market- and demand-led research agenda, and it has appointed Commodity Research Boards that include experienced farmers, processors, and exporters from the private sector to advise the major institutes. This is a good step toward engaging stakeholders in setting the research agenda but is unlikely to succeed unless the boards are empowered to implement research priorities and monitor progress.

5.2.2.2. Efficiency

Factors that influence cost-effectiveness in research may include collaboration to achieve economies of scale, avoidance of duplication, flexibility to import technologies from elsewhere, cooperation with upstream science providers such as PARC or universities, a focus on public goods (leaving other areas for the private sector), and reliable funding that is sustained across the years and allocated appropriately between salaries, operating costs, and capital costs.

The Team concludes that the Punjab agricultural research system is inefficient because it is highly fragmented. The system is characterized by a bewildering array of 25 institutes plus several centers or sections within AARI organized on commodity, disciplinary, and regional lines. In addition, there are provincial institutes outside of AARI, such as the eight adaptive research stations under agricultural extension, the AMRI under field operations, institutes focused on livestock under the DoL&DD, research at three agricultural universities and the University of Punjab, and a number of federal and other research entities located in the province.

This complexity is illustrated for the five major crops in Table 15. Each of the commodity research institutes has a full complement of disciplines, with the notable exception of economics. Meanwhile the disciplinary

TABLE 15. APPROXIMATE NUMBER OF RESEARCH "PROJECTS" BY DISCIPLINE AND INSTITUTE FOR FIVE MAIN CROPS, PUNJAB, 2014

	Breeding†	Pathology	Entomology	Management	Soil and water	Postharvest	Economics	All
Institute								
Cotton RI	12	1	2	3	2	1		21
Wheat RI	18	4	1	3	2	6		34
Rice RI	14	3	2	4	3	2		28
Sugarcane RI	26	3	1	5	4	2		41
Maize and Millet RI	11	2	1	1	2	0		17
Agronomy RI	5			16	6			27
Soil Chemistry RI			1	1	20			22
Soil Fertility RI					45			45
Soil Salinity RI	4				18			22
Entomology RI	3		7					10
Pathology RI	5			2				7
Post-Harvest Centre						2		2
Economics Section							4	4
Bahawalpur RRI	15	1	2	5	4			27
Other								
Adaptive research			X	X	X		X	NA
PCCC	X	X	X	X	X	X		NA
UAF	X	X	X	X	X	X	X	NA
NARC	X	X	X	X	X	X		NA
NIAB	X	X	X	X	X			NA

Note: "X" indicates some activities, but numbers of experiments are not known. RI is Research Institute. RRI is Rice Research Institute. PCCC is the Pakistan Central Cotton Committee. UAF is the University of Agriculture, Faisalabad. NARC is the National Agricultural Research Centre. NIAB is the Nuclear Institute of Agriculture and Biology.

†Includes screening of germplasm for tolerance of (resistance to) abiotic and biotic stresses.

Source: Computed from a review of the AARI Annual Report, 2014, and websites for other research organizations.

BOX 2. THE COMPLEX LANDSCAPE OF SOIL AND WATER RESEARCH IN PUNJAB

A large number of institutions in Punjab have overlapping mandates for monitoring and addressing soil and water management problems, with little coordination among them. At the international and federal levels these include:

1. Salinity Monitoring Organization of the Water and Power Development Authority, Lahore
2. Water Resources Institute, National Agricultural Research Centre (NARC), Islamabad.
3. Pakistan Council of Research in Water Resources (PCRWR), Islamabad
4. International Waterlogging & Salinity Research Institute, Lahore
5. International Water Management Institute (IWMI), Lahore

At the provincial level, another nine institutions have similar mandates:

6. Directorate of Land Reclamation, Lahore
7. Irrigation Research Institute, Lahore
8. Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore
9. Rapid Soil Fertility & Survey and Soil Testing Institute, Lahore
10. Institute of Soil Chemistry and Environmental Sciences, Faisalabad
11. Soil Salinity Research Institute, Pindi Bhattian
12. Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad
13. Water Management Research Centre, University of Agriculture, Faisalabad
14. Soil and Water Conservation Research Institute, Chakwal

institutes for pathology, entomology, agronomy, soils, and water also work on the major crops, but with no apparent division of responsibilities between them and the commodity institutes. The regional research stations under AARI and adaptive research also work on the major crops relevant to their region or agro-ecological zone. Federal institutes such as NARC, the Pakistan Central Cotton Committee (PCCC), and NIAB have a similar line-up of major commodity programs. Research on soil and water management is highly dispersed within provincial and other entities (Box 2). The end result is the splintering of research into thousands of generally uncoordinated and very small budget activities across the various institutes.

The PARB attempts to integrate specialized expertise through much larger projects (about Rs 20 million on average) organized around a specific problem or opportunity and generally involving more than one institute (see below). At one time, PARC ran programs at the national level to help coordinate research across provinces and across institutes within provinces. The coordinated program for wheat has been sustained for decades, contributing to the relative success in that crop. Other coordinated programs died, and PARC has only recently secured funding to reinstate them.

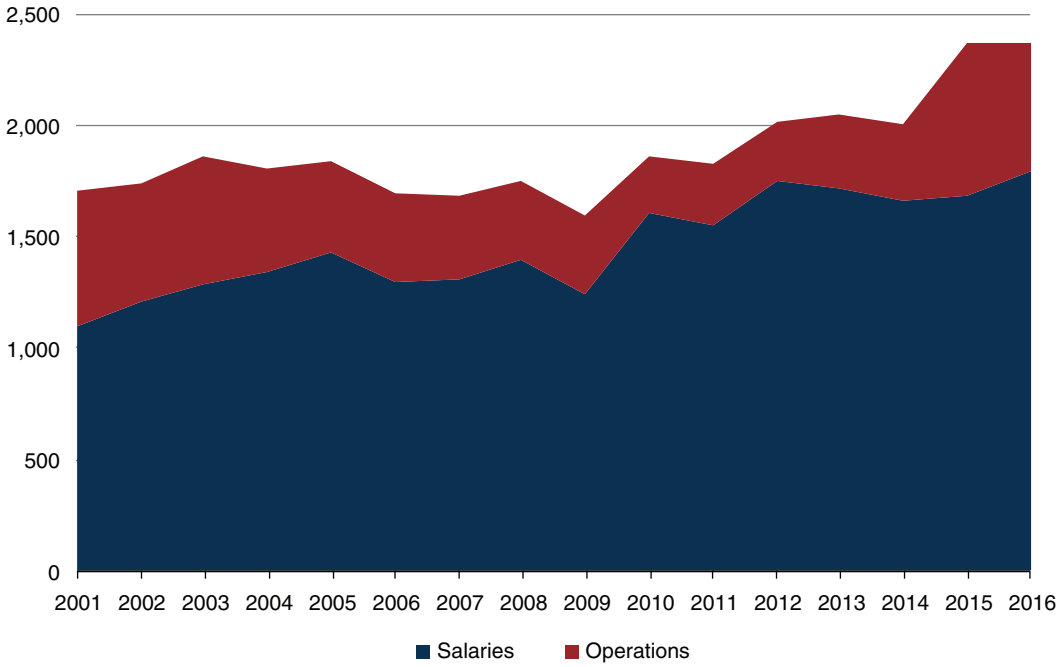
In the past, efficiency was seriously undermined by the low share of budget allocated to operations relative to salaries (Figure 11).[96] Without operating budgets, researchers in the provincial system were confined to the station to carry out programs that involved minimal expenditure (unlike university researchers, they had little incentive to seek funding from outside sources). Equipment and machinery could not be maintained.

During the current decade, the share of operating budget has doubled from a low of 13% in 2010–11 to 24% 2016–17. This substantial improvement only amounts to an operating budget of US$ 5,000 per scientist per year, however (mostly for utilities and other necessary expenses) and remains well below the standard of allocating 40% of the budget for operations.

Research managers indicated that the development budget was generally adequate to provide basic equipment and

[96] If the development budget is considered operational and added to the non-development budget, the share of operations in the total budget increases to 50%. The development budget, in part, is provided to relax some specific operational difficulties such as low maintenance, low work-space capacity, obsolete equipment, and so on. Financing operations through the development budget is restricted in certain areas and is not as flexible as when a higher proportion of operational budget is included in the non-development budget.

FIGURE 11. REAL ANNUAL SALARY AND OPERATING BUDGET OF AARI (2017 MILLION Rs)



Source: AARI presentation. Nominal data have been converted to real terms using the Pakistan GDP deflator.

cover other capital costs for the type of applied research being carried out. The Team observed several refurbished and relatively well-equipped laboratories. The DoAg and DoL&DD operate hundreds of research stations, LS farms, hospitals/dispensaries, and other facilities across the province; this infrastructure is more than adequate and probably a burden rather than an asset. Outside of development projects, the research system has no formal mechanism to regularly maintain its infrastructure and keep it running on a daily basis, especially laboratories, veterinary hospitals, LS farms, and AdR farms.

One further source of inefficiency is the high ratio of support staff to scientific staff, averaging about 3:1 but much higher in some institutes. In modern scientific establishments, computerization has sharply reduced support staff levels, especially for secretarial and administrative tasks, but this savings has yet to be realized in Punjab. The quality of the support staff is low, as skills were never upgraded to adapt to the changing technological requirements in the offices.

5.2.2.3. Quality of Science

Publication in recognized journals that provide good peer review is central to maintaining quality in science. Respected peer-reviewed journals apply credible standards of science and help to improve scientific skills and knowledge by providing sustained feedback. Another important reason for scientists to publish in recognized peer-reviewed journals is to communicate their results more widely.

The Team conducted an analysis of publications of Punjab research organizations in journals listed in the International Scientific Index (ISI) using the Scopus tool provided by the largest scientific publisher, Elsevier. The ISI list is based on a number of criteria, including citation and peer review standards, and it essentially constitutes an internationally recognized accreditation system for journals. Some Pakistan journals are ISI listed, including the *Pakistan Journal of Agricultural Science*, the *Pakistan Journal of Phytopathology*, the *Journal of Animal and Plant Sciences*, the *International Journal of Agriculture and Biology*, and the *Pakistan Journal of Zoology*. The results, summarized in Table 16, are revealing both for the bad news as well as the good news.

The publication output of the main Punjab research organization, AARI, in ISI journals is extremely low. In 2014, AARI listed 248 publications in its Annual Report, but only about 15% were in ISI journals (and over half of those 15% were published in ISI-recognized Pakistan

TABLE 16. PUBLICATIONS FROM PUNJAB RESEARCH ORGANIZATIONS IN ISI-LISTED SCIENTIFIC JOURNALS

	Average number of publications per year, 2013–17	Full Time Equivalent (FTE) scientists, 2014	Publications per FTE per year, 2013–17	Citations per paper published in 2014
Punjab				
AARI	27	750	0.04	2.2
UAF	807	132	6.11	5.7
University of Punjab (agriculture and genetics)	230	22	10.45	4.4
PMAS Arid Agriculture University	237	45	5.26	6.6
UVAS	227	50	4.55	2.7
Other research institutes				
NARC (Pakistan)	110	270	0.41	4.3
Bangladesh Agricultural Research Institute	158	738	0.21	3.2
Ethiopian Institute of Agricultural Research	47	670	0.07	6.0
Embrapa (Brazilian Agricultural Research Corporation)	1,359	2,470	0.55	4.7
INIFAP (National Forestry, Agriculture, and Livestock Research Institute) (Mexico)	158	918	0.17	4.8
Shandong Academy of Agricultural Sciences (China)	172	NA	NA	6.1
Other University				
Punjab Agricultural University (India)	337	433	0.78	4.1

Sources and notes: All publication data are from Elsevier Scopus as of October 8, 2017. Publications are listed by institutional affiliation, but this listing may miss some publications by scientists that are not located at the institute headquarters and are listed under a subsidiary institute with its own name. A quick check of AARI found very few publications if any at the institutes outside of Faisalabad, however. FTEs are from ASTI (sourced at www.asti.cgiar.org) or unpublished data provided by ASTI to the Team. FTEs take account of scientists that have multiple duties besides research, such as teaching at universities, and may underestimate the time that university scientists spend on research.

journals). The VRI provided a list of 54 publications issued during 2013–17, but scientists in the DoL&DD had too few publications in ISI-listed journals to carry out an analysis—an indicator that most livestock research institutes are active in services rather than research, although as already seen, the VRI has produced several locally adapted vaccines. In terms of publications per scientist, AARI ranks lower than NARC and equivalent agricultural research organizations in Ethiopia and Bangladesh. Citations per article are also much lower.

The major problem is that AARI and VRI publish in many non-ISI journals. Some are published in Pakistan, notably the *Punjab Journal of Agricultural Research* of the DoAg, and these articles have a legitimate role in communicating results within Pakistan to potential users. Yet a large number of articles appear in non-ISI, internationally published journals that are generally of very poor quality and serve no useful purpose, either in providing peer review of science quality or in communicating research results. Many of these journals have been established over the past decade as publication fees allow publishers to profit while online publication reduces their costs.

The good news is that the publication output of the three main agricultural and livestock universities in Punjab and in agriculture and genetics at Punjab University is strong, totaling some 1,500 articles annually in ISI-listed journals. This record reflects the accreditation system of the Higher Education Commission that sets publication standards for the recruitment and promotion of university scientists. Indeed, the publication output of UAF is higher than for Punjab Agricultural University in India. The citation rate of the UAF publications is also good.

The strong publication record of the universities should not be equated with greater impacts of research, however. Much university research may not be very relevant and, even if it is relevant, there is no mechanism to translate results into practice. Even so, the strong publication record of the university researchers is a good indication that the province has a major human resource base that can be better utilized to strengthen the overall Punjab innovation system.

The quality of science also logically reflects the quality of human resources in research institutes. The Team noted that about 14% of the human resources engaged in crop research hold a PhD degree, 98% from local universities, and that only a few post-doctoral fellows are supported in the whole research system. The remaining 86% hold master's or bachelor's degrees, nearly all from local universities. In contrast, the PhD and post-doctoral ratio in the total staff is 30% in Bangladesh, 67% in India, and 75% in Brazil, with a large proportion of those degree holders having foreign qualifications.

Another parameter for assessing the quality of scientific staff in research institutes is the diversity of the universities from which they obtained their last degree. The Team's survey suggests that almost all scientific staff in the crop sector graduated from UAF, whereas all scientific staff in the livestock sector graduated from UVAS, thus offering little diversity of opinion on scientific issues and methodologies. In addition, the survey results indicate that over half of the scientific staff belongs to no professional association. Most are unaware of such associations or see no benefit in becoming a member; almost none is a member of any relevant international association. About 20% of the scientific staff will retire within the next five years, and most of the foreign-qualified personnel are from this age cohort.

The quality of scientific staff is also affected by the very limited opportunities to build capacity. Attending a training event is considered a luxury rather than an investment in building quality human resources for the future, and thus not much appreciated at the bureaucratic level. Requests to attend a training event, especially abroad, are often turned down on this pretext, even if no government funding is required. Administrators have a negative attitude toward training activities and programs because they are unaware of their impacts. For example, universities conduct many training courses for researchers, but their quality and impacts are never evaluated. Scientists have few opportunities to upgrade their qualifications and skills after they join an institute. The Team's survey of professional staff in research suggests that during the past five years about half never attended any conference or workshop, and those events were almost entirely locally arranged. Similarly, over 36% had never attended any training courses, and another 34% attended just one or two courses during the past five years. The courses were also entirely local, arranged by local professionals, and because the impact of the training was never evaluated, its quality is unknown.

In sum, effectively closing the research system to outside engagement has negatively impacted the quality of science. Few opportunities exist for foreign training, short or long. Only a handful of scientists (mostly directors) can travel to international workshops, seminars, and similar events. No staff member has obtained any post-doctoral training or taken sabbatical leave with any international research organization or foreign university. Despite its large size, the research system in Punjab undertakes very little significant collaborative research with any international research centers or universities across the globe.[97] It is untenable that such a large system should choose to benefit so little from opportunities to broaden collaboration and learning.

5.2.2.4. Incentives

A longstanding grievance of scientists working under the provincial government is that salary scales are low compared to those for scientists working in federal organizations. The salary difference across grades varies from a minimum of 62% to a high of 79% (Table 17). Similar differences occur between government scientists and scientists in agricultural universities, where the entry point is one grade higher than in the GoPunjab system, although the entry requirements are similar. Many of the

[97] The situation in agricultural universities is significantly better, however, offering many opportunities for foreign interaction through the Higher Education Commission and federal government programs.

TABLE 17. SALARIES OF GOPUNJAB RESEARCH STAFF COMPARED TO SALARIES IN OTHER RESEARCH ORGANIZATIONS, 2017

Scales	Basic Pay Scale (AARI, VRI, etc.)	17	18	19	20	21	22
	Special Pay Scale (NIBGE/NARC)	8	9	10	11	12	13
Salaries (Rs/month)†	AARI	47,230	58,604	88,114	98,472	107,968	116,093
	NIAB/NIBGE‡/NARC	76,306	102,515	128,581	156,864	183,968	207,547
Total difference over AARI		29,076	43,911	40,467	58,392	76,000	91,454
Difference in percentage over AARI		62	75	46	59	70	79

Source: Director General AARI, personal communication.
†Salaries in each pay-scale are initial basic pay salary.
‡NIBGE is the National Institute of Biology and Genetic Engineering.

good professors and assistant professors in universities are on tenure tracks that promise more than double the salary of a corresponding post in the GoPunjab system.

A further disincentive for scientists under government pay scales is that opportunities for promotion are very limited and the process is slow. AARI, for example, has only 1 grade 20 post (the Director General), 26 grade 19 posts (the Directors), 145 grade 18 posts with a token Rs 165 per month supplement, and 287 grade 18 posts. The remaining 619 posts (well over half of the total) are at grade 17 (entry level). The slim chance of promotion offers little incentive to scientists to work hard and achieve success.

Under the present incentive structure in which promotions are based almost entirely on seniority, an output and outcome delivery culture cannot be promoted. The research system imposes none of the standard conditions that encourage scientists to strive for scientific outcomes—for example, meeting a fixed number of years of service in certain grade(s), no court enquiry, no negative remarks in the annual evaluation, and no missing annual evaluation. Some weight is given to the annual performance review (the Annual Confidential Report), although it does not objectively evaluate a researcher's outputs or outcomes. Currently, only one-third of the scientific staff surveyed believe that professional merit or the need to fill an identified skill gap are the main criteria for promotion to the next grade, while the remaining two-thirds believe that personal favoritism and seniority are the main criteria. Where a culture of "keeping the boss happy" or "getting the right connection" prevails, it is natural that science and its outputs and outcomes will take less precedence.

5.2.2.5. Effectiveness

Factors determining research effectiveness include strong partnerships with delivery agents such as extension, private input providers, or processors; a conducive policy environment; and a results-oriented culture and incentive system that reward results on the ground and increase the research system's accountability to those who fund it.

A "results culture" is lacking throughout the research system, even in the universities. Scientists regularly report inputs to research and sometimes their outputs, but they pay little attention to the outcomes and impacts of their work, and (as noted) have little incentive to do so. Research programs rarely define an explicit "theory of change" that explains how they expect to realize results on the ground incorporating the local demographic, political, and social conditions, while clearly laying out the impact pathways and major assumptions behind those pathways. Instead, the standard approach is to regard the delivery of technology as somebody else's responsibility further downstream, usually in the public sector—the Punjab Seed Corporation or the DG(E&AR). Scientists typically do not pay sufficient attention to local socioeconomic conditions while developing technologies, and have little experience in working with private delivery agents and other private actors in the value chain. Until recently they have had no incentives to do so, but now the private sector is a major force in disseminating new technologies through input suppliers and processors (see Section 6.3.4 on private extension).

Reforms to improve effectiveness met with some success but were not sustained. The major reform was the revamping of PARB in 2007 to meet the conditions of

the Asian Development Bank loan. The new PARB management team, led by an internationally recruited CEO, changed the board's profession-based structure to an activity-based structure (Annexure 3), developed proposals, and funded 69 multi-disciplinary and multi-institute problem-solving projects at a total cost of Rs 1.1 billion. The projects, which linked researchers from various disciplines across institutes within the country and abroad, provided considerable incentives for researchers to deliver project outputs and for participating institutes to improve their research infrastructure. In 2013, with a gap in top leadership and a board that included mostly public officials, some with a conflict of interest (their organizations competed for PARB grants), PARB entered a crisis of leadership, funds, continuity, and commitments. With appropriate upgrades to its leadership and governance, PARB has much potential to contribute to the renewal of the Punjab research system, as discussed in Chapter 6.

Another reform (now in the design stage) is the introduction of an incentive system to reward research institutes and their scientists by charging royalties on research outputs auctioned to the private sector. The Team agrees with the need for a more commercial orientation to research that such a system would promote, but it has reservations about the current design. First, the major objective should be to work with the private sector to disseminate technologies as widely as possible, not to make money for scientists. The experience of technology transfer offices in public research institutes and universities is that most do not pay for themselves, since expectations of royalties and other rewards are often greatly overestimated.[98] Second, such incentive systems reward scientists producing distinct technological products that are easily traceable, such as new varieties or vaccines. Scientists working in more complex types of management technologies, such as IPM or livestock nutrition, would be disadvantaged by the proposed incentive system, yet these research areas are precisely where more and better research is needed. The Team believes that a more effective system of incentives is needed, based on results on the ground, regardless of the discipline (see Chapter 6).

[98] For example, see Fischer and Byerlee (2002).

5.2.2.6. Private sector regulations

As noted, Pakistan issued a new Plant Breeders Rights Act 2017 and amended the Seed Act (1976) (after nearly 10 years of discussion) to recognize the role of the private sector in agricultural R&D. Even now, according to World Bank indicators on the ease of doing agribusiness, Pakistan rates low relative to most other countries such as India, Bangladesh, and Thailand with respect to seed regulations affecting the private sector (Table 18). The lack of a mechanism for implementing plant breeders' rights is a major constraint on the establishment of local R&D capacity by private companies, which is why so much of the hybrid maize and vegetable seed available in Pakistan is imported. Licensing of public varieties to private seed enterprises is just being initiated and also remains limited by the lack of effective plant breeders' rights. Countries such as Thailand, Turkey, and Kenya, with over 20 years of effective plant breeders' rights, now have strong private R&E.

5.2.3. EXTENSION

Many critical observers contend that a major underlying cause of low agricultural productivity in Punjab, especially where smallholders are concerned, is the ineffectiveness or complete absence of extension services.[99] Issues and constraints affecting the performance of the extension system are summarized in Table 19 and discussed more fully in the following sections.

5.2.3.1. Relevance

The relevance of the extension system is judged by the extent to which stakeholders are involved in decision making, the variety of issues and commodities addressed, and the system's flexibility in responding to emerging demands.

Public extension efforts remain largely supply driven. Despite the adoption of various modes of delivery, remarkably little has changed during recent decades. The system continues to emphasize the promotion of improved cultivars of major "political" crops—wheat, rice, cotton, and sugarcane—and vaccines to curtail the threat of

[99] Abbas et al. (2009); Ali, Mirani, and Magsi (2014); Safdar et el. (2016); Lodhi, Muhammad, and Ghazanfer (2006).

TABLE 18. INDICATORS OF SEED REGULATIONS IN PAKISTAN IN 2017 AND IN OTHER COUNTRIES IN 2016

Indicator	Pakistan	Bangladesh	India	Thailand	Turkey	Kenya
Does the country currently have an implemented regulation governing plant breeders' rights?	No	No	Yes	Yes	Yes	Yes
Years since plant breeders' rights introduced	0	10	15	27	25	20
Are private enterprises eligible to produce breeder/pre-basic seed of local public varieties?	Pre-basic=Yes Breeder=No	No	Yes	Yes	No	Yes
Are private enterprises eligible to produce foundation/basic seed of local public varieties?	Yes	Yes	Yes	Yes	Yes	Yes
Can the private sector access germplasm from the national gene bank?	No	Yes	Yes	Yes	No	Yes
Is there an established system for licensing public varieties to private seed enterprises?	No	Yes	Yes	Yes	Yes	Yes

Source: World Bank, *Enabling the Business of Agriculture* (www.eba.worldbank.org). Data for Pakistan were assembled by the authors.

widespread animal diseases. For those crops and animal diseases, the system's coverage of farmers is quite extensive, especially during crop maximization campaigns and recently through mobile dispensaries, but the system is relatively poor in reaching producers with advice on minor crops such as pulses, vegetables, and oilseeds and for livestock management and nutrition practices. Advice frequently consists of the one-way delivery of rather general information that is often not based on high-quality research. The Team perceived a general tendency among extensionists to push information to producers, regardless of its relevance, rather than to build producers' capacity and skills to search out and use relevant information. Despite claims that on-farm research is conducted on AdR farms and LS farms, there is no systemic process to identify the demand for specific information from farmers or other value-chain actors. Few mechanisms are in place to make market assessments and conduct insightful analyses of emerging opportunities.

The extension staff has little financial and administrative flexibility to adjust quickly to an emerging crisis in agriculture or livestock, to manage the recurrent crises (such as those periodically affecting cotton, citrus, mango, and potato production), and to cope with the chronic quality crises in milk and meat production.

The Directorate of AdR under the DG(AE&AR) was supposed to cover a broad spectrum of agricultural commodities, activities, and issues, but contrary to the spirit of farming systems research, it could not expand its efforts beyond crop production to livestock and other high-value commodities. With this narrow focus, the extension system has been incapable of addressing emerging issues in fruits, vegetables, and livestock, although demand for products of these value chains is increasing rapidly. Given that Punjab produces many crops beyond the "big five," especially fruits, vegetables, oilseeds, and pulses, each with its own production and marketing dynamics, it is natural to question the availability in the DG(AE&AR) of the requisite (often quite specialized) skills in the diverse elements of crop management (pest management, sustainability) as well as pertinent business and marketing skills. Similarly, the skills for promoting knowledge and technologies related to value chains are almost non-existent. Nor does the DoL&DD have a specialized extension service focused on developing value chains for livestock products in Punjab.

The DoAg has attempted to remedy the low coverage of high-value crops by initiating projects on fruits and vegetables and creating a D(H) in the DG(AE&AR), but it has made no efforts to create capacity related to neglected crops within the Directorate. The DoL&DD has expanded its coverage from "curative" to "preventive," but again mainly focusing on a "medicinal" approach rather than a "management" approach.

5.2.3.2. Efficiency

The efficiency of extension staff is determined by each individual's dedication to work, effective coordination

TABLE 19. OVERVIEW OF WEAKNESSES IN THE PUBLIC ADVISORY SERVICES OF PUNJAB

Relevance	Efficiency	Quality of communication	Incentives	Effectiveness	Regulations
No systemic process to identify emerging farm issues and opportunities and set priorities taking account of markets, policy goals, and comparative advantage. Lack of involvement of women in the design and implementation of extension strategies	Budgets for crop extension operating costs vs. salaries under-funded. Inflexibility in moving budget across budget head categories. Except for livestock extension, lack of mobility to interact with farmers and private sector crop extension workers. Insufficient female extension staff limits to women farmers.	Communication should be a two-way process. Because channels for listening to farmers' problems are insufficiently developed, the communication of problems to researchers is limited.	Very limited career growth opportunities, even for highly effective extensionists.	Lack of a "results culture," since incentives do not reward outcomes and impacts.	The public sector monopoly on free extension tends to crowd out private sector information delivery services.
Inadequate priority assigned to management practices, especially in livestock nutrition, pest control, soils, and water. Lack of expertise in post-harvest and value-chain opportunities.	Geographically organized and centralized arrangements mean a lack of specialized knowledge to serve non-major crops and provide anything other than generic advice.	The top-down approach of public extension means that the views of bureaucrats dominate the extension agenda and are too little informed by research findings or farmers' needs.	Salary scales for extension staff in DoAg and DoL&DD are well below those of private competitors.	Absence of sufficient "new practices" suitable for dissemination to farmers.	The public sector monopoly in agricultural education, which gives limited attention to agribusiness, affects the supply of good quality managers needed in private sector extension.
Low participation of stakeholders in setting the public extension agenda.	Insufficient engagement with the diverse array of private extension providers.	Insufficient well-trained staff.	Extension managers appointed by seniority.	Lack of effective coordination among researchers and delivery agencies at the field level (despite some coordination at a macro level).	Reluctance of the public sector to share technology information with the private sector is unhelpful to private extension provision.
Lack of participatory on-farm and value-chain R&D, including extension.	High ratio of support to technical staff. Bureaucratic rules in fund releases and utilization. Insufficiently trained human resources.	Opportunities to attend regional and international workshops are not given or are bypassed because of lengthy, bureaucratic approval processes.	Weaknesses in on-the-job training for extension field workers and managers.	AdR and LS farms have limited capacity to fine-tune wide-ranging research products to better meet local needs.	

Source: Team's review of previous reviews (Section 5.1) and interviews with stakeholders, September 2017.

between R&E agencies and with other extension organizations and NGOs, decision-making power for extensionists to adjust their efforts to meet stakeholders' needs, effectiveness of the methods of communications adopted, type of technology being promoted, and sufficient funding to give extensionists a rapid means of transportation. They must not be distracted from performing their core role by being assigned to other temporary duties. Currently the extension staff expends much valuable time on arranging Ramazan Bazars, assisting in wheat procurement, helping the Revenue Department to maintain land records, and controlling the quality of inputs such as fertilizers, pesticides, and feeds. (For some services that extend beyond pure extension advice, however, such as the delivery of veterinary vaccines, there is perhaps no better time utilization than presently seen in the DoL&DD.)

Many observers have long acknowledged the poor coordination between extension, research, and education, even where coordination mechanisms exist. For example, mechanisms exist for regular engagement between extension and the research wings of DoAg at the zonal level. Regular zonal coordination meetings are held, at which Applied Research experiments are discussed, but these sessions have become more of a ritual than a forum where farmers, researchers, and extensionists can interact in an innovative, problem-solving mode. Moreover, zonal committees have no financial or administrative powers to implement any change in the existing extension activities. In this way, the activities of AdR farms have become a big liability, without contributing much to productivity or sustainability.

Quick and widespread adoption of an innovation is facilitated when the technology or service is properly adjusted to local tastes, needs and preferences. Immature technologies—those not properly adapted to the market—are unlikely to be adopted.[100] A mechanism for adjusting new technologies to local conditions exists in Punjab through AdR farms and LS farms in various ecoregions. This mechanism is poorly used, however, because the farms have poor professional capacity and no links with researchers, farmers, manufacturers, marketing specialists, and other private sector extension agents. None of the farms has any capacity to test and adapt any credible technology along the value chain, although the farms possess huge tracts of land to test traditional technologies like varieties of major crops, cropping patterns, fertilizer manure rates, and so forth, and maintaining their land has become a liability. In fact, LS farms have even less to test and demonstrate, despite the huge cost of their maintenance. It is worth noting that many other public and private organizations work in areas where public extension service operates. They include the Punjab Rural Support Program, Pakistan Poverty Alleviation Fund, Pakistan Horticulture Development and Export Promotion Board, Pakistan Zarai Taraqiati Bank, and several other private entities communicating messages related to agriculture, livestock, input supply, and credit. The Team observed that coordination of public sector extension with these organizations and private sector entities is very limited and thus less efficient than it needs to be, if it is to deliver knowledge and understanding to Punjab's farmers.

In extension for both agriculture and livestock, decision-making power lies with the top management, which dramatically reduces efficiency. For example, the surveillance of animal diseases in different species is conducted by four different laboratories stationed in PPRI, VRI, FMDRC, and DG(LSE). Each laboratory simply collects disease data and produces reports, without much analysis or the power to take decisions if an epidemic arises locally. It takes weeks if not months to transmit the information to higher echelons responsible for making decisions. The same dilatory practices prevail in crop disease surveillance conducted by the DG(PW&PQC). In 2015, for example, the directorate was reporting that it had identified spots heavily populated by pink bollworms in many cotton-growing areas early in the cotton season, but nobody took action until the problem was visually evident to every farmer. By then it was too late.

Efficiency is also affected by the mobility of extension staff and operational funds, especially for transportation as and when needed. Until recently, the front-line forces of extension—the Field Assistants and Baildars—have had little mobility. Agricultural Officers covering a whole

[100] Johnson (2015).

tehsil of hundreds of villages had only a bicycle. Now both DoAg and DoL&DD Field Assistants have been supplied with bicycles and Agricultural Officers with cars to travel across large jurisdictions, but operational funds for agricultural extension in both departments are meager. On average, each agricultural extension staff member has less than US$ 30 per annum for operational work, while each livestock extension worker has about US$ 100 per annum (including medicines). More importantly, the control of these funds is highly centralized, so it is almost impossible for lower-level staff in the field to obtain funds as and when needed. All purchases are centralized and supplied to the individual staff member based on his/her previous record. The reimbursement of travel costs is cumbersome and lengthy. The DoL&DD, however, has recently improved the mechanism for supplying medicines and other materials on a needs basis.

The patriarchal extension staffing also limits the efficiency of the agriculture message delivery system. While many agronomic activities are conducted conventionally and manually by female workers,[101] male extension staff can hardly reach women farmers in rural socio-political settings. For example, improving the quality of cotton picking has remained an illusive task as male extension agents have been unable to take appropriate messages to female cotton pickers. Similarly, milking of animals remains performed under poor hygienic conditions as male extension agents cannot take appropriate messages to the mostly female dairy farmers.

5.2.3.3. Quality of Extension

The competency of extension field personnel (the depth of their expertise and their ability to communicate) and the extension methods they use are the basis for convincing the farming community to adopt sophisticated agricultural technologies and recommendations.[102] Reviews of literature on the quality of extension staff suggest that the professional and technical competencies of extension/outreach workers are not up to meeting the needs and demands of the rural community in Punjab.[103] The Team's limited personal interaction with the staff during this review supports that assessment.

As in many parts of the world, in Punjab perceptions of the low status of employment in the public extension services add to the challenge of recruiting staff with the capacities that are essential for modernizing agriculture. The share of PhD holders in the total professional extension staff is very low. These individuals have virtually no opportunity for outside travel and learning, and they publish so little that their work does not appear in most search engines.

The quality of extension staff and services depends heavily on the strength of training arrangements. The Team found a plethora of training institutes and mechanisms in R&E in the DoAg and DoL&DD, as well as substantial training activities in universities, but the quality of training provided in most of them is poor. Training functions and activities are duplicated across the training institutes in departments and universities. Most courses last one or two days, and even these very short courses are not accessible to all field staff, who not surprisingly have an outdated understanding of modern production technologies for the crops and livestock produced in their respective areas. The training staff itself has little opportunity and few incentives to make the effort to maintain or upgrade skills. The communication and presentation skills of both trainers and trainees are also rather weak.[104]

The low communication skills of extension staff (particularly in agriculture) observed by the Team in its brief interactions must be set alongside the inadequate communication methods employed. As noted, the Team observed truckloads of glossy materials being delivered to farmers but has grave doubts about the utility of the mostly generic, less-than-innovative, and certainly not particularly novel "information" shared in this way. Some televised talks on particular issues seem technically impressive but are unlikely to attract farmers' attention, as most farmers do not consider television to be an important source of information.[105] Even private extension fails to deliver messages effectively through effective

[101] Batool and Nosheen (2015).

[102] Mengal, Mirani, and Magsi (2014).

[103] Yaseen et al. (2015).

[104] Safdar et al. (2016).

[105] Lodhi, Luqman, and Khan (2006); Arfan et al. (2013).

BOX 3. EXAMPLES OF GAPS AND DISCONNECTS ACROSS DIRECTORATES IN AGRICULTURAL EXTENSION, RESEARCH, AND EDUCATION

Gaps and disconnects that limit the effectiveness of extension in Punjab include:

- The Directorates of Information and AE&AR sometimes move in different directions, and almost independently of other directorates.
- The DG(PW&PQC) under the DoAg has little coordination with the Directorate of IPM in the DG(AE&AR), and both have little connection with similar activities in research and education.
- The hierarchical control of the extension staff is tight. Everything moves downward from the top, leaving little flexibility to adjust for needs-based activities at the local level.
- There is no extension activity for farm machinery and equipment, despite a big directorate in Agriculture (Field). This gap is serious, especially because agricultural farm machinery workshops are not well established in rural areas.
- A heavy emphasis is placed on major crops and relatively low priority is assigned to fruits, vegetables, oilseeds, and pulses.
- Nearly all extension and training activities are confined to crop production.
- The DG(AE&AR) and DG(AE&M) pursue very few activities on value-chain development, although lately the Agriculture Delivery Unit (ADU) has started some value-chain development projects.

channels—particularly through "interactive" channels such as demonstrations of results, group discussions, and "interactive" media.[106]

One-way communication appears to be the order of the day. Except for training in the poultry sector, seemingly no training in the whole GoPunjab is driven by stakeholders. Most courses do not even have set modules, and trainers just come on call. No outcome indicators have been set for training, and the impact of training never appears to have been evaluated. In addition, training activities focus on production. No training is provided on developing agricultural value chains or agribusinesses in rural communities.

5.2.3.4. Incentives

The quality of human resources is mainly determined by salary structures, promotions, and incentive structures, which for extension workers are widely perceived as unattractive: salaries are meager (especially in relation to the private sector), promotion is very slow, benefits are minimal, and rewards are lacking. In an environment of shifting and unpredictable priorities, the lack of focus and excitement adds to the challenge of attracting and continuing to motivate the best graduates and diplomates. About half of the professional staff in agricultural and livestock extension will never be promoted and will retire in the same grade at which they entered. The situation is even worse for non-professional staff. Unless current incentives change, it is difficult to imagine the extension services capably stoking the fires of agricultural innovation.

5.2.3.5. Effectiveness

Some positive indications of the effectiveness of extension in Punjab wheat production were noted in Section 3.1. Effectiveness of extension operations is negatively influenced by the large jurisdiction area per extension worker, old methods of communication, lack of clarity of particular extension activities, and disconnects between various directorates within extension, research, and education. Disconnects and gaps within in the hierarchical setup within DoAg are clearly evident (Box 3).

Methods of communication that are consistent with local community traditions and norms are also very important in determining the effectiveness of the massage delivery system. For example, most farmers in Pakistan have access to radio and television and understand and speak Punjabi, yet the agricultural programs broadcasted predominantly use Urdu, frequently with jargon and technical terms in English. This language barrier forces farmers to turn toward traditional sources of information, mostly from the experiences of fellow farmers or peer groups.[107]

[106] Ali, Ahmad, and Ali (2011).

[107] Javaid (2017).

Education and age of farmers were found to be the major factor in the effectiveness of public sector extension,[108] thus emphasizing the need to simplify the extension message in local languages or use more effective extension tools such as videos,[109] interactive group discussions and communications,[110] TV channels and telephone calls,[111] helplines,[112] and so on to take extension messages effectively to uneducated, older farmers and resource-poor farmers.

Trust also plays a strong role in the effectiveness of communication. Farmers believe that the most effective means of communication are the helpline and extension field staff, mainly because they do not have personal motives. On the other hand, fertilizer and pesticide companies and seed dealers were found to be the least effective, perhaps because farmers believe that they provide biased information.[113]

5.2.3.6. Regulatory Framework

Aside from the extension services offered by private companies in relation to their own products, the regulatory framework in which the AIS operates does not favor the establishment of private information delivery services. First, the monopoly of the public sector on the free provision of extension services, even for those who can afford it, tends to crowd out the private sector. Second, the public sector monopoly on an agricultural education system that gives limited attention to agribusiness limits the supply of appropriately trained managers needed to set up a good information delivery company in the private sector. Third, the fact that the public sector declines to share new technology and information with the private sector has not been helpful in assisting private entities to offer extension advice, except in relation to their own research and products. Due to the disconnect, presently the public and private agricultural extension services often provide competing, overlapping, and conflicting programs.[114]

5.3. DIAGNOSIS FROM AN INNOVATION SYSTEMS PERSPECTIVE

The discussion of R&E in the previous sections highlight the strengths and weaknesses within each domain, but when the analysis is taken to a higher level—the entire innovation system—more glaring weaknesses become apparent.

First, the Team looked for but did not find a Punjab-wide AIS perspective that considers, and indeed facilitates, interaction between a wide variety of actors to address important problems or respond to emerging market opportunities. This lack of articulation is evident at several levels. Beginning with the public sector, the bureaucratic separation of efforts in crops and livestock is a major hurdle for addressing some of the big challenges in livestock, especially livestock nutrition. The fodder institute is located in the DoAg, along with other crop institutes, while the DoL&DD conducts some simple testing of fodder species, and neither effort amounts to an integrated approach to improving livestock nutrition that considers livestock feeding in a holistic manner, including efficient management of crop residues, fodder production and conservation, natural pastures, and commercial feeds and supplements.

Second, the articulation between basic, applied, and adaptive research is often weak. Basic research tends to be located in agricultural universities (which are not well connected with applied research), general universities such as the University of Punjab CEMB (which are not part of the mainstream agricultural research system), or in federal institutes such as the National Institute of Genomics and Biotechnology in NARC and the National Institute of Biotechnology and Genetic Engineering (NIBGE) under a different jurisdiction. These basic research institutes may have excellent scientific skills, but without strong links to downstream research those skills

[108] Davidson (2005).

[109] Videos in local languages are ten times more cost-effective than traditional extension at reaching farmers, and farmers with access to them adopt new practices seven times faster.

[110] Javaid (2017).

[111] Ali, Ahmad, and Ali (2011).

[112] Arfan (2013).

[113] Arfan et al. (2013).

[114] Davidson (2005).

are not contributing to solving major problems in Punjab agriculture.[115] Likewise, adaptive research under the DG(AE&AR) is administratively separated from applied research. As indicated earlier, however, the universities, with their large and well-trained human resource base, could potentially play a much greater role. In a few cases, such as PARB projects, good attempts were made to link different institutions (including federal institutions) to address a common problem, but the number of projects was constrained by a lack of capacity and funds, and the capacity within universities remained under-exploited.

Third, although the Team noted the growing importance of the private sector in many parts of the Punjab AIS, there are still few examples of public and private actors engaging in mutually productive partnerships in value-chain development. Part of the problem lies with incentive structures and "cultural" differences between the two sectors. Another dimension of the problem is that most value chains still lack a governance structure to facilitate the coordination and partnerships essential to develop value chains. Recent initiatives by the sugar industry and the PAC in chilies show promise in bringing the public and private players together.

Fourth, the Team observed (especially through its survey) that the AIS of Punjab lacks sufficient outside research collaboration and capacity-building opportunities, which are not properly harnessed. Many scientists are not even aware of the international research organizations in their area, such as the International Livestock Research Institute (ILRI), International Center for or Agricultural Research in the Dry Areas (ICARDA), and others. Opening the AIS to national and international collaboration will not only bring exposure to new scientific ideas but help to upgrade scientific capacities and skills.

Finally, a well-developed innovation system has mechanisms for feedback and learning to iterate toward solutions for improvement. With so little emphasis on assessing outcomes and impacts, the AIS currently offers little scope for the learning and feedback that support continuous improvements in innovation processes. Accordingly, business as usual tends to rule the day, but in its interactions during the review, the Team detected some impetus for creative change in this and many other aspects of the AIS.

5.4. CONCLUSIONS

The Team used multiple metrics to analyze R&E in terms of relevance, quality, incentives, efficiency, effectiveness, and private sector regulations. The advantage of that framework is that it helps to identify only those measures that can objectively improve those parameters.

For research as well as extension, the Team noted relatively limited coverage of vegetables, fruits, pulses and oilseed crops. Public R&E is largely confined to promoting varieties and administering vaccines. Very few activities, if any, support agribusiness development, the development of value chains for different commodities, natural resource management, impact evaluation, and agricultural economics and policy research. Few ex-ante or ex-post impact evaluations of large provincial programs are conducted, so most decisions by the GoPunjab are made on purely technical grounds, which dramatically reduces the relevance of the public AIS.

The research system does not focus on delivering outputs and outcomes that have been well defined in a policy document. Activities are more likely to reflect the interests of individual professionals than to coherently and strategically reflect national priorities, emerging market opportunities, and stakeholders' needs. Stakeholders, especially along the value chains, rarely participate in defining priorities, which reduces the relevance of R&E programs. The system operates inefficiently because its components—upstream and applied research, education, extension, and the private sector—lack coordination, it has little flexibility to import technologies, and it contends with unreliable and insufficient funding, including little operational funding. Regulations to encourage private investment in R&E are not implemented.

Punjab's public R&E system simply does not offer sufficient incentives for innovative and collaborative problem-solving approaches. Scientists in the GoPunjab feel that they are treated as inferiors compared to scientists with similar qualifications in universities and federal organizations. The Team notes that Punjab has the world's only remaining

[115] Ashraf (2007).

large R&E system to be controlled through bureaucratic rules that give system participants little flexibility to set their own financial and administrative rules conducive to good science. Bangladesh, Brazil, China, India, and others have all moved on to systems that provide such autonomy.

The lack of a results culture in delivering extension and advisory services to agricultural communities in Punjab does them a great disservice. The Team observed that more attention was given to ensuring the timely programmed visits of field staff and mobile veterinary services to the appointed villages than to tracking the productivity and income-earning outcomes of the agricultural practices advocated by the extension staff. This state of affairs is consistent with the rather weak monitoring and evaluation arrangements that were also observed, in which inputs tend to be monitored, rather than outputs and outcomes.

The Team noted the scarcity of opportunities for capacity building throughout the system. Many training activities are conducted in the universities, research institutes, and training centers under the DGs of Extension in the agriculture and livestock departments, but the quality of these efforts is often questionable. Training courses often lack set modules; even if modules are developed, they are outdated. Some are internally validated, but most are not validated and updated by independent professionals. The intended beneficiaries of training courses are rarely targeted or followed after training, although they could provide useful information for analysis and feedback. Support is not available after training to improve its impact. The bureaucracy's dim view of the value of training tends to deflect opportunities for training outside Pakistan. The philosophy of training needs to evolve to regard training as an investment in the future, with wider scope to benefit from international training opportunities as and when they arise.

The purpose of this diagnosis of the AIS is to develop a realistic picture of the starting point for change. The next chapter turns toward the options for moving forward.

CHAPTER 6
OPTIONS FOR MOVING FORWARD

The AIS must dramatically improve its performance to meet the demand for "knowledge-based" agricultural growth in Punjab. The province must introduce a stronger, scientifically-based AIS that is efficient, relevant, responsive, and fosters interactions among all of the system's elements—universities, research, extension, producers, and other value-chain stakeholders in the public as well as the private sector. To keep abreast of rapid advances in science, changing demand for agricultural commodities, new problems, and new opportunities, the system must be agile and adept at taking advantage of the most recent research.

The Team believes that such a system has 10 key characteristics:

1) Recognition of the need for a **pluralistic** AIS structure that includes public agricultural research, public extension, universities, the private sector, farmer organizations, and NGOs. In such a system, **partnerships** will be an important mechanism for integrating players to exploit complementarities and improve effectiveness.
2) Increased **separation of funders from providers of services** as an important mechanism for integrating different players across the AIS.
3) Increased attention to **product diversification**, **quality,** and **value addition** and the inclusion of a wider range of **clients beyond farmers**—agribusinesses, the food industry, policy makers, environmental groups, and consumers—that have different needs and objectives.
4) Creation of a demand-oriented system with active **engagement** of stakeholders in the identification, design, and implementation of R&E activities to meet their needs.
5) Development of a **results-oriented research** culture that measures results through outputs of the farm and industry sectors and not just the completion of research experiments.
6) Increased **flexibility and institutional autonomy** for public institutions and for scientists working in these institutions, combined with increased accountability.

7) Development of appropriate **service rules** that define the career path of scientists; provide competitive salaries to attract and keep highly qualified scientists and extension advisers; give rewards linked to a well-defined, output-based incentive structure; and honor outstanding innovators.
8) Provision of abundant opportunities for **capacity building** and flexibility and openness to interact with other training institutions, universities, and the private sector, within the country and abroad.
9) **Diversification of funding** sources to increase the amount and sustainability of funding, as well as empowering a range of stakeholders.
10) An appropriate **policy and regulatory framework,** such as **intellectual property rights,** to incentivize a growing role for **private sector R&E**, especially in commercial crops and livestock, and recognition of the potential gains in effectiveness through **private-public sector collaboration**.

A comprehensive approach is required to tackle these key policy reforms. **Note that the immediate issue is not to increase funding, but to better utilize the resources available in the system and better allocate those resources to high-impact areas.** Additional funding is counterproductive if the more fundamental issues of human resources, incentives, autonomy, regulatory framework, and opportunities for cost savings are not addressed. Past reviews and recommendations for reforming the Punjab AIS, such as the PARMP of 1996, laid out overly ambitious plans[116] that failed to be implemented. The approach considered most practical by this Team is two pronged. First, undertake only three high-profile initiatives relevant for research as well as extension to pilot and demonstrate new ways of doing business. Second, move forward with a series of smaller steps to steadily improve the performance of the existing system. This chapter outlines options for each prong of this strategy as the basis for the additional stakeholder consultations that must take place to arrive at concrete recommendations.

[116] GoPunjab (1996).

6.1. HIGH-PROFILE INITIATIVES

The Team suggests three high-profile initiatives. The expected impacts of these initiatives on AIS performance are summarized in Annexure 4 with detailed numeration in the following sections.

6.1.1. DRIVING REFORMS VIA A MAJOR UPGRADE OF PARB

PARB should be the driving force in the creation of a dynamic, forward-looking agricultural R&D system in Punjab. It would have four roles or functions: (1) provide competitive grants for high-priority R&D clearly tied to an explicit plan to get results on the ground; (2) provide strategic guidance to the whole system in research planning, coordination, and evaluation through large-scale consultations with the stakeholders along the value chain and impact and foresight studies; (3) provide support for capacity building through sponsoring national and international conferences, seminars, training courses, post-doctoral fellowships, and sabbatical leaves of scientists with international research centers, elite universities, and other institutions; and (4) communication of research results to various stakeholder groups, including production of project briefs.

For PARB to become the leader of this system, it needs to be revamped with the appropriate autonomy, governance structure, staffing, and assured funding:

- It would be constituted as an autonomous body under the company law with the flexibility to sets its own rules for hiring and funding.
- It would have a small but high-quality governing board with strong representation from the private sector and a highly respected chair from outside the GoPunjab. The GoPunjab, through the DoAg and DoL&DD, would have seats on the board, given that most of the funding is initially likely to come from the GoPunjab. To avoid conflicts of interest, heads of research organizations or universities would not be members, nor any scientist bidding for a grant.
- It would be led by an internationally recruited CEO (Pakistani national preferred) with experience in agricultural science and management appointed by the board.

- To undertake the duties entrusted to PARB, the board would recruit, at competitive salary scales, a small cadre of highly qualified staff with a broad understanding of the AIS (rather than experts in a particular discipline).
- The reporting department for PARB would shift from the DoAg to the higher level of the P&D Department, to avoid inherent turf issues between the DoAg and DoL&DD. [117]

Three specific actions, discussed next, are suggested to undertake a major revamping of PARB. First, create a dedicated fund for agricultural innovation in Punjab; second, strengthen planning, coordination, and evaluation; and third, station PARB in a permanent building.

6.1.1.1. Create a Punjab Agricultural Innovation Fund

A Punjab Agricultural Innovation Fund would support a state-of-the-art Competitive Grant System for research and innovation. PARB has substantial experience and processes in place to administer such a fund, but several adjustments are needed:

- All development funds for agricultural research, especially for output-oriented projects, should be channeled through PARB.[118]
- To engage a large number of scientists in each round of competition for the grants, research proposals may be solicited around predefined themes, each with clearly set priorities and specific goals to be achieved. The fund would provide grants for policy, institutional, and marketing innovations as well as technological innovations. The selection of the project under each theme and issues within the theme should clearly reflect the priority for the themes and issues therein.
- One funding window, however, might be left open for highly innovative bottom-up ideas that do not fit the priorities. The fund might also commission research through non-competitive processes for urgent problems such as pest outbreaks, but only with the clear consensus of the board.
- The competition would be run in two stages—a concept note of no more than five pages in the first stage, and then a second stage in which full proposals are developed for the most promising concept notes. Recent experience is that less than 5% of proposals are funded, which discourages scientists from putting their best effort forward in developing proposals. The objective with the two-stage process is to raise the approval rate in the second stage to at least 33%.
- Grants would be relatively large to foster multi-institutional and multi-disciplinary partnerships bringing together complementary research skills from different organizations in Punjab, elsewhere in Pakistan, and abroad (to fill the skill gap), as well as to bring value-chain actors together to commercialize research outputs. The grants may also support foreign travel to identify promising technologies and skill development.
- Special grants may be arranged to import promising technologies with appropriate intellectual property rights.
- Any applied research projects that are funded must include a clearly articulated "theory of change" (in other words, a plan explaining how research products will be translated into real impacts on the ground). Partnerships with public sector extension and the private sector within a value-chain framework would be strongly encouraged. Private firms would be eligible to lead grants provided they co-finance the grant and demonstrate that the project has a strong "public good" component.
- Some grants may be made available for scaling up proven local successes in the field; they would focus on extension.
- Initially funds would be provided by the GoPunjab, but over time PARB would be strongly encouraged to raise funds from multiple sources to diversify its funding base. One option that should be explored is to create an endowment to sustain funding (see Section 6.2.3 for details).
- Best international practices in calling for proposals, submitting proposals for peer review, contracting service providers, and monitoring and evaluating progress and impacts would be

[117] This proposal was also given by the PARMP in 1996. In 2012, DoL&DD sent a summary to the Punjab Chief Minister to this effect.

[118] This proposal was also given by the PARMP in 1996 and was agreed and notified by the DoAg in 2007.

employed to ensure the highest standard of transparency and professionalism.
- Monitoring of projects funded by PARB as well as the public R&E system would strictly follow the pre-defined key performance indicators (KPIs) clearly spelled out in the project documents.

Fortunately, a wealth of international experience in establishing and managing such funds is available to guide these efforts.[119]

6.1.1.2. Strengthen Planning, Coordination, and Evaluation

The PARB has to significantly strengthen its planning, coordination, and evaluation functions. It has to provide the analytical studies to influence priorities, efficiency, quality, and effectiveness of the whole research system in Punjab. However, PARB would not manage research. The research management role would be clearly placed at the level of DGs and directors of institutes (see below). The main activities to strengthen planning, coordination, and evaluation include:

- Continuously consult a large number of stakeholders along the value chain to identify and prioritize the emerging issues in the agricultural, livestock, forestry, fisheries, food, and irrigation sectors.
- Work with private and other public extension and value-chain actors to develop strategies for the commercialization of research outputs.
- Work with other public sector research institutes, especially with the federal-level institutes, to improve coordination and remove redundancies in R&E activities.
- Conduct foresight studies and workshops to analyze major trends and opportunities in transforming agriculture in the province to develop informed research priorities for the Punjab Agricultural Innovation Fund and for research and innovation in the province in general.
- Commission periodic external reviews of research programs and themes across the R&E system with a set of recommendations for improving performance.
- Foster coordination within the system through scientific workshops and exchanges.
- Build an impact culture by commissioning impact evaluations of major research programs.
- Mount a major communication effort to build awareness of the role of R&D in transforming Punjab agriculture.

The current structure of PARB may be appropriate to deliver these functions. Consistent with empowering PARB, however, the CEO with his/her board would have to decide if the structure and skill mix of members and staff also need to be updated appropriately.

6.1.1.3. Improved Regulatory Framework

To promote R&E in the private sector, it will be the responsibility of PARB to work with the provincial government to develop a private-sector-friendly regulatory frame work. The Board will also encourage the government to implement a proper incentive structure for public sector scientists and extensionists.

6.1.1.4. Station PARB in a Permanent Building

Migrating PARB from one rented building to another adds to the perception of instability. It erodes stakeholders' trust in the institution, breaks the work tempo, and discourages staff. It is necessary to place such an apex body for research in a permanent building reflecting its stature near the DoAg. This gesture will build trust among donors and other stakeholders, attract good staff, and solidify researchers' confidence in the board.

6.1.2. PILOTING A STATE-OF-THE-ART R&D INSTITUTE IN HIGH-VALUE AGRICULTURE

Reforms of research systems conceptually distinguish the funding of research from the supply of research services. The revamping of PARB would be a major step in funding R&D in Punjab. On the supply side, the Team proposes

[119] For one example, see Reifschneider, Byerlee, and de Souza (2000). A Google search ("best practices for managing competitive research funds") elicits a wide range of recent and relevant guidance. The United States Department of Agriculture, National Institute for Food and Agriculture, has used competitive grants to integrate the three components of innovation (research, education, and extension). See https://nifa.usda.gov/resource/integrated-programs-application-information.

that the GoPunjab pilot a state-of-the-art R&D institute dedicated to R&D for high-value agriculture, which may be called the Punjab Horticulture Research and Development Corporation (PHR&DC).[120]

The Team feels that this pilot institute should focus on horticulture for several reasons. First, with rising incomes, horticulture, defined here to include both fruits and vegetables, is one of the fastest-growing sectors in agriculture. Second, Punjab—with its large irrigated area, diversity of agro-ecological zones, cheap labor, and proximity to growing markets in Asia and the Middle East—should have a strong comparative advantage in horticultural exports. Third, horticulture is a labor-intensive industry that could play an important role in absorbing a rural labor force that is projected to continue to grow for decades. Fourth, from a nutritional viewpoint, diets in Pakistan are seriously deficient in many micronutrients that horticultural products provide. Finally, current research in horticulture is fragmented and deficient in all areas, including breeding, pest control, and value-chain development.

For many of the same reasons, the Team sees a parallel need for a state-of-the-art R&D institute focusing on bovine livestock production and nutrition. At the same time, the Team recognizes that it would be prudent to pilot the horticultural institute and use that experience to initiate the livestock production and nutrition institute later.

The main features of a world-class PHR&DC to promote horticultural development in Punjab would be:

- It would be a public company with an internationally recruited CEO who is a well-respected professional in the area and has experience in public and private sector governance. It would be chaired by an independent, highly respected individual in the horticultural sector from outside of government, preferably from the private sector.
- It would have a relatively small, high-quality core staff that would undertake some in-house research but also commission research from external organizations such as universities with relevant experience, or even from foreign research organizations.
- It would recruit—not get on deputation—the best scientists nationally, including, if appropriate, from current AARI institutes, but with service rules attractive for scientists, on five-year contracts.
- It would be multidisciplinary, with notionally half the scientists in business development (value chains), economics, information and communication technologies (ICTs), social mobilization, post-harvest management, and nutrition.
- It would have a strong emphasis on commercialization through partnerships with the private sector. Part of this strategy would be to build capacity in industry associations for the various crops.
- It would pro-actively link with international partners. Logical partners would be the World Vegetable Center headquartered in Taiwan and the new tropical horticultural initiative of the Queensland Alliance for Agriculture and Food Innovation.
- Initially the PHR&DC would depend largely on public funds, but it would be strongly encouraged to diversify sources of funding through partnerships with the private sector and a levy on exports. Within 10 years, the objective should be to bring expenditure on horticultural R&D to 1% of the value of sector output, with about half provided by the private sector.
- The PHR&DC will start collaborative programs with the private sector R&E players with shared funding and incentives to the private players.
- PHR&DC will work with the government on improving the regulatory environment for high-value agriculture with the purpose of promoting R&E activities as well as encouraging private sector investment in value chains for high-value agriculture.

6.1.3. SHIFTING THE PARADIGM ON CAPACITY BUILDING

6.1.3.1. A Capacity Building Strategy

How should concerns about the quality of human capital within the Punjab AIS—a central concern voiced throughout this review—be addressed? Advanced, relevant, and state-of-the-art training of professionals is a lifeline for quality R&E, because it brings new and

[120] The PHR&DC will focus on development of the horticulture value chain through research. It will compliment (not substitute for) efforts of a similar organization at the federal level—the Pakistan Horticulture Development & Export Company (PHDEC)—which is mainly a development organization in the horticultural sector and is not very effective so far in Punjab.

renewed skills and methodologies to bear on those activities. Training for stakeholders along agricultural value chains is also important to facilitate the adoption of new technologies and bring strong productivity growth to the sector. The Punjab AIS needs an overarching **Capacity Building Strategy**, reflecting a positive attitude toward training as an investment for the future, to build capacity in staff and value-chain stakeholders alike. The Capacity Building Strategy should:

- Consider training as an investment in high-quality human resources for the future.
- Build capacity rather than just share knowledge.
- Involve the ultimate beneficiaries or stakeholders in identifying training needs as well as in developing and evaluating training initiatives.
- Cover a wider range of skills in its training activities, in line with the needs identified by stakeholders.
- Coordinate with other training providers in the area, such as the universities, Rural Support Program, Pakistan Poverty Alleviation Fund, and TEVTA, to cite a few.
- Efficiently harness foreign capacity-building opportunities.
- Insist on a clear objective for each training course and define change pathways.
- Provide support after training to enhance the impact.
- Track the impact of training activities.

The following steps should be taken to implement the Capacity Building Strategy:

1. Establish a separate Directorate General of Training with highly qualified training specialists performing the following functions:
   a. Evaluate the training needs of DoAg and DoL&DD staff and develop/update modules accordingly.
   b. Evaluate the impact of the existing training programs, identify constraints that lead to low impacts, reform the strategy and functions of existing in-service training institutes, and change their training programs accordingly.
   c. Conduct large-scale consultations with agricultural industries, farmers, and other stakeholders to assess their needs for professional staff and training.
2. Create a state-of-the-art in-service training institute to serve the agricultural and livestock sectors through the **training of trainers.** The institute would cover wide-ranging issues, have sufficient funds to support invited lectures by highly qualified professionals, and possess state-of-the-art training and lodging facilities.
3. Upgrade the existing in-service training institutes, especially their training staff and infrastructure.
4. Build capacity of the private sector, farmers, and value-chain stakeholders in key areas, such as the selection of parental lines for hybrid development, tissue culture seed and seedling production, disease management in animals, and other specialized skills.
5. Involve the private sector in the identification, development, funding, and evaluation of training courses.
6. Provide after-training services to mentor trainees and seek feedback to continuously upgrade training courses and enhance training impacts.
7. Independently evaluate all training courses after every two to three years.

6.1.3.2. A Modern Training Institute

An emphasis on new skills in communication, ICTs, business, marketing, participatory approaches, and other features of cutting-edge advisory services is needed in the four training ATIs of the DG(AE&AR) and the seven training institutes of the DG(LSE) (the Livestock Training Institutes). The Team examined the prospect of a major upgrade that would enable one of these institutes to become a center of excellence for extension and possibly serve as the national center for extension training.

The Team considered MANAGE in India (near Hyderabad) as a model.[121] MANAGE is an autonomous

[121] As stated on its website (http://www.manage.gov.in/aboutUs/our Organization.asp, accessed October 24, 2017), "The National Institute of Agricultural Extension Management, known as MANAGE, formerly the National Centre for Management of Agricultural Extension at Hyderabad, is an autonomous agricultural education institute located in Hyderabad, Telangana, India. The aim of the institute is to instil managerial and technical skills to Extension Officers, Managers, Scientists and Administrators in the agricultural economy, to enable them to provide support and services to farmers and fishermen for practicing sustainable agriculture."

training institution with a diverse array of offerings that range from very short refresher courses to year-long post-graduate diploma courses. Its mission is to "Transform the Public Extension Functionaries into Professional Cadre of Farm Advisors." If the establishment of such an institute is pursued in Punjab, it could, in addition to serving other provinces, become a strong competitor in the international market for modern training in agricultural advisory services. It may be advantageous to badge it with an analogous catchy name, such as ADVISE. The proposed institute would naturally champion the development of skills by employing the latest pedagogical tools and, in line with good practices discussed throughout this review, would provide after-training services to mentor and solicit feedback. Among the skills to be addressed in its training menu are those involved in effectively monitoring, evaluating, and learning from advisory activities. ADVISE would form strategic alliances and exchange arrangements with leading relevant institutions around the world, such as the Modernizing Extension and Advisory Services (MEAS) project, based at the University of Illinois at Urbana-Champaign and supported by the United States Agency for International Development (USAID).

6.2. IMPROVING THE PERFORMANCE OF THE RESEARCH SYSTEM

The Team makes eight proposals to reform the existing research system without changing much of its structure. The expected impacts of these initiatives on RIS performance are summarized in Annexure 5 with detailed numeration in the following sections.

6.2.1. GRANTING AUTONOMY TO RESEARCH SYSTEM

As noted earlier, AARI is the only (and largest) centrally controlled system with little flexibility to set its own rules. AARI should be made an autonomous or privately incorporated body that sets its own rules and governance system in line with good international practice, especially in hiring and financial practices.

6.2.2. EMPOWERING COMMODITY BOARDS

The boards appointed to the major research institutes should gradually move from an advisory role to a governance role. A possible sequence for this process could be to empower the commodity boards to:

- Establish priorities and approve annual work programs of the corresponding institute consistent with the priorities.
- Monitor annual progress reports of the institute according to agreed milestones (see later) and terminate non-performing programs and research activities.
- Receive and act on external evaluations of the institute.
- Conduct an annual performance evaluation of the director as well as participate in the selection of new directors.
- Pro-actively seek to raise funds for the institute, including levy funding (discussed below).

Note that full empowerment of the boards should be accompanied by training programs arranged by the center of excellence on training (until such centers are in place, this activity can be arranged by PARB) to sensitize board members on their governance roles, as well as the risks of engaging in institute management.

6.2.3. SECURING SUSTAINABLE FUNDING

Insufficient, unreliable, unsustainable, and undiversified funding is a major, chronic constraint on innovation in the AIS and major cause of inefficiency in research. Recent efforts to improve funding for the AIS, especially in the livestock sector, are welcome, but funding still remains lower than the desired target (research funding should be equivalent to 1% of Punjab agricultural GDP). Much can be gained by additional efforts to increase the funding for AIS on a sustainable basis and diversify the sources of funding in a manner that engages stakeholders in providing funds and controlling their use. A number of countries in Africa and other regions have increased the diversity of their funding sources for agricultural innovation through income from sales of products or services, contractual arrangements with public and private enterprises, and

contributions from producer organizations through taxation of exports or production.[122] It bears repeating that the objective of levies extends beyond raising funds for public research and includes giving farmers and industry a role in setting the R&E agenda. Industry representatives that have a seat at the table are more likely to support levies to fund research.

Several proposals made here could make financial resources in the AIS more reliable and sustainable for Punjab and the whole of Pakistan. They include levies on agricultural commodities for R&E, the retention of income generated by institutes, collaborative R&E projects with the private sector, and endowment funds for PARB to support operational R&E, training, and the importation of technologies.

6.2.3.1. Using Levies to Fund Research and Extension

The levy system of funding is widely used in many countries although it is organized in different ways.[123] In Punjab it should be initiated only as the reforms outlined in this review become effective and industry has gained confidence in the system. Generally, levies do not exceed 0.5% of the value of agricultural output and are collected at the point of export, although they could also be collected at other points of concentration in the value chain, such as wheat millers, cotton ginners, and others.

Cotton and sugarcane already have levies, and part of the proceeds is allocated to research. The cotton levy is a practice of long standing and supports a separate Central Cotton Research Institute, although the institute's website offers no evidence that cotton growers and the cotton industry more generally have a strong presence in its governance. In contrast, under the recent (more positive) initiative in sugarcane, the Chairman of the Sugarcane Mills Association has been appointed Chairman of the Sugarcane Research and Development Board. Other candidates for levy funding are wheat, rice, mangos, and citrus. They already have Commodity Research Boards that, once empowered, could promote the idea of levies.

Once there is broad ownership of the levy concept, the implementation of levies requires legislation to ensure that it is binding for all. The first step, then, would be for Punjab to pass the enabling legislation for levy funding that could be applied to any industry that votes to do so. Some countries have incentivized levy funding by also legislating that the government will match funds collected through levies. Good examples are the commodity research corporations for most major crop and livestock products in Australia, the National Agricultural Research Institute in Uruguay, and the eight commodity research institutes in Colombia. Punjab should review these experiences and draft appropriate legislation.

6.2.3.2. Retaining Earned Incomes

Agricultural R&E institutes currently have no incentive to maximize income from their land and human resources, as any income generated through these resources goes back to the treasury. Parallel to the public sector agricultural universities, once R&E institutes become autonomous, the income generated by their resources and activities should stay with them, including (for example) the income from land, revenue from services provided to different public and private organizations, and a share of the personal consultancy fees of scientists.

6.2.3.3. Fostering Private and Public Sector Collaborative Programs

The GoPunjab should have serious discussions with the federal government, especially with PARC, Atomic Energy Commission, Pakistan Council for Research in Water Resources (PCRWR), and Pakistan Central Cotton Research Institute (PCCRI), on the division of responsibilities and respective roles in research to avoid duplication and waste of resources. The GoPunjab should also encourage the federal organizations to initiate collaborative projects, especially on issues of national interest, and pursue the federal organizations to mainly focus on upstream and basic research.

Collaborative R&E programs with the private sector not only will reduce the financial burden on the public sector but will improve the capacity of the private sector. It will create ownership of the program that will serve to improve the commercialization of agricultural technologies.

[122] Beintema and Elliott (2009).

[123] Byerlee (2011).

6.2.3.4. Creating an Endowment Fund for PARB

The Team believes that PARB should be the pivotal institute in reforming the AIS. Through its Competitive Grant System, the board should play a key role in overcoming the constraints arising from a scarcity of operational funds, but funding for PARB itself is quite unreliable. To put PARB on a sustainable funding track, which will improve the sustainability of the whole AIS, it is suggested to provide an endowment fund. PARB should initially expand its activity to a level of at least Rs 1 billion annually. To generate this amount, it needs an endowment fund of approximately Rs 10 billion. It is suggested that Rs 5 billion may be sought from development agencies with the remaining Rs 5 billion from the GoPunjab's own resources.

6.2.4. EMPOWERING THE AIS LEADERSHIP

The Directors General and Directors (or Managers) of R&E organizations, and the Deans and Department Chairmen of public agricultural universities, must be appointed on the basis of merit rather than seniority. Clear and transparent criteria need to be established for the selection of dynamic, younger research and teaching leaders, and active efforts made to recruit from outside the system, and if needed from outside the country.

This new generation of leaders should then be empowered to manage their institutes according to a well-defined results framework. Key elements in this empowerment include:

- Making operating budgets fully fungible so that managers can move funds to the most productive areas.
- Empowering managers, especially in universities, to plan and spend resources according to the needs of the research programs in place without interference from the central management, with, of course, a strict monitoring mechanism in place.
- Implementing a well-defined performance evaluation system that adequately rewards the best scientists.
- Providing a strong voice to managers in the hiring and transferring of staff in their respective institutes.
- Implementing a results culture through a strong monitoring and evaluation system based on outcomes and impacts.
- Empowering managers and scientists to develop collaboration with any other organization within the country or abroad, even if it has financial implications.
- Empower the institute heads through an executive order from the Chief Minister (CM) to issue No Objection Certificate for foreign travel once scientists of the institute obtain foreign funding following the normal security clearance procedures.

In return, directors general and their institute managers will be accountable to the GoPunjab for delivering results on the ground. Accountability will require periodic third-party external evaluations and impact assessments.

6.2.5. STRENGTHENING THE QUALITY OF SCIENCE

The Team recommends that scientific quality be sharply upgraded through three options discussed below: rewards for publishing, reviews, and reinforced capacity.

6.2.5.1. Rewards that Recognize Publications in Certified Journals

Once the appropriate service rules and annual performance evaluations are in place, publications should be one measure to assess performance and assure scientific quality. It will not be the only measure; evidence on outcomes and impacts will be another important element of the performance evaluation. For some disciplines, the release of commercial varieties, or vaccines or patents along with their commercial use, may substitute for publication.

Following the example of the Higher Education Commission, only publications in ISI-listed journals should be recognized. Points could also be given for publication for communication purposes in well-established Pakistani journals such as the *Punjab Journal of Agricultural Research*, managed by the DoAg. In that case, however, the journal editors should work with the international standards system to try to become ISI listed. Publications in non-ISI journals outside Pakistan should be strongly discouraged.

The experience of the Higher Education Commission amply demonstrates that including this metric in incentive systems produces a strong behavioral response from scientists. Nonetheless, PARB could also support training courses in scientific writing as well as provide small grants to enable scientists to participate in international scientific congresses to present their work and receive feedback. PARB should also cover the cost of publishing in scientific journals (ISI recognized only), because this expense currently discourages scientists from publishing in international journals. The publication of technical books should also be funded after appropriate review.

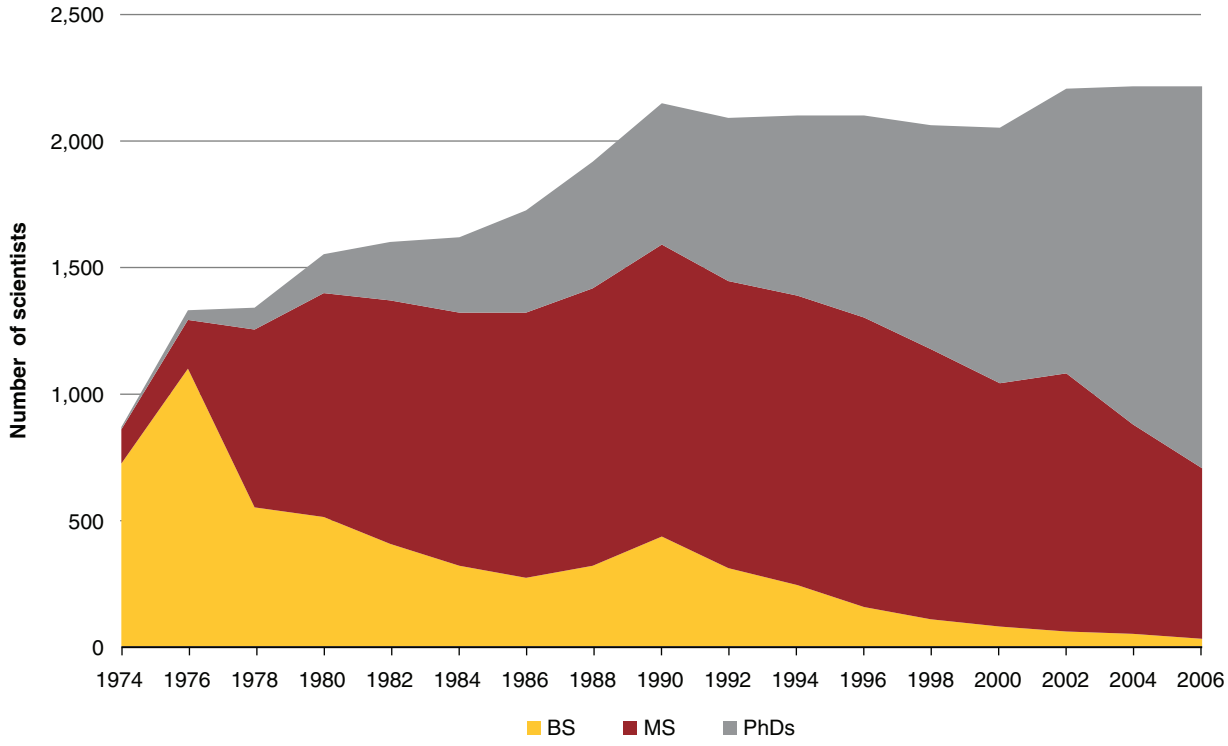
6.2.5.2. External Reviews of Research Programs

A standard practice in science is to organize periodic external evaluations of research institutes or programs by a panel of distinguished scientists. The reviews would employ the same framework the Team has used (research relevance, efficiency, science quality, and effectiveness). These reviews could be carried out at the institute level, but the Team believes they would be more effective if conducted at the program level. For example, for wheat, in addition to reviewing the Wheat Research Institute, the panel would review related wheat research across the province to provide a holistic picture. The findings of these external evaluations would feed into the design of the research programs recommended below. The newly constituted PARB would be best placed to organize these evaluations.

6.2.5.3. Long-Term PhD Training

With an aging population of scientists (almost 30% of government scientists are over 50 years old), the system must bring in new blood and sharply increase the share of scientists with PhD qualifications. Hiring of BS degree holders in research positions should be halted immediately. Punjab should set a target for increasing the share of its scientific staff with PhD qualifications to 50% within 10 years. Post-graduate training abroad will also be required in fields where Pakistan has little capacity, such as some areas of natural resource management, post-harvest management, and economic policy. Figure 12 shows how Brazil's Embrapa, one of the premier agricultural research organizations in the world, steadily upgraded the qualifications of its staff over 25 years using funds from

FIGURE 12. IMPROVEMENT OF QUALIFICATIONS OF EMBRAPA SCIENTIFIC STAFF OVER TIME



Source: Embrapa.

local sources, international scholarships, and loans from international financial organizations.

6.2.6. CONSOLIDATING RESEARCH INTO STRATEGIC PROJECTS AND PROGRAMS

The 1996 PARMP laid out a major restructuring and consolidation of the Punjab research system into 8 commodity programs, a central laboratory for some disciplines such as biotechnology and soils, and farming systems institutes for each of the 5 agro-ecological regions, amounting to about 14 institutes, or about half of the current number. Livestock would be similarly restructured into three institutes—livestock health, livestock breeding, and livestock nutrition and management.

Clearly the trend since 1996 has been for institutes to proliferate rather than consolidate. The Team believes that over the long term the proposed PARMP structure has much merit for improving the overall performance of the AIS. An intermediate measure would be to move operating funds into major projects and then programs that cover more than one institute.

A first step would be to begin consolidating the highly fragmented research activities in the province around significant projects. For example, a project on managing a disease in commodity X would integrate activities on that disease in the AARI plant pathology institute and the AARI commodity institute, together with related activities in the regional institutes and universities. In some cases, depending upon the size of funding, a project can be built around one disease, say, cotton leaf curl virus, or several diseases can be clustered in one project, or in other cases, all breeding, disease, and management activities for a commodity can be clustered together in one project.

Administratively, each scientist will be required to justify the time allocation across various projects, and the Director General should closely monitor the human and financial resource allocations according to the set priorities, deliverables, time frames, and implementation plans. The project managers should have special allowances (about 1% of the operational cost) as an incentive to initiate, organize, and implement the projects. The project managers would be responsible to achieve the KPIs specified in the project documents and would also act as the financial hub for the scientists involved, while the quality of science used in delivering KPIs would be ensured by the heads of the institutes/departments to which scientists belong and which have administrative control of them.

This coalescing of research within significant projects could open the way toward strengthening disciplinary institutes and departments (such as those focused on agronomy, plant pathology, entomology, breeding, post-harvest management, and so on) by transferring the professionals from commodity institutes to these disciplinary institutes/departments. All scientists shall belong to one of the disciplinary institutes, where they can enhance their professional skills along with or in competition with their peers in these institutes. Ultimately, the commodity institutes would be left with managers and can buy the time of scientists from any discipline they need in a given project. Scientists whose services do not have enough demand from any project or cannot deliver would be retired or redeployed.

A second step would be to consolidate projects into major programs, which could be defined in terms of value chains or agro-ecological zones. Some of this integration should be accomplished through PARB projects, but the task is much bigger than PARB. The Director General AARI would be empowered to consolidate all funding (from PARB as well as other donors) to allow such programmatic consolidation.

Key elements of each major program would be:

- A well-defined strategy, program of work, and results framework with clear milestones for a five-year period, based on wide consultation within the research system and with key stakeholders.
- Funding subject to a satisfactory peer review of the program proposal and appropriate adjustments. The PARB, with its peer review expertise for competitive grants, would be a logical choice to organize the review process.
- A strong monitoring and evaluation system to track progress, learn, and make mid-course adjustments. Each year, disbursement would be subject

to satisfactory progress in meeting agreed and well-defined milestones.

- A clear partnership strategy for delivery of technologies, including budgetary resources allocated to the partnership.
- A five-year life of the program that would require a favorable review to be renewed for a further five years.

As an example, a value-chain program for cotton could integrate the research activities and projects from the Cotton Research Institute of AARI, the disciplinary research institutes at AARI, PCCRI, NARC, UAF, Bahawalpur Regional Research Institute, and perhaps some research by pesticide and seed companies. Value-chain programs would eventually cover wheat, rice, cotton, sugarcane, pulses, oilseeds, horticulture (possibly several), and dairy. For maize and poultry, it is expected that most research would continue to be undertaken by the private sector.

The eco-regional-based programs could largely be implemented within the existing regional research structure. In some cases, the choice is fairly obvious, such as the Barani Agricultural Research Institute, Chakwal (for the barani region), the Bahawalpur Agricultural Research Institute (for cotton-wheat), the Rice Research Institute, Kala Shah Kaku (for rice-wheat), the Arid Zone Research Institute, Bhakkar (for the arid areas). In addition, the Team believes that crop and livestock research needs to be integrated within the research program for each zone, given the close interaction between crops and livestock in Punjab's farming systems. It would be highly desirable to co-locate scientists working on livestock nutrition and management in the same zonal institutes, or alternatively use one of the livestock stations to spearhead the zonal research and locate crop researchers on that station.

6.2.7. REFORMING SERVICE RULES

To a significant extent, the service rules determine the career and promotion opportunities and incentive structure for public sector R&E staff, who perceive their terms of service to be inferior to those offered to similarly qualified staff in agricultural universities and the federal system. Several reforms could improve this situation.

6.2.7.1. Establish Entry Rules Similar to Those in the Federal Agricultural Research System

The Team highly recommends equalizing the GoPunjab research staff grades with federal research staff grades. Parity in grade levels should help to attract better-qualified candidates, help to retain them by keeping their morale and motivation high as they pursue their careers, and will offer them the dignity and honor the scientists deserve.

6.2.7.2. Provide Better Incentives for the Better-Performing Professionals

At least 10% of all positions in the GoPunjab R&E system should be for Tenure Track Scientists (TTS) with salaries equivalent to those of tenure track professors in agricultural universities/faculties. The criteria for selecting TTS should be output and outcome oriented and clearly defined. Each staff member's curriculum vitae should be evaluated against the TTS criteria in a confidential review, including review by foreign professionals working in the discipline concerned. The initial term of the TTS should be for three years and its continuity for the next term should be based strictly on the successful delivery of the agreed outputs and outcomes.

6.2.7.3. Hire all Directors General and Directors through Open Competition

Only able leadership with appropriate drive can deliver on this transformative agenda for an output- and outcome-oriented R&E system. All Directors General and Directors should be hired through open competition. Internationally competitive salaries should be offered to attract international scientists for these positions, and flexibility should be shown in terms of nationality and other criteria to bring new, energetic leadership from abroad.

6.2.7.4. Base Promotions on Eligibility, Not Availability of Positions

Any professionals fulfilling the criteria should be promoted to the next grade in the same institute or department irrespective of the availability of the higher-grade position. A minimum, not a maximum, target should be fixed to grant promotion every year.

6.2.7.5. Use Output-Based Evaluation Criteria

The DoAg recently signed performance contracts with all Directors General in the department, who in turn will be signing performance contracts with their directors and the staff under their purview. Each performance contract fixes the deliverable targets during the two-year contract period. In the future performance will be evaluated based on whether the mutually agreed targets stipulated in the contracts have been reached, not through the traditional Annual Confidential Report. Performance contracts are a step in the right direction to foster a culture of delivering results in R&E institutes. Performance contracts move beyond setting a research direction for scientists and encouraging them to complete experiments; they specify the outputs and outcomes that are the basis for evaluating performance. It is strongly suggested that such performance contracts be adopted by the DoL&DD.

6.2.7.6. Making the Public Sector Leaner and More Gender Balanced

As mentioned, the public R&E system has four administrative and support staff for every scientist and eight for every extension professional. At least half of all resources are spent on administrative and support staff. These ratios and level of expenditure are too high for any modern scientific institution. The ratio of support staff to scientists must be reduced to approximately 1:1 within the next five years, which should generate significant savings for the institutes and improve the efficiency of the system. For this to occur, service rules for supporting staff have to be changed appropriately.

As most crop production and animal husbandry activities are carried out by females, improving the gender balance in the staff of both public sector research and extension will not only improve the relevance of the AIS but also enhance its efficiency.

6.2.8. STRENGTHENING THE REGULATORY ENVIRONMENT FOR PRIVATE RESEARCH AND DEVELOPMENT

The proposed changes in the governance and orientation of PARB should allow much greater participation of the private sector in R&D, especially through public-private partnerships. The other major requirement demanded by the private sector is to strengthen the regulatory environment for private sector engagement.

At the federal level, the most urgent requirement is to finalize the rules for implementing plant breeders' rights, decide on the implementation authority of the provinces, and put implementation capacity into place. Plant breeders' rights may be difficult to implement at the farm level, but they are essential to protect companies from appropriating the intellectual property of their competitors. A strong and transparent plant breeders' rights framework would increase private companies' confidence in importing inbred lines and other proprietary genetic material, forming partnerships with public breeding programs to license germplasm, and investing in R&D.

The Punjab is also considering its own seed law and regulatory authority. This practice is common in countries organized along federal and state lines, such as the USA and India, which tend to delegate most agricultural matters to the states. Any Punjab regulations should be consistent with federal regulations to minimize the transaction costs of doing business for private seed companies, and for that reason, Punjab must seek to have a strong voice in setting the federal regulations. The Team believes that most of the reforms for which the Punjab Seed Act is being promoted, such as truth in labeling provisions and mechanisms to facilitate the approval and release of varieties from the private sector, can be achieved within the framework of the amended Seed Act (2016).

The private sector investment in R&D depends on the broader macroeconomic and investment climate in a country. Following the International Finance Corporation (IFC) (www.eba.worldbank.org) framework, Pakistan and more specifically Punjab should review the overall environment for agribusiness, assess Pakistan's ranking among countries at a similar stage of development, and identify measures to ease agribusiness investment. For example, neither Pakistan nor Punjab appears to offer any tax incentives to invest in R&D, although such incentives are common almost everywhere else. Similarly, loans for agricultural R&D investment at subsidized rates are available in many countries but not in Pakistan. Application of the IFC tool would likely identify other areas for improving the business environment for private R&E.

Finally, the public sector shall assess the evolution of the private sector and adjust the public program accordingly to avoid crowding out the private sector. Where the private sector is already reasonably well established, the public sector should minimize or even withdraw its activities.[124] Public sector R&E should mainly focus on the provision of public goods, leaving the supply of economic goods to the private sector and empowering the private sector to supply them.

6.3. IMPROVING THE PERFORMANCE OF EXTENSION

The Team noted the need to improve the effectiveness of the system (public and private) for delivering agricultural messages, enhance its access to the grassroots level, extend its reach from farm to value-chain issues, and improve the delivery system's responsiveness to emerging issues at the farm and value-chain level. Fortunately, the public extension services for agriculture and livestock do not have to massively expand their workforce to massively expand their coverage; they can improve their efficiency by using new communication technologies and organizational strategies. The most promising possibilities are to use interactive media and other ICTs to reach producers and others along the value chain, to bring extension to the grassroots level through more effective producer organizations, and to join forces with other suppliers of extension advice, such as NGOs and the private sector, which are discussed in the following sections and summarized in Annexure 6.

6.3.1. USING MODERN TECHNOLOGIES IN EXTENSION COMMUNICATION

The Team was pleased to learn of the GoPunjab's strong commitment to using ICTs in support of agricultural development, which is a central theme of the Sector Plan 2014–2018. Recent progress includes the provision of smartphones to extensionists in DG(LSE); DG(AE&AR) is following the suit.

Smartphones are not the only tool in the box. The Team suggests that many additional tools in the broad spectrum of ICTs should be deployed in advisory services. Embracing digital innovation has many advantages. It helps to contain or reduce overall costs, especially for reaching new farmers. It offers new ways to document the time, effort, and success of extensionists and their programs. By appealing to young people, it may change perceptions of agriculture and the value of extension advice.[125]

One example is for community extensionists and social workers to use videos produced locally in local languages as the basis for discussions with small viewing groups (using digital projectors, movies, tablets, or other low-cost, small-format viewing devices). The Team also suggests that the Punjab Agriculture Helpline (PAH) be converted into a call center equipped with the latest interactive tools and software to respond instantly to farmers' queries, given that farmers already regard the Helpline as their most effective source of information.[126] The Helpline should incorporate advice from experts along the value chain to reach other stakeholders in the value chain.

6.3.2. BRINGING PUBLIC EXTENSION TO THE GRASSROOTS LEVEL

Currently the public extension services are supply driven, highly centralized, top-down, and bureaucratic, limiting their relevance as discussed in Chapter 5. While advice is working its way down to extensionists in the field, losses have multiplied or the problem has disappeared. Decisions made at the top are often less relevant to stakeholders and seldom owned by them.

The devolution of decision making to the local level has succeeded in many countries, but an attempt in Pakistan during 2001–16 was not very successful. The Team recommends making another attempt on a pilot basis in a few

[124] Two examples where the public sector needs to realign its R&E activities are maize and poultry. Rather than continue investing resources in the development of new maize hybrids and commercial poultry birds, the public sector should help the private sector in strengthening its R&E capacities, testing new technologies, and adapting technologies to local conditions. Such realignment will not only strengthen the private sector but also save public resources for high priority issues.

[125] For example, see Burton, Glassman, and Black (2017).

[126] Arfan et al. (2013).

districts, but in a different manner, taking into account the factors behind the initial mixed results described in Section 3.6.2.

The new attempt at devolution would be structured roughly along the lines of India's Agricultural Technology Management Agency (ATMA) (Box 4). The extension staff would remain administratively under their current headquarters for technical backstopping, capacity building, and other kinds of support, but their operations would be directed by a local, non-political Farmers' Association (FA) specifically formulated/elected for this purpose at the tehsil level and not under the control of the local political administration. More than one extension team could work in a tehsil, depending upon the local social setup, farming systems, or demands of the FA. The FA through a resolution passed in consensus in its general body would set the targets for extension staff for one year. The targets would be approved by the Agricultural Officer at the tehsil level and monitored both by the FA and tehsil-level extension establishment. The FA would be able to recommend that any extension staff member be transferred or fired, if it reasonably establishes that the staff member has failed to meet the target. Initially the FA would share a minimum prescribed percentage of the total cost of the staff. Each extension team based under an FA would use a holistic farming systems perspective and pro-actively reach out to all potential suppliers of technology and information (research and universities), rural development NGOs, market institutions, and others.

This system would bring extension closer to farmers, orient it to their demands, and keep it away from political establishments, while preserving its connections to the extension directorates for technical backstopping. The devolved services should improve monitoring and evaluation by making extension services accountable to the local FA. The task of planning and launching any specific campaign to combat local disease outbreaks would rest with the FA, and for a special campaign the FA may pay the actual cost.

6.3.3. MOVING TOWARD SPECIALIZED EXTENSION

Many countries have replaced public sector "generalized" (G) extension with "specialized" (S) extension. In G-extension, currently in vogue in Punjab (and throughout Pakistan), the extensionist is supposed to cover every problem in a commodity (crop or livestock), following generic guidelines prepared on the issues to advise farmers. S-extension, as the name implies, is designed to provide more targeted and specialized advice. In S-extension, after a specific problem or management practice that affects a particular crop or value chain in a region is identified, standard operating procedures (SOPs) are designed to solve the problem or to replace the practice, and then implemented through a group of extension specialists selected on merit from the public and private sector. The SOPs are prepared by professionals who specialize in that particular subject, and their efficacy is validated through experimentation across the region.

BOX 4. THE AGRICULTURAL TECHNOLOGY MANAGEMENT AGENCY IN INDIA

The Agricultural Technology Management Agency (ATMA) was piloted in the late 1990s and scaled up in the mid-2000s in India. A key concept or goal underlying the creation of ATMA was to move decision-making related to extension advice to the district level. A second goal was to increase farmers' input into extension program planning and resource allocation, especially at the sub-district level, and to increase accountability to local stakeholders. A third major goal was to increase program coordination and integration, so that specific programs (for example, emphasizing farming system innovations, developing farmer organizations, closing technology gaps, and managing natural resources) could be implemented more effectively and efficiently. The ATMA would be increasingly responsible for all technology dissemination at the district level and develop links with all agencies and NGOs associated with agricultural development in the district. Research and Extension units within the project districts, such as zonal research stations or substations, farm science centers (KVKs), and key line Departments of Agriculture, Animal Husbandry, Horticulture, and Fisheries, would become constituent members or key stakeholders of ATMA. Each Research and Extension unit would retain its institutional identity and affiliation, but programs and procedures concerning district-wise research and extension activities would be determined by the ATMA Governing Board and be implemented by its Management Committee.

Source: Adapted from http://www.manage.gov.in/atma-shimla/atma.htm, accessed 13 January 2018.

A group of extension specialists in the public or private sector selected on merit is trained to use the SOPs, and these specialists can then train large numbers of stakeholders along the value chain to use the SOPs. A small group of extension experts will be needed in the public sector at the provincial level to monitor the implementation of S-extension. S-extension is often auctioned out to the private sector on a competitive basis, especially if particular S-extension skills are not available in the public extension organization. In this way, a large number of outdated management practices can be replaced with improved practices by a small number of public extension staff, often in conjunction with private advisory service providers. For example, to promote the production of horticultural crops, a core S-extension group, with the collaboration of the private sector, can meet the demand for various services from large numbers of stakeholders along the value chains of a range of horticultural commodities (say fruit tree pruning, packaging, transportation, and so forth) by arranging separate group for each service (some of these groups can be picked from the private sector). The extension departments in DoAg and DoL&DD should ultimately move toward S-Extension; the financial arrangements that would permit greater provision of advisory services by the private sector are taken up in the next section.

6.3.4. PROMOTING PRIVATE SECTOR EXTENSION: OPTIONS AND MECHANISMS

Historically agricultural extension in Pakistan was treated as a public service rather than a commercial activity, with the private sector focusing mainly on providing their own product-specific information. Now agricultural extension is mostly a private good in many countries, and public extension (to the extent that it is sustained) focuses on those with a limited capacity to pay for advice.[127]

Although private advisory services have their own biases, it is important to recognize that they are necessary, given that public extension providers, who number in the thousands, are challenged to reach clients numbering in the millions. The creation of stronger human capital in the public and private sectors through the proposed new Capacity Building Strategy will boost the provision of high-quality agricultural advisory services in Punjab. Some of these trained individuals, even in the public sector, can move toward providing advice on a fee-for-service basis, as is the case in many parts of the world, from Australia to Chile and beyond. To facilitate these efforts, the public extension services—the DG(AE&AR) and DG(LSE)—should set up an accreditation body to assess prospective providers of private advisory services based on their qualifications and experience and register the accredited providers. Needless to say, it would be key to set up governance arrangements to guard against potential corruption and political capture of such a regulatory body. The Team feels that the dozens of private sector firms and NGOs active in Punjab's agricultural development, as well as the growing number of farmer-based organizations, could make great use of such an accreditation system in hiring decisions—not to mention the public agencies in Punjab, such as the DGs themselves. Accreditation can also help to accommodate a major thrust toward horticulture, which will require institutional innovation in providing extension services. Once the trained human resources for extension are available in the public and private sector, they can be engaged in S-extension. They can also be used in the accreditation bodies and training institutes both in the public and private sector.

The GoPunjab could usefully consider other mechanisms for fostering the development of private advisory services. The GoPunjab should evaluate different financing and service provision arrangements with the private sector as depicted in Table 20. Cell (1) of the table displays the typical public sector model, in which state agencies finance and provide extension services. A "pure" model of private sector extension provision is displayed in Cell (5) in which private companies provide extension services on a market basis, implying that the farmers pay the full cost of the extension service. Cell (8) presents another "pure" model, in which companies that contract with farmers for their products provide extension services as part of their contracting arrangement (such as Rafhan Maize in Punjab). The extension literature often refers to this institutional arrangement as "embedded services".[128] Similarly, input suppliers have incentives to provide free information to

[127] Swanson and Rajalahti (2010).

[128] Birner et al. (2009).

TABLE 20. OPTIONS FOR PROVIDING AND FINANCING AGRICULTURAL ADVISORY SERVICES (SHADED CELLS INDICATE EXTENSION FUNDING ARRANGEMENTS THAT INVOLVE THE PRIVATE SECTOR)

Who provides the service?	Who finances the service?			
	Public sector	**Farmers**	**Private companies and NGOs**	**Farmer-based organizations (FBOs)**
Public sector organizations	(1) Public sector extension services provided free to farmers	(4) Fee-based public sector extension services	(7) Private companies or NGOs contract extensionists from public sector extension agencies	(10) FBOs contract staff from public sector extension agencies
Private sector companies and NGOs	(2) Publicly funded contracts to private extension service providers or NGOs; publicly funded vouchers	(5) Private sector companies or NGOs provide fee-based extension services	(8) Embedded services: Companies provide information with input sale or marketing of products	(11) FBOs contract extensionists from private service providers or NGOs
Farmer-based organizations (FBOs)	(3) Publicly funded contracts to FBO extension providers	(6) Extensionists hired by FBOs, farmers pay fees	(9) NGOs fund FBOs to hire extensionists that provide services free to FBO members	(12) FBOs hire extensionists and provide services free to members

Source: Feder, Birner, and Anderson (2011).

their farmer-clients on best practices involving the input (such as Engro and Fauji Fertilizer in Pakistan). Because the range of agricultural crops, activities, and farming populations that are amenable to embedded extension services is inevitably limited, the state often remains involved in financing extension services. The state may contract private companies to provide those services, however (Cell 2). An alternative to the contracting arrangement is the provision of vouchers to farmers, who then give the vouchers to companies that provide extension services. The companies get the vouchers reimbursed by the state. The public and the private sector may also jointly finance the provision of extension services. A joint venture arrangement is not displayed in Table 20 but discussed in Annexure 7 in the context of the experience in Peru.

Table 20 also includes NGOs. In principle, they are different from private business enterprises as they are nonprofit organizations, but in extension models financed by the public sector, NGOs may play a role similar to that of private enterprises—for example, by providing extension on the basis of contracts or vouchers financed by the state.

Table 20 also lists various institutional arrangements that involve farmer-based organizations (also referred to as community-based extension services). In principle, farmer-based organizations could contract extension services from private sector providers (Cell 11), but if they are involved in extension, they may hire their own extension staff (Cell 12).

Farmer-based organizations may be involved in institutional arrangements in which the state contracts private sector or NGO extension providers. The inclusion of farmer-based organizations can help to make this model more demand driven, since it gives the farmers a voice in publicly financed contracts, and they can aggregate their demands for extension through their organizations. The type of involvement by farmer-based organizations may vary considerably, however.[129] So in designing any farmer-based program, such variation of farmers' involvement must be considered.

[129] Feder, Birner, and Anderson (2011).

Regardless of whether private extension services are financed by the public sector, farmers, communities, or individual extension users, there is a need for government to assume regulatory responsibility for certifying extension providers, as the qualifications of the provider to perform the task adequately may not be apparent a priori to farmer-users. While bad performance will be revealed over time and the market will eliminate unsatisfactory performers, farmers will incur an actual or (imputed) loss of income along the way. Regulatory oversight should reduce such losses.

Just which of the many possibilities for furthering private sector development in Punjab's agricultural advisory services might work best will require further careful assessment by the GoPunjab. **The Team suggests that the Peruvian experience with a public-private scheme involving farmer-based organizations is worthy of consideration, perhaps by way of a pilot operation in the near term**. The main features of that scheme, known as INCAGRO, are set out in Annexure 7. Whatever model is selected, it should be very problem-specific for high-priority problems, strongly results oriented, and tested on a pilot basis. It can invite open bids within a set of priorities and have strong monitoring, learning, and evaluation mechanisms.

6.4. STRUCTURAL REFORMS

It is suggested that all DGs in both the agriculture and livestock departments, in collaboration with concerned agricultural universities and federal research organizations, carefully analyze all R&E activities and suggest administrative reforms, including merging or closing some of their own activities. This review, however, provides clear evidence for some immediate reforms, which are separately discussed for DoL&DD and DoAg in the follow two sections.

6.4.1. LIVESTOCK SECTOR

Currently, livestock vaccine production is emphasized far more than research in the DG(LSR). In this setup applied research in the DoL&DD is very limited, creating big gaps in the supply of relevant technologies in the livestock sector. It is suggested to divide DG(LSR) into two Directorates: (1) a Directorate of Livestock Research D(LSR) and (2) a Directorate of Livestock Vaccine Production D(LSV), with clearly defined responsibilities and dedicated staff for each. The D(LSV) should gradually transfer its activity to the private sector and move toward new high-end vaccine development. The production of vaccine may be confined only to those vaccines that the private sector does not find it economically viable to produce.

The Team noted that many livestock-related research institutes are placed under the DG(LSE), in recognition of the fact that mainly pursue non-research activities like extension and development. The Team suggests that all animal research-related institutes in the DoL&DD be placed under the DLSR with a clear focus on research in each. The research capacity of the staff in the DLSR and its allied research institutes should be upgraded significantly and appropriate incentives offered for high research achievement. Research institutes that do not fit into any defined research agenda may be either closed or transferred to the DG(LSE).

The D(LSR) under the DG(LSR) should have three divisions (or units): (1) Livestock Disease Management, (2) Livestock Nutrition Management, and (3) Livestock Marketing and Product Development. The Livestock Disease Management Unit should conduct research on both curative and preventive measures using medicinal as well as management approaches. Similarly, the Livestock Nutrition Management Unit should explore the whole range of nutritional issues related to fodder, hay, silage, grazing, and commercial feeds, as well as the management practices to improve the nutritional status of animals. Finally, the Livestock Marketing and Product Development Unit should cover all value-chain issues related to animal and livestock product marketing, quality, exportability, new product development, and so on. These units should organize projects from core funding, PARB, and other sources and engage university professors (from UVAS, UAF, and elsewhere), NARC scientists, international scientists, and the private sector in these projects.

While the DoL&DD has effectively developed mobile veterinary facilities, the huge but deteriorating animal hospital infrastructure should be privatized. Similarly,

the infrastructure of LS farms should be rationalized and placed under the DG(LSR) in VRI.

6.4.2. AGRICULTURAL SECTOR

All research activities related to IPM should be coordinated by the Plant Pathology Research Institute of DG(AR) and IPM extension should be coordinated by the Directorate of Integrated Pest Management under the DG(AE&AR), and the DG(PW&PQC) should transfer all of its relevant infrastructure related to R&E for IPM to DG(AR) or DG(AE&AR).

The Directorate of Information should be placed under the DG(AE&AR).

The Floriculture and Landscaping Research Institute should be shifted to the DG(AR) in AARI. The capacity of the floriculture institute requires a major overhaul and upgrading. It should be assigned major responsibility for developing new flower varieties under different stress situations, promoting floriculture seedlings of improved flower varieties, developing and introducing new scientific flower and seedling production and post-harvest handling techniques, and exploring the international flower market.

Adaptive research should be placed under the DG(AR), AARI. The huge area occupied by the AdR farms should be rationalized, and the infrastructure and capacity to test value-chain technologies should be created instead. Mechanisms should be developed for stakeholders along the value chain to express their demand for technologies.

The AMRI should be transferred to AARI, and a large percentage of the professional human resources (over 100 qualified engineers) working in the DG(AF) just to maintain the records on bulldozers should be shifted to AMRI to improve research on machinery. The Team suggests that not more than one professional with BSc(Eng.) qualification be left in the field in each district, if field activities are at all politically necessary, and the remaining staff should be transferred to AMRI with appropriate incentives for research.

The Agricultural Economic and Statistical Sections should be combined into one institute with strong coordination with the PARC Regional Economic Center in Faisalabad to incorporate the socio-economic aspects of technology development and dissemination and conduct credible ex-ante and ex-post impact evaluation studies on various technologies of AARI. The capacity of the new institute needs to be greatly enhanced.

The Agricultural Marketing Institute under DG(AE&M) should be transferred to AARI, perhaps under a strengthened Socioeconomic and Statistical unit.

6.5. IMPROVING LINKAGES WITHIN AN INNOVATION SYSTEM FRAMEWORK

Improving integration between the universities, research directorates, and extension directorates will not only enhance the efficiency of the AIS but increase overall knowledge creation and utilization in the service of agricultural stakeholders. Better coordination between research, education, and extension may be achieved at three levels, discussed in the sections that follow: (1) administrative unity; (2) functional coordination, at the micro level (among individual experts and scientists) and the macro level (among leaders, policy and decision makers, and others); and (3) institutional coordination.

6.5.1. ADMINISTRATIVE UNITY

One approach, generally referred to as the "Ludhiana Model," implies putting all the three pillars of the innovation system under the control of one administrative entity. Most stakeholders involved do not prefer this option because they believe it would not work for Punjab, for several reasons (Box 5). The Team will not go into the merits of the model here, being of the view that the GoPunjab should not try to unify the system at the administrative level.

6.5.2. IMPROVING FUNCTIONAL LINKAGES

An improvement in these linkages involves building functional relationships between scientists, professors, and extensionists as well as their leaders, without disturbing the administrative setup of any of the institutes. Such

BOX 5. IMPEDIMENTS TO PLACING ALL ELEMENTS OF THE AIS IN PUNJAB UNDER ONE ADMINISTRATIVE ENTITY

Punjab has a long history (50 years) of separate institutional development of research, education, and extension, each managed under different administrative rules and regulations and run by different personalities. This institutional history has resulted in: differences in service structures (specifically, in recruitment and promotion methods); differences in pay structure and reward systems (specifically, in the tiers in the career structure and the technical parameters used in promotion); and differences in the nature of administrative and financial autonomy (while universities have full autonomy at the macro level, individual scientists in research institutes enjoy more administrative and financial autonomy). Other impediments include:

- An administrative merger would require lots of homework to amend the laws, regulations, rules and administrative setups that govern these institutions. Even if changes in laws and regulations are made, they will lead to endless litigation and negatively affect the operations of the institutes.
- Aside from legal battles, turf wars will invariably start among institutes. Who will go under whom? If an agricultural university has to lead, then which university?
- Administrative unification was attempted in Khyber Pakhtoonkhwa (KPK) Province in 1995 under the TAIPAN project financed by USAID. It failed mainly because of the reasons just cited, and the system reverted to its initial configuration (separate administrative control), having lost considerable resources and energy in the process.
- Several committees formulated earlier by the government on these issues have not recommended administrative unification of the system.

coordination can happen at the micro and macro levels, as discussed next.

6.5.2.1. Micro-Level Coordination

With little exception, individual experts and scientists have proven to be possessive of their ideas. They are reluctant to develop collaborative relationships without incentives and without institutional rules that provide flexibility and encouragement to develop such collaboration.

Research projects supported through competitive grants from PARB can provide exactly these incentives to functionally link scientists from different organizations. The projects will need to seek knowledge from the universities to develop technologies through research, and they must incorporate a commercialization phase, to be detailed in the project documents. Although scientists who have developed a technology may lead the commercialization phase, they will most likely need to rely on a commercialization team of extensionists, processors, manufacturers, and others for S-extension. Links between scientists across research, extension, and education institutes should be strengthened through PARB by engaging as many scientists across institutes as possible. The growing number of PARB projects should create major focal points for strengthening collaboration among scientists.

6.5.2.2. Macro-Level Coordination

Macro-level coordination integrates decision-making and implementation processes so that various decisions taken by different policy makers are in harmony with each other to achieve the same or different goals. This coordination is very important, because most policy makers (the PARC Chairman, vice chancellors of agricultural universities, federal and provincial agriculture secretaries, and others) are part of different administrative setups and report to different bosses. The Team recommends strengthening the existing mechanisms or creating certain new means to improve integration among policy makers:

- Expand and regularize the existing Commodity Management Groups. So far, Cotton, Wheat, and Rice Management Groups have been established, and in some years they have performed well. The groups are headed by the Minister for Agriculture and other members include Director General (AR), Director General (AE&AR), relevant professors from agricultural universities, scientists from research institutes, processors, farmers, and others. The Commodity Management Groups

should meet regularly to diagnose the major problem in the ongoing crop season, make decisions to resolve the issue, and develop mechanisms to implement the decisions.

- The Team is of the view that the existing commodity groups may be strengthened by including representatives of relevant agricultural universities and PARB. New commodity groups may be formulated on similar lines for all the major crops, including fruits and vegetables.
- Formulate a Technical Advisory Committee (TAC) which includes the Chief Executive of PARB as Chairman, vice chancellors of all agricultural universities, directors general of research and extension in the agriculture and livestock departments, prominent agricultural scientists, and progressive farmers. The main task of the TAC would be to help PARB to prioritize and allocate funds for high-priority research areas after their identification through stakeholder consultations organized by PARB. The TAC can also be used to improve coordination among policy makers in research, education, and extension.

6.5.3. INSTITUTIONAL COORDINATION

At the same time when individual scientists and professors improve their linkages through collaborative, competitively funded projects, institutional coordination should be improved to increase the mobility of scientists and professors across institutes. For this purpose, the Team endorses the following recommendations of the Letter of Intent signed between the Vice Chancellor, UAF and Director General (AR) in 2012:

1. The AARI may be declared as post-graduate campus of UAF.
2. Scientists of the research institutes may be declared as Adjunct Faculty at UAF.
3. Scientists of research institutes can utilize the laboratories of agricultural universities and vice versa for the teaching staff and students of the universities.

CHAPTER 7
SUMMARY AND CONCLUSIONS

This review was undertaken to suggest a reform framework for the Punjab AIS, after careful and extensive diagnosis of the system to the extent possible in the time available to the Team. The Team met with a large number of stakeholders engaged in education, research, and extension in the public and private sector. The Team also conducted a survey of researchers to assess their views on constraints, and it reviewed related studies and earlier reform efforts.

This review differs from earlier reviews in its approach and analysis. It includes the whole innovation system for agriculture in its scope—education, research, and extension in the public and private sector. It highlights the system's achievements during the past two decades and then analyzes the strengths and weaknesses of the system's components based on six aspects of performance (relevance, efficiency, effectiveness, quality, incentives, and private sector regulations). To some extent it quantifies the impacts of those strengths and weaknesses at the system level.

Several lessons from earlier reviews remain highly relevant for the outcomes of this one. First, the implementation of earlier reforms was curtailed because a strong champion of the reform agenda was not identified, and whatever leadership was available to implement the reforms changed frequently. Second, the "devil lies in the details," and the sequencing of reforms was problematic. Third, stakeholders—especially those who would apply agricultural technology, such as farmers, processors, traders, and others—never came to own the reform agenda. Finally, concerns over the loss of position and privilege among scientists, and over the waning of power and influence among bureaucrats, likely also halted reforms.

What may be different this time is that the Team perceives a significant change in the attitude of the government, not only toward the crop and livestock sectors but toward the provincial AIS. For example, the DoAg envisions an agricultural sector that is profitable, diversified, driven by markets and the private sector, and farmer-centric, and that also embraces high-precision, high-value agriculture.[130] At the same time,

[130] The vision for agriculture is available at http://www.agripunjab.gov.pk/vision (accessed January 14, 2018).

the DoL&DD, based on its Livestock Policy (2016),[131] envisages a shift from curative to preventive measures to control animal diseases, from public sector to market-led growth, from creating PhD professionals to developing large numbers of trained human resources with new skills and capacities, and from traditional to new extension approaches to reach livestock farmers.

To achieve these paradigm shifts, Punjab requires an efficient, effective, and relevant innovation system—and stakeholders appear receptive to the reforms that can bring it into being. For that reason, the government requested that the World Bank undertake this review and suggest a reform framework for the AIS.

The Team finds that the AIS has expanded reasonably well to cover almost all agricultural commodities, ecoregions, and disciplines. The system generates a number of outputs—new varieties of major crops, vaccines and diagnostic kits for major animal diseases, information and knowledge, and mechanisms (not so effective) to disseminate some outputs, and improvements in the regulatory framework. When it comes to generating and disseminating advanced management techniques, processes, and machinery, within a value-chain framework, the public R&E system appears less capable. Few technologies are designed using scientific methods, and technologies often fail to reach stakeholders, except for the successful introduction of laser leveling of fields and lining of water channels. In some instances, however, especially in the poultry and maize industries, the private sector is playing a big role in promoting advanced management practices and machinery.

Little attention has been given to aspects of the system that will speed the pace and strengthen the quality of agricultural innovation—effectiveness, efficiency, relevance, quality, and regulatory framework. The system is largely supply driven; its performance is held back by its lack of engagement with stakeholders in identifying, designing, and implementing R&E activities. Similarly, the public AIS is limited to farm-level issues; its effectiveness is curbed because it bypasses the needs of other stakeholders along the value chain. It currently lacks a mechanism of incorporating socioeconomic dimensions of technology development and dissemination. The quality of research (based on an evaluation of publications) and quality of extension (based on an evaluation of interaction with stakeholders) are relatively poor, although universities have recently improved the quality of their research.

The constituent organizations in the public AIS have dramatically different service structures, to the detriment of the provincial government's capacity to manage, motivate, and improve the quality of the human resources dedicated to carrying out its agenda for agriculture and livestock. Incentive structures discourage the formation of an output-oriented culture and affect the quality of work. Professional staff, once they enter any government institute, encounter very few opportunities for sustaining or building their capacity. The inefficient duplication or overlap of activities across institutes, directorates, and departments cannot be remedied without effective mechanisms for coordinating and assigning activities based on relative advantages. Aside from these internal issues, the provincial R&E system is also inefficient because it sustains so little external interaction with federal organizations, NGOs, and the private sector. The PARB attempted to link some of these scattered components through coordinated projects but could not make much of an impact throughout the system because it had no resources to support a large number of projects. The public R&E component of the AIS is tightly and bureaucratically controlled, offering the actors little autonomy and flexibility to decide on collaboration and to generate and use funds. The structure of the system is highly patriarchal thus fails to reach and address the issues of a large number of female farmers and workers in agriculture and livestock sector.

Now is the time to improve the relevance, efficiency, quality, and effectiveness of the system, and to offer proper incentives and an improved regulatory framework to all of the system's actors and institutes. The 10 principles of such reforms defined by the Team are: (1) recognize the **pluralistic** structure of the AIS; (2) **separate** the funders from the service providers; (3) emphasize **product diversification, quality, and value chains** and embrace a **wider range of clients** beyond farmers; (4) transform the system to **demand-driven priorities;** (5) create a **results-oriented culture,** in which results

[131] Government of the Punjab (undated).

are defined not as completed experiments or meetings with stakeholders but instead are assessed by measured parameters that indicate the impacts on stakeholders; (6) increase **autonomy** for institutes and scientists; (7) **provide appropriate service rules;** (8) foster wider concepts and approaches **for capacity building;** (9) **diversify funding sources**; and (10) implement an appropriate **policy and regulatory framework** to encourage private sector participation, collaboration, and investment.

The Team has developed a detailed reform framework based on these principles. First the Team outlines a series of high-profile initiatives, including a major upgrade of PARB, , a pilot of a state-of-the-art R&D institute in high-value agriculture, and the development of a new Capacity Building Strategy. Second, the Team suggests detailed steps to improve the research system, which include granting autonomy to the research system, empowering the commodity boards, creatingsustainable funding, empowering the AIS leadership, strengthening the quality of science, reforming the service rules, consolidating and rationalizing research into programs, and strengthening the regulatory environment for private R&D. Third, the Team proposes strategies and steps to improve the extension system, which include scaling up the use of modern technologies in communication, bringing public extension closer to the grassroots level, and transforming the extension approach from general to specialized extension. The team also presents options for promoting and funding private sector extension.

Fourth, the Team proposes structural reforms in both agriculture and livestock departments. In agriculture these reforms include putting the Agricultural Machinery Research Institute, Punjab Agriculture Marketing Institute, Floriculture and Landscaping Research Institute, and adaptive research farms under the DG(AR). Similarly, all IPM-related research activities in the DG(PW&PQC) should go to the Plant Pathology Research Institute of DG(AR) and its extension activities to the Directorate of IPM of the DG(AE&AR). The Agricultural Economics and Statistics Section should be upgraded to the level of an institute and its capacity should be significantly enhanced.

In the livestock sector, the Team proposes to divide the DG(LSR) into a Directorate of Livestock Research D(LSR) and a Directorate of Livestock Vaccine Production D(LSV), with clearly defined responsibilities and dedicated staff for each. The D(LSV) should gradually transfer its activities to the private sector and move toward new high-end vaccine development. The D(LSR) should have three divisions: (1) Livestock Disease Management, (2) Livestock Nutrition Management, and (3) Livestock Marketing and Product Development. All research related institutes in DoL&DD should be transferred from the DG(LSE) to the appropriate division of the D(LSR).

Fifth, the Team proposes strategies for enhancing research, education, and extension, including administrative coordination at the micro level (among individual experts/scientists) and macro level (among leaders, policy/decision-makers, and so on), structural coordination, and institutional coordination. Finally, the Team proposes strategies to improve service rules so that all players in the system have equal opportunities to progress, are motivated to work for the system, and have better incentives to deliver the desired outputs and outcomes. These improvements include suggestions for the rules governing new entrants, similar to those in universities and the federal agricultural research system; providing incentives for professionals who perform well; hiring all directors general and directors through open competition; basing promotion on eligibility and not availability of positions; adopting output-based evaluation criteria; and making the public sector leaner and gender balanced. In proposing these strategies, the Team cites relevant international good examples wherever possible. With these strategies in hand and agreed upon, a detailed implementation plan with timelines can be prepared.

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ANNEXURE 1
MISSION CONSULTATIONS AND MEETINGS

Punjab Agriculture Department (DoAg)

1. Mr. Muhammad Mahmood, Secretary
2. Dr. Ghazanfar Ali Khan Additional. Secretary (Planning)
3. Mr. Akhtar Mahmood, Chief Planning and Evaluation Cell
4. Mr. Mian Muhammed Azher, Deputy Chief, Planning and Evaluation Cell

Punjab Agricultural Research Board (PARB)

5. Dr. Noor-ul-Islam, CEO, PARB
6. Dr. Muhammad Abdullah, Executive Member (M&E)

Agricultural Extension and Applied Research (AE&AR)

7. Mr. M. Zafar Yab Haider, Director General (AE&AR)
8. Mr. Malik Muhammad Akram, Director (AE General-HQ)
9. Mr. Shahzad Sabir, Director, Agr. (Ext.) HQ
10. Dr. Qurban Ahmed, Director General (AF)
11. Dr. Khalid Mahmood, Director General (Additional Charge), PW&PQC)
12. Ch. Abdul Hameed, Director (AE)
13. Mr. Mahmood Akhtar, Chief, M&E Cell
14. Dr. Shahzada Munawar Mehdi, Director, Rapid Soil Fertility & Survey and Soil Testing Institute
15. Dr. Ehsan ul Haq, Director Soil Chemistry and Environment
16. Mr. Muhammed Ilyas, Director Soil Salinity Research Institute
17. Chaudhry. Abdul Ghafoor, Director, AdR & Training
18. Ch. Muhammad Shabbir Afzal, DO (AE)
19. Mr. Azim Azfar, Legal Advisor. Esp. Marketing Policy, ADU
20. Mr. Muhammad Raza Khan, M&E Adv, ADU
21. Mr. Sharjeel Murtala, Project Director, ADU
22. Mr. Kashif Jamshed, Coordinator Model Farm Project)
23. Ms. Sobia Akram, Ag. Officer (Tech), DG(AE&AR)
24. Mr. Mazar Hussain, Ag. Officer DG(AE&AR)

Directors General (Research)

25. Dr. Abid Mahmood, Director General (AR), AARI, Faisalabad
26. Mr. Makhdoom Hussain, Director, Wheat Research Institute, Faisalabad
27. Dr. Ghulam Muhboob Subhani, Director Agri. (Research), AARI, Faisalabad
28. Muhammad Aftab, Director, Oilseed Research Institute, Faisalabad
29. Dr. Khalid Hussain, Director Arid Zone Research Institute, Bhakkar
30. Mukhtar Ahmad, Director, Agronomy Research Institute, Faisalabad
31. Dr. Khawar Javad Ahmad, Director, Entomology Research Institute, Faisalabad
32. Dr. Muhammad Abrar, Director, Post-Harvest Research Centre, Faisalabad
33. Muhammad Iqbal , Director Plant Pathologist Research Institute, Faisalabad
34. Dr. Muhammad Zaffar Iqbal, Director, Agri. Biotechnology Research Institute, Faisalabad
35. Ch. Muhammad Rafiq, Director, Pulses Research Institute, Faisalabad
36. Dr. Muhammad Arshad, Director, Maize & Millets Research Institute, Yousafwala (Sahiwal)
37. Muhammad Najeeb Ullah, Director, Vegetable Research Institute, Faisalabad
38. Dr. Syed Ijaz-Ul-Hussan, Director, Potato Research Institute, Sahiwal
39. Dr. Hameed Ullah, Director, Mango Research Institute, Multan
40. Dr. Muhammad Ishaq Javeed, Agri. Economist, AARI, Faisalabad
41. Riaz Ahmad Kainth, Cotton Botanist, Cotton Research Station, Faisalabad
42. Mr. Makhdoom Hussain, Director, Wheat Research Institute, Faisalabad
43. Mr. Muhammad Rafique, Maize Botanist, Maize Research Station, Faisalabad
44. Dr. Muhammad Arshad, Director, Maize & Millets Research Institute, Yousafwala (Sahiwal)
45. Dr. Javaid Ahmad, Wheat Botanist, Wheat Research Institute, Faisalabad
46. Dr. Khalid Hussain, Director Arid Zone Research Institute, Bhakkar
47. Muhammad Najeeb Ullah, Director, Vegetable Research Institute, Faisalabad
48. Syed Ahmad Chiti, Vegetable Botanist, Vegetable Research Institute, Faisalabad
49. Dr. Akhtar Saeed, Assistant Botanist, Vegetable Research Institute, Faisalabad
50. Dr. Muhammad Abrar, Director, Post-Harvest Research Centre, Faisalabad
51. Dr. Hameed Ullah, Director, Mango Research Institute, Multan
52. Dr. Atta-ur-Rahman, Food Technologist, AARI, Faisalabad
53. Dr. Tahir Zahoor, Director General, National Inst. Of Food Sciences & Technology, UAF
54. Dr. Muhammad Atif, Randhawa, Professor, National Inst. Of Food Sciences & Technology, UAF
55. Mr. Muhammad Yaseen, Chief Executive, Ambassador Seed and Crop, Green Town, Millet Road, Faisalabad
56. Mr. Waqar Ahmad\Asst. Research Officer, Biochemistry Section, PHRC, Faisalabad
57. Dr. Ahmad Din, Asst. Food Technologist, PHRC, Faisalabad
58 Dr. Ahmad Din, Asst. Food Technologist, PHRC, Faisalabad
59. Mr. Zafar Iqbal, Asst. Research Officer, PHRC, Faisalabad
60. Mr. Muhammad Asghr, Food Technologist, PHRC, Faisalabad
61. Ch. Naseer Ahmad, Chief Executive, Al-Rafique Enterprises, Sargodha
62. Ch. Muhammad Rafiq, Director, Pulses Research Institute, Faisalabad
63. Dr. Aziz-ur-Rehman, Lentil Botanist, Pulses Research Institute, Faisalabad
64. Mr. Muhammad Shafique, Pulses Botanist, Pulses Research Institute, Faisalabad

Citrus and Fodder Research Institute, Sargodha

65. Mr. Hamid Saleem Waraich, President Kinnow Grower Association, Sargodha
66. Mr. Rizwan Saadiq, Citrus Asia Kinnow Factory, 104 NB, Sargodha
67. Dr. Muhammed Nawaz Khan, Director Citrus Research Institute, Sargodha

68. Dr. Muhammed Shabbir Shakoor, Director Fodder Research Institute, Sargodha
69. Mr. Saleem Akhter, Director Fodder Research Institute, Sargodha
70. Mr. Muhammad Aashiq Sanghi, Director In-service Agriculture Training Institute, Rahim Yar Khan
71. Dr. Muhammad Azam Khan, Director In-service Agriculture Training Institute, Sargodha
72. Mr. Muhammad Zakria, Director Agriculture Training Institute, Karor Pacca, District Layyah
73. Mr. Riaz Javed, Principle, Barani Agriculture Training Institute, Daghal, Rawalpindi
74. Mr. Abdul Ghafoor Ghafari, Director Agriculture Extension, Sahiwal
75. Mr. Fida Hussain Bloch, Instructor, IATI, Rahim Yar Khan
76. Mr. Muhammad Riza Malik, Assistant Horticulturist, Citrus Research Institute, Sargodha
77. Mr. Ehsan-Ul-Haque, Assistant Food Technologist Citrus Research Institute, Sargodha
78. Mr. Akbar Hayat, Assistant Research Officer, Citrus Research Institute, Sargodha
79. Mr. Muhammad Asim, Assistant Research Officer, Citrus Research Institute, Sargodha

Private Sector

80. Mr. Daniyal Jawed Quereshi, Chairman Four Brother
81. Mr. Hamza Nadeem Quereshi, Four Brothers, Director FB Genetics
82. Mr. Qamar Uz Zaman, Engro Fertilizers, Manager Farmer Connect Project
83. Mr. Nadeem Zafar Mirza, DuPont Pioneer, Country Manager
84. Mr. Azeem Khan Niazi, Monsanto Pakistan, Corporate Engagement Lead
85. Mr. Jamshed Iqbal Cheema, Auriga Group, Chairman
86. Mr. Waqar Ahmad, Nestle Pakistan, Head Corporate Affairs
87. Mr. Mujahid Ali, Citrus Asia, Export Manager
88. Mr. Shahid Ghauri, OzDelicious, Export Manager

Farmers and Civil Societies

89. Mr. Sarfraz Ahmed Khan, Kissan Board PK, VP
90. Plus some 16 other (mainly middle to large size farms) farmers attended this group meeting in Lahore
91. Ch. Hamid Malhi, Basmati Growers Association, President
92. Mr. Arif Nadeem, CEO, Pakistan Agriculture Coalition

PARC / NARC

93. Dr. Yousaf Zafar, Chairman, Pakistan Agricultural Research Council
94. Dr. Muhammed Azeem Khan, Director General National Agriculture Research Center
95. Dr. Umer Farooq, Member Social Science, Pakistan Agricultural Research Council
96. Muhammed Anjum Ali Bhutter, Member Plant Sciences
97. Dr. Nadeem Amjad, DG Agricultural Engineering Division
98. Dr. Munir Ahmad, Member Natural Resource Division
99. Dr. M. Kamal Sheikh, Technical Staff Officer to Chairman PARC

Punjab Livestock & Dairy Development Department (DoL&DD)

100. Mr. Irfan Khalid, Deputy Secretary
101. Dr. Abdul Rauf, DG (Research)
102. Mr. Muhammed Iqbal, Director (VRI)
103. Dr. Sajjad Hussain, Additional Director (F&MDRC)
104. Dr. Zafar-ul-Ahsan Qureshi, APVO
105. Dr. Muhammad Anees, APVO
106. Dr. Azam Ali Nasir, APVO
107. Dr. Nofil Mustafa, VO
108. Dr. Girham Gill DG (LSE)
109. Dr. Asif Rafiq, Director, Communication & Extension
110. Visit to inspect services of mobile dispensary [3 officers, including 1 female veterinarian, about 12 farmers]]

University of Agriculture, Faisalabad

111. Dr. Muhammad Amjad, Dean, Faculty of Agriculture, acting for the VC

112. Dr. M. Sajjad Khan, Dean, Faculty of Animal Husbandry
113. Dean, Faculty of Economics
114. Dr. Masood Sadiq Butt, Dean, Faculty Food, Nutrition & Home Sciences
115. Dr. M. Asghar Bajwa, Dean, Faculty of Sciences
116. Dr. Allah Bakhsh, Dean, Faculty of Ag. Engineering & Technology
117. Dr. Rashid Ahmad, Director, External Linkages
118. Dr. Muhammad Ashfaq, Prof. Agriculture & Resource Economics.
119. Dr. Allah Bukhsh, Director Research Planning

University of Veterinary and Animal Sciences

120. Dr. Tallat Naseer Pasha, Vice Chancellor, UVAS
121. Dr. Nasim Ahmad, Pro Vice Chancellor, UVAS

Forman Christian College

122. Dr. Kauser Abdulla Malik, Distinguished National Professor (Biotechnology)

World Bank

123. Dr. Dan Petrescu, ICT consultant, World Bank
124. Mr. M. Usman Zahid, Performance Management consultant, World Bank

ANNEXURE 2
AGRICULTURAL RESEARCH AND EXTENSION AGENCIES OPERATING IN PUNJAB, 2017

ANNEX TABLE 2.1. FEDERAL, INTERNATIONAL, AND PROVINCIAL AGENCIES, UNIVERSITIES, AND PRIVATE COMPANIES INVOLVED IN AGRICULTURAL RESEARCH AND EXTENSION, PUNJAB, 2017

Federal/ International	Provincial	Universities	Private sector
Ministry of Food, Agriculture and Livestock **1. Arid Zone Agriculture Research Institute (AZRI), Bahawalpur** **2. PARC Research and Training Station at Multan** **3. Social Sciences Research Institute, Faisalabad** ***Pakistan Atomic Energy Commission*** **1. Nuclear Institute for Agriculture Biology (NIAB), Faisalabad** **2. National Institute of Biology and Genetic Engineering (NIBGE), Faisalabad**	***Planning and Development Department*** **1. Punjab Economic Research Institute (PERI)** **2. Agency for Barani Area Development (ABAD)** ***Department of Agriculture*** **1. Punjab Agriculture Research Board (PARB)** **2. DG(AR)** *At Headquarters in Faisalabad:* *1)* Wheat Research Institute *2)* Sugarcane Research Institute *3)* Oilseed Research Institute *4)* Pulses Research Institute *5)* Research Institute *6)* Horticulture Research Institute *7)* Post-harvest Research Institute *8)* Agronomic Research Institute *9)* Plant Pathology Research Institute *10)* Entomological Research Institute *11)* Institute of Soil Chemistry and Environmental Sciences *12)* Agriculture Biotech Research Institute *13)* Economic Section *14)* Statistical Section	***Agricultural Universities/Colleges*** **1. Offices of Research Innovation and Communication (ORIC)** *All agriculture and livestock universities in the province have established ORICs to assist university innovators in taking technological solutions developed at the university to stakeholders* **1. University of Agriculture, Faisalabad** *1)* Water Management Research Center *2)* US-Pakistan Center for Advanced Studies: Agriculture and Food Security *3)* Institute of Soil and Environmental Sciences *4)* Research projects *(currently 89)*	***Private Sector (local companies)*** **1. Punjab Rural Support Program** **2. Four Brother (Pvt)** *Screening materials and pursuing limited breeding activity on cotton, basmati rice, and selected fruits* **3. Ali Akbar (Pvt)** *Engages in extension and farmer training, while selling its pesticide and seeds* **4. Guard Agricultural Research and Services** *Testing and screening hybrid rice imported from China* **5. Auriga Group of Companies** *Conducting research on micronutrients and developing growth promoters*

(continued)

ANNEX TABLE 2.1. Continued

Federal/ International	Provincial	Universities	Private sector
Ministry of Textiles **1. Pakistan Central Cotton Committee Research Institute (PCCRI), Multan** **2. Textile College, Faisalabad** ***Ministry of Commerce*** **1. Pakistan Tobacco Board (PTB)** **2. Pakistan Horticulture Development and Export Company (PHDEC)** ***Ministry of Education*** **1. Centre of Excellence in Water Resources** ***Ministry of Science and Technology*** **1. Pakistan Council for Research in Water Resources (PCRWR)** ***Ministry of Environment*** **1. Pakistan Forest Institute** ***Ministry of Water and Power*** **1. Irrigation Research Institute** ***International Water Management Institute (IWMI)*** **1. Regional Center in Lahore**	*Outside Headquarters:* *15)* Maize and Millet Research Institute *16)* Cotton Research Institute *17)* Citrus Research Institute *18)* Mango Research Institute *19)* Rice Research Institute *20)* Fodder Research Institute *21)* Barani Agricultural Research Institute *22)* Regional Agriculture Research Institute *23)* Rapid Soil Fertility & Survey & Soil Testing Institute *24)* Soil and Water Conservation Research Institute *25)* Soil Salinity Research Institute **3. DG(AE&AR)** *1)* Directorate of Agriculture Extension (Headquarters), *with 9 Divisional Agriculture Extension Offices and 36 district offices with staff at union council level* *2)* Add. DG of (Farms and Training) *has 8 Adaptive Research Farms* *3)* Directorate of Horticulture *has 5 officers in major fruit-growing areas* *4)* Directorate of In-service Agricultural Training Institute *has four in-service training institutes* *5)* Directorate of Integrated Pest Management *runs 31 Plant Clinics in 31 out of 40 districts.* **4. DG(AF)** *1)* Agriculture Mechanization Research Institute *2)* Field staff to provide land development services, including land leveling, building small and medium dams, landscaping, etc. *3)* No extension of farm machinery and equipment **5. Directorate of Pest Warning and Pesticide Quality Control** **6. Directorate of On-Farm Water Management (OFWM)** **7. Directorate of Agriculture Information** *1) Journal of Agricultural Research* (JAR) **8. Director of Floriculture (R&T)** *1)* Floriculture and Landscaping Research Institute	**2. PMAS-Arid Agriculture University, Rawalpindi** **3. Muhammad Nawaz Shareef University of Agriculture Multan (MNSUAM)** **4. University of Veterinary and Animal Sciences (UVAS), Lahore** *1)* Poultry and Dairy Animals Training and Research Center, Pattoki **5. Agriculture College of University of Sargodha** **6. Agriculture College, Bahauddin Zakariya University (BZU), Multan** **7. Agriculture and Animal Husbandry Colleges in Islamia University, Bahawalpur** **8. Punjab University, Lahore** *1)* Centre of Excellence in Molecular Biology (CEMB) of Punjab University *2)* Agriculture College **9. Forman Christian College, Lahore** *1)* Agriculture Biotechnology Laboratory	**6. Lahore Waste Management Company and Lahore Compost** *Manufacturing organic fertilizer from Lahore waste and promoting it among farmers.* **7. Neelum Seed Corporation** *Testing genetically modified cotton seed* **8. Agriculture Farms** **9. Emkay Seed** *Engages in developing high-yielding, disease-resistant basmati rice varieties and hybrids in collaboration with IRRI and NIBGE* **10. Pakistan Agriculture Coalition (PAC)** *Engages in value-chain development, provision of trained manpower to agricultural industries to meet specific needs, and recently started to provide quality seed* ***Private Sector (international companies)*** **1. Pakistan Nestle (Pvt)** *Engages in livestock extension and service delivery (especially insemination of exotic animals) in selected districts* **2. Engro Fertilizer** *Helps farmers in soil testing and limited fertilizer trials*

ANNEX TABLE 2.1. Continued

Federal/ International	Provincial	Universities	Private sector
	9. Directorate of Agriculture (Economics and Marketing) *1)* Agriculture Marketing Research Institute *2)* Agriculture Marketing Information Services (AMIS), Punjab **10. Soil Survey of Pakistan** ***DoL&DD*** **1. DG(LR)** *1)* Veterinary Research Institute, Lahore *2)* Foot and Mouth Disease Research Centre, Lahore *3)* Poultry Research Institute, Rawalpindi *4)* Animal disease diagnosis and surveillance **2. DG(LSE)** *1)* LS Farms *2)* Buffalo Research Institute, Pattoki *3)* Livestock Production Research Institute, Bahadurnagar *4)* Barani Livestock Production Research Institute, Kherimurat *5)* Research Centre for Conservation of Sahiwal Cattle, Jhang *6)* Directorate of Livestock Training (LST) » LST Centre Bahadurnagar, Okara » LST Center, Sheikhupura *7)* Directorate of Animal Breed improvement *8)* Punjab Wildlife Research and Training Center *9)* Directorate of Communication and Extension *10)* Hospitals and Dispensaries: » District/division level Veterinary Hospitals (574) » Dispensaries (1605) » Artificial Insemination Centers (161) » Subcenters (602), mobile dispensaries (191) ***Department of Forestry and Fisheries*** **1. Punjab Forestry Research Institute** **2. Punjab Fisheries Research Institute** **3. Fisheries Research and Training Institute** ***Department of Irrigation*** ***Directorate of Land Reclamation (Experiment Stations)***		**3. Pioneer Seeds** *Developing and testing hybrids from imported inbred lines* **4. Monsanto** *Testing improved inbred lines and chemicals for adaptation to local conditions*

Source: Developed by the authors.

ANNEXURE 3

THE FORTY-YEAR HISTORY OF PARB AND ITS ROLE IN REFORMING THE RESEARCH AND EXTENSION SYSTEM

When the three components of the AIS bifurcated—education remaining with the UAF, while research and extension moved under the Secretary of Agriculture—the need for coordination was immediately apparent. To meet that need, Punjab Agricultural Research Coordination Board (PARCB) was established in 1978 through an Ordinance of the Government of the Punjab. The function of the board was to coordinate research under provincial and federal research organizations and universities. The board soon became ineffective because its coordination function was inherently limited, and it lacked funds.

In 1996, a Punjab Agriculture Research Master Plan (PARMP) for agriculture (including crops, livestock, forestry, and fisheries) was prepared by consultants from Australia with financial support from the World Bank. The PARMP suggested that a rolling research plan be prepared that would identify high-priority research areas every year for prospective funding through competitive grants. To implement the PARMP, the Punjab Agriculture Research Board (PARB) was created through an Act of Provincial Assembly in 1997. The PARB Act mandated the establishment of a 15-member Board of Governors, with the Minister (Agriculture) as its Chairman, 5 bureaucrats from different departments, 5 members of the Provincial Assembly, 3 other members to be nominated by the DoAg, and the Chief Executive of PARB as its member secretary. The Chief Executive was given powers to implement the decisions of PARB. The PARB Act gave the board limited autonomy to make its own rules (to be approved by the provincial government) within the framework of government rules, although the government had the power to override any decision of the board.

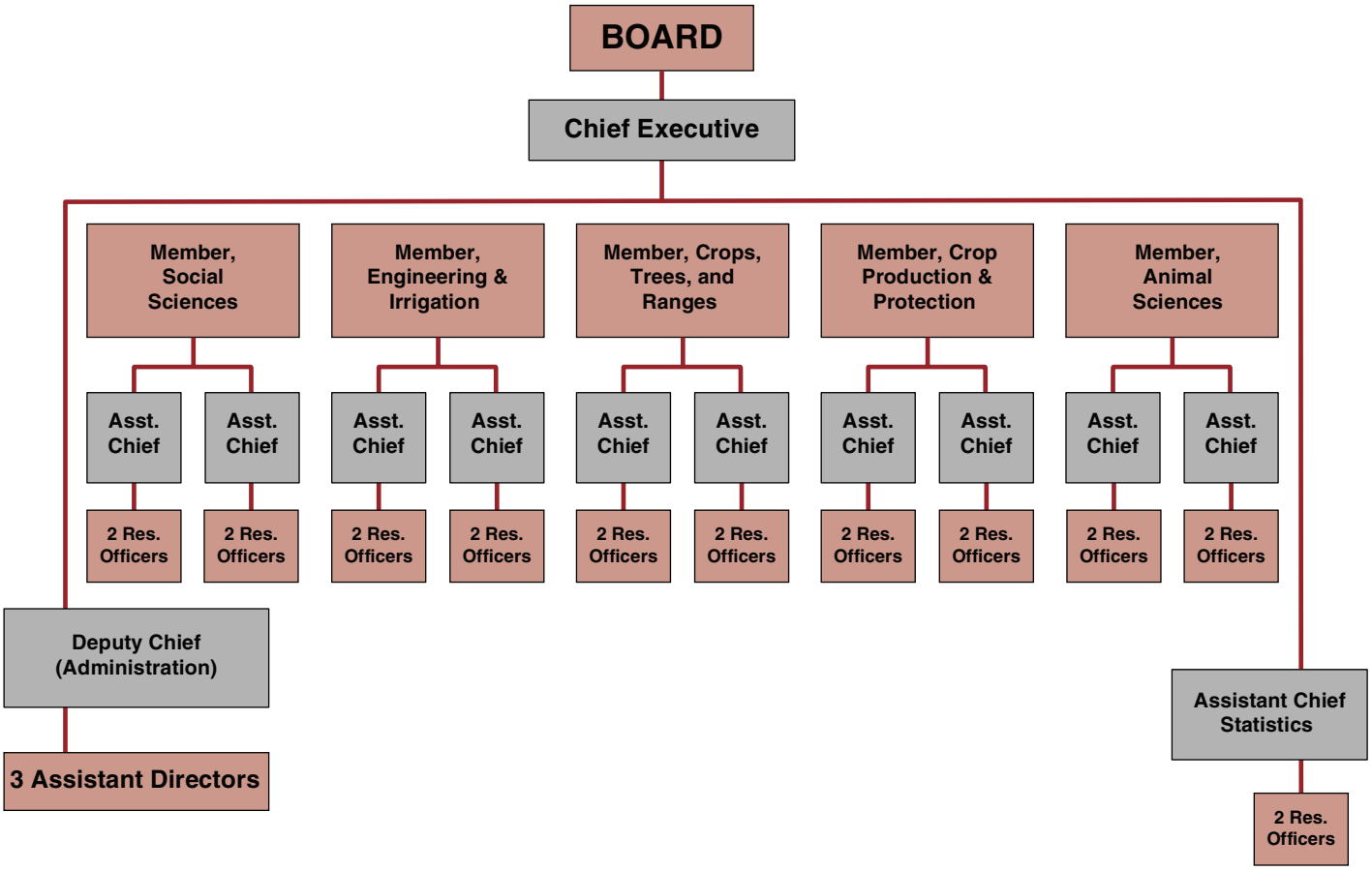
The PARB Act expanded the board's functions from its previous advisory and coordination roles (in its incarnation as PARCB). The board was now to conduct, plan, fund, monitor, coordinate, and commercialize agricultural technology and those functions would cover all agriculture-related departments, such as crops, livestock, forestry, fisheries,

irrigation, food, and so on. Although the PARB Act did not specify a structure for PARB, the consultants that prepared the PARMP suggested that it should have five divisions, each representing a particular disciplinary area and headed by an Executive Member (Annex Figure 3.1). In addition to the administrative staff directly under the control of the CEO, each Executive Member has two Assistant Chiefs each with two Research Officers, all hired under government rules and subject to government pay scales. Most personnel were temporarily deputed from different departments, however. The discipline-based divisions created disciplinary divides within PARB and generated disciplinary-based rather than problem-solving projects in each division.

After approval of the PARB Act, the board was shifted from Faisalabad to Lahore, and it funded some high-priority projects through competitive grants. All project funding stopped after World Bank funding ended, reflecting a lack of commitment and ownership by the provincial government and research system. All of the professional staff returned to their original departments. The Chief Executive went to the Secretary of Agriculture and the professional responsibilities of the Executive Members and Chiefs were assigned to non-professional staff of PARB.

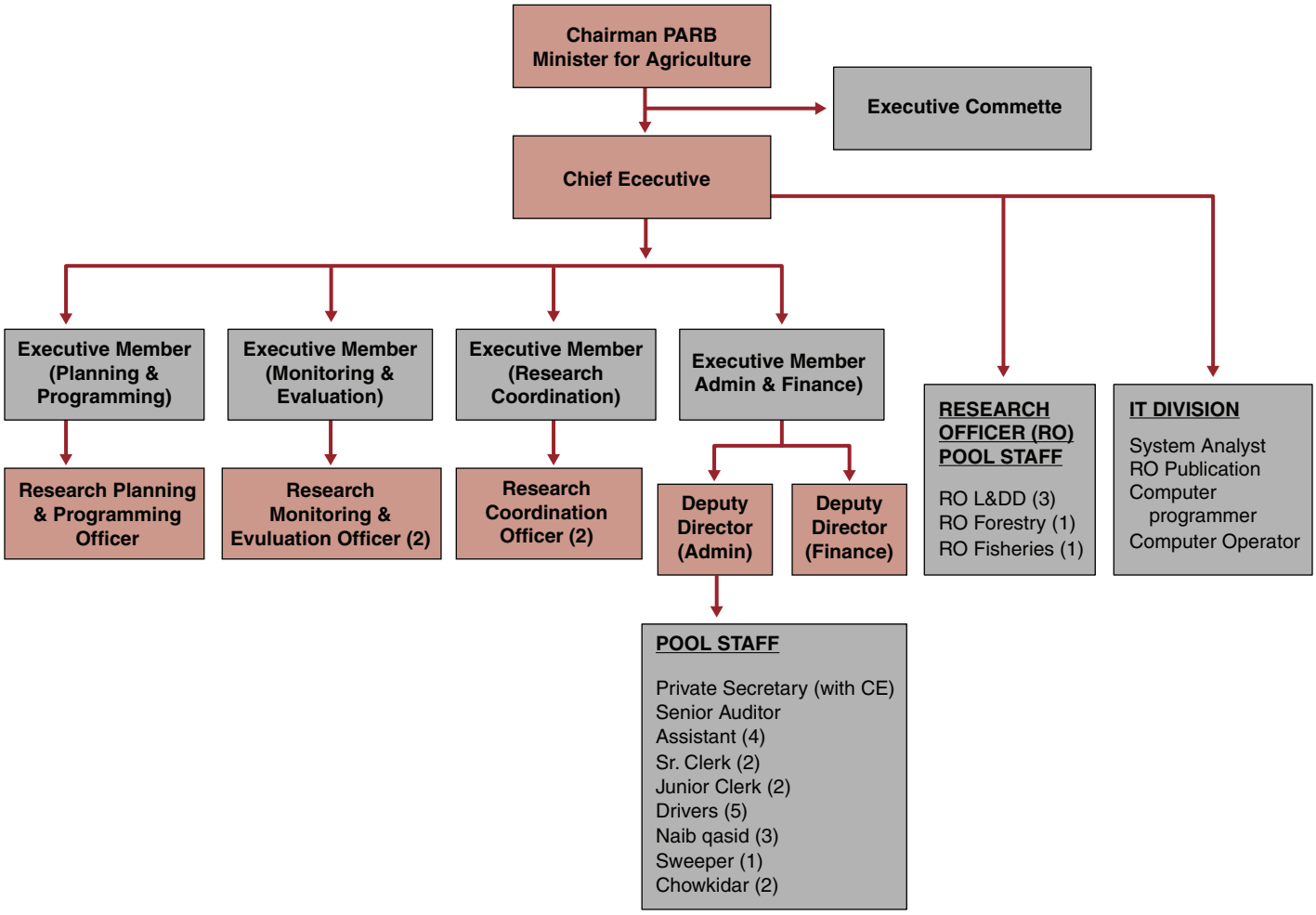
The PARB was resurrected in 2007 as a condition of an Asian Development Bank loan. An internationally recruited CEO was hired, the Executive Members and other technical staff were hired in 2009, and the regulations for operating the revamped PARB were approved in 2010. The board's new management team replaced the five disciplinary divisions with four activity-based divisions (Annex Figure 3.2) Each division was again headed by an Executive Member, each with three Research Officers (the Assistant Chief positions were removed). The administrative and professional staff hierarchy was also reduced significantly.

ANNEX FIGURE 3.1. DISCIPLINE-BASED STRUCTURE SUGGESTED FOR PARB BY PARMP, 1996



Note: Asst.= Assistant and Res.= Research.

ANNEX FIGURE 3.2. FUNCTION-BASED STRUCTURE OF PARB SINCE 2007



After wide consultation with stakeholders, the new team identified researchable issues under five themes, and each Executive Member as well as the CEO was made a Theme Leader (TL) for one theme. The whole research plan, organized under the five themes, was placed on the newly established website, and research proposals were solicited through a widely-circulated advertisement. Training on proposal writing skills was provided. A large number of proposals were received, as the new setup for PARB promised researchers 5% of the project costs as an incentive if they successfully delivered their research outputs, and 20% of the project costs could be used finance improvements in research laboratories and institutes.

The proposals were short-listed internally by each TL, and technically evaluated by Technical Working Groups specifically formulated for each project. The three members of each working group were given financial incentives to evaluate proposals and guide the project scientists during implementation if their project was approved. After three rounds of advertisement in three years, 59 multi-disciplinary and multi-institute problem-solving projects were approved by the Board of Governors at a cost of Rs 1.1 billion. These projects linked researchers from various disciplines across institutes within the country and abroad, and PARB became a meeting place for researchers who had not previously collaborated.

The Monitoring Division developed and used SOPs to monitor progress in the approved projects against the agreed KPIs. The Administration and Finance Division also developed SOPs and strictly monitored the release and use of funds. The Commercialization Division developed delivery strategies with the public and private sector and other stakeholders along the value chain to commercialize the research outputs. In addition,

more than 100 scientists received funding to attend international conferences if their papers were approved for presentation at the conference. Publication fees were also paid by PARB if papers were selected through a proper review process. Several national and international conferences were also sponsored.

As PARB was becoming a vibrant, well-recognized sponsor of research among the province's R&D community, the bureaucracy intervened. The Executive Members were removed in 2012 because the board had not followed government hiring rules (despite the fact that the board had been granted the authority to develop its own hiring rules). The terms of the CEO was not extended in 2013. The Board of Governors was restructured, and stakeholders with conflicts of interest as grant recipients (university vice chancellors and directors of research institutes) became members. The DoAg issued a notification to stop approving funds for participation in international conferences. The new leadership was not hired for nine months.

The PARB again experienced a crisis of leadership, funding, and commitment. During 2014–17, only 15 new projects were funded. Two out of four Executive Members are not in place, and most lower technical positions are vacant. The Board remains in a rented building with poor access to scientists and stakeholders.

ANNEXURE 4

HIGH-PROFILE INITIATIVES AND THEIR EXPECTED IMPACTS ON THE PUNJAB AIS

Approach	Suggested reforms	Issue(s) to be addressed and impacts
High-profile initiatives	**Major upgrading of PARB:** » Autonomous board with high representation of private stakeholders with Chair outside GoPunjab and their selection on merit. » Internationally recruited CEO and Executive Members. » Strong M&E program in place including periodic assessment of impacts of all major programs. » Effective and continuous planning and commercialization activities. » Create an endowment for Agricultural Technology Innovation Fund. » Arrange training courses, workshops, fund international workshop participation, etc. » Competitive funds for import of new technologies, priorities or innovative ideas. » All projects should clearly include "theory of change" to boost impact. » Work with the government to provide proper regulation to encourage private sector R&E and incentives for public sector scientists and extensionists.	» **Improved relevancy of AIS due of:** – Preparation of longand short-term plan by PARB. – Providing mechanism for policy makers in setting the research and extension agenda. – Involvement of stakeholders in research planning. – Improved links with research users along the value chain and public-private partnerships for implementation. – Funding programs covering the whole value chain. – CGS funding for emerging issues and needs of stakeholders. » **Enhanced efficiency of AIS due:** – Enhanced coordination among scientists and public and private institutions along the value chain. – Improved international coordination. – Enhanced capacity of scientists with participation in workshops, training courses, etc. – Supply of sustainable funding. – Availability of operational funds for R&E. – Continuous monitoring of the R&E system. » **Impact of R&E will be enhanced due to:** – Funding research programs with high priority. – Stakeholders' involvement in research planning and commercialization. – Clear pathway for "change" defined in each CGS project. – PARB provide a stage for researchers to influence policy agenda. – Commercialization of research outputs through commercialization Division. » **Improved incentives:** – Incentives for the scientists and extensionists in the CGS after successfully delivering the outputs of the project.

(continued)

Approach	Suggested reforms	Issue(s) to be addressed and impacts
		» **Improved quality of science:** – Participation of scientists in international workshops. – Available funding for publications. » **Improved regulations:** – Improved regulation for private R&E and incentives for public sector scientists and extensionists.
High-profile Initiatives	**Piloting a state-of-the-art R&D institute in high-value agriculture (PHR&DC):** » Autonomous board, including key private stakeholders in the board. » Covering all aspects of the value chain. » Shared funding from stakeholders. » Develop international collaboration. » Work with the government for improved regulation for value chain development for high-value agriculture. » Continuous dialogue with farmer organizations, processors, and other value-chain players in setting the research agenda through Programming and Planning Division. » Continuous monitoring of R&E through Monitoring and Evaluation Division. » Collaborative programs with the private R&E players.	» **Improved relevancy of AIS due to:** – Involvement of stakeholders along the value chain in the planning and evaluation of R&E. – Shift R&E activities from major crops to high-value agriculture. – Shift of R&E activities from farm issues to value chain issues. » **Enhanced efficiency of AIS:** – Enhanced coordination among scientists and public and private institutions along the value chain. – Enhanced and sustainable funding from private stakeholders. – Availability of operational funds for R&E. – Strategic link with other national and international R&E players. » **Enhanced impact due to:** – High profiling for high-value agriculture in policy circles. – Involvement of stakeholders in planning, funding, and commercialization of agriculture. – Defined pathway for "change" in every project and activity of the Punjab Horticulture R&D Corporation (PHVC). » **Incentives:** – Incentives for the private R&E players to get engaged with PHR$DC. » **Improved regulations:** – Improved regulatory framework for value chain actors of high-value products for R&D activities as well as for investment in value chain development.
High-profile Initiatives	**Shifting the paradigm on capacity building:** » New strategies on capacity building where training is an investment in the future and emphasis is on capacity building in wider areas to meet stakeholders' needs, with defined pathways for impacts rather than just sharing knowledge on limited areas of trainers' choice without looking other opportunities for training within the country and abroad. » A state-of-the-art training institute for the capacity building of trainers and implementing new training strategies. » A separate directorate general of training. » Improving the existing training infrastructure.	» **Improve efficiency of RIS:** – Significant enhancement in the quality of human resources in both research and extension. » **Improved quality of RIS:** – The quality of publication in research and quality of communication is expected to improve with capacity enhancement of scientists and extensionists. » **Enhanced impact of RIS:** – The impact of R&E will also improve with better communication skills of extensionists.

ANNEXURE 5

STRATEGIES FOR REFORMING THE EXISTING RESEARCH SYSTEM AND EXPECTED IMPACTS ON THE PUNJAB AIS

Suggested reforms	Issue(s) to be addressed and impacts
Granting autonomy to the research system: » Autonomous or privately incorporated AARI. » Sets its own rules and governance system. » Adopt international good practices in hiring and financial practices.	» **Improved relevancy of AIS due to:** – Involvement of stakeholders in R&E planning, monitoring, evaluation, and commercialization. » **Enhanced efficiency of AIS:** – Help to overcome funding constraints as private sector starts to share resources. » **Enhanced impact due to:** – Involvement of stakeholders in planning, funding, and commercialization of AARI. » **Incentives:** – Private sector will be incentivized by having training on management issues and the prestigious involvement in R&E planning and evaluation.
Empowering commodity boards: » Involve stakeholders in research planning and evaluation. » Collect funds from stakeholders including promoting levies for research. » Training of stakeholders to conduct research planning and evaluation.	» **Improved relevancy of AIS due to:** – Involvement of stakeholders in R&E planning, monitoring, evaluation, and commercialization. » **Enhanced efficiency of AIS:** – Help to overcome funding constraints as private sector starts share resources. » **Enhanced impact due to:** – Involvement of stakeholders in planning, funding, and commercialization of the concerned crop. » **Incentives:** – Private sector will be incentivized by having training on management issues and the prestigious involvement in R&E planning and evaluation.

(continued)

Suggested reforms	Issue(s) to be addressed and impacts
Securing sustainable funding: » Using levies to fund research and extension. » Retaining earned incomes. » Fostering collaborative programs with other public and private sector research organizations. » Creating an endowment fund for PARB.	» **Enhanced efficiency of AIS:** – Help to overcome funding constraints. – Mitigate uncertainty in research funding. – Empower the managers to shift funds on need basis.
Empowering the AIS leadership: » Make operating budgets fully fungible. » Implement a well-defined performance evaluation system. » Provide managers a strong voice in hiring and transferring of staff. » Implement a results culture through a strong monitoring and evaluation system. » Empower managers and scientists to develop collaboration with other organizations. » An executive order from CM to empower the DG to issue no-objection certificate for foreign training.	» **Improved relevancy of AIS due to:** – Quick movement of funds on need basis. » **Enhanced efficiency of AIS:** – Reduced funding constraints. – Output oriented culture. – Increased collaboration with other R&E players. » **Improved incentives:** – Performance oriented culture will provide incentives for better performing scientists. – Easier participation in international conferences will be an incentive for scientists. » **Quality of science:** – Improved international collaboration through easier participation in international conferences.
Strengthening the quality of science: » Rewards that recognize publications in certified journals. » External reviews of research programs. » Long-term PhD training.	» **Improved relevancy of AIS due to:** – Frequent review of research programs will improve the relevancy of AIS. » **Improved efficiency of AIS due to:** – Well defined research activities through research projects and programs. – Reducing the redundant unskilled supporting staff. – Strengthened private sector. » **Improved quality of AIS due to:** – Quality publication. – External review of research programs. – Increased ratio of PhD staff. – Better quality staff hired. » **Improved incentives of AIS due to:** – Reformed incentive structure will give dignity and honor to the scientific staff.
Consolidating research into strategic projects and programs: » Projectize all research activities in AARI, VRI, PRI. » Every project should specify the deliverables, human and financial resource required, collaboration with other disciplines and institute scientists, how to take project outputs to stakeholders, and how to maximize the outcomes of the project. » Well-defined commodity or ecoregional based programs containing several projects to deliver the outputs and outcomes. » Scientists should be encouraged to seek external funding. Core funding for the project can only be for the regular activities or for the long-term projects. » All the programs have mid-term and final external reviews.	» **Improved relevancy of AIS due to:** – Careful planning of research projects and programs by the DG of AARI will improve relevancy. – Seeking external funding will also improve relevance. » **Improved efficiency of AIS due to:** – Improved documentation of scientists' time and financial resources. – Improved collaboration with other scientists and institutions. – Reduced financial constraints due to external funding. – Rationalization of organogram in terms of commodities, disciplines and production systems. » **Improved impact of AIS due to:** – Project and programs with clear commercialization strategies and change mechanism built in.

Suggested reforms	Issue(s) to be addressed and impacts
Reforming service rules: » Establish entry rules similar to those in the federal agricultural research system. » Incentives for the better-performing professionals. » Hire all directors general and directors through open competition on fixed terms. » Base promotions on eligibility, not availability of positions. » Use output-based evaluation criteria. » Making the public sector lean by changing hiring rules for supporting staff.	» **Improved efficiency of AIS due to:** – Better qualified research and management staff will enter the research system. – Dignified staff will work harder. – Encourage performance culture. – Generate pressure on the management with fixed term to deliver. – Saving costs on supporting staff. » **Improve quality of science due to:** – Better qualified staff at entry point and in management position.
Strengthening the regulatory environment for private research and development: » Greater participation in PARB board. » Finalize rules for implementing PBR Act (2017) at federal level. » Develop regulatory framework for checking seed quality through truth-in-labeling within the Seed Act (2016). » Improved mechanisms to facilitate approval and release of varieties from the private sector within the Seed Act (2016). » Offer tax incentives to invest in R&D. » Offer loans for agricultural R&D investment at subsidized rates. » Review the overall environment for agribusiness, apply IFC tool for improving the business environment, and identify measures to ease agribusiness investment for private R&E. » Public sector should adjust its program according to the evolution of private sector research to avoid crowding out the private sector.	» **Improved private sector regulation will:** – Enhance investment in R&E and reduce burden on public funding. – Improve relevancy of R&E. – Improve efficiency in the public sector due to healthy competition.

ANNEXURE 6

STRATEGIES FOR REFORMING THE EXISTING EXTENSION SYSTEM AND EXPECTED IMPACTS ON THE PUNJAB AIS

Suggested reforms	Issue(s) to be addressed and impacts
Scaling up through modern technologies: » Embracing digital innovation, especially Interactive communication tools: – Videos in local languages shown through projectors. – Movies. – Group discussions after movies, videos, etc. – Equip Punjab Agriculture Helpline (PAH) with the latest interactive tools. » Expand the coverage of value chain issues while using these tools.	» **Improved relevancy of AIS due to:** – Greater coverage of the PAH for issues along the value chain will improve the relevance of extension. » **Enhanced efficiency of AIS:** – Videos are many times more efficient than traditional extension approaches of reaching the stakeholders personally. – PAH is more efficient at reaching large numbers of farmers with little cost. » **Improve quality:** – Precision in message delivery through videos, helplines, movies, etc.
Bringing public extension to the grassroots level: » Devolution operationally under farmers' organizations without disturbing current administrative hierarchy similar to ATMA in India.	» **Improved relevancy of AIS due to:** – Involvement of stakeholders in R&E planning, monitoring, evaluation, and commercialization. – Focus on larger issues of the value chain, rather than just farm-level production issues. » **Enhanced efficiency of AIS:** – Help to overcome funding constraints as FA and value chain agents will share extension costs. – Synergistically link all extension and development agents in the area. » **Enhanced impact due to:** – Involvement of stakeholders along the value chain in planning, funding, and commercialization. – Focusing on emerging issues of stakeholders.

(continued)

Suggested reforms	Issue(s) to be addressed and impacts
Moving toward private sector specialized (S) extension: » Identify issues along the value chain for large number of agricultural products with the involvement of stakeholders. » Prioritize the impacts of these issues on stakeholders. » Take high-priority issues and prepare SOPs to resolve the issues. » Train a group of master trainers from the public sector on SOP implementation. » Validate these SOPs with a small number of farmers. » Select and train a larger group recruited from the public or private sector on merit to train and implement the SOPs. » Use the larger group to implement the SOPs (cost paid by the public sector) with large numbers of farmers who are the intended clients for resolving the issue (farmers may be selected on a first-come, first-served basis or depending on whether they can pay the cost). » Use of modern technologies in implementing the SOPs and communications to show the problem and its resolution. » Monitor the implementation of SOPs on the larger scale. » Evaluate institutional arrangements for financing and service delivery arrangements with private sector extension, giving special consideration to the INCAGRO model.	» **Improved relevancy of AIS due to:** – Focus on identification of issues with the involvement of stakeholders. – Focus on larger issues of the value chain, rather than just farm-level production issues. » **Enhanced efficiency of AIS:** – Focused staff for focused task will reduce the cost. – Use of modern technology will also reduce the cost. » **Enhanced impact due to:** – Effective output-oriented monitoring of S-extension will enhance its impact. – Focusing on high-priority issues will also improve impact. » **Enhanced incentives due to:** – Better salary for private sector extension employees. – Better working environments. » **Improved quality due to:** – Better paid staff will have better qualifications, better communication skills.

ANNEXURE 7

THE INCAGRO MODEL FOR DEVELOPING A MARKET FOR AGRICULTURAL INNOVATION SERVICES

In 1999, the Government of Peru and World Bank launched the Innovation and Competitiveness Program for Peruvian Agriculture, known as INCAGRO. INCAGRO's main objective was to establish a modern national agricultural science and technology system that would be decentralized, pluralistic, demand driven, and led by the private sector. The INCAGRO program fostered innovation through an Agricultural Technology Fund (FTA was its Spanish acronym) that supported projects put forward by farmer organizations for extension services. The model works as follows:

> Project proposals are based on business plans and use standardized logframes. Independent, three-member panels of agribusiness leaders rate the proposals and determine which projects will be funded. The panels may also recommend changes in the content or size of the proposed projects. The INCAGRO team receives guidance from the evaluation panels for adjusting proposals with the farmer organizations. The exercise of developing a business plan, submitting proposals for competitive review, negotiating with INCAGRO "innovation brokers," and the follow-up monitoring and evaluation data demonstrates, particularly to farmers, that a positive return can be made on the investment in agricultural innovation services. Extension activities supported have included a diversity of crop and livestock farming initiatives. An important aspect of the FTA model is that farmers own the project. They contract extension providers to complete a specified number of activities. Farmer groups are required to make a financial contribution in cash, plus any in-kind contributions. The cash contribution ranges between 15 and 30 percent of the total costs for extension projects. Farmers must form legal entities to sign contracts and receive government support. To meet these requirements, participants must be willing to collaborate, handle considerable legal paperwork, and have the capacity to manage and implement their projects. Competitive funds have expanded the market for extension service providers through various means. Producer organizations have hired their own extensionists, contracted individual private extension

providers, signed agreements with NGOs, and partnered with cooperatives for the provision of extension services. The FTA guidelines for project proposals support a more holistic approach to agricultural innovation by including collaborating entities in the project proposal, such as private input and marketing firms in the value chain as well as public agencies. Together, these collaborators form a strategic alliance that is formalized in an Agreement of Participation. The agreement establishes the roles and responsibilities of each member of the alliance, their respective contributions to the project, and the final disposition of any items obtained as a result of the project. The idea is that a strong strategic alliance will raise the probability of success. In addition to developing extension-based projects, farmer organizations can develop adaptive research projects to verify the technical and economic suitability of research findings in the local setting.

Preissing (2012: 241).

The research is participatory, requiring the producer-clients to become involved in identifying problems or opportunities in their fields and contribute actively during all stages of the research.[132] INCAGRO has also supported other novel approaches to fostering private extension services, and the Government of Peru has sustained the spirit of the project under revised post-project arrangements, including a further lending operation for a National Agricultural Innovation Program.

For an independent evaluation of INCAGRO and three other competitive grant schemes supported by the World Bank in Latin America, see http://lnweb90.worldbank.org/oed/oeddoclib.nsf/b57456d58aba40e585256ad400736404/9aed3d83ce82bb0d85257767004fdf91/$FILE/PPAR_Nicaragua-Peru-Colombia-Brazil_AgriTech_Dev_Projects_.pdf.

[132] Preissing (2012).

ANNEXURE 8
BRIEF BIOGRAPHIES OF THE REVIEW TEAM

Mubarik Ali, a Pakistani, graduated from University of the Philippines at Los Baños in 1986, is an expert on food security, agriculture productivity, diversification, value-chain analyses, agriculture regulations, and peri-urban agriculture, and has studied the process of technological innovations, adoption, and their impact under a wide array of socio-economic environments. He has worked in multi-disciplinary teams and analyzed the research systems in various countries and regions, especially in South, Southeast, and Central Asia. Ali has diverse experience working in national and international organizations such as IRRI, World Vegetable Center, World Bank, IFPRI, and USAID, and has provided vision and strategic direction to agricultural research system in Punjab as CEO PARB and to the World Vegetable Center as senior economist. His research on mung bean won the presidential award from the Government of Taiwan.

Jock R. Anderson studied agricultural science at the University of Queensland and then pursued a PhD in agricultural economics at the University of New England, Armidale, NSW, Australia, where he continued as a staff member, including as Professor of Agricultural Economics, and Dean of the Faculty of Economic Studies. He has worked with most of the CGIAR Centers, including CIMMYT (Mexico 1973, Islamabad 2013 for the launch of USAID's Agricultural Innovation Program), ICARDA (Syria 1983, Pakistan 1993), ISNAR (Pakistan 1987 to work with the World Bank Agricultural Research Project preparation, later visited in Bank supervision missions), and IFPRI (Pakistan 2012, when he led the Third-Party Independent Evaluation of PARC). He joined the World Bank in 1989 and served in various roles, including Adviser, Agriculture Department, before retiring in 2003.

Derek Byerlee, an Australian, is an agricultural economist who specializes in agricultural development and food security. He has held senior positions at Michigan State University, USA, CIMMYT (in Mexico and South Asia), and in the World Bank, where he was the lead author of the 2008 *World Development Report* on food and agriculture. He currently holds appointments with Stanford University and Georgetown University working on agribusiness, land use, and food security. He is also Editor-in-Chief, *Global Food Security* journal, and Chairs the Technical Advisory Committee,

Global Agricultural and Food Security Program. He has a long history of working with Pakistan agricultural research, beginning as CIMMYT's regional representative based in Islamabad in 1984.

Hans Jansen, a Dutchman, is an agricultural economist with 30 years' experience in international agricultural development in Asia, Latin America, and Africa. He was educated at Erasmus University Rotterdam (Bsc and MSc) and Cornell University (PhD). At the World Bank, Hans has worked mostly in the South Asia Region, posted in Washington DC, Afghanistan, and (following a posting in Ghana) Pakistan, where he started working in 1982 as an MSc student assistant. Before joining the World Bank, Hans was a Senior Research Fellow at the International Food Policy Research Institute; Sr. Development Economist at the Dutch Agricultural Economics Research Institute; Resident Director of the Wageningen University and Research Center in Costa Rica; Agricultural Economist at the World Vegetable Center in Taiwan; Livestock Economist at the International Livestock Research Institute in Nigeria; and Farming Systems Economist for FAO in Rome. Hans has edited a number of books and authored more than 100 professional publications.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