International Trade Centre

LUMS | Centre for Water Informatics and Technology

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Climate-smart technologies and practices for horticulture and livestock in Pakistan

Growth For Rural Advancement and Sustainable Progress (GRASP) is a project funded by the European Union and implemented by the International Trade Centre (ITC)

About the paper

A wide range of climate smart technologies and practices exist in Pakistan. Their uptake is essential for maintaining productivity and building resilience to climate change. This report assesses their availability and accessibility for horticulture and livestock in the Balochistan and Sindh provinces of Pakistan. It finds that despite the technologies being available both commercially and through local innovation, their uptake by farmers and agribusinesses remains low. This can be attributed to the farmers' and businesses' limited knowledge of the technologies and practices and their lack of financial resources.

There are tech-support providers, however, they have a very limited outreach. Public sector support services lack capacity and budgetary resources to promote and demonstrate at scale. The report outlines a series of recommendations to improve climate-smart technology and practices uptake. This includes for example, developing a rental model to help farmers afford technology and creating demonstration sites to train farmers.

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Photo credit: Alexander Kasterine

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Foreword

Despite Pakistan making only a minimal contribution to climate deterioration and changing the albedo effect, climate change has become a big threat to the livelihoods of millions of people particularly those relying on agriculture. The current climate catastrophe has caused extreme monsoon rainfall from mid-June to the end of August 2022, inundating areas of already vulnerable communities in Sindh and Balochistan. To cope with growing food security threats, the revival by adopting climate-smart technologies and practices has become inevitable.

The report focuses on the horticulture and livestock sectors in Balochistan and Sindh. It suggests a way forward for local manufacturing of such technologies to make them affordable and available to local farmers. It also recommends rental model and farmer trainings for capacity building.

I am hopeful that this work will go a long way to improve productivity of the agriculture and livestock sectors and the quality of livelihoods of the farming community.

Aijaz Ahmed Mahesar

Secretary Agriculture, Supply & Prices Department Government of Sindh

Despite water scarcity in Balochistan, drought and increasing temperatures, the agriculture sector is growing with prospective progress. Nevertheless, extreme weather events have also hindered social and economic development within the province as demonstrated by the recent catastrophic floods of 2022. Innovative climate technologies are critical in supporting conventional agriculture transition towards climate resilient agricultural system. For this reason, the report produced by The Centre for Water Informatics and Technology at Lahore University of Management Sciences in partnership with the International Trade Centre (ITC) is published at an opportune moment.

As stated in the report, climate-resilient technologies can effectively be made available to smallholder farmers through soft loaning by financial institutions along with innovative extension awareness mechanisms that include modern production, irrigation post-harvest and value chain technologies,

This report contributes to efforts to shift conventional agriculture towards transition and modernization with the help of innovative climate technologies tools, by identifying the commercial providers of climate technologies, classifying business models, and illustrating the importance of advisory services. The report provides clear recommendations which if implemented, will increase the adoption of climate technologies to increase quality production and address food security.

Umaid Ali Khokhar

Secretary, Agriculture and Cooperations Department, Government of Balochistan

Acronyms

Unless otherwise specified, all references to dollars ($) are to United States dollars and all references to tons are to metric tons.

ADB	Asian Development Bank
ASF	Agribusiness Support Fund
CABI	Centre for Agriculture and Bioscience International
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GHG	Greenhouse gases
GRASP	Growth for Rural Advancement and Sustainable Progress
HEIS	High-efficiency irrigation systems
ICT	Information and communications technology
ITC	International Trade Centre
LUMS	Lahore University of Management Sciences
NGO	Non-governmental organization
PARC	Pakistan Agricultural Research Council
PCRWR	Pakistan Council of Research in Water Resources
R&D	Research and development
USAID	United States Agency for International Development

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Executive Summary

Pakistan is among the top 10 countries in the world to be the most affected by climate catastrophes such as floods, droughts, heatwaves, and earthquakes. This is mainly due to the country's geography, reliance on glaciers as natural regulators of regional water supplies and heavy dependence on agriculture for livelihoods and food security. However, poor agricultural practices further add to the climate-change related disasters.

Agriculture is central to Pakistan's economy, contributing 19% to gross domestic product (GDP) and absorbing more than 42% of the labour force. Farmers need climate-smart technologies to increase agricultural productivity, raise incomes, adapt to environmental changes, build resilience to climate change and reduce or remove greenhouse gas emissions.

A wide variety of climate smart technology is available in Pakistan. With respect to horticulture, hybrid seeds, drip irrigation, laser levelling, tunnel farming, pre-cooling systems, hermetic packaging and solar dehydration have been examined in this report. For livestock, the identified technologies include the ones used for silage bailing and wrapping, artificial insemination, milking, poultry waste management total mixed ration and biogas.

Despite the availability, climate-smart technologies are used by very few farmers and agribusinesses. This can be attributed to their limited technical and financial capacity. Additionally, most are unaware of the benefits and availability of the technologies due to the lack of demonstration centres and model farms. On the supply side, there are few available tech-support service providers, with a very limited outreach. Nearly all technology providers in Pakistan are based in the Punjab province, which accounts for two-thirds of total climate-smart technologies. Furthermore, public support services lack capacity and resources for climate-smart technologies.

There is also a disconnect between the research institutions and farmers. As a result, little to no written material exists on the benefits of different climate-smart technologies and practices that farmers can use. The information that does exist is more academic in nature and not easily digestible by or relevant to farmers. Cost–benefit analyses and impact studies for various climate-smart technologies need to be conducted and disseminated in a form that farmers can easily digest. It is also important that, in cooperation with interested private sector entrepreneurs, business models be created for various technologies to make them attractive and self-sustaining.

With respect to affordability, little has been done by financial institutions to promote climate smart technologies. Rental models for climate-smart technologies can increase the private sector's engagement to commercialize climate-smart technologies and practices. It could be done directly or by establishing common facility centres and farmers' service centres. Public–private partnerships can support the formation and leverage existing resources most effectively.

Grants and technical assistance should be offered to entrepreneurs to set up private farmer service companies. These companies could improve responsiveness to farmers' needs in terms of input supply (e.g. fertilizers, seeds and pesticides), services (e.g. mechanized labour, technical advice, certification and marketing) and information, especially regarding climate-smart technologies.

To complement this, farmer marketing collectives could be formed for collective selling, making it convenient for buyers to access volume-based products through a single source. One of the important conclusions of the study was that the government cost-sharing programmes and donor projects play an important role in spreading use of agriculture technologies.

Additionally, there is a wide range of indigenous practices that combine local knowledge with modern technologies, including biopesticides, biofertilizer, cooling sheds, rehabilitation of saline soil, homemade remedies to address livestock illness and local irrigation techniques. It is recommended that to improve the uptake of indigenous and indigenized technologies and practices, scientific research should demonstrate and document regenerative practices.

Furthermore, supporting organizations should be created to help academia scale up and generate low-cost indigenous technologies at factory rates rather than lab bench rates. Moreover, a unique number (Computerized National Identity Card) should be issued to document capacity-building programmes and offer follow-up trainings, with proper tracking. Also, there is a need to create seed banks and ensure farmer field schools' curricula is up to date.

With respect to rules and regulations, a growing number of federal and provincial policies address climate change, food and agriculture. Federal initiatives are in place to build evidence-based research and guidelines for climate-smart interventions and technologies. The National Climate Change Policy, the National Water Policy[1] and other national policies mention climate change and technology adoption to improve irrigation efficiency. However, implementation of these policies has been limited. Additionally, certain national policies on agriculture and the water sector – for example, supporting water-intensive agriculture – conflict with climate-smart agriculture and thwart mitigation and adaptation objectives.

Summary of recommendations to improve climate smart-technology adoption rates

There is a need for more coordinated research, awareness and action at all levels of the value chain for agricultural technologies and practices to be climate smart. These steps can promote climate-smart technologies and practices for horticulture and livestock in Pakistan:

- Develop a rental model to help farmers afford technology;
- Create demonstration sites to train farmers, build capacity and raise awareness, not only for technology, but also for regenerative agricultural practices;
- Provide verified and authentic information through ICT;
- Carry out cost–benefit analyses of technologies and practices for farmer uptake;
- Develop viable business cases to commercialize private sector technology;
- Build the capacity of all stakeholders.

[1] National Water Policy 2018. Government of Pakistan. Accessible at http://waterbeyondborders.net/wp-content/uploads/2018/07/Pakistan-National-Water-Policy-2018.pdf.

Chapter 1: Impact of climate change on agriculture

Agriculture is likely to be the most vulnerable economic sector due to its dependence on climate and weather (Arora, 2019). Increased temperatures, shifts in rainfall distribution and increased frequency of extreme weather events are expected to adversely affect livestock and horticulture production and productivity around the world (Bhattacharyya et al., 2020).

This chapter focuses on the impact of climate change on agriculture, specifically in Sindh and Balochistan. In both these provinces agriculture serves as one of the main sources of income for their population.

Pakistan

Agriculture in Pakistan

In Pakistan, 28% of the area is cultivated. The remaining territory comprises culturable waste, dense forests and rangelands. The cropped area constitutes 23.3 million hectares, while forests cover 4.6 million hectares of the total land (Food and Agriculture Organization, 2021).

Agricultural productivity remains low in Pakistan despite its importance to food security, livelihoods, economic growth and export revenues. Moreover, the yield gaps are significant compared to global averages in key crops such as wheat, rice and sugarcane (Molotoks et al., 2021).

The average farm size in Pakistan is 2.6 hectares. Approximately 43% of the farmers are categorized as smallholders with holdings of less than 1 ha, while only 22% own more than 3 ha of land (World Bank, 2017).

In 2016, for the first time in fifteen years, the sector experienced a negative growth rate of 0.2%, primarily due to the impact of extreme weather events affecting key crops, lack of access to key inputs and global downturn in commodity prices (World Bank, 2017).

Livestock has emerged as the largest subsector in agriculture. It is a major source of foreign exchange earnings. More than 8 million rural families are engaged in livestock production and derive more than 35%–40% of their income from this sector (Pakistan Economic Survey, 2019–20).

Agriculture production is mostly irrigated, using both surface and groundwater. Approximately 94% of the agricultural area in Pakistan is equipped for irrigation (Caldera et al., 2021). The country has an extensive irrigation system relying on rivers, dams, barrages and canals. However, erratic monsoon patterns, increased glacial melt, low water storage capacity and ongoing cross-border water disputes add uncertainty to water availability and affect production patterns.

Climate change impacts on agriculture in Pakistan

Pakistan is ranked as the fifth country most affected by climate change in the Global Climate Risk Index 2021 (Eckstein et al., 2021). The Asian Development Bank (ADB) and World Bank (WB) estimated that Pakistan is facing up to $3.8 million in economic losses due to climate change.

Climatic extremes are common now. Periods of severe droughts, followed by devastating floods have contributed to low crop yields, loss of livestock, damage to irrigation infrastructure and food shortages in recent years.

In the recent floods of 2022, there was a severe heatwave prior to the flooding event – the Pakistan Meteorological Department has reported that the country received 36.1% less rainfall than usual from October 2020 to May 2021, where Sindh recorded 64.5% less rainfall than usual, while Balochistan saw 59.5% below usual rainfall. Following this, in Sindh and Balochistan average monthly totals for rainfall were exceeded by 6 and 7 times respectively causing the severe floods (Ministry of Planning Development and Special Initiatives, 2022)[2], indicative of the climate extremes faced.

This "1-in 1,000" year event caused drought, crop losses, power outages and forest fires, with a loss of USD 3,725 million in damages. 82% of this is associated with damages and losses to crops, with 4,410 million acres of agricultural land lost and 0.8 million livestock perished. The impacts were most severe in Sindh (71% of damage and losses) and Balochistan (21% of damages and losses). (Ministry of Planning Development and Special Initiatives 2022).

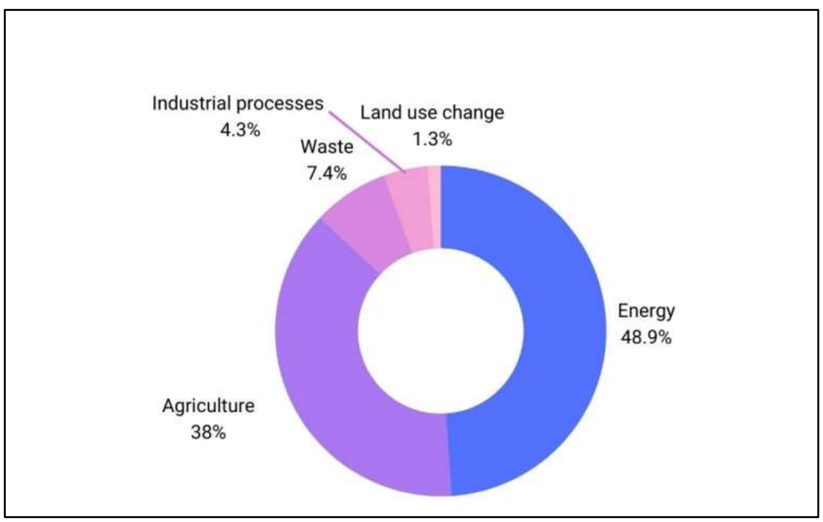
This is not a new phenomenon. For example, economic losses associated with the 2010–14 floods amounted to $18 billion, affecting the livelihoods of 38 million people and causing damage to approximately 4.3 million ha of cropland. Additionally, Pakistan faced droughts in 1998 and 2004 (Hussain & Mumtaz, 2014), during which its largest province, Balochistan, was severely hit. Nearly 84% of its population was directly affected due to the loss of 76% of their livestock. Droughts in Tharparkar and Cholistan, the intense heatwave in Karachi (and southern Pakistan in general) in July 2015 and severe windstorms in Islamabad in June 2016 displayed similar effects.

Agriculture, and horticulture in particular, has suffered due to the changing climate and this is reflected in Pakistan's economic conditions. In 1960, the agricultural contribution to Pakistan's GDP was 43.19%, whereas, in 2020, it was recorded as only 22.69%. This translates to urgency in the agricultural sector, especially for the small-scale farmer.

Climatic upheavals impact the livestock by causing contagious and even fatal diseases. Climate change affects the water, fodder and rangeland for livestock grazing, resulting in a sharp decline in meat and milk production. (Hamid, 2015; Melissa, R.D.M. et al., 2017).

Agriculture is the second-biggest contributor to GHG emissions in Pakistan after the energy sector. This is illustrated in in Figure 1. The livestock sector (included under "agriculture" category) contributes to climate change by emitting greenhouse gases (GHG) (carbon dioxide, methane and nitrous oxide) either directly (e.g. from enteric fermentation and manure management) or indirectly (e.g. from feed-production activities and conversion of forest into pasture) (Abas, M. et al., 2017).

Figure 1 Total greenhouse gas emissions in Pakistan (2019)



Source: Author, based on FAOSTAT (2021)

[2] Ministry of Planning Development and Special Initiatives (2022). Pakistan Floods 2022 Post-Disaster Needs Assessment. Accessed at https://www.pc.gov.pk/uploads/downloads/PDNA-2022.pdf

Balochistan

Balochistan is the largest province of Pakistan geographically, comprising approximately 43.6% of Pakistan's total area. It has a coastline of approximately 760km. The mountainous terrain and scarcity of water make the population density very low

The geographic areas in the province can be divided into four zones: upper highlands, lower highlands, plains and deserts. The upper highlands climate is characterized by very cold winters and warm summers. Winters of the lower highlands vary from extremely cold in the northern districts to mild conditions closer to the coast. The plain areas are also very hot in summer, with temperatures rising as high as 50°C and average annual precipitation in Balochistan varies from 50–500 mm. Winters are mild on the plains, with the temperature never falling below the freezing point. The desert climate is characterized by hot and very arid conditions. Occasionally, strong windstorms make these areas very inhospitable.

Agriculture in Balochistan

Balochistan's agroecological diversity permits the cultivation of a wide range of field crops and horticulture. Cereals are an important source of fodder for livestock. The high-altitude arid environments provide ideal conditions to produce deciduous fruits. Balochistan's share of deciduous fruits (apples, plums, pears, apricots, peaches, and pomegranates) and non-deciduous fruits (dates) is 35%–85% of Pakistan's production. In the case of grapes, almonds and cumin, the province has a near monopoly in the country (Pakistan Agricultural Research Council, 2019).

In Balochistan, two types of dryland systems prevail:

- *Khushkaba*: It is a type of farming in which only localized (within the field) run-off is generated and crops suffer moderate to severe moisture stress during the crop cycle.
- *Sailaba*: It is a type of farming in which water is harvested through temporary streams and crops complete their life cycle on the stored moisture.

Yield expectations are low, ranging from only 100–800 kg/ha for *khushkaba* and 1,000–1,500 kg/ha for *sailaba* farming. Farmers expect cultivation 3–5 years out of 10 years. In this high-risk environment, agricultural inputs are minimal. In Balochistan's arid uplands, environmental stresses are the main yield-limiting factors in crop production. Major stresses are cold and drought in winter and the combined effects of drought and heat and a short growing season during spring (Pakistan Agricultural Research Council, 2014).

Livestock production is one of the major income sources for approximately 70% of the rural population. Approximately 92% of the province's geographical area of Balochistan is rangelands, which provide grazing to an estimated 20 million small ruminants (sheep and goats).

Many livestock owners are transhumant (45%), who commute between winter and summer quarters to adjust to seasonal feed requirements and nomadic (50%), who constantly move between highlands and plains and sometimes cross international borders. Stock owners are entirely dependent on livestock for their livelihoods, trading livestock and livestock products (International Centre for Agricultural Research in the Dry Areas, 2010).

The agriculture sector's performance in 2020–21 is encouraging as it grew by 2.77% against the target of 2.8%. The growth of important crops (wheat, rice, sugarcane, maize, and cotton) during the year is 4.65% (Pakistan Economic Survey 2020–21). Other crops, having a share of 11.69% in agriculture value addition and 2.24% in GDP, showed growth of 1.41% due to an increase in production of fodder, vegetables, and fruits. Water availability in *Kharif* 2020 remained at 65.1 million acre-feet (MAF), showing a slight decrease of 0.2% compared to 65.2 MAF in Kharif 2019.

Climate change impacts on agriculture in Balochistan

Changing climatic conditions and their associated negative impacts thus have far-reaching negative effects on not only Balochistan's agriculture and livestock sector, but also on the country's overall food security owing to reduced crop yields, adverse effects on livestock health, productivity and reproduction, as well as from water scarcity and extreme weather events. Cereal crops, wheat in particular, are grown by most dryland farmers as dual-purpose crops, with the grain used for human consumption and the straw as animal feed.

Irrigated agriculture is dependent on both surface water and groundwater resources. Approximately 30% of floodwater is harnessed for agriculture through sailaba diversions, storage dams and minor perennial irrigation schemes. Groundwater is available for irrigated agriculture through springs and wells. With the increased availability of electricity from the national grid, there has been a tremendous increase in the number of tube wells. Although this has facilitated agricultural growth, indiscriminate installation of tube wells and pumping of water above recharge have caused the water table to lower, resulting in the drying out of dug wells and springs (Food and Agriculture Organization, 2000). Groundwater mining and lowering of the water table are cause for serious concern regarding the sustainability of groundwater-irrigated agriculture (International Centre for Agricultural Research in the Dry Areas, 2010).

Sindh

Sindh is Pakistan’s second-largest province. Nearly one-third of the Indus River traverses the province. Sindh is Pakistan’s economic hub with a major coastline, seaports and waters rich in seafood that are some of the best fishing spots in the world.Three irrigation barrages have been constructed across the Indus in the province within the last 45 years. Though chiefly an agricultural and pastoral province, Sindh has a reputation for textiles, pottery, leatherwork, and carpets, etc. The artisanship of the people of Sindh began during the period of Mohenjo-daro civilization.

Owing to its prevalent aridity and the absence of monsoons, Sindh’s climate ranks among the hottest and is the most varied. The average temperature in summer is 35°C and is 16°C in winter. However, the thermometer frequently rises to 45°C and occasionally to 50°C in summer.

Agriculture in Sindh

Sindh has the most favourable environment for different fruits and vegetables, including bananas, mangoes, dates, tomatoes, and onions. The population of the arid zone is solely dependent on livestock and the public and private sectors are urged to make joint efforts for its promotion to help improve the national economy and the lives of millions who depend on it.

Cotton, rice, wheat, and sugarcane are the main crops produced in Sindh. Rice is by far the most important crop cultivated. The city of Larkana leads the rice crop, followed by Jacobabad, Sukkur, Badin, Thatta and Dadu. Cotton is produced mainly in Sanghar, Nawabshah and Hyderabad. Banana is the most important fruit crop and is grown in all provinces of Pakistan. Sindh shares the major portion, which is approximately 82%, with Punjab at 5%, Khyber Pakhtunkhwa (KPK) at 10% and Balochistan at 3% in overall production. In Sindh, Khairpur leads in producing bananas, followed by Thatta.

By virtue of its geographical location and climate, Sindh is able to grow some crops, such as mangoes, tomatoes, onion, wheat and other crops, one month earlier than Punjab. Farmers in Sindh have benefitted from this, as market prices are generally high at the beginning of crop season.

Livestock is a source of income for small farmers, especially in rain-fed areas, including the desert and mountainous areas of Sindh. Climate change could affect livestock in these areas through the spread of vector-borne diseases, macroparasites and a shortage of fodder due to droughts. For rural households and dwellers of Thar Desert, this means a push into chronic poverty due to their substantial dependence on livestock. Livestock productivity is also expected to be affected by climate change due to high temperatures. The impacts could include physiological stress on animals, reduction in milk and meat production, stressed conception, increased water requirements and reduced fodder crops.

Climate change impacts on agriculture in Sindh

Sindh is in the intense heat zone and a rise in temperatures due to climate change can further aggravate these conditions. For agriculture, Sindh is in the southern part of the Indus River and thus stands to suffer not only directly from the local climatic and weather changes, but also from weather activities in the upstream Indus River and from coastal environments.

For the past decade, Sindh has faced an increased frequency of extreme events such as heatwaves, urban flooding and droughts. Floods in Sindh have mostly been associated with precipitation and excess water flow from upper part of the Indus River. Similarly, the effects of water shortage and droughts in Sindh are aggravated by less precipitation and less water flow from upper part of the Indus River. Furthermore, Sindh's coastal areas are affected by sea intrusion and rising sea levels in the Arabian Sea.

Climate change and weather variability could change current crop cycles, resulting in uncertainty and riskier returns to farmers. Due to Sindh's diverse geography, climate and weather variability are likely to create a great deal of uncertainty about the agriculture sector and other economic sectors that depend on agriculture, which will have impacts on income, livelihood and poverty.

Low education levels limited institutional access and less knowledge about the changing climate are the main hurdles at farm level that can restrict farmers from adoption of CSA practices. (Sardar, A. et al., 2021).

Policy environment

A favourable policy environment is important to ensure the adoption of climate smart technologies and practices.

Misguided policies often result in high costs for producers, consumers and taxpayers. Further, these huge costs pre-empt possible investment opportunities often available on investing in innovative or indigenous technologies. The most common divergence occurs due to policy failure, often measured by the amount of direct or indirect subsidy provided. A good example is large subsidies that go in the water and fertilizer subsector, which could bring high returns by investing in climate-smart technologies and practices.

There is a lack of measures to address climate change and climate smart technology challenges in Pakistan. Policy documents produced in the last two decades mention climate change, but it is often unclear how climate change is included as a cross-sectoral issue that impacts all aspects of agricultural enterprise production, marketing, processing and transportation. Most policy documents on agriculture and water only have a casual mention of climate change.

Furthermore, policies in the agriculture and water sector continue to promote policies contradictory to promoting climate-smart agriculture and are duplicative and sometimes undermine climate change mitigation and adaptation. For example, granting loans for additional sugarcane mills and promoting rice and sugarcane while they are the most water-intensive crops runs. Another example is the electricity subsidization issue in Balochistan that has depleted the aquifers beyond recovery. These policies need to be rationalized and reformulated without delay.

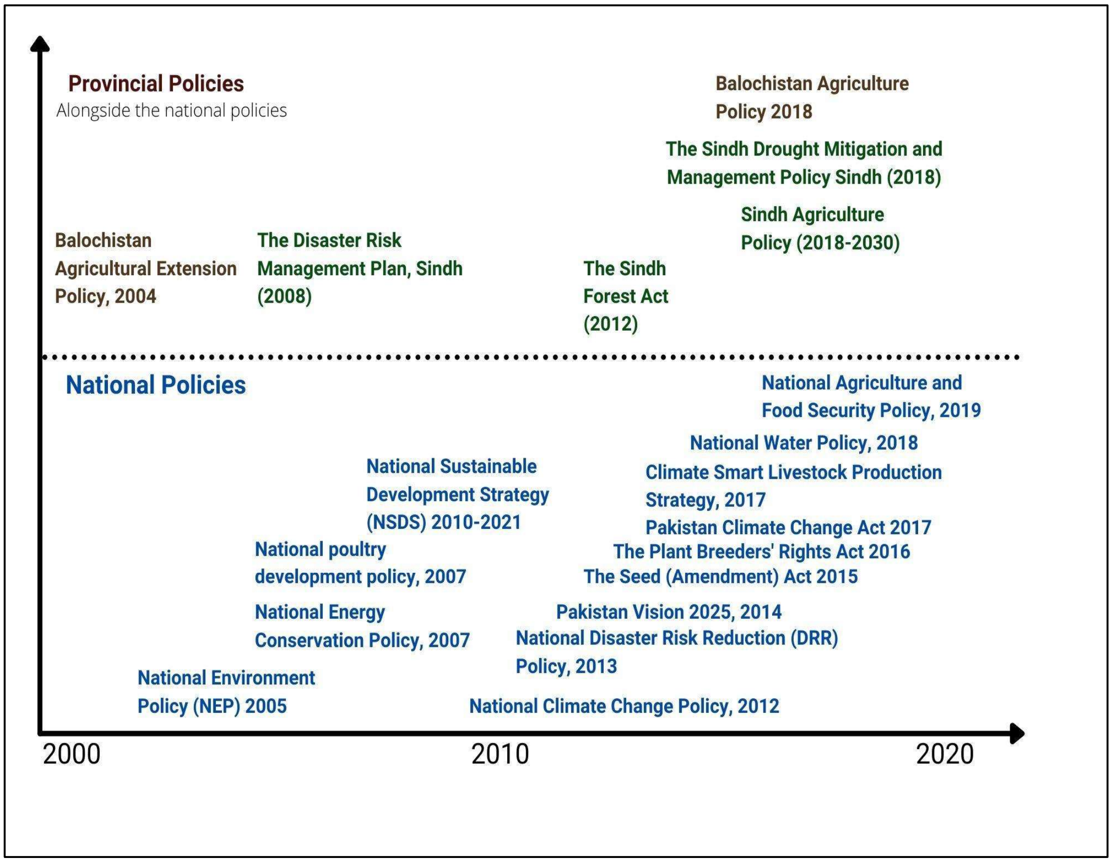
Pakistan has signed several international conventions.It is important that the policy documents reflect the commitments and actions it has taken to address the covenants of the conventions.

Most studies touch on the forecasting, modelling, and simulation of the effects of the changing climate on crop yields and cropping patterns for the development of early warning systems. A large volume of work is now being reported on the effects of global climate change on crop yields, livestock production, forests, and rangelands. At the same time, GHG emissions from agricultural lands and animal farms are well documented.

A desirable policy regime needs to be pursued that promotes production systems that are no longer extractive (i.e., that protect the field from water run-off and soils from erosion and maintain soil fertility by restoring organic matter and plant nutrients exported from the field).

The key to a sustainable future is to move towards more ecologically friendly farming systems that are more effective in harnessing nature to sustain higher levels of productivity. Critical to this is an increase in quantities of organic matter in soil to provide surface protection, energy and nutrients required by soil-inhabiting flora and fauna that constitute the life of a soil, playing a vital role in maintaining its porosity, enhancing its moisture-holding capacity, and extending the availability of nutrients to crops. This paradigm shift needs to be reflected in the formulation process of future agriculture and water policy. Some policies are highlighted in Figure 2.

Figure 2 National and provincial policies concerning agriculture and climate change



Source: Author

It is important to note that, while several documents and action plans have been prepared at the national and provincial level, their implementation has not taken place. Except for the Clean Green Pakistan Movement, aided by the Billion Tree Tsunami, not many aggressive projects have been carried out.

- The National Climate Change Policy aims to ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate-resilient development. The policy also recommends the use of local technologies, based on innovation and technological advancement in the field of climate change, as an effective way to implement adaptation and mitigation measures and capture renewable energy, among others.

- The National Water Policy addresses adaptation through the ‘more crop per drop’ concept, which calls for improved irrigation methods, a modernized irrigation network, banning flood irrigation and participatory management for more effective decision-making, all of which will likely have associated benefits for productivity and nutrient use efficiency.

- The Livestock Production Strategy acknowledges that mitigation options are available along the entire livestock supply chain. They are mostly associated with feed production, enteric fermentation, and manure management. It also mentions climate-smart agriculture practices such as grassland restoration and management (e.g., sylvo pastoral systems), manure management (e.g., recycling and biodigestion) and crop–livestock integration.

- Balochistan's new agricultural policy highlights two areas of critical importance to be rangeland development and water resources management.

- The Sindh Agricultural Policy (2018–2030)[3] proposes that the government will focus on producing and promoting public goods. The focus is on new technologies for processing, transport, storage, and production, including new seed varieties and high-yielding milk and meat animals, establishing a regulatory framework to ensure quality supplies of input and output, acting as a champion for the poor and deprived to raise their incomes and have access to an adequate diet and addressing emerging issues such as resource degradation and climate change.

- The Sindh Drought Mitigation and Management Policy makes forecasting and early warning a top priority, particularly to the most vulnerable populations, such as those who will lose their crops and livestock. It also recognizes the importance of planning and capacity building and working with the agriculture and water resource sectors to strengthen resilience to drought. The policy mentions several CSA opportunities, such as addressing soil degradation, modernizing irrigation techniques and new crops to increase soil fertility.

There are other policies that have improved production and yield but have impacted natural capital. For example, to help the growth of fruit production in the province, the government introduced a policy of subsidizing the pumping of groundwater by electricity-powered tube wells. Farmers were to be charged a very low fixed cost (PKR 6,000 per month irrespective of the hours worked or amount of water pumped). The difference between this price and actual costs is shared between the provincial and federal governments. As a result of the large expansion of tube wells for fruit production in the province, this policy has resulted in a huge fiscal drain on the government (currently approximately PKR 8 billion per year), as well as overexploitation of aquifer and a rapid lowering of the groundwater table. Farmers' response to falling water table is to dig deeper and install larger-capacity tube wells. This further exacerbates the overexploitation and the fiscal cost.

Poor access to and the high cost of finance, inefficient markets, limited skills, electricity shortages and a weak enabling environment hinder growth in the agribusiness sector. Lack of funds limits the size of most rural enterprises and 30%–40% of them make very small, fixed investments. Lack of credit at reasonable interest rates and appropriate maturities are key constraints for most rural enterprises, including agribusinesses. Major barriers to institutional credit include the lack of collateral, poor financial records, and an inability to prepare business plans. Most constraints and opportunities were highlighted in the technology section and are reiterated in this section.

Methodology for assessing climate smart technology market.

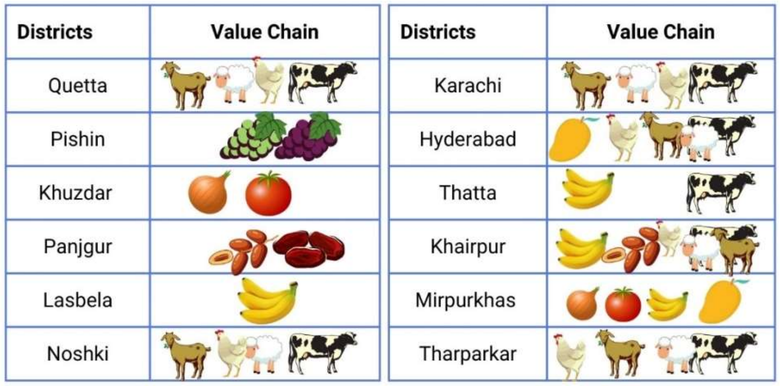
This report aims to provide a list of recommended technologies and an extensive analysis of climate-smart practices in the provinces of Sindh and Balochistan. The report has been prepared by keeping in mind the small-scale farmer's reach and supporting the adoption of CSA practices.

The objectives of the study are:

- Assess the state of climate technology market in horticulture and livestock across Pakistan.
- Provide a list of recommended technologies to guide GRASP to support the innovation of climate technologies.
- Their commercialization and adoption in the horticulture and livestock value chains in Sindh and Balochistan.

[3] See http://extwprlegs1.fao.org/docs/pdf/pak191432.pdf.

Figure 3 Districts and Value Chains prioritized for this study



Source: Author, in consultation with the ITC team.

Before designing the methodology for this study, a meeting was held with ITC for agreement on the sample size for each theme, as the overall scope of this report was very broad and spread across several stakeholders in Pakistan's horticulture and livestock value chains. The agreed sample size is presented in Table 1.

Table 1 Key themes and samples size

Theme 1: Assessment of climate technology market in horticulture and livestock	**Theme 2: Informal adaptation and indigenous knowledge practices**
Seed developers (15–20 companies) Agriculture and irrigation service providers (20–25 companies) Improvement in packaging and handling, waste management (5) ICT interventions (5)	Cases of innovation and adaptation with potential for commercialization (>20)
Theme 3: Ancillary support industries to CSA- across value chains	**Theme 4: Rules and regulations**
Public–private extension services: 5 each; total: 10 Market information providers: 10 (5 formal; 5 informal) Academia and research organizations (10) Tech-promoting networks, bodies, public organizations (10) Access to finance (5)	Federal Provincial

Source: ITC's defined themes and author's work.

The criteria developed for shortlisting the technologies and practices is presented in the following subsection.

Selection criteria for technologies and practices

The United Nations Environment Programme (UNEP) technology needs assessment guideline was used to guide selection of technologies to analyse in this study. A 'mixed technology identification approach' was adopted whereby technologies applied by both horticulture and non-horticulture crops were considered. Key considerations for selection of climate-smart technologies in horticulture and livestock sectors were based on themes of the terms of reference (TOR) as agreed by WIT, LUMS and ITC, namely:

- Small farmers' affordability (low-cost technologies).
- Small farmers' need for technology (access to market).
- Small farmers' capacity to adopt technology.
- Availability of the proven technology in Pakistan.
- Technologies where technology providers recognize the growth potential.
- Technologies with high social, environment and economic impact (value chain).

Table 2 shows the definitions of three categories of indigenous practices established.

Table 2 Definitions of indigenous practices shortlisted in the report

Indigenous practice	Indigenized practice	Indigenized technology
Practices that have relied on simple animal power and locally made tools to practice agriculture (improved irrigation, harvesting and reduced losses) and store water, etc. Their continuous use ensures mitigation (no GHG emission), better adaptation to resources available and improved productivity with local knowledge.	A combination of local and global knowledge and tools for agriculture. The practice has considered combining local knowledge with modern technologies and is helping farmers in mitigation, adaptation and better income generation.	Technologies developed locally for mitigation, adaptation (through early warning systems) and productivity (improved input). The technologies aim to reduce cost and improve informed decision-making. These technologies are otherwise very expensive to import.

Source: Author

During field visits, the team met with all key government stakeholders in Balochistan, Sindh and Islamabad. The literature, desk reviews and interviews were considered while shortlisting key stakeholders in the agricultural value chain in horticulture and livestock in Sindh and Balochistan.

During field visits, an active effort was made to engage with marginalized communities. In the regions visited, women's organizations were not at the forefront and their engagement in activities was perhaps minimal. Therefore, several grassroots organizations were contacted for meetings via Zoom and in person. The team also reached out to women in agriculture value chains to highlight the opportunities and hurdles that they face.

Chapter 2: Assessing climate-smart technologies for horticulture

In horticulture, some technologies are widely available for increased efficiency and conservation in the use of water, farm production, post-harvest, ICT, and bioenergy, etc. Other advanced technologies, such as those used for precision agriculture, greenhouses, hydroponics, and digitalized technologies are limited in terms of their availability and use.

This section of the report has made a comprehensive list of all these available technologies.

A summary table (Table 8) is given at the end of this chapter to highlight the constraints and recommendations for selected technologies.

Input-level technologies

Hybrid Seeds

Hybrid seeds refer to high-yielding, drought- and flood- resistant and heat-tolerant improved varieties of seed. Such varieties can help overcome the negative influence of erratic weather patterns on plant growth, flowering, fruit setting, ripening and quality, as well as fight off pest infestations and improve yields.

The total vegetable seed market in Pakistan is estimated to be PKR 1,320 million, constituting 65% of hybrid seeds and 35% of open pollinated (OP) seeds (Syngenta, 2022).

Status of adoption in Pakistan:

There is limited production and commercialization of hybrid seeds in the country, with an estimated 96% of vegetable and fodder seeds being imported (Table 3).[4] Most of the stress-tolerant varieties have been introduced for main crops such a maize, wheat and cotton. Overall, in the vegetable sector, importing hybrid seeds is mostly limited to high-yielding varieties – importing and provision of stress-tolerant and pest-tolerant varieties remains limited. For onions, only pest-tolerant varieties have been adopted.

There are two mechanisms for seed supply in Pakistan – formal and informal networks.

The formal network consists of multinational and local private companies distributing hybrid seeds all over the country. More than 200 vegetable seed companies are registered with the Federal Seed Certification & Registration Department (FSC&RD), out of which approximately 80 of them are active importers and distributors of vegetable and fodder seeds. There are approximately 15–20 key players who hold 70% of the market share (CKD Group). Almost all vegetable seed providers are based in Punjab; the main hub is Gujranwala, followed by Faisalabad, Multan and Lahore. Only in Balochistan, public sector plays a bigger role in supplying seeds – seeds sold directly to farmers by agricultural extension services, agricultural research institutes and 19 sales points established by the provincial Department of Agriculture.

In the informal sector, local seed supply and diffusion is mostly based on traditional channels of information and exchange within farmer communities. In addition to cash transactions, non-cash transactions such as seed swaps, in-kind seed loans and seed exchange for labour are common. The informal sector forms the basis of the seed system prevalent in the country. It could be characterized by a seasonal cropping cycle – selecting desirable seed types, seed harvesting, cleaning and storage, exchanging between relatives, trading/bartering at a local marketplace or purchasing from seed shops or arthi.[5]

[4] Vegetable seeds are mainly from China, India, Thailand and Malaysia. Fodder seeds are mainly from the USA, Australia, France, Turkey and Egypt.

[5] An arthi is the market functionary who procures commodities from farmers to sell in the market and farmers often rely on this as a source of seeds, planting and cultivation.

Table 3 Area, Seed Requirement, Seed Availability (2019-20)

Crop	Area (ha)	Total Seed Requirement (Tons)	Seed Availability (tons)			
			Public	Private	Imported	Total
Vegetables	280	8400	0	1171	2987	4158
			0%	14%	36%	50%
Fodder	2038	61140	10	4441	22015	26456
			0%	7%	36%	43%

Source: Federal Seed Certification and Registration Department

Box 1 Women-led and women-specific interventions for genetically modified-driven agriculture

A female grassroots activist, Azra Sayeed, runs Roots for Equity, a Karachi-based organization working with and for small and landless peasants. It also advocates and train communities about sustainable agriculture. In partnership with Roots for Equity, Pakistan Kissan Mazdoor Tehreek (PKMT) launched the Save Our Seeds (SOS) campaign in Sindh, Punjab and Khyber Pakhtunkhwa to store indigenous seed varieties and create seed sovereignty. High-yielding varieties were exchanged and saved by farmers. In 2018, the PKMT developed 89 individual seed banks in its operational districts, 52 of which are based in Sindh. The seed banks now contain 11 different indigenous seed varieties.

Similarly, In Nara Mughlan, Punjab, PODA formed a women's network and trained them for creating a seed bank where several varieties of seeds were collected and distributed among deserving farmerettes who would return the seeds to the bank after harvesting (Haider & Ahmed,

High-efficiency irrigation systems (HEIS)

The drip, bubbler, conventional sprinkler, rain gun and centre pivot, etc. are together referred to as high-efficiency irrigation systems (HEIS), which use pipes for conveying water from the source to points of use (Box 2).

Box 2 Defining different HEIS

Drip or trickle irrigation: water is provided to individual plants by means of small emitters in the form of droplets. Best suited for orchards and high-value row crops such as vegetables, cotton, maize, and sugarcane. The advantages of drip irrigation include maximum use of available water, reduced water availability for weeds and, therefore, increased nutrient availability for crops. In addition, drip irrigation also presents an increased yield, efficient use of fertilizer, relatively low operational cost and labour, no soil erosion, ready adjustment to sophisticated automatic control, no run-off of fertilizers into groundwater, less evaporation losses of water as compared to surface irrigation, improved seed germination and reduced tillage operations.

Bubbler irrigation: very similar to trickle irrigation except that the water is delivered to the plants through micro sprinklers mounted on small spikes.

SPRINKLER IRRIGATION:

- **Rain gun irrigation:** water is pumped at a high pressure through a piped system and sprayed over the field.
- **Central pivot irrigation method**: Sprinklers are placed along a series of bowed pipes, which is pivoted at one end and moved around the field in a circular fashion.

Sprinkler systems are more suitable for field crops such as wheat and fodder.

Drip and sprinkler irrigation can be practiced on a variety of soil conditions, including uneven topography, odd field configurations, rolling sandy areas and long lengths of run. They are the best-known water-saving technologies for irrigation purposes.

This technology's environmental benefits include reduced risk of groundwater over and the potential to improve water quality through filtration and fertigation systems (more efficient application of less fertilizer overall).

Status of adoption in Pakistan:

Major HEIS have been installed in:

1. **Punjab:** citrus, mango, grape, olive and guava orchards
2. **Sindh:** mango, date, banana orchards
3. **Balochistan (mostly in water-precious zones)[6]:** guava, loquat, lemon, citrus, lychee, apple

Approximately 70% of HEIS are installed in new orchards that have not attained maturity. Thus, the level of achievement could not be measured, and it is too early to describe impact in values. However, figures from the Department of Agriculture in Punjab show a yield increase of 3.4% of mangoes and 4.5% of guavas. As shown in Table 4, the impact is highest for vegetables with tunnels.

Table 4 Economic impact of drip (HEIS) in Punjab

S.No.	Crops	Income/year/acre without HEIS	Income/year/acre with HEIS	Impact (Net value)	Impact % (Increase in income)
1	Vegetables (tunnel)	94 118	188 530	94 412	100%
2	Orchards	77 300	118 394	41 094	53%

Source: Department of Agriculture Punjab.

With the technical support provided by the Water Resources Research Institute (WRRI) in Islamabad, drip irrigation system components are now made available through Griffon Corporation in Lahore. MECO Instruments Pvt Ltd in Lahore manufactures pumping systems for any configuration of pressure and discharge. The pumping systems are available with electric motors or diesel engines. Many other industries now produce low-density polyethylene (LDPE) pipes, which can be used for drip irrigation systems. Leading companies are DADEX Eternit Limited in Karachi, Engro Polymer & Chemicals Limited in Karachi, NEWTECH-Pipes in Islamabad and Popular Pipes in Lahore.

Government programmes such as Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP) and the Sindh Irrigated Agriculture Productivity Enhancement Project (SIAPEP) (Box 3) can be replicated in Balochistan and Khyber Pakhtunkhwa. This would encourage adoption of drip systems in farmers.

There is an opportunity for supply and services companies to increase their sales and provide relevant services to farmers. There are some pre-qualified registered companies in the country, but only five of them are active. These companies provide the layout and design of the whole system, including the planning of agronomic aspects and act as service providers. They work with the PIPIP in Punjab and are also involved in the installation of HEIS in Sindh through the SIAPEP.

[6] The northern areas, Dera Ghazi Khan, Kohat, Bhalwalpur, Nowshera, Haripur and Attock

Box 3 Province-level government programmes to increase adoption of HEIS

A notable early success in Pakistan has been the private sector's active involvement in the production and installation of pressurized irrigation systems. However, the major adoption of HEIS is due to government programmes, the **Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP)** in Punjab and the **Sindh Irrigated Agriculture Productivity Enhancement Project (SIAPEP)** in Sindh. These provincial governments have taken initiatives by providing HEIS to farmers on a cost-sharing basis. Drip systems were to be installed for orchard, vegetables, and row crops, while sprinkler systems were to be installed for fodder. Under the SIAPEP, approximately 2,600 HEIS have been installed on 35,000 acres of irrigated and irrigable land. Progressive farmers in Sindh are showing a keen interest in adopting HEIS technology, which can be gauged by having 402 farmers who have applied to the SIAPEP to install HEIS. However, the implementation has been slow, as, from 35,000 acres, only 19% has been installed since the programme's inception. In Punjab, under the PIPIP, the installation of HEIS is planned on approximately 120,000 acres. Only 30,000 acres have been completed under the original programme in 2017. The high adoption rate can be gauged by PIPIP installing 15,000 acres in 2020 alone. A similar government support programme, the **Balochistan Irrigated Agriculture Productivity Enhancement Project (BIAPEP),** has been initiated in Balochistan, which is expected to promote drip irrigation in the province (Jaffer Brothers, 2021).

Laser levelling

Laser levelling is done through a laser beam, which is emitted from a device situated at a fixed point at the edge of the field. This beam scans the field to generate an elevation map, which is converted to an electric signal, which is transmitted to a receiver box on a plough. The receiver box adjusts the plough as it moves, producing a consistent field for uniform water and moisture distribution.

It significantly improves water use efficiency and land productivity, minimizes the cost of operations, increases the efficiency use of fertilizer, and reduces waterlogging and salinity. The use of laser land levellers over conventional land levellers has proved to reduce GHG emissions through decreased water pumping time, decreased cultivation time and better use of fertilizers (Aryal et al., 2015).

Status of adoption in Pakistan:

Laser levelling is promoted to farmers and service providers in Sindh and Punjab through 50% subsidy programmes. However, it is not yet widely adopted across the country due to differing provincial priorities and funding support (World Bank, 2017).

Precision laser land levelling is practiced on 6 million hectares in the country. There are more than 25,000 laser land levellers in Pakistan, out of which 20,000 units are in service in Punjab alone (Mushtaq Gill, 2022). Under the SIAPEP, the government has provided 1,290 laser land levellers at various locations in Sindh.

The laser land leveller costs approximately PKR 500,000 to PKR 600,000 and requires a tractor to operate it, making it beyond the financial capacity of a small farmer to own. Most laser land levellers (90%) are owned by progressive farmers or cooperatives and are made available to farmers for rental. These service providers can recover their investment in one year, as they charge PKR 5,000 per acre and, in one year, they level approximately 280 acres, resulting in an income of PKR 1.4 million (PC-1 of Water Management, 2015).

Solar submersible pumps for drip irrigation and tube wells

Solar-powered water pumps use solar photovoltaic (PV) panels to convert sunrays into electricity, which operates the water pump to lift and/or distribute groundwater for irrigation. Since groundwater provides 60% of water for agriculture in Pakistan (PCRWR, 2020), this technology can play a significant part in increasing overall cropping intensity, especially in areas with limited access to electricity.

For tube wells: Solar pumps are used to lift water for the tube well, that can then be taken to its final consumption point.

For drip irrigation systems: Solar pumps can be connected to drip, sprinkler, and pivot irrigation methods. A system can also include filtration or fertigation equipment. Solar pumps are often combined with a low-pressure drip and the required pressure is typically achieved by pumping water into an elevated water tank and releasing it through gravity. Solar trackers could help to maintain the power output and, therefore, the pressure for more hours during the day.

The advantages of the technology, mostly like solar-driven drip, include low maintenance and easy operation, no GHG emissions, uninterrupted water supply for irrigation during the day (leading to possible unsustainable water use), potentially long panel life and feasibility in remote areas. However, there is a need to monitor aquifers before installing more tube wells.

However, they have higher initial investment costs[7] and lower discharge capacities than diesel-powered pumps. There is the risk of the unsustainable extraction of groundwater as evidenced in many areas, including Balochistan.

Status of adoption in Pakistan:

Many farmers have installed solar irrigation pumps through private investments. The photovoltaic (PV) market is dominated by Chinese products due to price competitiveness. The basic solar submersible pump costs between PKR 500,000 and PKR 800,000, depending on the area, depth of the well and discharge capacity (Alkhidmat Foundation, 2021).

All the provincial governments have planned and/or launched subsidized solar irrigation pump schemes, mostly coupled with HEIS, especially in Punjab and Sindh. Currently, only Punjab has succeeded in implementing its programme to some extent (the highest number of solar irrigation pumps are installed in the Rawalpindi division and the least number installed are in the Bahawalpur division). The programmes are at pilot stages in Khyber Pakhtunkhwa and Sindh. However, the programmes have not materialized at all in Balochistan.

IoT-based soil moisture sensor

Internet of things (IoT) solutions based on real-time farm sensor data and intelligent decision support systems have led to many smart farming solutions, thus improving water usage. The sensor data is wirelessly collected via the cloud and a mobile application, as well as web-based information visualization and a decision support system makes irrigation recommendations. The soil moisture sensor allows for information-based decision-making to irrigate farms, resulting in great water savings.

These systems are relatively costly and complicated in their design and often require professionals to plan and implement. The cost ranges from PKR 50,000 (lab-scale) to PKR 750,000 (imported), depending on the sophistication and technological module (Farm Dynamics Pakistan, 2021).

Status of adoption in Pakistan:

There is a budding ecosystem of social media influencers who disseminate knowledge-based practices among farmers. Also, there are channels with thousands of subscribers and millions of views targeted at the farming community, which can be used for information dissemination. Farmers can be incentivized to use digital agricultural technologies such as soil moisture sensors by offering performance-based discounted microcredits.

[7] Contrary to the belief that the investment for solar-powered pumps is low, the costs increase with an increase in pumping depth and discharge. For depths greater than 100 feet, the cost of solar tube wells increases significantly and becomes uneconomical (Ali Shah, M.A. & Akbar, M.Z.B, 2021).

Box 4 Water and climate informatics for measuring soil moisture and planning irrigation.

Simple changes in the irrigation schedule can save water, increase yields, reduce energy use, improve product quality and curtail nutrient costs (Directorate General Agriculture, On Farm Water Management Section, Punjab, Lahore, 2015). Several devices have emerged for the accurate measurement of soil moisture, leading towards efficient use of irrigation water. The use of irrigation scheduling devices can remove the guesswork in irrigation management by providing an accurate assessment of the soil water status. Numerous instruments are used for moisture measurement, including highly sophisticated ones such as weather stations, EnviroSCAN, time domain reflectometry and time delay transmission and relatively simple devices such as tensiometers, gypsum blocks, neutron probes, soil moisture meters/sensors and FullStop.

Automatic weather stations (AWS)

Automatic weather stations (AWS) measures atmospheric conditions and transmits them to a network, forecast, or display. They have several different components, with each component measuring and transmitting different atmospheric data, for example, wind speed and direction sensor, lightning sensor, rain gauge, data-logger, network appliance, weather display.

Monitoring soil moisture and temperature can optimize crop irrigation patterns, especially for cash crops that have short harvest cycles. Information on temperature and wind speed can be used to find the right time to spray pesticides and reduce wastage of chemicals and labour.

Status of adoption in Pakistan:

Adoption of AWS is not significant owing to scarcity of reliable data and limited resources of the national meteorological agency to absorb the high capital cost. There is also low demand for AWS because farmers do not have the capacity to interpret the data produced by AWS and there is a lack of service providers who could do it for them.

However, some work is being carried out to increase the adoption of AWS.

Efforts have been made, mainly by donor programmes, academia, and corporate sector organizations such as Jazz Bakhabar Kissan, to install automated weather stations in Attock, Chakwal, Badin, Swabi, Mirpur, Haripur and Sargodha providing real-time weather conditions to farmers.

Community-owned AWS are now installed in Gilgit-Baltistan and Sindh. This provides an opportunity to private hydromets service providers to develop revenue generating activities such as sales of value-added information to supplement costs of implementation. Such activities could complement Pakistan Meteorological Department’s (PMD) research and data processing functions. Another opportunity exists for mobile network organizations, which can allow the usage of their telecommunication masts for AWS installation. This would minimize the need for PMD to acquire land, thus reducing operation and maintenance costs.

Most of the weather stations in Pakistan are imported, while some lab-level ones have been designed locally, such as one developed by WIT/LUMS. Various studies show that the lab-made weather monitoring system is equally efficient at measuring various weather parameters. The price is PKR 40,000 to PKR 80,000 (lab-scale) and PKR 150,000 to PKR 750,000 (imported), depending on the system’s sophistication (Farm Dynamics Pakistan, 2021).

Lastly, the government plans to install 200 automatic weather stations, mainly aiming to upgrade and expand various technical and institutional aspects of the early warning system (EWS).

Box 5 Mubarakabad Farm: A weather station by the community, for the community

The major argument against investment and adoption of weather stations is often presented to be a lack of awareness and interest by farmers and information readily available on various online platforms. In Mirpur Khas, a farm has not only installed a weather station, but is disseminating weather information to 40 farmers in the area via a WhatsApp group, and to many other neighbouring farmers who don't have smartphones via call and word of mouth. This service is free, and the farmers are, therefore, willing to benefit from it. Demonstrations like these show farmers' interest in having certainty on weather conditions for saving water or ensuring timely harvest.

Tunnel Farming

Tunnel farming involves constructing hut-like structures swathed in plastic that serve as cocoons, usually for growing off-season summer vegetables. As it is not possible to grow summer vegetables in open fields from December to February due to low temperature and high frost levels, these are grown inside polythene tunnels so the proper environment can be given to plants for maximum growth and yield.

Hydroponic is the most advanced tunnel technology. Hydroponic is a method of growing plants in water with nutrient-rich solutions. Hydroponics does not use soil; instead, the root system is supported using an inert medium such as perlite, rockwool, clay pellets, peat moss or vermiculite.

Tunnels with HEIS have been found to be water and nutrient efficient and the most appropriate option to address various crop production issues. The yield increment of a tunnel under HEIS is 74% and the income increase is 109% compared to a tunnel with surface irrigation.

There are typically three types of material that are used to build tunnels:

1. **Bamboo tunnel:** is less durable but cheap. Bamboo is simply buried in soil. It can last 2-3 years and can be modified.
2. **T-iron tunnel** consists of angle iron pipes with 15-20 years of life. Foundational pipes T-irons are fixed in soil through concrete. This structure is moveable. To reduce costs, iron roof can be replaced by bamboo.
3. **Iron bars:** This structure is made of 5 mm iron bars, narrow bamboo, or mulberry wood; 2–3-metre-long bars of iron or wood are bended and fixed in soil to make a 1-metre-high tunnel.

Tunnel types are given in Table 5.

Table 5 Tunnel types

Tunnel type	Tunnel height	Suitable summer vegetables
High tunnel	10–15 feet high and 30–35 feet wide; 20-foot length of support material; covered with 0.10 mm thick plastic sheet	Cucumber, tomato, bottle gourd, chillies/pepper, brinjal
Walk-in tunnel	8 feet high and 12 feet wide; support material of 20 feet in length	Sweet pepper, hot pepper, cucumber, vegetable marrow
Low tunnel	3.5–4 feet high and 4 feet wide; one-quarter inch diameter iron rod of 10 feet length, in D-shape; 0.04 mm thick, 10-foot-wide plastic sheet to cover	Suitable for heavy individual fruit bearing crops like bitter gourd, sponge gourd, musk melon, watermelon, squashes

Source: Authors' interviews

Box 6 Costs and yields of tunnel farming.

With a high tunnel, production can reach 100,000–150,000 kg of tomatoes per acre. In a walk-in tunnel, the yield is approximately 40,000–60,000 kg and approximately 30,000 kg per acre in a low tunnel. Compared to this, per acre yields of tomatoes in conventional farming are approximately 15,000–18,000 kg. Tunnels vary by cost and size. On an area of 1 acre, a high tunnel would cost approximately PKR 2,000,000 to PKR 3,500,000, a walk-in tunnel would cost PKR 1,000,000 to PKR 1,500,000 and a low tunnel would cost PKR 400,000 (Jaffer Brothers, 2021). With drip, it would add PKR 100,000 per acre to the cost.

Status of adoption in Pakistan:

Hydroponic is new in Pakistan and not funded by any government programme.

In Sindh, tunnel farming has not gained a lot of attraction. The province has moderate and high temperature all year round, so demand for tunnel farming is low. Even in areas where there is a demand, the adoption remains low due to no financial or technical support from government to offset the high capital cost. A few high tunnel (some with drip irrigation) farms have been established by the private sector, mainly in Tando Allahyar (55 acres), Nawabshah (150 acres) and Karachi (100 acres) (Jaffer Brothers, 2021).

In Punjab, farmers are fast shifting away from conventional farming and adopting tunnel farming technology with drip irrigation system. It is practiced in many areas of Punjab, including Faisalabad, Gujranwala, Mamokanjan, Sahiwal and Okara, although cultivation is not yet at any significant level. This can be attributed to the provincial climate-smart technology package that is being implemented through financial assistance by the Asian Development Bank and the World Bank. Additionally, Chief Minister of Punjab's Khadim-e-Kissan Package has a component on tunnel farming, which provides a 50% subsidy for the installation of tunnel on three thousand acres.

To resolve the problems faced in the form of the initial high cost of setting up the basic structure for tunnels, the Government of Balochistan is encouraging the private sector to invest in tunnel farming systems in various districts by starting joint ventures with farmers or providing financial assistance to farmers for the start-up cost. Presently, low-cost low tunnels are used in Balochistan to grow mainly tomato nurseries for early planting, while in a very limited scale cucumber is being grown at Qilla Saifullah, Mastung and Dhakki.

Hybrid seed dealers also have vast experience in growing vegetables under tunnels at a commercial scale. Linkages between farmers and seed dealers would benefit in the adoption of tunnel technology through sharing their experiences and would also provide low-cost viable hybrid seeds tested under local circumstances.

Post-harvest technologies

Dehydration technologies

There are three different processes for drying/dehydration:

1. **Sun drying:** done through direct, indirect, or solar hybrid drying in the open or in a solar dryer.
2. **Atmospheric drying:** uses kiln, tower or cabinet dryers in a batch or continuous drying in a tunnel or continuous belt, etc. It is the most widely used commercial method.
3. **Sub atmospheric drying:** taken place at low external pressure by creating a vacuum to remove moisture at less than the boiling point under ambient conditions. This process requires higher capital and operational costs and is thus used only for material that could deteriorate due to oxidation by exposure to air.

Dehydration increases produce's shelf life, meaning less wastages, which translates to higher income for farmers and less pollution/GHG emissions, as the technology is not dependent on conventional energy.

Status of adoption in Pakistan:

Solar dehydration plants have been introduced in Pakistan, especially in the northern areas through donor-assisted programmes such as ADB's Agribusiness Support Fund (ASF). The ASF has installed 90 locally manufactured solar dryers at different farms across the country. Solar dryers were installed in Khairpur Mirs, Peshawar, Swat, Skardu, Gilgit and different areas of Balochistan. These were mainly used for drying dates, apricots, grapes, bitter gourd and onions and other fruits and vegetables.

As part of the Government of Pakistan's Public Sector Development Programme, 10 unglazed collector-type hybrid (solar and biomass) dryers were designed, developed, and installed. They have a capacity of 500kg and are used for drying dates in Punjab and Sindh.

Table 6 Key dehydrator unit providers

S.No.	Company
1	Koldware Industries Pvt Ltd, Karachi/Lahore
2	Pakistan Council of Renewable Energy Technologies (PCRET), Islamabad
3	Engineering World Pvt Ltd, Rawalakot, Azad Jammu Kashmir

Source: Authors' interviews.

Collapsible dryer case

The collapsible dryer case is made of woven coated polyethylene (PE), which is two times stronger than ordinary tarpaulin and two times lighter than reinforced PVC. In case of anticipated rain or during the night, the collapsible dryer case can be covered instantly using pulling straps. The flap makes the case water resistant, protecting commodities from moisture re-absorption. Collapsible dryer cases dry commodities with minimum losses through reduced spillage and without additional operational costs.

Status of adoption in Pakistan:

This is a fairly new technology and has been recently introduced in Pakistan by Haji Sons of Lahore.

Pre-cooling system

Pre-cooling preserves product quality by inhibiting the growth of decay producing microorganisms, restricting enzymatic and respiratory activity, inhibiting water loss and reducing ethylene production. Following are types of pre-cooling systems:

1. **Hydro-cooling – immersion and shower:** The simplest and least expensive cooling methods. Bulk bins can be hydrocooled before packing, either by immersion in cold water or by showering cold water over them. Some chemicals are also mixed with water used in hydro-cooling to prevent diseases. Shower-type coolers can be built with a moving conveyor for continuous flow operation, or they can be operated in a batch mode.
2. **Mobile pre-cooler/containerized pre-cooler:** This allows product to be cooled at or very close to the field, thus reducing transport losses. It is suitable for small farming units growing high-value products.
3. **Evaporative cooling:** It consists of allowing air to pass through a wet pad. It provides an opportunity to hold the product at cooler than ambient temperatures and at a high relative humidity, which reduces dehydration or wilting. The reduction of more than 10°C and a change in the rate of moisture loss of a factor of five can be achieved through this technology (Dr. Chris Bishop, 2013).
4. **Vacuum cooling:** Applying the vacuum to the product causes evaporation of water and associated cooling. Every 6°C of cooling is accompanied by a 1% moisture loss, which can be reduced by spraying produce with water before or during the cooling process. It is a less common cooling method suitable for leafy vegetables such as lettuce.
5. **Forced air cooling:** It is accomplished by exposing packages of produce to higher air pressure on one side than on the other. This technique involves definite stacking patterns and the baffling of stacks so that the cooling air is forced through (rather than around) the individual containers. For successful forced air-cooling operations, it is required that containers with vent holes be placed in the direction of the moving air and packaging materials that would interfere with free

movement of air through the containers be minimized. This method is usually 75%–90% faster than room cooling and was developed to accommodate products requiring relatively rapid removal of field heat immediately after harvest.

Status of adoption in Pakistan:

There is relatively little published information about the suitability of small-scale hydro-cooling, evaporative cooling and mobile forced-air cooling systems. Efforts to introduce technologies are being undertaken by donor interventions such as Winrock International, which is establishing packing houses with pre-cooling technology in banana clusters in Sindh.

Cold Storage

Cold Storage is a refrigerated space, the temperature of which is kept very low. Its function is to create a favourable environment for storage of goods below the outdoor temperature to preserve them. The types include ammonia-based technology, controlled atmosphere (CA) technology[8] and modified atmosphere (MA)[9] technology. Ethylene can be scrubbed for products responsive to it, regardless of the storage system used. A good control of temperature, humidity and atmospheric composition maximizes a product's storage lifespan.

Status of adoption in Pakistan:

Pakistan's existing cold storage is mainly for long-term storage of products such as potatoes, apples and citrus fruits. Most of the cold storage facilities are in urban and suburban areas, close to wholesale markets and within processing industries such as kinnow (mandarin hybrid developed for India and Pakistan) and potato processing units. There is a high proportion of refrigerated storage in potato clusters, mainly in Okara and Dipalpur, followed by the citrus cluster in the Bhalwal/Sargodha area, where most of the processing industry is established.

Most of these facilities are still based on ammonia-based technology and not compartmentalized. This causes odour transfer between different commodities placed within cold stores.

Table 7 Cold store technology providers

S.No.	Company	S.No.	Company
1	KoldKraft Refrigeration, Lahore	4	Pakistan Air Conditioning Engineering Co., Lahore
2	Koldware Industries, Karachi/Lahore	5	EKN Cooling Systems, Lahore
3	Dastgir Engineering, Lahore	6	AgroGreen, Karachi

Source: Authors' field interviews.

Additionally, Pakistan lacks an integrated network of modern cold chain infrastructure. Existing cold storage facilities are unevenly distributed across the country, with Punjab dominating with 512 units, followed by Sindh (25 units), Khyber Pakhtunkhwa (16 units) and Balochistan (2 units), with 0.9 million tons of storage capacity, against more than 15 million tons of fruit and vegetable production (Ministry of National Food Security & Research).

Hot Water Treatment (HWT)

HWT consists of dipping freshly harvested fruits in 52-to-55-degree Celsius heated water for approximately 10 minutes.

Status of adoption in Pakistan:

There are 15 units of HWT, mostly around the mango cluster in Multan (Punjab), three units in Mirpur Khas (Sindh) and three units in Karachi. Most of the units in the mango clusters have been established under the United States Agency for International Development (USAID) grant programme. The units are of small capacity (3 tons per hour). The owners of these units are mostly exporters, but

[8] CA storage controls the concentrations of oxygen and carbon dioxide, in addition to temperature and humidity.
[9] MA storage controls oxygen and carbon dioxide concentrations, although not as precisely as controlled atmosphere.

also provide services to other exporters. The technology was manufactured locally by Technology International based in Faisalabad. Another technology provider is Koldware Industries.

Given that many importing countries have made HWT mandatory for mangoes to be imported from Pakistan,[10] more HWT plants in the mango production/cluster hubs need to be established. It is suggested that all the export and 5% of the mango output destined for the high-end domestic market will be passed through the HWT plant. For this purpose, a total of 23 new HWT plants will be required (CABI, 2017).

Packaging technologies

Hermetic Packaging

Hermetic storage is a technology to store produce in an airtight container such as a drum or a plastic bag/cover to prevent air and water getting into the stored crop from outside. Using hermetically sealed bags can reduce the use of pesticides, the need for fumigation and GHG emissions.

Status of adoption in Pakistan:

The knowledge of hermetic storage technologies among stakeholders in the grain/seed value chain is very limited. However, some commercial hermetic storage products have been introduced in the market and are available in Pakistan. There is market potential for commercialization of the technology, for example, in the storage of seeds.

The University of Agriculture Faisalabad, in collaboration with Concern Worldwide and sponsored by UK Aid, has developed cost-effective hermetic Anaaji bags and drums that are useful for the storage of cereals, oilseeds and pulses and do not affect seed and grain qualities. In 2018, hermetic bags and drums were distributed among farmers in Sindh and southern Punjab.

GainPro Storage Cocoon

A storage cocoon is a water-resistant and gastight storage solution for dry agricultural commodities. Made of food-grade, ultraviolet-resistant flexible PVC, it is designed for both indoor and outdoor installations. It can store commodities at or below a safe moisture level for prolonged periods without the risks of moisture ingress, pest infestation and fungal growth. This eco-friendly and pesticide-free product preserves the quality and germination capability of stored grains.

Status of adoption in Pakistan:

In Pakistan, it is still in its introductory stage. Tests and trials have been undertaken on various crops such as seed, maize, rice, chilli and dry fruits. Although it has shown promising results, its adoption has been slow, mainly due to its initial high cost. Presently, the sole importer and distributor of this technology is Haji Sons.

Considering a capital-intensive technology and successful test trials, Haji Sons and GrainPro came out with a new concept to commercialize the technology through rental hermetic storage solutions, especially for small farmers. Hermetic cocoons were placed at multiple locations in Punjab, where farmers store their product under hermetic technology on a rental basis and also have access to bank financing of up to 70% of their commodity value to overcome their immediate financial needs. Haji Sons also links farmers with processors to sell their products. During six months' storage, the trial results showed up to 87% product recovery in hermetic technology compared to 62% in ordinary polypropylene bags. This provided an advantage of 25% more product recovered, giving better profits to farmers (Haji Sons).

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[10] This is mainly due to mangoes being highly susceptible to infestation by fruit flies. Presently, it is controlled through pesticide spray and pheromone traps mostly used by progressive farmers. However, export to the European Union is only done through HWT and the process is monitored and approved by the Department of Plant Protection (DPP).

Modified atmosphere packaging (MAP)

Modified atmosphere packaging (MAP) alters the internal atmosphere of packaged products, reducing oxygen and increasing carbon dioxide levels, which slows the ripening process. This is mostly used for storing perishable food like fresh produce.

Status of adoption in Pakistan:

The MAP bags technology was first introduced in 2012 by NESPAK, a consortium of Dutch and Pakistani technical experts of fresh fruits, vegetables and flowers to export fresh produce by sea instead of by air from Pakistan over long distances.

Despite its worldwide acceptance, MAP is not a very popular technology in Pakistan, mainly on account of limited research work and technology providers.

Table 8 Summary of major constraints and recommendations for selected climate-smart technologies in horticulture

	HYBRID SEEDS
Major Constraints	**1. Limited production and commercialization of hybrid seeds at local research institutes –** *limited availability of resources, lack of private sector interest and the long duration and process required to develop a variety.* **2. Local production is not practiced at a commercial level –** *market size for locally produced hybrid seeds is small because global seed companies have wider varieties as well as efficient distribution networks.* **3. Weak execution of intellectual property laws –** *Lack of proper mechanism to enforce relevant laws, for e.g. penalizing back-crossing unregistered sales.* **4. Weak quality control mechanism at market level –** *no checks to discriminate between substandard and high-quality seeds.* **5. Small farmers prefer to sow their own seeds or buy it from another farmer at nominal prices –** *approved varieties are unaffordable* **6. Seed supply chin and distribution mechanisms are weak** Other constraints include: lack of information on advantages of using hybrid seeds and limited number of technically competent support service providers.
Recommended Interventions	1. Establish and execute proper screening processes, registration procedures and enforcement, aligned with the legal framework provided in the Plant Breeders' Rights Act 2016. 2. Support farmers in saving their seed, which will continue to be an important source for several crops. 3. Establish demonstration plots at cluster level and undertake cost–benefit analysis to be disseminated to potential farmers (tomato/onion – Mirpur Khas, Sindh) (tomato/onion – Khuzdar, Balochistan). 4. Promote through arthis, as it is in their interest to have safe and high-yielding crop to secure investment. 5. Encourage branded seed suppliers to have a physical presence within or around wholesale markets (mandis) where the target stakeholders (i.e. farmers and arthis) are accessible for promotion and sales. This also assures quality seed supply (Karachi, Hyderabad in SIndh) (Quetta, Balochistan). 6. Bulk purchases through cooperatives/associations to lower prices through economy of scale. Storage in hermetic packaging (tomato/onion – Mirpur Khas, Sindh) (tomato/onion – Khuzdar, Balochistan).
	DRIP IRRIGATION
Major Constraints	**1. There is a high initial capital investment (PKR 100,000 per acre) , additional to the water pimp and infrastructure cost. Cost of maintenance is also high.** Despite available subsidies, the cost is still high for smallholder farmers to adopt this technology. **2. Subsidies also often come with attached requirements that might not be feasible for farmers to adopt.** For example, Punjab government provides 60%-90% subsidy to farmers but requires farmers to use only solar pumps with HEIS. This combination is not appropriate for certain existing cropping patterns. **3. Farmers lack knowledge and capacity to operate these systems.** There is lack of service providers close to areas of installation and most of the farmers that have adopted solar-powered drips in Sindh and Balochistan are big progressive farmers. **4. There is an absence of strong policies and institutional framework on water management.** The current irrigation water pricing is inefficient and does not encourage water saving.
Recommended Interventions	1. Government cost-sharing programme such as PIPIP and SIAPEP to be initiated in Balochistan. 2. Financial institutions, especially microfinance institutions and Zarai Taraqiati Bank Limited, need to develop a package for loans at discounted rates. 3. Establish demonstration plots at cluster level and undertake cost–benefit analysis to be disseminated to potential farmers (mango – Hyderabad and Mirpur Khas; banana – Thatta, Khairpur, Mirpur Khas; dates – Khairpur; tomato/onion – Mirpur Khas in Sindh) (grapes – Pishin; tomato/onion – Khuzdar; dates – Panjgur; banana – Lasbela in Balochistan).

	4. Collaboration with relevant NGOs for technical support and dissemination. Need to build their technical capacities, including production and managerial skills. 5. While contracting the funding agency, include a mandatory clause where the technology provider also provides technical support for a period so the farmer can absorb the technology and production dynamics. 6. Government should create an enabling environment for the existing pipe/plastic to start local manufacturing of drip/sprinkler components for technology indigenization.
LASER LEVELLING	
Major Constraints	**More service providers need to be supported with the technology due to its high capital cost.**
Recommended Interventions	1. SIAPEP to be scaled up and similar government-subsidized programme to be initiated in Balochistan. 2. Rental model to be promoted. Provision of loans and lease arrangements on soft terms to service providers. Relevant NGOs can become service providers.
TUNNEL FARMING	
Major Constraints	1. **Initial high capital cost –** *there is lack of support from the government in Sindh.* 2. Price distortion at wholesale markets
Recommended Interventions	1. Baluchistan's government should initiate cost-sharing programmes. 2. Financial institutions, especially microfinance institutions and Zarai Taraqiati Bank Limited, need to develop a package for loans at discounted rates. 3. Promotion of high tunnels in Mirpur Khas in Sindh (all-year production). Due to moderate temperatures, a low/walk-in tunnel is not attractive to Sindh farmers. 4. Promotion of low/walk-in tunnels for tomato in Khuzdar in Balochistan (off season). 5. Collaboration with relevant NGOs (e.g., Sindh Rural Support Programme and Balochistan Rural Support Programme) and cooperatives, building their capacities to provide technical and managerial support services to farmers. 6. Contract farming: linking producers to high-end markets and value-addition industry. 7. Hybrid seed dealers also have vast experience in growing vegetables under tunnels at commercial scale. Linkages between farmers and seed dealers would benefit the adoption.
PRE-COOLING	
Major Constraints	1. Costly for farmers to adopt 2. Lack of awareness of benefits
Recommended Interventions	1. Establishment of common facility centres providing pre-cooling and grading/packaging services at cluster levels, mainly for grapes and tomatoes at targeted clusters (banana – Thatta, Mirpur Khas; mango – Hyderabad, Mirpur Khas in SIndh) (tomato – Khuzdar; grapes – Pishin in Balochistan). 2. Mobile and containerized pre-coolers need to be introduced through a cooperative mechanism for targeted cluster (banana – Thatta, Mirpur Khas; mango – Hyderabad, Mirpur Khas; dates – Khairpur) (tomato – Khuzdar; grapes – Pishin). 3. Financial institutions, especially microfinance institutions, need to develop a package for loans at discounted rates.
HERMETIC PACKAGING	
Major Constraints	Knowledge of hermetic storage technologies among stakeholders in the grain/seed value chain is very limited.
Recommended Interventions	1. Storage of seeds in hermetic packaging (cocoons) purchased in bulk by cooperatives on rental model). Hermetic drums and bags introduced by the University of Agriculture Faisalabad (UAF). 2. Collaboration with technology providers – Haji Sons and the UAF to create awareness in dissemination of technology (tomato/onion – Mirpur Khas in Sindh) (tomato/onion – Khuzdar in Balochistan)
SOLAR DEHYDRATION	
Major Constraints	1. High capital cost 2. Lack of availability 3. Lack of awareness of benefits
Recommended Interventions	1. Solar dehydration needs to be introduced to targeted clusters (individual and under common facility centres) and undertake cost–benefit analysis/business model to disseminate to potential farmers (dates – Khairpur; mangoes – Hyderabad and Mirpurkhas in Sindh) (grapes – Pishin; dates – Panjgur in Balochistan). 2. Collaboration with technology providers to build technical capacities of relevant NGOs and farmer cooperatives to provide technical support services to farmers.

Indigenized technologies

Indigenization of technology describes substituting an imported item with one that is manufactured within the country. It can functionally be the same as the imported item but could have parts that are either imported or indigenous. Many research groups are now indigenizing these tools and practices for use in Pakistan. Table 9 summarizes some of these interventions.

Table 9 Summary of indigenized technologies in horticulture

Intervention	Application	Status	Organization	Organization type
Pest trap	An app and artificial insemination-based trap for mango flies and other pests to create an early warning system for farmers and decision markers.	The app is still in the user testing phase with 25 farmers in south Punjab.	Muhammad Nawaz Shareef University of Agriculture	Academia
Canal gauge	Canal water level monitoring for demand-driven irrigation.	Designed for government departments for efficient and equitable distribution of water and installed at more than 45 stations.	Centre for Water Informatics and Technology (WIT), LUMS	Academia
Weather station	Weather monitoring and early warning system.	Assembled in-house for use in agriculture, academia and research.		
Water quality sensor	It is a cloud-connected hydrological monitoring solution to measure the physicochemical parameters (temperature, pH, electrical conductivity and redox potential) of water in real time.	The sensor can be deployed at various locations in the basin for an early warning on the quality of water used for irrigation. Currently, it is only being used for research purposes.		
Forest health app	Forest health monitoring app that can be used for monitoring the health of orchards.	The app offers on-board artificial insemination to estimate tree height, diameter at breast height and canopy size alongside biomass and carbon content.	National Agricultural Robotics Laboratory (NARL), LUMS	Academia
Indigenous hydroponics system for small farming in Pakistan	Soil-less agriculture in greenhouse sheds using growth medium such as cocoa waste and rice husk, etc.	This can be applied in areas where suitable land availability is an issue. (Scaling up seems to be a bigger challenge for this compared to others).	University of Arid Agriculture Rawalpindi (UAAR)	Academia
Rhizogold biofertilizer	Rhizogold (RG)$^{+}$ is a multi-strain biofertilizer developed from the efficient strains of plant growth-promoting rhizobacteria (PGPR) containing ACC deaminase to mitigate the impact of salinity stress on cereals, while Rhizogold (RG)^{D} is an effective multi-strain biofertilizer to mitigate drought stress in cereals.	Commercialized	Environmental Sciences Department, University of Agriculture Faisalabad	Academia

Source: Authors' field interviews.

Chapter 3: Assessing climate-smart technologies for livestock

Livestock, a vital subsector of agriculture in Pakistan, accounts for 11.22% of the overall GDP, which is 60.54% of agriculture's contribution to GDP (Pakistan Economic Survey, 2018–19). It provides milk, meat, and other by-products of animal origin for human nutrition. It has directly been impacted by climate change due to erratic weather patterns, resulting in decreased animal productivity and fodder production.

Climate-smart technologies in livestock took root in Pakistan with the establishment of corporate dairy industries in 2007. This section of the report has made a comprehensive list of all these available technologies.

A summary table (Table 12) is given at the end of this chapter to highlight the constraints and recommendations for selected technologies.

Feed and fodder technologies

Silage baling and wrapping

Silage is preserved pasture that is made through fermenting the grass. When the grass is cut, it is left to reduce the moisture content down to 60-75% and then compacted either manually (by storing in the pit) or mechanically (by balers). Then it is baled. Baling is a process of wrapping compacted and inoculated grass in polypropylene sheets to provide an airtight environment for fermentation of the grass. Silage production and baling allows a consistent supply of fodder for the livestock, especially in periods of scarcity.

Status of adoption in Pakistan:

In Pakistan, silage production technology was initially introduced through demonstrations by preparing silage in silo pits and plastic drums. Later, it was adopted by the private sector at a commercial level through mechanical intervention consisting of harvesters and balers.

The machinery and equipment for silage baling has been adopted by service providers, mostly in Punjab and to some extent in Sindh and Khyber Pakhtunkhwa and has shown positive financial returns (USAID-funded Pakistan Agricultural Technology Transfer Activity). It can be adopted by an individual farmer or as a business by an individual (can be a farmer or technology supplier) to use in a rental model.

Most supply-side companies are in Lahore and Okara. These companies import silage making/baling machinery from the Republic of Italy, China and Turkey. Some of these companies offer locally manufactured machinery. The technology initially acquired popularity in Punjab and Sindh, followed by Khyber Pakhtunkhwa. However, Balochistan and Gilgit-Baltistan are still lagging.

Total Mixed Ration (TMR)

In conventional TMR, chopped green fodder or silage are blended with cereals, cereal by-products, protein sources, minerals, vitamins and feed additives in order to provide a balanced ration to dairy animals. TMR is made by using a mixer wagon. To make 'pure' TMR, the mixer wagon is loaded with both hay and silage, according to the proper mixture ratio.

TMR provides a complete nutrition mix, which reduces feed and labour costs as well as GHG emissions. Feeding a TMR that's correctly balanced for cows can increase milk production 1–3.5 kg per cow daily (Sachin Tripura, 2020).

Status of adoption in Pakistan:

The adoption of TMR has been slow in Pakistan. It is expensive for smallholders and affordability is a challenge.

Breed improvement technologies

Artificial Insemination (AI)

Artificial Insemination is a method of breeding livestock using straws of semen, with the chief purpose of passing desirable characteristics of the male livestock to the progeny. It can significantly upgrade Pakistani dairy animals' poor genetic potential.

Status of adoption in Pakistan:

Pakistan has a huge infrastructure for artificial insemination services. There are 189 artificial insemination centres and seven semen-production units in the country.

The semen of buffaloes (both Nili Ravi and Kundi) and cattle (Sahiwal and Red Sindhi) is produced locally at four semen-production centres in Punjab, two in Sindh[11] and one in Khyber Pakhtunkhwa. In addition to these, semen from Holstein-Friesian and Jersey cattle is produced locally and imported from other countries.

Additionally, several exotic breeds of cattle, notably Holstein-Friesian, Jersey, Red Dane and Australian Illawarra Shorthorn, have been imported with different objectives such as establishment of nucleus herds, used in crossbreeding programmes or as demonstration and commercial units of modern dairy farming.

Bulls for the public semen production units are generally sourced from government farms, based on cows' lactation yield. Most of the bulls for private semen production units are bought from private farmers. There are approximately 14 importers and 66 semen distributors in Pakistan.

Table 10 Semen importing companies in Pakistan

S.no.	Company	S.no.	Company
1	International Traders	8	Trust Pharmaceuticals
2	Green Tech International Traders	9	ProFarm Pakistan
3	SBS Pvt Ltd	10	Ghazi Brothers
4	ICI Pakistan	11	Maxim Agri Pvt Ltd
5	Hamza Dairy Mart	12	Matra Asia Pvt Ltd
6	Dairy & Beef Solutionz Pakistan	13	Zag Impex International
7	Solve Agri Pak (Pvt) Ltd.	14	Apex International

Source: Author's interviews.

The total estimated semen quantity, including imports by the private sector, is approximately 3.6 million doses per year. High-quality imported semen is available on the market for PKR 200 to PKR 400 per straw (some selected Friesian straws are available at up to PKR 10,000/dose). Sexed semen imported from European breeds is available at PKR 4,000 to PKR 7,000 per dose (Martin de Jong, 2013; USAID/ CNFA/ASF).

Even with the large scale of AI's infrastructure in Pakistan, only 5% of buffaloes and 7% of cattle are bred through AI. This can be attributed to the low number of progeny-tested bulls and mismanagement of reproductive performance in animals such as heat detection, silent heat, low AI success (Box 7).

[11] One at Korangi in Karachi for production of enzootic and exotic semen doses and the other at Rohri to produce Kundhi Buffalo semen.

Box 7 Breed (Genetic) Improvement

Artificial insemination for productivity improvement is only justified if the bulls used in the semen production units are of higher genetic quality than the average population. Some of the government programmes geared towards addressing productivity issues include land grants, herd book schemes, provision of pedigree bulls, establishment of government livestock farms, provision of artificial insemination service, progeny testing programmes for Nili Ravi buffalo and Sahiwal cattle, import of exotic stock and crossbreeding. However, systematic genetic improvement programmes for livestock by the government have been limited as selective breeding has a long incubation period and the government has a preference to sponsor projects that yield quick and visible results. As a result, superior germplasm remains unavailable and the interested dairy investors are unable to get animals of the required breed in the desired number from anywhere in the country. In 2008, the Punjab Standards for Public and Private Semen Production Units and Quality Control Regulations was prepared, but never enacted. Except for the efforts by the Research Centre for Conservation of Sahiwal Cattle in Jhang, at the Buffalo Research Institute in Pattoki and at the Livestock Production Research Institute for cattle and buffaloes, there is no continuous and consistent pedigree and performance recording scheme in place. Experts believe that the unplanned artificial insemination resulting in hybrid cow breeds would not yield results. It is feared that, if proper research and development efforts are not carried out, many of the livestock genetic resources (breeds) will be lost. Despite 50 years of breeding services through artificial insemination, milk production genetics have deteriorated due to the non-existence of an F2 generation framework.

Milking and milk handling technologies

Milking machine

There are two types of milking machines: portable milking machines and barn milking systems. The first one is suitable for small herds and the latter is useful for farms with 20–50 animals. Corporate farms with 50 or more animals require milking parlours.

As opposed to traditional hand milking, machine milking decreases the risk of bacteria and other impurities in milk. It also prevents damage to animal’s milk tissues.

Status of adoption in Pakistan:

Milking machines have become popular in Pakistan, especially due to the increasing trend in corporate dairy farming. Technology providers are mostly based in Lahore to meet the growing demand. These companies import machinery from Turkey, Italy, China, and the United States to meet the country’s demand for milking machines.

Companies have started discouraging the purchase of milk drawn through traditional means due to impurities and the presence of oxytocin. The proposed milking machine, single cluster single bucket, is suitable for small herd sizes and is viable for even a herd size of two animals with a low yield of 12 litres per day per animal. The demand of such portable milking machines is expected to rise among small farmers due to increased awareness, preference given by milk processing companies and stricter government regulations.

Milk handling (cooling) and pasteurizing

Pasteurizing and chilling raw milk increases its shelf life, which usually is 4-6 hours due to bacterial growth. It can prevent considerable milk loss,[12] especially during summer. It also helps in increasing

[12] According to an Asian Development Bank report, an estimated 15%–20% of the total milk production in some areas is lost due to the unavailability of cold storage.

farmers' bargaining power with other value chain actors, especially the *dhodhi* in urban and peri-urban clusters.

Milk cooling tanks will cool the fresh milk from 42°C to < 5°C within two hours and this will reduce bacterial growth in the milk. This will lead to a longer shelf life of processed milk products.

Status of adoption in Pakistan:

Value chain infrastructure such as collection centres equipped with chillers, pasteurizers and proper milking places for animals are missing at the village level to maintain milk quality. Although private processors have provided chillers to large farmers, such a facility is not available for small farmers. Agents in the existing marketing chain rarely have access to cold storage facilities.

The major reason behind the unavailability of cold chain facilities is the high operating expense and irregular supply of electricity. As electricity supply is interrupted several times a day and is absent in most rural areas, a back-up generator/solar is usually required. This brings the investment per unit to be around $5,000–$10,000, a sum well beyond the reach of a small farmer. Most milk cooling tanks are locally manufactured. UNITECH International has 70% of the market share in Pakistan.

With respect to small-scale pasteurization units, investment required is $25,000 - $100,000 per unit. However, as consumer trust is shifting from open bag milk (delivered by dodhis) to pasteurized milk from shops, pasteurization units in milk clusters in rural areas can encourage small farmers to cater to the growing market for pasteurized milk.

Biogas

Biogas can be obtained by using livestock waste, which have been used to burn fires and as soil fertilizers for centuries. The promotion of biogas technology seems to be one of the best options that could partially offset fossil fuel and fuel wood consumption and facilitate the recycling of agro-animal residues as a biofertilizer. Moreover, being clean and renewable, it would also contribute to environment protection, ecosystem sustenance and biodiversity conservation.

Status of adoption in Pakistan:

There are mainly two types of small biogas plants installed Pakistan:

1. **Floating Drum Plant:** It is known as a constant pressure biogas plant because the drum (gas storage) moves upward and downward with the gas pressure inside the fermentation chamber, thus keeping gas pressure constant.
2. **Fixed Dome Plant**: These plants' main purpose is to supply gas for domestic energy needs or power generation at a small scale.

A combination of floating and fixed dome plants has also been developed and is known as a hybrid biogas plant. This plant is being promoted in China. The hybrid systems have been found to be the most efficient. However, the cost is a major barrier in adoption of these plants in Pakistan (Maxbiogas, 2014). Bag-type plants are not yet popular in Pakistan.

Despite the very high potential and previous experience with household biogas technology in Pakistan, the number of biogas plants in the country is limited to approximately 6 thousand. Some efforts have been made by public and private sector to increase the adoption (Box 8, Box 9 and

Table 11).

Table 11 Biogas-related technology providers

Government organizations	Private Sector Organizations (NGOs)	Private sector organizations (Business firms)

• Pakistan Council of Appropriate Technology (PCAT) • Directorate General of New Renewable Energy and Energy Conservation • Pakistan Council of Renewable Energy Technologies (PCRET) • Pakistan Dairy Development Company (PDDC)	• Initiative for Rural and Sustainable Development (IRSD) • Koshish • Association for the Development of Pakistan • Punjab Rural Support Programme (PRSP) • Foundation for Integrated Development Action (FIDA) • Rural Support Programme-Network (RSPN) • Green Circle Organization – community-based projects	• Beta Pak • PAK-Energy Solution • Revgreen Biogas • Canadian High Mark Biogas Company • Ravi Biogas Construction Company • Reon Energy Limited • Organisation of Strategy and Business Development

Source: Authors' interviews.

The average total manure produced in one day is estimated to be 3.5 million tons from 196 million livestock. It is estimated that at least 5 million biogas plants can be installed in Pakistan based on cattle/buffalo dung availability. However, this number can be increased if horses, mules, and poultry waste is included.

Box 8 Women in agripreneurship

Iqra Zaheen, a young woman from a small town in Mailsi, Vehari in Punjab, was selected by the British Council's COP26 Challenge Fund for a biogas plant installation in her hometown. She is pursuing her MSc (Hons) in Climate Change from the Mohammad Nawaz Shareef University of Agriculture, Multan (MNSUAM). The team visited Mailsi, southern Punjab during the field trip to Multan and was able to see the biogas plant. The set-up is shared between five households where cow dung is fed. This has led to a reduction in GHG emissions through capturing the methane in bio-waste, reduced use of natural gas and provision of organic fertilizer for agriculture on their farms. Ms. Iqra plans to set up more profit-driven agri-ventures for women in her region. She and her brother highlighted the importance of their late father's dream and support for her achievements. With the technical support from Punjab Biogas, financial support of the British Council, Muslim Hands, the Multan University of Agriculture and the local community, she has been able to install four biogas plants in the rural area of Mailsi. This community-based project is benefitting 20 families, a local mosque and more than 2,500 individuals directly and indirectly.

Box 9 Biogas programmes in Pakistan

Only a small number of NGOs and individual masons are actively building biogas plants and the private sector has not entered the market. Most of the biogas plants installed have been through government subsidy or a grant from a donor.

1. The Punjab Rural Support Programme (PRSP) network initiated a biogas programme in 2009 and installed 5,360 fixed dome biogas plants by 2014. The use of biogas was mainly for cooking and heating purposes and 90% of the plants were small (4–15 m^3). Training of skilled labour and beneficiaries were given under this programme. In June 2007, the PRSP installed 12 dome-type biogas plants in Pasrur Tehsil in Sialkot district with the help of the Foundation for Integrated Development Action (FIDA).
2. An NGO, Koshish*,* helped villagers to build more than 200 biogas plants in Sialkot.
3. The Pakistan Council of Renewable Energy Technologies (PCRET) installed 4,015 biogas plants with a net generation capacity of 17,980 million m^3 per day on a cost-sharing basis with the private sector throughout the country. In addition, the PCRET installed 30 commercial-sized biogas plants ranging from 50 million m^3 to 250 million m^3 by providing technological support and plant designs to end users, which helped generate power for irrigation and domestic consumption (International Trade Administration, 2019).
4. Revgreen Pakistan (private sector) is a biogas company that has recently been working on different projects in Pakistan and mostly installs larger-sized plants (capacity 200–1,000 m^3) (Wajahat Ullah Khan Tareen, 2019).
5. Reon Energy Limited, a subsidiary company of Dawood Hercules Chemicals, offers services for the construction of fixed dome biogas plants with an improved design. Reon installed 22 large biogas plants (50–400 m^3) for power generation in 2008–13 on a payment basis. Clients include large farmers, companies and entrepreneurs.

Poultry sheds

A poultry shed is a type of housing that features big exhaust fans on one side and evaporative cooling pads on the opposite side, with automatic feeding and drinking systems. The housing maintains ventilation, temperature, relative humidity and lighting.

A farm of 35,000 birds needs an estimated PKR 25 million (National Bank of Pakistan, ND), which includes machinery, equipment and working capital, making it out of reach for small farmers. Since the housing is climate-controlled, it reduces the animals' exposure to adverse climatic conditions and temperature-related stresses.

Additionally, as chicken manure contains ammonia, better manure management in this system allows for a reduction in the associated greenhouse gasses. Normally, broilers are raised on floors where, if too much manure starts to accumulate, the ammonia produced by the manure starts to affect their eyes and feet. This phenomenon is more prevalent in a humid environment such as Pakistan. A broiler cage ensures that the birds are never in contact with the manure. Additionally, there is a manure belt that can be cleared out periodically to ensure that ammonia never accumulates within the cage.

Status of adoption in Pakistan:

Locally manufactured mobile poultry sheds for free-range, layer and desi poultry farming have been introduced in Pakistan and could be promoted to small farmers. It is similar to an open-sided shed but is technically a better environmentally controlled/efficient air circulation system shed. The shed is different sizes, hosting 300–1,000+ birds (a 13 x 30-foot shed holds 1,000 birds). The cost ranges from PKR 250,000 to PKR 700,000. For cross-ventilation, the shed is opened from the sides and the floor using metal mesh, which also manages the litter problems. The shed is well lit using a solar system, especially during the night. This is cheaper and ensures pest control. This technology can be adopted by small farmers.

Poultry waste management

Poultry waste can be managed in notably three ways:

1. **Biogas:** One of the most common approaches for poultry excrement managed by water flushing is anaerobic digestion, which yields biogas. Biogas can be used as an on-farm energy source for heat or as a fuel for various engines that generate electricity.
2. **Fish feed:** Broiler poultry litter contains 25%–50% crude protein and 55%–60% total digestible nitrogen and is also rich in essential minerals. When poultry litter is processed by an acceptable method, it serves as a very economical and safe source of protein, minerals, and energy for fishery.
3. **Fertilizer:** Chicken manure contains ammonia and has been efficiently used as a fertilizer.

Status of adoption in Pakistan:

The Muhammad Nawaz Shareef University of Agriculture (MNSUA) in Multan developed fish feed from poultry litter but requires support in its commercialization.

Table 12 Summary of major constraints and recommendations for selected climate-smart technologies in Livestock

SILAGE BAILING AND WRAPPING	
Major Constraints	1. High capital cost 2. Low availability of silage 3. Lack of awareness of benefits
Recommended Interventions	1. Rental model to be promoted. 2. Provision of loans and lease arrangements on soft terms to service providers (farmers, technology providers or farmer associations/cooperatives) (Hyderabad, Thatta and adjoining areas of lower Sindh). 3. Large-capacity units to produce and market large bales for corporate farmers and livestock clusters such as Landhi and small bales (40 kg) for small farmers (including women) in rural areas. A well-established stocking and distribution system is required for outreach to small farmers, probably through common facility centres or feeder markets. 4. Collaboration with technology providers to create awareness in dissemination of technology (technology demonstration). 5. Localize the technology through support from PARC, Centre for Agricultural Machinery Industries (CAMI), Mian Channu and the UAF. 6. Dire need to introduce high-yielding/drought-tolerant multi-cut fodder varieties using farmer field schools approach – ryegrass, Rhodes grass, Lucerne grass, SS hybrid and mott grass. Establish demonstration plots and undertake cost–benefit analysis/business viability for further dissemination of the technology (Hyderabad and Thatta, Tharparker). 7. A well-established bulk stocking and distribution system is required for outreach to small farmers, probably through stockists, common facility centres or feeder markets. 8. Hermetic bags and drums introduced by Haji Sons and the UAF need to be introduced to farmers for the storage of cut green silage (see https://pdf.usaid.gov/pdf_docs/PNADQ897.pdf).
TOTAL MIXED RATION	
Major Constraints	1. High capital cost 2. Low availability of TMR 3. Lack of awareness of benefits
Recommended Interventions	1. Rental model to be promoted. Provision of loans and lease arrangements on soft terms to service providers (technology providers, stockists or farmer associations/cooperatives) (Karachi, Hyderabad, Thatta and Tharparker). 2. Collaboration with technology providers to create awareness in dissemination of technology (technology demonstration). 3. Localize the technology through support from PARC, Centre for Agricultural Machinery Industries (CAMI), Mian Channu and the UAF.
BIOGAS	
Major Constraints	1. High investment cost 2. Lack of an organized approach to scale up 3. Poor-quality and performance of small plants 4. Lack of appreciation for fertilizer value of bio-slurry
Recommended Interventions	1. Grant/subsidy at initial stage to reduce the cost of plant construction to scale up demand, attracting the private sector to establish manufacturing facilities adapting quality control. The subsidy should be routed through participating private companies to give the project a lever to ensure quality control. 2. Target community-based projects and rural commercial farmers with enough manure for plant requirement. Develop success stories (Karachi (Landhi)[13], Hyderabad, Thatta and Tharparker in Sindh) (Quetta and Noshki in Balochistan).

[13] The cattle colony of Landhi in Karachi is the most feasible site in Pakistan for a biogas plant project. This cattle colony covers approximately 3 km^2 and has an estimated population of 400,000 animals, making it one of the world's largest cattle

	3. Collaboration with relevant NGOs with experience, technical expertise and outreach, such as Rural Support Programs Network and the Pakistan Council of Renewable Energy Technologies (PCRET), to disseminate technology. 4. Establish demonstration farms for creating awareness among farmers of the benefits of using bio-slurry/compost. Support producers to develop a proper compost product, packaged and marketed through distribution system. 5. In addition to the potential for household plants, Pakistan has good potential for larger biogas plants that can be used to meet the energy needs of larger farms and as a convenient way to manage and even market manure. It is estimated that this commercial market might be as large as 100,000 biogas plants in Pakistan in the 30–100 m^3 size range (Bikash Pandey, United Nations Development Programme, 2007). If diesel tube wells are converted to biogas. 70%–80% of the high-speed diesel cost (PKR 200 billion) can be saved every year. 6. Formulate a policy with incentives to promote the technology.

Indigenized technology

The most common practice for livestock in Pakistan, especially for open grazing, is to create multiple sheds using local wood for animals to rest.

Some businesses have introduced mobile poultry sheds and other research such as inexpensive evaporative cooling for poultry settings. Similarly, researchers have shown that inexpensive evaporative cooling can be used to reduce a shed's temperature in warm weather. Broilers, unlike human beings, lack sweat glands and undergo panting to mitigate their latent heat. Therefore, moisture production inside the poultry shed needs to be maintained. Shahzad et al. (2021) developed low-cost and environmentally friendly improved evaporative cooling systems (direct evaporative cooling, indirect evaporative cooling and Maisotsenko cycle evaporative cooling). Maisotsenko cycle evaporative cooling performed better than the other two (Table 13).

Table 13 Energy-efficient evaporative cooling systems for poultry farm application in Multan

Evaporative cooling technique applied	**April, May and June (Decrease in Temperature)**	**July, August and September (Decrease in Temperature)**
Direct evaporative cooling	7°C–10°C	5.5°C–7°C
Indirect evaporative cooling	5°C–6.5°C	3.5°C–4.5°C
Maisotsenko cycle evaporative cooling	9.5°C–12°C	7°C–7.5°C

associations. The animals produce approximately 4,200 tons of manure each day and, thus, have an electricity-generating capacity of 20–22 MW. The Karachi Electric Supply Company set a target of 500 MW in 2020, which will increase to 1,500 MW in 2030. Electricity generated from this plant will be fed into the national grid to meet the country's growing energy demands (Wajahat Ullah Khan Tareen, 2019).

Chapter 4: Climate-smart practices

Climate-smart practices are activities that are locally applied with the aim of overcoming challenges posed by climate-change and improving farm productivity and profitability. This could include for example, water management techniques and soil moisture conservation.

Persian Wheel

Subsistence farmers who cannot afford to switch to newer systems still use Persian wheels in many parts of Pakistan. The technology is still costly and difficult to maintain, as animal power and maintenance is needed. It is, however, interesting to see how the bullock-driven Persian wheel has also found its application with other machines such as fodder chopping, especially when labour availability is limited.

The same practice was modified for the *barani* (rain-fed) region where the Potohar Organization for Development Advocacy (PODA) trained farmers to store and maintain excess rainwater and raise it using earthen pots and animal power for irrigation.

Karez

Karez is an indigenous method of irrigation in which groundwater is tapped by a tunnel. After running for some distance, the tunnel comes out in the open and the water is conducted to the command area. In Pakistan, this practice is limited to Balochistan. However, due to extreme groundwater extraction, the water levels are so low that the practice has become redundant.

Mulching

Mulching is the method of covering soil, which makes soil more favourable for plant growth and nourishment. Different types of materials are used for mulching, such as kitchen scraps, hay, straw, leaves, grass clippings, shredded bark, sugar bagasse, animal manure, sawdust, shells, whole bark nuggets and wool. Natural materials for mulching include straw, leaves, hay, farm residues, compost, bark, saw dust and even wool, while the inorganic mulches include plastic mulch, organic sheet mulch, rock and gravel. Organic sheet mulch has the advantage of being biodegradable.

According to a field study conducted in Nuclear Institute of Agriculture's experimental farm in Tandojam, wheat straw retained maximum soil moisture and yield, followed by rice husk and then poultry litter. These findings suggest that wheat straw could be used effectively for mulching to conserve soil moisture and increase crop productivity (Depar, 2014). Some benefits of organic mulches include reduction in the evaporation losses from the soil surface, enhanced water use efficiency and chemical control of weeds, which create environmental hazards and have residual effects on crops.

In difficult climatic and soil conditions like that of Sindh, local drought- and saline-resistant plants and are used to reduce salinity and improve the soil's organic content.

Plastic can also be used as mulch. Plastic mulch controls weeds and moisture more efficiently and a mulch with a drip shows even better results compared to an organic mulch. Biodegradable plastic mulches offer an alternative to polyethylene mulches, which is desirable, because they can reduce non-recyclable waste, conserve resources, and decrease environmental pollution. However, it is an expensive option. Black mulches are usually used, as they are the least expensive. There is no analytical data available on plastic mulching for fruits and vegetables in Pakistan, but statistics for India show a 45.23% yield increase in mangoes and a 33.95% yield increase for bananas (National Committee on Plasticulture Applications in Horticulture, New Delhi).

The use of plastic in mulching is gaining importance in Pakistan due to its benefits. Its success has particularly been demonstrated for crops such as strawberries, which are delicate (PARC).

Due to limited demand, there are few companies manufacturing plastic mulch sheets locally and some companies are importing it from China.

Major plastic mulch suppliers for farmers include Agribusiness Pakistan in Rawalpindi and Premier Plastic Industries Pvt Ltd in Karachi.

Local stores selling plastic sheets supply low-quality plastic to farmers across Pakistan. Various studies have identified that most farmers in Pakistan use local low-cost plastic mulches, which are thin and tend to tear and fragment, after which they are difficult to recover, leading to soil contamination. Crops grown in soil containing plastic debris exhibited low yields (Zhang, D., Ng, E.L. & Hu, W. et al., 2020), discouraging farmers from adopting the technology.

Lastly, the manual installation of plastic mulch is also time-consuming and labour-intensive, thus, costly.

Bunch-covers (for dates and bananas)

Bunch covers are bags that are put over dates and bananas bunch to physically protect them against damage, including from rains, insects, birds. They also improve crop productivity, quality and hasten the fruit ripening process. With the date harvesting season coinciding with the monsoon rains in July and August (that can cause huge losses of 60% or more)[14], bunch covers are becoming increasingly important.

DuPont Pakistan Operation Pvt. Ltd is the sole supplier of bunch covers in Pakistan. It provides Tyvek® banana and date covers through its authorized distributor, S.K. Enterprise, which promotes bunch covers through distribution of leaflets and messages on WhatsApp groups. Moreover, S.K. Enterprise assembles farmers from the surrounding areas at demonstration sites to educate them about the use of bunch covers and practically show them the results.

There is a need to establish demonstration sites for dates and grapes at cluster level and undertake cost–benefit analysis/business viability to be disseminated to potential farmers (banana – Thatta and Khairpur; dates – Khairpur, Sindh) (dates – Pangjur; grapes – Pishin, Balochistan).

Plantation of salt-tolerant species

Hurri plantation is a block plantation method of a local species, *Acacia nilotica*. It is an indigenous agroforestry practice where trees tolerant to salinity are planted to combat land degradation and reclaim the soil fertility of land facing desertification. The Research and Development Foundation (RDF), a local NGO, has been helping farmers in Sindh to sow hurri by providing acacia seeds and financial support for land preparation. It is now spread across several districts and has helped farmers get their lands back to cropping other staple crops. Other crops that are more salt tolerant can also be used (e.g. barley). A similar process of land rehabilitation using local shrubs was also reported for Pishin, Balochistan, but more information was not made available.

Agroforestry is often also used for land demarcation and security by many farmers across Pakistan. It is also important to note that more farmers are converting their lands into horticulture for improved income.

Composting

Composting is a process of degradation of organic waste in aerobic conditions. The by-product can be used as a soil conditioner. This reduces the load on solid waste dumpsites and the issue of methane plumes emerging from them. The nutrients in compost reduce the need for fertilizer and, therefore, reduce input. The organic waste on farms is generally divided into browns (carbon-rich), greens (nitrogen-rich) and water-rich.

Not many farmers are aware of composting as a practice to create nutrient-rich soil conditioner. Farmer field schools have started including composting into their training modules. There are, however, some small and large-scale organizations that propose composting in urban settings to sell compost as a product for kitchen gardening. Two organizations that are revolutionizing composting in urban settings are a start-up called TrashIt (based in Karachi) and the Integrated Resource Recovery

[14] In 2022, unprecedented rains caused heavy damage to dates (approximately 85% destroyed).

Centre (IRRC), an NGO that has set up compost units for communities in Islamabad (for a sector) and Mardan (for 39 out of 72 neighbourhood councils) and plans to install more, with government support.

Animal manure's use for biogas production reduces the emission of methane, reduces reliance on fossil fuels and is a good source of fertilizer.

Weather – Early Warning Systems

The most advanced practice of the early warning system is developed by elders in village of Nahar Kot, Barkhan district, Balochistan for disaster risk reduction. The community has passed on knowledge through generations about early warning of weather-related calamities for disaster management. Approximately 96 families reside in the village, with the majority relying on cultivation for their livelihood. The community, like other vulnerable communities in the region, has a keen observation of wind and animal behaviour to forecast the weather and prepare early for it. The two ways in which weather is forecast by the community are:

1. Wind-based early warning system (Table 14). The local people recognize approximately seven types of winds, which enable them to predict the weather, its severity, droughts and other climatic changes.
2. Animal behaviour-based early warning system (Table 15).

Table 14 Wind-based weather forecasting in Barkhan, Balochistan

Wind	Start	End	Direction	Expected outcome
Dakanr	Mid-June	Mid-Sept.	East to west	Good rain – growth of herbs, shrubs, crops and trees
Gari	Mid-Jan	Mid-March	North to south	Severe increase in cold, impacting human health and reduction in yield due to crop damage. Reduced fodder also impacts livestock health.
Lakhe watt ti	–	–	West to east	Drought, famine and rain scarcity
Phal Vikerni or Run Choor	April	July	North to south	Anti-cloud wind. This type of wind devastates the crop and reduces yield.
Purkho	Mid-July	Mid-Aug.	East to west	Useful in decreasing weather severity.
Lawar (summer wind)	Peak summer		–	Increase in severity of heat; the possibility of rain is reduced; herbs, shrubs and crops damaged; stomach issues and diseases in livestock
Khooni	Three days with dust storm		West to east and south to north	Distresses animals and humans

Source: Authors' interviews

There is special regard for sheep in the community. Sheep are considered to be harmless, innocent and sacred. Natives believe that an ewe has certain spiritual powers that enable her to predict any expected change in the environment.

Table 15 Animal-based weather forecasting in Barkhan, Balochistan

Animal	Behaviour	Expected outcome
Sheep and goats	Keep their face towards the east, put their fore limbs on a stone and look upward to the	Indication of clouds and rain

	sky	
Sheep	Move their head very fast at night, causing their large ears to strike their faces and make a noise	A symbol of clouds and rains – farmers prepare for rain
Sheep and goat herds	Animals look happy on the way to and from the meadows from their shelter	Taken as good news for rain and prosperity in the area
Dog	Barks in a loud, drawn-out manner	The danger of some unknown disaster likely to occur soon
Jackal	Comes close to the village and howls	Symbol of impending calamity
Ants	Move in long rows carrying their eggs and other food items to a new destination	Rain is expected within a few days
Frogs	Make a lot of noise	Indicators of rain within a week
Others	A large yellow termite is seen in the field	An indicator of rain in coming days

Source: Bakhsh et al. (2012)

Pest Management

The concept of integrated pest management (IPM) is taught at several farmer field schools (FFS) and commercial suppliers have started selling biopesticides and fertilizers under commercial banners. For example, BinQain Agro Services provides biofertilizers and pesticides online. They also run educational consulting for farmers to make better decisions. Similarly, the success of case studies of neem plant biopesticide as repellents on Dua Foundation farms is also demonstrated for trees (in Sindh). In general, the increased use of pesticides has caused great damage to the natural management of pests. However, with regenerative agriculture practices such as PQNK, friendly bugs can be welcomed back to farms.

The general practice of putting a dummy human in the field or playing noise to scare away flies and locusts is also a common practice in several regions all across Pakistan.

Artificial pollination for Dates

Artificial pollination is a technique of pollinating plants without the help of wind or insects and is carried out by humans.

In Pakistan, commercial date production requires artificial pollination, which ensures fertilization and overcomes dichogamy as well as a reduction in the number of male palms. There are three common techniques of pollination used for date palms:

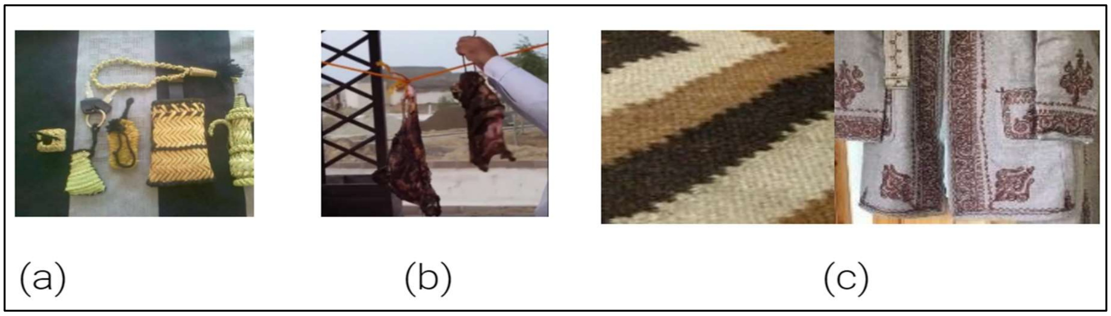
1. **Fresh male strands:** The most common pollination practice is to cut the strands of male flowers from a freshly opened male spathe and place two to three of these strands, lengthwise and in an inverted position between the strands of the female inflorescence. This should be done after some pollen has been shaken over the female inflorescence. To keep the male strands in place, it is recommended to use a twine to tie the pollinated female cluster 5 – 7cm from the outer end.
2. **Pollen suspension:** Pollination sprays are found to be as good as hand pollination in relation to fruit setting. A suspension solution containing pollen grains can also be aided with sucrose, boron and glycerine.
3. **Dried pollen:** This pollination technique is more economical and allows proper use of the pollen as well as adequate control of the timing of pollination. Dried pollen could originate from the last season, from early maturing males of the same season, or from male flowers that are a few days old. There are several techniques to apply dry pollen, such as cotton swab (dust dry pollen on cotton pieces between the strands of female inflorescences) or an insecticide duster called puffer.

The number of spikes depends on the cultivar. For example, for aseel, 4–5 spikelets are used for good fruit quality, but 2–3 spikelets can also be used to get less fruit with a bigger size. As fruit quality depends on the pollen grain source, farmers used to buy male spathes at the beginning of the season from the market.

Agriculture by-products

Localized food, horticulture and livestock by-products are of more economical value. For example, a single woollen carpet can sell at the same price as the income achieved from an acre of land. Some such products are highlighted in Figure 4.

Figure 4 Localized agriculture by-products



a) Banana leaves that are otherwise burnt can be used as mulch or products as displayed.

b) Dabaahg, an ancient Balochi technique of marinating meat with pomegranate, has been demonstrated to improve the shelf life for many months.

c) Rugs and coats made from livestock wool in the north of Pakistan.

Source: Shared by locals.

Traditional dairy products such as butter, *hard* (*Quruth/sheelanj* in Balochistan and north of Pakistan), local jams and murrabas, as well as locally processed meat, can also be branded for agritourism of these communities. Date syrup is also prepared locally in Balochistan. Sun-dried tomatoes, grapes and dates are examples of how the community has adapted to saving food losses using simple sun-drying processes.

Raised bed technology

Raised bed is an agricultural technique of building crop beds above the existing levels of soil. They can be rectangular or irregular in shape and do not need to be too deep to be productive. There are two types of raised bed design:

1. Without support: This requires no additional material and looks like a flat top mound. This is usually used in large-scale and commercial farming
2. With support: This is a framework made of plastic/brick/stone/untreated wood that supports the raised bed.

The advantages of raised beds include water saving of up to 50% and yield increase of up to 25%. Raised beds also increase water and fertilizer efficiency, reduce GHG emissions due to reduced input, improve nutrient use efficiency, especially in drought-prone areas. They are easy for manual and combined harvesting, with less weed infestation, increase crop intensity and income and better drainage of water in the rainy season.

It should be noted that beds are neither suitable for sandy soil nor all crops (owing to bed sizes).

The adoption is high due to lower costs compared to HEIS. However, bed-making machinery is not readily available in Pakistan.

More relevant in Pakistan is the idea of permanent raised beds i.e. Paedar Qudrati Nizam e Kashtkari (PQNK). It is also known as paradoxical agricultural, which was designed using a self-sustainable model of a natural ecosystem (Figure 5) by founder of Pedaver in Punjab. He also designed the relevant machinery, the designs of which are open and free for people to replicate. The key features of the PQNK practice include:

- Making the bed and furrows where furrows will act as waterways while the plantation will take place on the beds.
- The soil is not disturbed, so the beds made are permanent and only reshaped (no tillage);
- The soil is always covered. Organic mulch is used to cover the soil while waste roots also improve the permeation of air and water into the soil.
- These features allow for the soil's natural biota (bacteria and fungi) in nitrogen fixation and plant communication, diminishing the need to use fertilizers.
- The practice does not allow the use of pesticides, because, as a farm transforms into a PQNK farm, there will be no pest attacks.

Figure 5 How PQNK works

- Beds are permanent and are not watered.
- Furrows, compacted by tractor tyres, allowing for the water to move laterally towards the bed. Similarly, the roots also reach out for water, resulting in spread-out roots that also act as tunnels for biota during and after a plant's life.

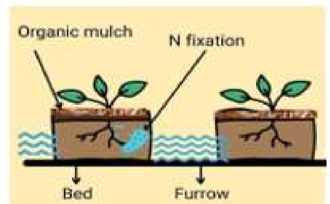
In natural ecosystems, the soil is always covered and hardly ever distributed. The nutrients keep recycling back to the soil. Bacteria have a key role to play in fixing nutrients and creating more food. The soil pH, temperature and natural biota are maintained and play a key role in biodegrading and availability of nutrients.

Advantages

- No input/low input for fields in transition, revival of soil microbiota, reduced water application due to soil cover and hardpan furrow, and no pests attracted.

Challenges

- Practice and machinery testing in different context; scaling up of the practice (capital).



Machinery	Role
Scrapper (soil shifter)	Land preparartion
Laser leveler	Land leveling
Subsoiler	Deep ploughing/ chisel for sowing season
Bed Maker machine	Implant for permanent bed making and bed shaping
Planting machine	Precision planter for smart and controlled sowing of seed

Source: Author

Chapter 5: Recommendations

A wide variety of climate smart technology is available in Pakistan. With respect to horticulture, hybrid seeds, drip irrigation, laser levelling, tunnel farming, pre-cooling systems, hermetic packaging and solar dehydration have been examined in this report. For livestock, the identified technologies include the ones used for silage bailing and wrapping, artificial insemination, milking, poultry waste management total mixed ration and biogas.

There is a need for more coordinated research, awareness and action at all levels of the value chain for agricultural technologies and practices to be climate smart. Some recommendations are given below to increase the uptake.

For sector associations and business development support services

Develop a rental model to help farmers afford technology

These technologies can effectively be made available to smallholder farmers by promoting the rental mechanism through properly organized and funded service centres.

Provide grands and technical assistance to help set up private farmer service companies.

It is also recommended that private sector entrepreneurs be assisted through grants and technical assistance in setting up private farmer service companies. These companies will improve responsiveness to farmers' needs in terms of input supply (fertilizers, seeds, and pesticides, etc.), services (mechanized labour, technical advice, certification and marketing, etc.) and information, especially regarding climate technologies. The companies would also act as hubs for knowledge and technology dissemination as well as marketing of agricultural and livestock commodities.

Create demonstration sites to build farmers' capacity.

It is essential that demonstration plots be used for farmer training and capacity building at these facilities, as dissemination and uptake among farmers in Pakistan is most effective through 'seeing is believing' and they learn best by doing.

Regenerative agriculture practices that combine ridges, mulching, irrigation efficiency and input reduction have been prioritized. However, it is essential that additional scientific research is supported to complement the scaling up of the practice, which should be adapted to Pakistan's varying local contexts. Machinery development and renting centres alongside training on the practice is also needed.

Documentation of agricultural practices can be prioritized and, where possible, kept side by side with modern technologies. Seed banks of local varieties should be created and local species in horticulture and livestock should also be documented for a more informed future alongside digital agriculture.

Carry out cost–benefit analyses of technologies and practices.

Cost–benefit analyses and impact studies for various climate technologies also need to be conducted and disseminated in a form that is easily digestible for farmers.

Develop viable business cases to commercialize private sector technology.

It is also important that, in cooperation with interested private sector entrepreneurs, economically viable business models be created for various technologies to make them attractive and self-sustaining.

Academic organizations that have focused on solving local and global challenges of food and water security faced on the ground should be supported for scaling up of indigenized technology. Scaling up includes mass manufacturing and deployment on the ground for academic and impact studies of the interventions on small watersheds and bigger basins. These tools and the information provided will help policymakers greatly, as most numbers are generated from hypothesized numeric and not through extensive studies on the ground.

Provide verified and authentic information through ICT and already established networks.

To raise awareness, disseminate information and highlight benefits regarding climate technologies, it is recommended that NGOs such as the Sindh Rural Support Organization (SRSO) and the National Rural Support Programme (NRSP), with good existing coverage in Sindh and Balochistan, be engaged for climate technology, practice awareness raising and develop verified and authentic information sources for farmers using ICT mediums.

Targeted activities should be drawn for women and vulnerable groups.

It is important that women and vulnerable groups are provided to technology. While doing so, it is important that a consultation is established for the women who cannot afford to take risks with finances. Existing businesswomen who have started businesses and lack the financial support to scale them up should also be supported. A value chain approach should be taken while building women's capacity. Depending on their role in the value chain or in the field, their capacity building should take place through the relevant organizations. The capacity building of provincial commerce, social welfare and women departments should take place simultaneously.

For policymakers

In terms of policy, there is a need to channel policies for sizable investment in research, specifically action-oriented research. Actions are already in place at the federal level to build evidence-based research/guidelines for climate-smart interventions and technologies, taking into consideration strategies/actions that have proven to be effective to increase their applicability in specific locations. Policies formed need to promote research priorities in climate-smart crop production, including the investigation of methods for adapting farming practices and technologies to site-specific conditions and needs.

Annexes

Annex I List of institutions, farms and universities visited.

1. Agriculture Delivery Unit (ADU), Davis Road, Garhi Shahu, Lahore
2. Agriculture Department, Punjab
3. Agro Power, Rohi Nala Road, Lahore
4. Australian High Commission, Diplomatic Enclave, Islamabad, Pakistan
5. Ayub Agricultural Research Institute (ARRI) Faisalabad
6. Bio-Being
7. Biogas Plant, Bedian Road, Lahore
8. Burak Agro
9. Ch Sharif Dairy Farm, Raiwind Road
10. FAO, Multan
11. Farm Dynamics Pakistan
12. Green Mark Tunnel Farming
13. Gujranwala Agricopak office
14. Gujranwala Mehr Muhammad Din & Sons (MDS) office
15. Gujranwala NTL Seed Company office
16. Haji Sons, Lahore
17. Haq Ice Cream
18. Horticulture Research Institute, Agricultural Research Center, 9 Cairo Univ. St., Orman, 12619, Giza, Egypt
19. International Water Management Institute, Pakistan
20. Biogas Plants for Communities Lead, Iqra Zaheen, Mailsi (near Multan)
21. Jaffer Brothers Pvt Ltd, Hyderabad
22. Balochistan University of Engineering and Technology Khuzdar; farmers; farmers' union
23. Kunri Market
24. Lasbela, district commissioner's office
25. Lasbela University of Agriculture, Water and Marine Sciences; tomato and litchi farmer; seed provider
26. Livestock & Dairy Development Department Punjab
27. Ministry of Climate Change
28. Chilli farmers in Mithi, Tharparkar
29. Mubarakabad: on-farm weather station
30. Muhammad Nawaz Shareef University of Agriculture (MNSUA), Multan
31. Munif Livestock Farm
32. Mustafa Farms owner
33. National Agriculture Research Centre (NARC)
34. National Agriculture Robotics Laboratory (NARL), LUMS
35. Nature's Best
36. Nushki, field visit
37. Panjgur district commissioner's office; livestock and agriculture departments; date farmers
38. Panjgur district commissioner's office; agriculture and livestock and extension
39. Pattoki livestock farm
40. Pedaver, Raiwind Road
41. Pishin: grape farmer
42. Pishin: livestock farm
43. Pishin: Murabbas farmer
44. Potohar Organization for Development Advocacy (PODA), Dr. Adnan
45. PQNK farm, Lahore
46. Punjab University Botanical Garden
47. Quetta: livestock and agriculture departments; extension department; Pakistan Environmental Protection Agency (EPA); women and social welfare departments; FAO
48. Rana Ashiq (World Bank), Hyderabad
49. Rural Development Foundation of Pakistan
50. Sabzi Mandi near Rohi Nala Road
51. SIAPEP, Hyderabad
52. University of Agriculture Faisalabad, Climate Smart Lab, Faisalabad
53. University of Agriculture Faisalabad, Institute of Business Management and Sciences (IBMS), Faisalabad
54. Umerkot drip irrigation farm visit
55. Umerkot mango orchard
56. University of Veterinary and Animal Sciences (UVAS), Lahore
57. Winrock International

Annex II Long List of Practices

1 Animal power/dug well irrigation
2 Phytoremediation
3 Laser land leveller
4 Tractors designed for bed and furrow
5 Scrapper for land preparation
6 Bed maker for permanent bed making
7 Planting machine
8 Subsoiler for deep ploughing
9 Soil-less agriculture
10 Smart (pest) trap
11 Evaporative cooling of poultry farms
12 Mobile poultry sheds
13 Canal gauge
14 Automatic weather station
15 Water quality sampler
16 Forest health monitoring app
17 Biopesticide
18 Biofertilizer
19 Artificial pollination
20 Earthen pots/matkas for drip
21 Waste food mixed with hay as fodder
22 Banana leaves by-products
23 Animal wool by-products
24 Food products
25 Compost
26 Biogas
27 Bullock-driven farming (tilling)
28 Noise to keep away flies/locusts
29 Agroforestry
30 Home-based remedy
31 Wooden tools for agriculture
32 Indigenous weather forecasting
33 Boomer spray
34 Zone disk tiller drill
35 Boom Sprayer
36 Rhizo gold
37 Glacier grafting
38 Wooden shelves for sun drying of apricot

Annex III Support Services in Balochistan and Sindh

This Annex describes the different support services available, their roles and the current gaps in service provision in the horticulture and livestock technologies sector in Sindh and Balochistan. The following categories of support service providers were considered:

- Public extension services;
- Private extension services;
- Informal market information providers;
- Formal market information providers;
- Access to finance (microfinance institutions);
- Academia and research and development (R&D) organizations;
- Networks, institutions, public bodies and platforms.

Public extension services

Public extension providers play a key role in Pakistan's agriculture sector. In both Sindh and Balochistan, these services come under the agriculture departments. Departments suffer from inadequate operational funds, lack of relevant technology, lack of capacity and awareness on climate technologies, top-down planning, centralized management and a general absence of accountability. Extension workers cover huge swathes of geographic area, much of which is rural in Sindh and Balochistan, and with a poor extension worker to farmer ratio (1:6,881 in Sindh). Services do not therefore reach most small farmers. Farmers interviewed by the team in Sindh and Balochistan noted little interaction with extension workers. The contact between extension workers and farmers in Sindh was better than in Balochistan. When it comes to climate technologies, high-efficiency irrigation systems (HEIS) and tunnels are the two major interventions being promoted by extension departments, with little work being done in any other area.

Like the rest of the country, in Sindh and Balochistan, agricultural extension is modelled around a training and visit system, which relies on contact farmers to diffuse technical information to surrounding farmers. There is little oversight on whether the diffusion of information through this manner is undertaken.

In Sindh, the Department of Agricultural Extension headquartered in Karachi falls under the Agriculture, Supply & Prices Department. The extension department works to equip farmers in all of Sindh, particularly in rural areas, with agricultural knowledge. The extension department aims to help farmers improve their farming capabilities and embrace and diffuse agricultural innovations, including climate technologies to some extent.

In interviews with farmers in Sindh, the WIT team found that, while extension workers in Sindh did provide good knowledge regarding practices and technology to farmers, their visits were confined to a few farmers and too spaced out to have a meaningful impact. Furthermore, farmers were of the view that extension workers need to present technical backstopping and problem-solving for farmers during major crop cycles, which is currently not the case. The extension department transfers agricultural knowledge to farmers through face-to-face consultation services, field demonstrations, mass media, electronic media and ICT technologies. The team found that most extension workers lacked proper knowledge regarding climate-smart practices and technologies (other than HEIS and tunnels) and were thus unable to raise awareness about them.

The Directorate General, On Farm Water Management assists farmers all over Sindh to increase productivity and optimize the use of irrigation water through the lining of watercourses, construction of water storage tanks and adoption of technologies such as HEIS. The on-farm water management sub-department is headquartered in Hyderabad and has offices in Dadu, Khandkot and Hyderabad (several others under construction). The team found that the department's focus was on lining watercourses (through different federal public sector development projects and Sindh annual development projects) and HEIS.

The Agriculture Research Wing of Sindh based in Tando Jam conducts research on high-yielding and climate-resilient varieties of field, fruit and vegetable crops concerning drought, heat, salinity, insect and disease tolerance. The research wing works to improve crop production and obtain optimum yields based on research experimentation. It was found that the wing lacked a proper research budget. Overall, it was noted that there needs to be greater synergies between the research wing and farmers' needs so that the wing could offer practical and cost-effective solutions to them. In addition to its research work, the wing also claims to offer consultation services to farmers through field visits and soil and water testing facilities.

The Livestock & Fisheries Department in Karachi offers services to all livestock and fishery farmers in Sindh. The department works to increase production of livestock, poultry and fisheries through initiatives that control diseases in livestock, introduce high-yielding new breeds, preserve domestic breeds and increase stocks and products by introducing new technologies and value chains (to transform the sector from subsistence to market-oriented farming). The department is also working to introduce new technologies in aquaculture, fish farming, dairy and poultry farming. The department has veterinary officers and para-veterinary staff who are deployed in the field, but the number of these veterinary professionals is not adequate to cater to Sindh's large livestock population.

The Sindh Seed Corporation (SSC) is mandated to work on streamlining the seed multiplication system to produce basic seed and to procure and distribute certified seed. The SSC is also charged with producing basic seed for further multiplication at registered growers' farms and supplying it to private seed companies. The certified seed is then supposed to be distributed to growers in Sindh by the SSC at affordable rates. Despite the SSC's efforts, the team found that there was a serious dearth of quality and certified seeds across Sindh, due to which farmers were suffering.

In Balochistan, the Directorate of Agriculture Extension falls under the Balochistan Agricultural and Cooperative Department. The directorate is headquartered in Quetta. It works to equip farmers and all farming communities in Balochistan with agricultural practices and technologies. During our visit to Balochistan, we found that the level of extension services outside of Quetta was sparse. Furthermore, the limited number of farmers we interviewed during our visit to Balochistan indicated little to no contact with extension workers. Farmers in Balochistan are generally less aware of good agricultural practices and technologies in comparison to the other provinces. Farmers we interviewed were more focused on getting access to conventional practices and technologies that improve productivity rather than those that are climate smart.

The team found that most extension workers lacked proper knowledge of climate-smart practices and technologies (other than HEIS and tunnels) and were thus unable to raise awareness regarding them. The team also found that, due to the high cost of the basic structure for tunnels, the Government of Balochistan is encouraging the private sector to invest in tunnel farming systems in various districts by starting joint ventures with farmers or providing financial assistance to farmers for the start-up cost to promote it at a massive scale through the extension department. However, despite this, adaptation has been slow.

The on-farm water management directorate located in Quetta works to maximize crop and water productivity. This is done by promoting efficient conveyance, application and use of irrigation water through the promotion of improved water management interventions. As per its mandate, the directorate does the following:

- Organizes and registers water users' associations;
- Renovation, rehabilitation and improvement of watercourses;
- Strengthening of precision land levelling services in the private sector;
- Promotion of high-efficiency pressurized (drip and sprinkler) irrigation systems;
- Provision of solar power systems with HEIS;
- Provision of subsidy on installation of tunnels with HEIS;

- Development of small-scale irrigation schemes in areas that do not come under canal irrigation;
- Construction of water storage ponds/tanks;
- Provision of on-farm surface drainage facilities;
- Identification, acquisition, pilot testing/evaluation, indigenization and promotion/upscaling of the latest irrigation water management interventions/technologies through adaptive research;
- Capacity building of stakeholders (technical staff, trainers/extension workers and farmers) in improved water management interventions.

The directorate, like other sub-departments in the Agriculture and Cooperative Department in Balochistan, lacks proper funding and workforce to be able to effectively deliver on all activities in its mandate.

The Department of Livestock and Dairy Development in Balochistan works on the conservation of indigenous pure-breeds, identification of quality stock, multiplication of superior germplasm and dissemination, technical training in the field of animal husbandry/management, examination of nutrition requirements of livestock and chemical composition of feed and research on different economic traits of livestock.

The department also handles livestock production extension and livestock feed resources development. Like the Agriculture and Cooperative Department, the Department of Livestock and Dairy Development in Balochistan also lacks adequate funding and workforce to be able to effectively deliver for farmers. The number of veterinary and para-veterinary staff is not adequate to effectively cater to the province’s small ruminant population.

Private extension services

Extension services are offered by companies as after-sales services. These companies have a strong presence and coverage in Sindh, where they sell their products and offer after-sales services as an extension. In comparison, in Balochistan, most private companies operate through arthis or intermediaries and only sell products without after-sales services.

Jaffer Agro Services (Jaffer Group of Companies) supplies farm inputs such as pesticides and fertilizers and provides consulting services to farmers for output optimization. Some of their products include water-soluble fertilizers, bio-organic stimulants, plant growth-promoting bacteria-fortified fertilizer products and HEIS. The company also provides complete agricultural solutions through its products and farm advisory services, offering expert guidance to farmers for optimizing their yields. The company casts a wide net with its network of offices and warehouses across Pakistan. The group has good coverage in Sindh and limited coverage in Balochistan.

Four Brothers Agri Services works to improve yields through new technologies and modern farming techniques. The company provides field service to farmers at their doorstep. They conduct farmer meetings regularly to timely communicate recommendations and solutions to their problems while also guiding them at every stage of the crop production process for better yield. The company’s Tarzan Markaz (Pakistan’s largest franchise network as per the company) sells quality products and provides after-sale services. Demos are given on model farms for cotton, wheat, rice and vegetables, etc. The group has good coverage in Sindh and limited to no coverage in Balochistan.

The Engro Agribusiness Solutions Division works with farmers in Sindh and Punjab. It provides a spectrum of services from seed delivery to harvesting. The company also offers advisory services, including recommendations on access to buyers/markets. It has also signed an agreement with a Dutch company, Nelen & Schuurmans, to provide geospatial information services.

By using the geospatial data, stakeholders in the agri-value chain have access to an overview of crop quality over large geographic zones. Engro’s eventual goal with this data is to help farmers, buyers and crop advisors in timely decision-making and assist Pakistan with cutting-edge crop monitoring practices in the future. The work that Engro is doing is commendable, but its reach is limited to a small number of farmers.

Market information providers

Several market information providers operate in Sindh and Balochistan. However, almost all of them, especially those in the public sector, lack regular updates. Many major private agriculture input companies, agriculture-related NGOs and agricultural universities have online information portals via which information is available in English as well as Urdu languages. However, most of the information is academic and lacks relevance for farmers. In terms of the use of ICT, we found that the general ranking was: TV > cell phone > radio > social networks > computer with Wi-Fi.

In rural and remote areas of Balochistan and Sindh, a lack of mobile coverage and internet facilities in remote areas, illiteracy, lack of knowledge about the use of ICTs and poor economic conditions are the main reasons for farmers' limited use of market information providers.

The team also found that farmers in Balochistan and Sindh were heavily reliant on unverified and informal information providers such as WhatsApp and Facebook groups and YouTube channels for market, technology/practices and product-related information. The farmers the team interviewed told us about numerous cases where the information they had followed had resulted in losses.

Due to a lack of information, it was found that climate-smart technologies and practices are not a priority or even on the radar for most farmers. Little to no material exists on the benefits of various climate technologies and practices that can be used by farmers and the public/private sector for propagation. The information that does exist is more academic in nature and not easily digestible or of relevance to farmers.

In the public sector, the Directorate of Information Agriculture Extension, Sindh based in Hyderabad disseminates agricultural information among the farming community across Sindh through mass, electronic and print media (including publishing *Sindh Zara'at Magazine*).

The Balochistan Agriculture Marketing Information System (BAMIS) was developed with initial funding by USAID, FAO and the Australian Agency for International Development (AusAID). BAMIS is an online platform, open to all, which contains agriculture marketing data for different commodities in Balochistan. Prices can be checked date-wise or for yearly trends. The platform also has other relevant agricultural data such as that on agroecological zones in Balochistan. However, at the time of the compilation of this report, BAMIS was not reflecting up-to-date pricing data. BAMIS became non-functional once the donor funding ceased and now efforts are underway to revive it and make it operational again under GRASP. It is important that GRASP works on how to make BAMIS sustainable after the end of the project.

An ICT Agricultural Extension Services Centre was established under the Sindh Agricultural Growth Project (SAGP) and falls under the Directorate General Agriculture Extension, Sindh in Hyderabad (Agriculture, Supply & Prices Department). The centre provides ICT agricultural extension services to the farming community and strengthens the existing extension services ecosystem by equipping field staff with ICT tools and various approaches to enhance their capacities. The centre's key activities include up-to-date agri-marketing and weather data, farmers' helpline, text and voice SMS, Facebook live programmes, Android applications, a YouTube channel, mobile cinema shows and crop production technology booklets. Our team learned that the centre was doing great work on assisting farmers and similar initiatives needed to be replicated in other areas of Sindh and Balochistan.

The Agriculture Marketing Information Service (AMIS), under the Directorate of Agriculture, Economics and Marketing, Punjab, is an online platform where prices and arrival quantities of different commodities in Punjab are available. In collaboration with Punjab Information Technology Board (PITB), an AMIS app has also been developed, through which the Punjab Agriculture Department's marketing wing disseminates prices to the public. AMIS also has consolidated data for the world and Pakistan on exports, imports, cropping, yields and support prices, etc. While AMIS has data for markets in Punjab, the portal is useful for farmers in Sindh and Balochistan who need to sell in Punjab or get an idea of where prices are heading in the rest of the country. AMIS has been operating smoothly for a few years and, if studied, could provide lessons that could be applied to revitalize BAMIS.

BaKhabar Kissan was developed and operated by a local company, Switch Solution (Pvt) Ltd Pakistan, and supported by Oxfam International, the Australian Agency for International Development (AusAID, Jazz, United Bank Limited (UBL), Allied Bank and ICI Pakistan, etc. The networking platform (accessed via phone, SMS, an app, YouTube and WhatsApp) boasts 4 million subscribers. It provides information on technologies, actionable information regarding inputs and their usages, alerts to farmers most likely to be impacted, a conduit for the farmer to directly access consumers, daily updated current market rates and advice on raising, breeding and housing livestock using the best farm management practices. BaKhabar Kissan can be used as a medium through which climate-smart technologies can be promoted in Sindh and Balochistan.

Pedaver (PA-PQNK) is a free-for-all resource, which has 2,940 subscribers on YouTube and 26,641 followers on Facebook. The main purpose of the YouTube and Facebook group is to share information regarding the regenerative agriculture production system. The resource offers information, advisory services and market information to farmers via the YouTube channel, a WhatsApp group and Facebook page.

Khushaal Zamindar (KZ) is a free-of-cost interactive voice response service by Telenor providing agricultural advice to farmers in Pakistan. It also provides access to real-time weather conditions, tips for effective harvesting and live audio advisory services to farmers through mobile phones. KZ is also a leading provider of social, agriculture and environmental solutions. As of May 2017, 2.9 million customers had registered for the service (with 20% of them being women).

As mentioned already, the SIAPEP provides information to farmers across Sindh via brochures, booklets and radio shows regarding climate change and how it affects them, water conservation and management, HEIS and improved agricultural practices.

The irrigation advisory SMS service for farmers, open to anyone who registers, is managed by the Pakistan Council of Research in Water Resources (PCRWR) and was launched in April 2016. A collaboration between PCRWR, the University of Washington and the National Aeronautics and Space Administration (NASA), the service informs farmers about their net weekly irrigation requirements, considering potential evapotranspiration and precipitation. The University of Washington provides real-time daily potential evapotranspiration and precipitation for Pakistan using NASA's remotely sensed data.

The Peepu app aims to reduce farmers' reliance on intermediaries. Peepu is an agri-trade platform for both farmers and traders and facilitates farmers in selling their products at the earliest possible time and at a competitive price. Peepu also provides farmers the right of negotiation and security.

Ricult Pakistan is a digital app that works to increase the productivity and profitability of small farmers in the country by providing them with agricultural information, solutions for their problems and access to credit and the marketplace. Through the easy application process, farmers can get access not only to free agricultural information, but also to market for purchases and credit at flexible terms.

Kisan Zar Zameen is a health analysis app that provides multiple services to farmers and includes the use of multi-spectral imagery from satellites. Soil condition, crop health analysis and weather updates are provided through this app, making it a one-stop digital solution for farmers. By using this app, the user can detect crop stress at an early stage, benchmark crop performance and monitor crop growth. They can also request drone spraying and a mapping service that digitalizes the agriculture sector and helps farmers to increase yield.

Kissan Bazaar is an online marketplace where a farmer can buy and sell agricultural items. The app includes separate sections for fruits, vegetables, poultry and livestock. It provides an e-commerce facility to farmers, making it easy for rural farmers to get access to the market directly through a smartphone.

Academia and research and development (R&D)

Academia and R&D organizations in Pakistan are largely unable to effectively assist in the propagation of climate technologies and practices for horticulture and livestock. Most of them have inadequate funding and a disconnect with the farmers on the ground, due to which their work lacks relevance with ground needs. A lot of duplication of efforts was also seen, with multiple organizations working on the same aspects with limited budgets. Therefore, climate-smart technologies and practices are not a priority or even on the radar for most farmers. Little to no material exists on the benefits of various climate technologies and practices that can be used by both farmers and the public/private sector for propagation. The information that does exist is more academic in nature and not easily digestible or of relevance to the farmer.

The Pakistan Agricultural Research Council and Southern Zone Agricultural Research Centre (PARC–SARC) houses research sub-units and conducts R&D in the crop and livestock sectors in addition to offering advisory services to farmers. As per its mandate, the PARC–SARC is supposed to undertake research related to climate, which includes identification of sources of resistance to major diseases found in wheat under hot and humid environments, arid and semi-arid agriculture and productivity enhancement, eco-friendly integrated management practices against major fungal/nematodes disease of vegetables and fruits and use of wastewater and water management.

However, despite its mandate, the SARC is unable to effectively conduct R&D activities due to a lack of funding. The SARC, like other centres under the PARC, barely gets enough budget to cover operational expenses, due to which R&D activities remain unfunded. Furthermore, a disconnect was observed in the R&D being carried out and farmers' needs.

The Balochistan Agriculture Research and Development Centre (BARDC) houses five institutes: the Horticultural Research Institute Khuzdar, the Coastal Agricultural Research Institute Lasbela, the Agricultural Research Institute Turbat, the Agricultural Research Institute Jafferabad and the Agricultural Research Institute Barkhan at Rakhni. As per its mandate, the BARDC focuses on agricultural productivity enhancement through:

- The efficient management of natural resources (water, land, range livestock and medicinal plants);
- Efficient management and use of water resources and improving the productivity of *sailaba* and *khushkaba* farming;
- Introduction and dissemination of knowledge and technologies for improving soil fertility through integrated nutrient management, including the use of biofertilizers;
- Selection of high-yielding, disease-resistant and drought-tolerant crop varieties for arid and cold environments of Balochistan;
- Identification of promising forage species for different agroecological zones of Balochistan;
- The development and promotion of technology packages for the cultivation of low delta fruit trees, wheat/barley and medicinal plants in Balochistan.

The organization comprises 66 scientists and 108 non-scientists. However, BARDC's budget only just covers operational expenses and R&D activities remain unfunded. Furthermore, a disconnect was observed in the R&D being carried out and farmers' needs.

PARC's National Sugar and Tropical Horticulture and Research Institute (NSTHRI) develops high-yielding sugarcane varieties that can perform well in different agroecological zones with resistance to drought, salinity, waterlogging and frost. It also researches tropical horticultural crops and soil and water to determine their optimal use for irrigation. The institute works to develop procedures for the reclamation of soil using modern techniques.

It has introduced new sugarcane varieties through local and exotic fuzz and multiplied elite exotic banana varieties in Sindh. However, the institute barely has enough budget to cover operational expenses. Therefore, R&D activities remain unfunded. Furthermore, a disconnect was observed in the R&D being carried out and farmers' needs.

The PCRWR is a corporate body established under the PCRWR Act 2007 and works under the Ministry of Science and Technology. It conducts, organizes, coordinates and promotes research on all aspects of water, specifically irrigation, drainage, surface and groundwater management, groundwater recharge, watershed management, rainwater harvesting, desertification control, water quality and the overall environment. The PCRWR also promotes partnerships with national and international research organizations to tackle emerging issues and future challenges in the water sector, especially under the climate change scenario.

CABI is an international, inter-governmental, not-for-profit organization that operates under an unregistered international treaty-level agreement. CABI's centre in Pakistan helps farmers increase yields, improve crop quality and access markets in a sustainable, environmentally sensitive way. The centre is the pioneer of the farmer field school approach and has delivered training on subjects including Good Agricultural Practice (GAP), sanitary and phytosanitary (SPS) measures, integrated pest and crop management and business and marketing skills. The centre's horticultural expertise helps local smallholder farmers improve their production and profitability by providing them access to better-quality seeds and encouraging them to adopt sustainable soil and production practices. Integrated crop management is encouraged, including managing agricultural pests and diseases through safe biological means. Regional plant clinics give farmers the information they need to lose less of their crops to pests and diseases. The centre also helps farmers overcome barriers to getting their crops to the market. CABI relies heavily on donor funding to undertake different programmes and activities throughout Pakistan.

The Sindh Agriculture University (SAU) in Tandojam is an independent public sector university that trains students and conducts research. It has:

- Four faculties: Faculty of Crop Production, Faculty of Agricultural Social Sciences, Faculty of Agricultural Engineering and Faculty of Animal Husbandry and Veterinary Sciences;
- Two institutes: Information Technology Centre and Institute of Food Sciences & Technology;
- Three affiliated colleges: Sub Campus Umarkot, Shaheed Z.A. Bhutto Agriculture College Dokri and the Khairpur College of Agricultural Engineering and Technology;
- The Directorate of Advanced Studies and Research.

Zulfiqar Ali Bhutto Agricultural College in Dokri, affiliated with the Sindh Agriculture University, is also an academic institute that trains students and conducts research. It consists of various departments such as the Department of Agronomy, Department of Plant Pathology, Department of Plant Protection, Department of Plant Breeding and Genetics, Department of Economics, Department of Islamic Studies, Department of Statistics, Department of Education Extension, Department of Agricultural Engineering, Department of Horticulture, Department of Soil Science and Department of Animal Husbandry and Veterinary Sciences.

The Shaheed Benazir Bhutto University of Veterinary & Animal Sciences in Nawabshah, a public university, trains students, conducts research and develops innovations for the livestock sector. The university was established to develop veterinary and animal sciences in Sindh and consists of three faculties, which are veterinary sciences, biosciences and animal production and technology.

The Lasbela University of Agriculture, Water and Marine Sciences (LUAWM) is a public university that trains students through higher education (undergraduate, graduate and postgraduate programmes), develops innovative technology and undertakes cutting-edge research. The LUAWM has three campuses: Lasbela (main), Quetta and Khuzdar. The university has seven faculties, which include agriculture, marine sciences, veterinary and animal sciences.

The Balochistan Agriculture College, Quetta (BACQ) is administratively controlled by the Secretary, Government of Balochistan, Agriculture and Cooperative Department and affiliated with the University of Balochistan for the degrees BSc (Hons) Agriculture and MSc (Hons) Agriculture. It is a public university that trains students (undergraduate and graduate programmes) through higher education and conducts research. The BACQ has six divisions, which include plant protection, crop production, crop protection, horticulture and crop improvement.

Access to finance

Microfinance institutes have made great strides in making financing more accessible in Pakistan. However, they lack awareness and are doing little to no work on promoting climate technologies.

Akhuwat Islamic Microfinance (AIM) supports poor families through interest-free loans. By providing interest-free loans, Akhuwat empowers the poor to overcome poverty in a self-determined and sustained manner. Women empowerment is a special focus, with more than 43% of total loans being disbursed to them. The organization has more than 800 loan centres/branches in Azad Jammu Kashmir, Punjab, Khyber Pakhtunkhwa and Sindh.

In Sindh, it has 30 loan centres located in Sukkur, Karachi, Malir, Khairpur, Jacobabad, Mithi, Tharparkar, Thatta, Tando Allahyar, Mirpur Khas, Karachi South, Karachi West, Badin and Tando Muhammad Khan. In total, it has disbursed 4.5 million interest-free loans (*qarz-e-hasan*) amounting to PKR 128 billion ($798 million) to more than 3 million families across Pakistan. AIM does not have any focus on promoting loans for the production and use of climate-smart technologies.

Sindh Microfinance Bank (SMFB), a subsidiary of Sindh Bank, serves the underprivileged through financial products that are easily accessible to those who are unable to use conventional banking services. The SMFB's goal is to empower women in Sindh and it has established service centres that provide credit facilities exclusively to women. The SMFB also works to promote micro-entrepreneurship by conducting awareness campaigns.

Zarai Taraqiati Bank Limited (ZTBL) is owned by the Government of Pakistan. The ZTBL is a public limited company with an independent board of directors. The bank provides agricultural credit and banking services to farmers across the country. It is the largest public sector agriculture development financial institution in the country, which provides affordable, rural and agricultural financial and non-financial services. It serves approximately half a million clients annually and has more than 1 million accumulated account holders, with a country-wide network of 488 branches.

The Khushhali Microfinance Bank operates under the supervision of the State Bank of Pakistan (SBP). The bank's board comprises seven members, including leading commercial bankers, fund managers and microfinance experts from across the globe. The bank has established a sustainable platform of financial services for the poor, accompanied by retail delivery mechanisms. It facilitates an environment where microfinance can prosper within Pakistan and aims to provide affordable financial and social services to the poor for a significant impact on poverty reduction. The bank is working on digitally transforming its products and services and equipping its customer base with the latest technological advancements. It is headquartered in Islamabad and operates across Pakistan with 193 provincial branches, 26 permanent booths and 15 post office booths.

The First MicroFinance Bank is one of the oldest microfinance banks in Pakistan, which was established with the mission to respond to poverty and contribute to Pakistan's social and economic well-being by providing opportunities to thousands of underprivileged households. Its products include First Kissan Sarmaya and First Mahvashi Sarmaya. The bank offers loans for:

- Agriculture (crop farming, mainly cotton, rice, wheat, sugar cane and vegetables, etc.);
- Livestock (purchase of small/large animals for rearing and fattening and dairy animals and construction of animal sheds and water tubs, etc.);
- Enterprises (purchase of inventories, small assets and common facility centre, etc.);
- General purpose (meeting expenses related to education, housing improvements and income-generating activities, etc.).

The majority ownership is by Habib Bank Limited (50.51%) and partial ownership is by the Aga Khan Agency for Microfinance (29.77%), the Aga Khan Rural Support Programme (10.99%) and others (8.73%). The First MicroFinance Bank operates more than 150 branches located all over the country, covering 66 districts.

Networks, institutions, bodies, and platforms promoting tech.

The Aurat Foundation and Hisaar Foundation established Women's Water Networks (WWN) in all provinces and national levels. WWN Pakistan has more than 250 members and several chapters across the country. It is also a part of the South Asia Women and Water Network. WWNs are provincial policy advocacy forums and powerful tools that seek to highlight women's problems, perceptions, perspectives and needs in the water sector. WWNs aim to bring into fold women from all sectors of society so their voices can be effectively channelled into mainstream policies, discussions and actions relating to water.

The Alliance for Water Stewardship is a global organization that comprises businesses, NGOs and the public sector. The Alliance for Water Stewardship has been instrumental in establishing the Pakistan Water Stewardship Network. The founding members of the Pakistan Water Stewardship

Network are Archroma, the Alliance for Water Stewardship, Bureau Veritas Pakistan, WIT, LUMS, the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) International Water Stewardship Programme, Helvetas Swiss Intercooperation, Nestle, PepsiCo, Rice Partners Ltd, Umbrella Consulting and WWF Pakistan.

The Climate, Energy & Water Research Institute (CEWRI) at the National Agriculture Research Centre (NARC) is promoting drip irrigation in Pakistan, especially in Balochistan. For this purpose, a model pilot was launched in 2019 to advise farmers on the efficient use of water. Farmers from water-stressed regions of Balochistan visited the pilot project to gain knowledge and adapt it to promote agricultural productivity. NARC also submitted proposals to the Prime Minister's task force on agriculture to consider encouraging the private sector to produce drip irrigation devices locally so it can be introduced at a massive scale.

The office of Climate Change and Food Security is engaged in promoting climate-smart, regenerative agriculture in Pakistan. It includes practices like no-till, raised beds and organic mulching as well as technologies such as precision planting and water metering. It is responsible for all policy, project planning and development for climate change, food security and nutrition at the federal level.

The Zamindar Action Committee (ZAC) in Balochistan works to support solar tube wells in the province. They are of the view that solar tube wells extract less water compared to electric tube wells and would promote water conservation.

Ayub Agricultural Research Institute provides technical know-how on tunnel farming and works to promote the technology to growers across the country. The institute also works to develop new varieties of crops, technologies for food safety and sustainable generation of exportable surplus for economic safeguard, value addition, conservation of natural resources and introduction of new plants.

The On-Farm Water Management Directorate General, Balochistan (main office, Quetta) is a sub-government department that promotes water conservation technologies in Balochistan, particularly drip irrigation and laser levelling.

The Society for Conservation and Protection of Environment (SCOPE) is an NGO that is engaged in networking, capacity building and advocacy. Recognizing that the lack of water is a major constraint to economic development in Sindh, SCOPE is working on developing physical infrastructure. This includes new wells, repair of wells, hand pumps, household water tanks, farm water tanks and rainwater harvesting ponds, windmills, water reservoirs, mini-dams and community-level bio-sand water filters exclusively for drinking proposes.

The Pakistan Rural Support Programmes Network (RSPN) undertakes work to promote biogas in Pakistan. In 2009–14, it installed 5,360 fixed dome biogas plants. These plants were mainly used for cooking and heating purposes; 90% of the plants were small (4–15 m^3). According to RSPN, 70%–80% of plants are still in operation (this is disputed by others, who indicate that a large number are non-operational due to technical problems and inefficiency in gas production in fixed dome plants).

The Balochistan Rural Support Programme (BRSP) is a registered Section 42 company that is part of the Pakistan Rural Support Programmes Network (RSPN). It works through the funding of local and international donors, including the Pakistan Poverty Alleviation Fund (PPAF). The BRSP develops community organizations throughout the province and assists them in becoming mature and self-reliant institutions.

The main areas of BRSP's work include community physical infrastructure, technology development, provision of basic health facilities, provision of basic education facilities, community mobilization, capacity building of community institutions, development and rehabilitation of water supply schemes and construction and provision of sanitation services, youth development centres and a livelihood enhancement programme.

In addition to this, BRSP provides some degree of extension services to its community organizations. It also works on natural water resources management where it has completed 732 irrigation schemes and 162 integrated water resource management schemes. Additionally, it has provided 658 households with solar electrification units, constructed 57 recharge check structures on upstream *karezes*, installed 132 solar pumps for drinking and agriculture purposes, planted 50,000 plants, improved 141 *karezes*, installed 65 poly tunnels and trained 93,680 individuals on natural resources management.

The Sindh Rural Support Programme (SRSP) is an NGO that was established in 1996 under the Trust Act 1882. It mobilizes disadvantaged groups in mostly underprivileged areas: women such as *haris* (peasants), small farmers and landless labourers, etc. for socioeconomic empowerment. It also provides microcredit to support these communities. The SRSP also supports communities for environmental upgradation and conservation of natural resources. Additionally, it engages in research and advocacy for water, health, sanitation, women empowerment and poverty alleviation.

Recommendations

Table 19 Support service constraints and recommendations

#	Support service	Major constraints	Main recommendations
1	Public extension services	• Under-resourced • Understaffed • Need to cover huge swathes of geographical area and ratio of extension agents to farmers is poor. In Sindh, ratio of extension agents to farmers is poor (1:6,881) • Generally found to lack awareness and capacity regarding climate technologies	• Establishment of common facility centres (CFCs) and farmers' service centres (FSCs). The FSCs and CFCs will provide inputs, machine rental services and training under one roof. It is essential that demonstration plots be used for farmer training and capacity building at these facilities, as dissemination and uptake among farmers in Pakistan is most effective through 'seeing is believing' and they learn best by doing. The FSCs and CFCs can be formed through public–private partnerships to leverage existing resources most effectively. An FSC project in Khyber Pakhtunkhwa and agrimalls in Punjab should be studied. • Build capacity of extension workers and awareness on climate technologies through exposure visits. • Strengthen and work with the ICT Agricultural Extension Service Center in Hyderabad to raise awareness and create verified and authentic sources of information.
2	Private extension services	• Limited coverage in Balochistan and rural areas of Sindh • Conflict of interest	• Through matching grants and technical assistance, support private sector entrepreneurs in setting up FSCs. • FSCs to improve responsiveness to farmers' needs in terms of input supply (fertilizers, seeds and pesticides, etc.), services (mechanized labour, technical advice, certification and marketing, etc.) and information, especially regarding climate technologies. • The FSCs would act as hubs for knowledge and technology dissemination as well as marketing of agricultural and livestock commodities.
3	Formal and informal market information providers	• Climate technologies are not a priority or on the radar of farmers • Little to no material on benefit of climate technologies for farmers • Public sector-based ones lack sustainability • Information available by academia/R&D organizations is more academic in nature and	• Work with NGOs having good coverage in Sindh and Balochistan on creating verified and authentic information sources for farmers, particularly using ICT mediums like WhatsApp and Facebook groups and YouTube channels for awareness raising, information dissemination and highlighting benefits. • Revitalize the Balochistan Agriculture Marketing Information System (BAMIS), but ensure its sustainability.

		generally lacks relevance for farmers • Farmers are heavily reliant on informal information providers for market, technology/practices and product-related information	
4	Access to finance	• Little to no work being done on promoting climate technologies	• Work with microfinance institutions to promote climate-friendly technologies and their financing, particularly focused on encouraging women and marginalized communities to start businesses
5	Academia, R&D organizations and donor/government programmes	• Lack of adequate funding • Disconnect with farmers • Lack of relevance of research with ground needs • Duplication of efforts	• Work with the Planning Commission, Ministry of National Food Security & Research and the agriculture departments of Balochistan and Sindh to develop a national climate technologies and practices development and research agenda through an annual consultative national workshop. A panel of renowned researchers to develop a matrix and thematic areas of research and development. Based on the agenda, development projects to be planned and funding to be provided for research. • Cost–benefit analyses and impact studies for various climate technologies need to be conducted and disseminated in a form that is easily digestible for farmers. It is also important that, in cooperation with interested private sector entrepreneurs, economically viable business models be created for various technologies to make them attractive and self-sustaining.

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