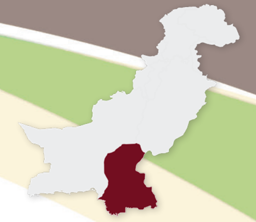
Food and Agriculture Organization of the United Nations



Climate-Smart Agriculture for Disaster Risk Reduction in Sindh, Pakistan

Climate-smart agriculture (CSA) highlights

- P $ Agriculture is the backbone of Sindh's economy and a significant employer, with 80 per cent of the rural population involved in the sector, hence contributing to rural livelihoods while safeguarding household and national food security.
- A D P I Low agriculture productivity in Sindh is linked directly with the supply of irrigation water from the Indus River. While most crop production takes place on irrigated lands in the plain areas of the Indus River basin, yields of most crops are below international standards, both in terms of land and water productivity.
- A D Climate change is increasing the frequency and severity of hydro-meteorological hazards within the province, specifically floods and drought, which have led to salinity, waterlogging and further crop loss. Repeated disasters have a severe long-term impact on livelihoods and food security, as well as contributing to reversing gains in alleviating poverty, agricultural development and in reducing hunger.
- P Wheat, rice, sugarcane and cotton are the major field crops and constitute about 68 per cent of the total cropped area, while mango, banana and chillies are the major horticultural crops.
- A M P D Of the prioritised CSA practices the highest scoring were those which built resilience within the sector to climate shocks and extreme events. Water saving techniques of laser land levelling, alternate wetting and drying, mulching and drip irrigation scored highly along with drought, heat, salinity and pest tolerant varieties.
- A P D The high prevalence of pest and disease attacks and their severe impact on production were identified as an ongoing and worsening hazard. Proposed practices of integrated pest management, biocontrol agents and crop rotation were promoted in response.
- A M P D Climate-smart agriculture (CSA) combined with community-based disaster risk reduction (DRR) measures present opportunities to mitigate the risks of natural hazards and extreme events whilst simultaneously promoting production gains and resource use efficiency, in both hazard and non-hazard situations.
- I $ The effective implementation and mainstreaming of both CSA and DRR activities will be reliant on increased inter ministry collaboration, comprehensive training programmes for institutional capacity building at different levels, a set of clear roles and responsibilities, and context-specific technical knowledge of CSA and DRR actions.

A Adaptation   M Mitigation   P Productivity   I Institutions $ Finance   D DRR

This profile examines the current risks within the agriculture sector posed by climate change and emerging social and economic trends in the province of Sindh. In order to effectively mitigate these risks, smallholders have the potential to enhance Disaster Risk Reduction (DRR) at the farm-level through the systematic integration of climate-smart practices and technologies. By linking climate-smart agriculture with DRR, farmers are afforded the opportunity to strengthen their resilience to natural hazards while increasing productivity and economic gains under the conditions of climate change. This profile highlights the interconnection between these two concepts and provides prioritized, context-specific measures to ensure effective implementation.

The CSA concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and to increase food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), requiring planning to

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address trade-offs and synergies between these three pillars: productivity, adaptation, and mitigation [1].

DRR is a systematic approach to strengthen resilience through the mitigation of risk. The DRR approch identifies four priorities: i) understanding risk, ii) strengthening disaster risk governance, iii) investing in disaster risk and iv) enhancing disaster preparedness for effective response [2]. Within the agricultural sector many of the practices that are defined as CSA would also fall under a DRR strategy through their contribution to risk reduction.

For agriculture to be climate-smart it must consider the priorities of different stakeholders to achieve more efficient, effective, and equitable food systems that address challenges in environmental, social, and economic dimensions across productive landscapes. While the concept is new and still evolving, many of the practices that make up CSA already exist worldwide and are used by farmers to cope with various production risks [3].

To date, much of the discussion around DRR has been focussed on large scale off farm structural projects, overlooking the potential impact of small scale preventative measures at a farm level. Small scale farm-level actions offer a low cost means for farmers to implement context specific DRR actions with considerable impact on their resilience. Such practices empower smallholder farmers who traditionally feel powerless when faced with extreme weather events and natural hazards. The implementation of such practices has been found to be particularly effective against high frequency, low severity events such as dry spells, extreme temperatures, pest and disease outbreaks and heavy rains [4].

Farm-level DRR best practices need to not only improve resilience to hazards, but present productivity gains in non-hazard scenarios, along with socio-economic and environmental co-benefits [4].Through this report the analysis of CSA (DRR) practices across productivity (socio-economic), adaptation (risk mitigation) and mitigation (environmental) pillars will further the understanding of farm-level CSA and DRR activities in Sindh, identifying best bets and lessons learned.

Mainstreaming and coordinating CSA and DRR activities requires critical stocktaking of ongoing and promising initiatives as well as an enhanced comprehension of how CSA contributes to the mitigation of specific risks. This provincial profile provides a snapshot of a developing baseline created to initiate discussion around the entry points for investing in CSA and DRR in Sindh.

The need to promote both CSA and DRR activities in response to climate change is well recognised in the international development agenda. The work covered in this report aims to better the understanding of how agriculture in Sindh can be improved to meet targets under the Sustainable Development Goals (SDG's), the Paris Agreement on Climate Change and the Sendai Framework for DRR 2015–2030.

Provincial context

Sindh is the third largest by area of the four provinces of Pakistan, occupying the lower Indus basin, covering 140,915km^2, 18 per cent of Pakistan's total land mass. Balochistan borders Sindh to the west, Punjab to the north, to the east the Indian states of Gujarat and Rajasthan, and in the south, the Arabian Sea. The Indus Delta, the sixth largest delta in the world, is located at the mouth of the Indus River and covers almost the entire coast of Sindh. Sindh's landscape consists mainly of alluvial plains flanking the Indus River, the Thar desert in the east close to the border with India, and the Kirthar Mountains to the west. The coastline of Pakistan extends 1,050km, with 250km falling in Sindh and 800km in Baluchistan.

The province consists of six divisions: Karachi, Hyderabad, Sukkur, Mirpurkhas, Larkana, Nawab Shah/Shaheed, and Benazir Abad. Each division comprises districts, of which there are a total of 29, further subdivided into 138 talukas or tehsils.

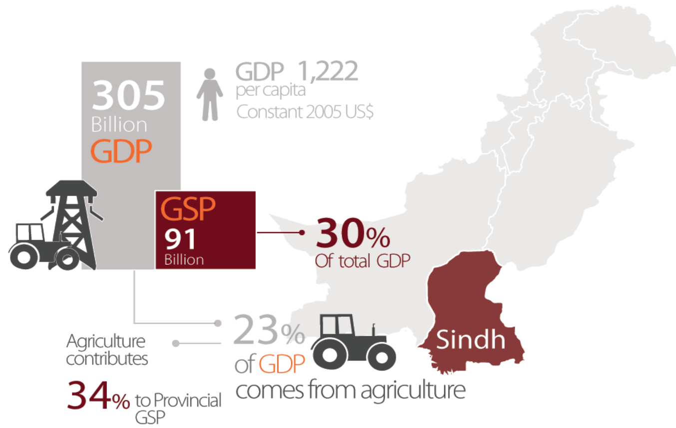
The province is the most urbanised and industrialised in the country, with a mixed economy ranging from heavy industry and finance to commercial agriculture. The Finance and industrial sectors are concentrated in the provincial capital of Karachi, while Sindh's agricultural base is found along the Indus. The agricultural commodities produced in Sindh, namely cereal, fruits, and vegetables are used for both domestic consumption and export. Sindh is also home to two of the country's largest ports, Port Bin Qasim and the Karachi Port.

Economic relevance of agriculture

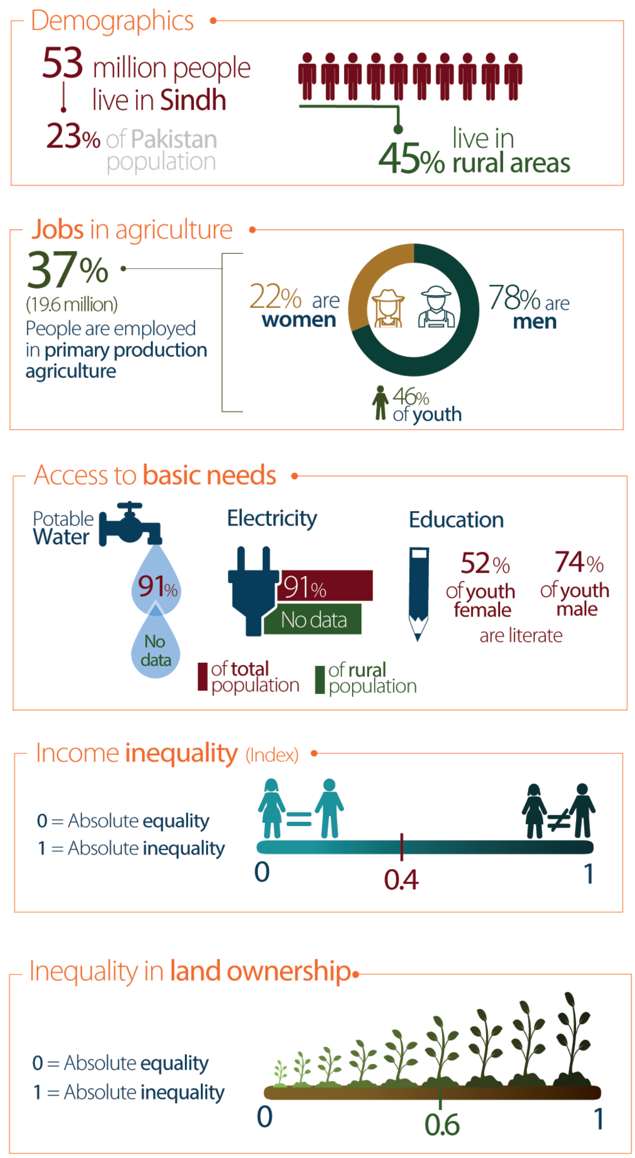
Sindh has the second largest economy of Pakistans provinces, accounting for 30% of national Gross Domestic Product (GDP), with a per capita Gross State Product (GSP) of US$1,748 [5]. Over the period 2000 to 2015, Sindh's Gross State Product (GSP) grew at an average rate of 4.3 per cent per year [5]. The GSP of Sindh, is, to a large extent, influenced by the economy of Karachi, with an estimated population close to 17 million, making it the seventh largest urban agglomeration in the world. Of Sindh's population, 45 per cent live in rural areas, with agriculture and livestock activities representing an essential source of income [6].

The agriculture sector in Pakistan as a whole, recorded growth of 3.81 per cent from 2017-18 due to increased yields, supportive production prices, enabling government policies, improved availability of certified seeds, pesticides, and agriculture credit, as well as intensive fertiliser use [9]. For the past two decades, however, this vital sector has seen the share of its contribution to the national GDP declining, coming down from 44 per cent in the 1960s to 23 per cent in 2017, due in part to the burgeoning growth in the industrial sector. The sector is facing various structural issues including low government spending, lack of certified seeds, use of traditional farming methods, insufficient storage capacity, lack of value addition, and weak supply chain management [10].

Economic relevance of agriculture in Sindh [5,7,8]



People, agriculture, and livelihoods in the Sindh [6,14,15,16,17]



Sindh is experiencing rapid population growth, a result of high fertility rates coupled with decreased mortality rates, along with migration from other parts of the country and abroad [11]. The fertility rate in Sindh - a measure of the average number of children a woman will have over her lifetime – has fallen from 5.1 children per woman in 1990 to 4 in 2014, remaining considerably higher in rural areas than urban areas. In the past decade, the population grew by just over 10 million (almost 30 per cent) from 38 million in 2006 to nearly 53 million in February 2019, with a density of around 340/km^2 [6,12].

Pakistan's agriculture sector is dominated by small farmers, however, farm size distribution is highly skewed. The 2010 Agriculture Census of Pakistan revealed 1.1 per cent of farm holdings covered 21.6 per cent of the total cultivated land, with each farm larger than 20 ha. In contrast, 64.7 per cent of farms comprise less than two hectares and account for only 19.2 per cent of the total holdings [13]. In Sindh, this trend is even more apparent, with 85 per cent of the property owned by less than two per cent of the population. In rural communities, most farmers are tenants or sharecroppers (haris). Many farm families lack clear and legally enforceable tenure over their farmland on which their livelihoods depend, which leaves them susceptible to poverty and abuse. Due to their subsistence existence, the small farmer household is more susceptible to food insecurity even in the event of the slightest drought. Small farmers have fewer coping strategies than medium or large farmers.

Land use

The total land area of Sindh is 14.1 million hectares (Mha) representing 18 per cent of the entire geographical area of Pakistan; of this, nearly 39 per cent or 5.45 Mha are cultivable. Currently, in Sindh, about 5.13 Mha (36 per cent) is cultivated, while 6.3 Mha is not available for cultivation; forest area accounts for 1.03 Mha.

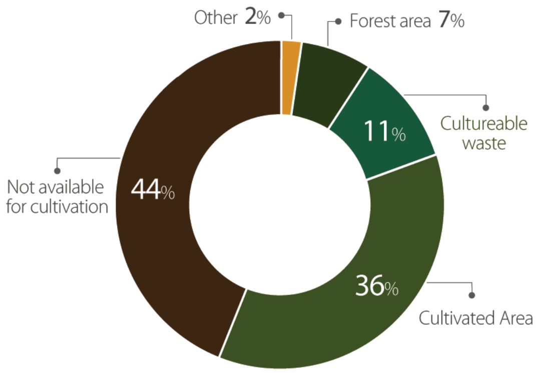
Across the province, fields that are actively tilled and used to produce annual crops, cover 28.5 per cent of the land. Dunes with natural vegetation, bare rocks and flat desert pans cover another 30.4 per cent of the land. The remaining area includes forests (0.8 per cent), marginal crop areas, rangelands, and mountainous areas.

Land use in Sindh [16]

Total land area Sindh
14,100,000 ha

Agricultural area
5,130,000 ha
= 36% of total land area

Cultivated and uncultivated area



Sindh is a mainly dry region and is relatively more arid than the upcountry areas. Irrigation is therefore critical for agriculture in the province, as the contribution of rain towards crop water requirements is negligible. About 75 per cent of the agriculture land of Sindh is cultivated through a controlled irrigation system. The agriculture sector depends significantly on the network of barrages and canals on the Indus River. The terrain is almost flat, and water drainage is a serious problem whenever there are floods or heavy rains. On the left and right banks, two major drainage systems have been developed to address this. The sub-surface water outside the river bed is generally brackish and unfit for agricultural purposes.

Canal water diverted from the Indus is the primary source of irrigation water, followed by groundwater pumping. Three barrages divert river water at Sukkur (commissioned in 1932), Guddu (1962), and Kotri (1955). It is then conveyed in 14 main canals to service the total design area of 5.1 Mha, with the annual irrigated area varying depending on the amount of available water, with an average of 3.8 Mha.

Nearly half the agricultural area – about 2.4 Mha – does not have land drainage facilities, which poses a severe constraint to crop production as much of the agricultural land is flat with low natural drainage. The flat topography combined with high water losses at the farm and excessive canal seepage have resulted in extreme waterlogging and salinity. Roughly 54 per cent of irrigated land is now salt-affected, and salinity poses a severe threat to the sustainability of irrigated agriculture in Sindh. Controlling waterlogging and salinity will substantially increase crop yields and production and as such should be an investment priority for the irrigation sector [18].

Agricultural production systems

Within this profile, the key production systems in Sindh have been determined using weighted economic, productivity, nutrition and environmental factors and verified through a participatory method involving the government of Sindh and consultations with local stakeholders and agronomy experts.

The major production systems in Sindh are wheat, cotton, rice, and sugarcane, which occupy the largest cropped area in the province. The remaining production systems are considered minor crops and include bananas, mangoes, citrus, vegetables and oilseeds. Livestock rearing is also an important likelihood strategy for many farming communities in Sindh.

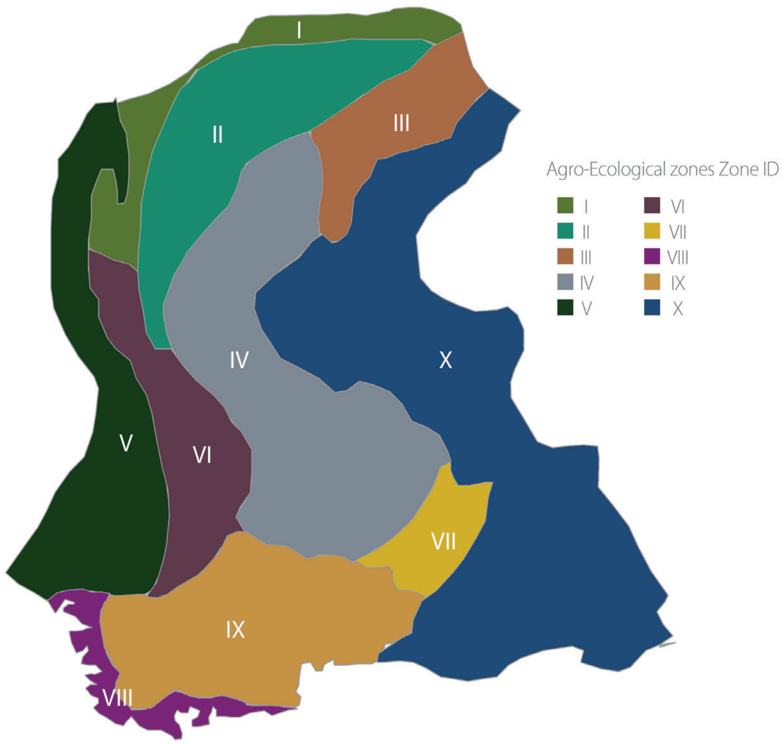
Pakistan's production systems are defined by the two growing seasons. The cropping season from October to December, generically referred to as rabi, is when winter crops like wheat are sown and later harvested between March and April. The summer crop-sowing season, called the kharif is typically longer, starting in February with sugarcane, March to May for cotton, and June to July for rice[a]. The harvesting of these crops begins in September and continues up to December, except sugarcane, which may extend to March or later [19]. Orchards and other trees are planted from February to March or during the monsoon season from July to August [20].

The large consumer markets of Karachi and Hyderabad have helped shape the cropping patterns in the province to meet the needs of its growing population—supplying wheat, cotton, rice and sugarcane fodder for animal feed. Vegetables, including onion, chillies, tomatoes and others, are also cultivated, as farmers are able to make good returns. Natural factors play a more significant role in determining Sindh's production systems and their respective success.

The Indus River brings rich silt and sandy loam, from the northern areas, which improves the fertility of the soil and enables agricultural activities throughout the province. A variety of ecosystems are also evident as Sindh is home to riverine, scrub, mangrove forest, desert, coastal areas, and wetlands. As such, Sindh provides a range of agriculture production systems key for food security. Using overlay analysis in GIS of agro-climatic and soil type maps, the FAO has delineated Sindh province into ten distinct agro-ecological zones (AEZ), varying by climate, topography, seasons, and suitability for different crops. Annex 1 shows details about the climate, soil and other characteristics of the AEZ.

[a] The major patterns are: (i) rice-wheat, (ii) maize-wheat, (iii) cotton-wheat, (iv) sugarcane-wheat, and (v) coarse grain-wheat, and some other minor patterns.

AEZ Map Sindh [21]



Production systems key for food security in Sindh [5, 10, 22, 26]

Land use (% of total harvested area)

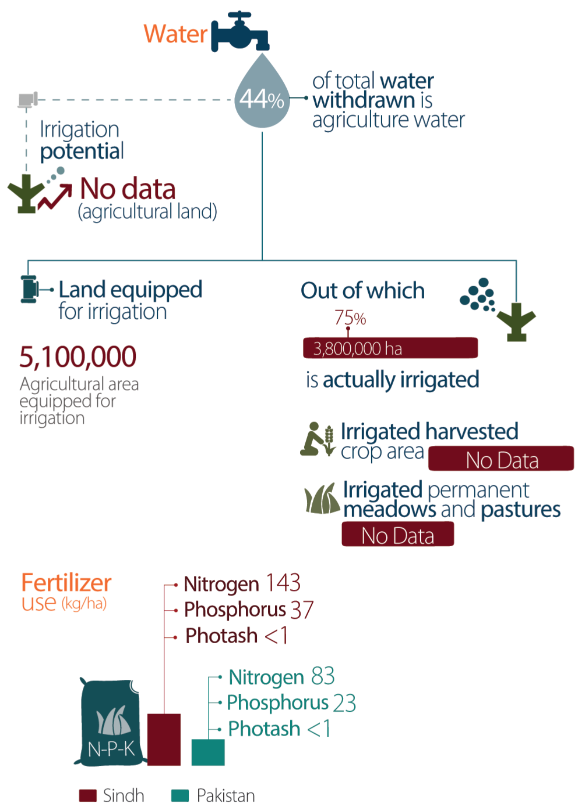
	Wheat	Rice	Cotton	Sugarcane	Fruit	Vegetables	Oilseed	Livestock
Land use	23%	15%	12%	6%	3%	1%	1%	ND
Sindh	3,387	3,546	952	57,500	5,854	6,638	1,058	No data
Pakistan	2,893	2,514	581	57,900	8,639	12,099	960	53,200

Sindh Pakistan

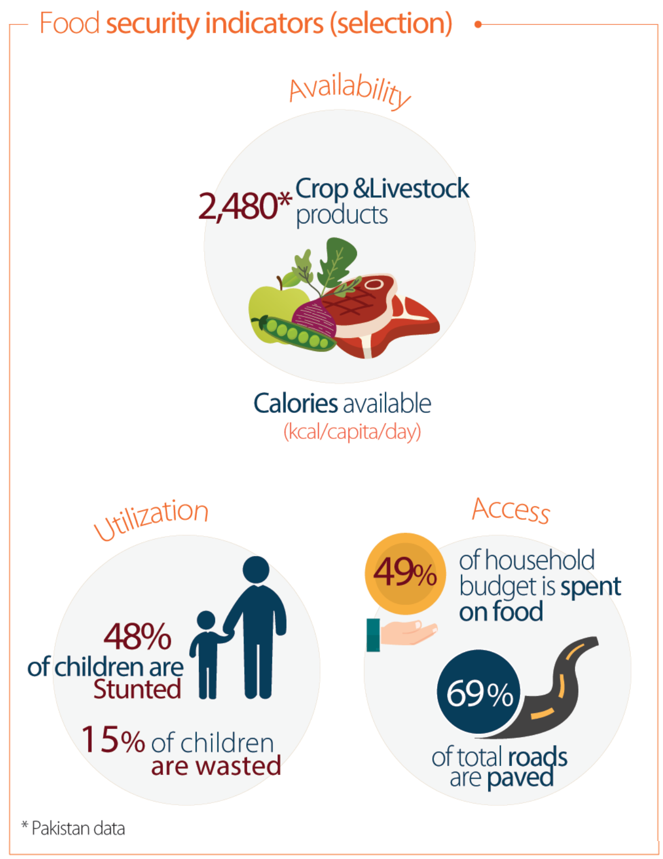
* Permanent meadows and pastures as % of total land

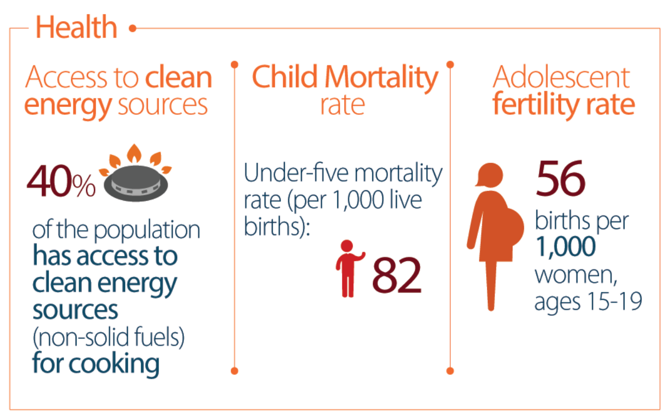
Yields (Crops: kg/ha; Livestock: kg/animal)

Agricultural input use in Sindh [23, 24]



Food security, nutrition, and health in Sindh
[14,28,29,30,31]





Food security, nutrition, and health

The Human Development Index Report (HDI) 2018 shows Sindh to have the second highest Human Development Index out of Pakistan's provinces, after Punjab, with an average of 0.64, indicating a Medium Level of Human Development. Pakistan ranks 150th globally, with a score of 0.56 [25].

In Sindh, 42 per cent of people of the total population is undernourished, 48 per cent of children under the age of five are stunted, and 15.4 per cent have a low weight for their height [6]. The prevalence of underweight children under five years of age increased in Sindh from 40 per cent in 2004/5 to 42 per cent by 2014, compared to the national average which fell from 38 to 31.5 per cent between 2004/5 and 2010/11 [6]. Half of all mothers are anaemic. There has been little improvement in addressing under-nutrition, despite periods of economic growth and reductions in poverty levels; in fact, some indicators of nutrition have worsened. The growth of agriculture can therefore be an essential driver of nutrition improvement [26].

In Sindh, 91 per cent of households were found to use improved water sources [14]. In cases where safe drinking water is not available, women and young girls are traditionally tasked with collecting it from nearby sources, reducing their time/opportunity to engage in education and employment [27].

Role of women and youth in agriculture

Gender inequality and discrimination are characteristic of the agricultural sector in Pakistan. When it comes to access to the latest technologies and techniques for crop production and livestock management, women lag behind their male counterparts, a result of weak extension services, and illiteracy among women. Women play a significant—albeit often invisible and unrecognised—role in the cycle of socio-economic development. In rural areas, from which most men have migrated in search of work, women manage many farms. Such women may not have legal control of the farms and are also required to carry out household tasks. Women contribute to livestock management, crop production (sowing, transplanting, weeding, and harvesting) as well as the post-harvest operations (threshing, winnowing, drying, grinding, husking and storing of the products). A working-class village woman in Sindh works from 12 to 16 hours a day [32].

In 2016, as part of the Sindh Union Council and Community Economic Strengthening Support Programme (SUCCESS) research in rural areas observed the additional burden placed on women to conduct both reproductive and productive tasks. The latter mainly involves livestock rearing, including cattle, buffalos, sheep, goats, camels, horses, donkeys, and poultry, as well as related tasks such as making dung cakes for use as fuel. The leading role of women in rearing livestock does not exclude them from actively participating in the production and harvesting of major crops such as wheat, cotton, rice and sugarcane. Women are thus engaged in many economically productive roles, although much of this work is either paid less than men or considered housework and therefore not documented as economic activity in any official records [33].

Livestock is regarded as a significant livelihood strategy for smallholder subsistence farmers, especially women and people without clear land ownership rights [34]. Research has shown that women were mainly involved in raising animals, but at the time of selling and buying male members of the household assumed the responsibility [33]. Livestock is seen as a tool for increasing the economic and social status of women and thus part of many poverty alleviation programmes.

According to official projections, young people aged 15-29 years make up 26 per cent of Sindh's population, of which 14 per cent are male and 13 per cent are female. Rural youths make up 12 per cent and urban youths 14 per cent of the total population [15]. The percentage of the youth population is suggestive that the province is also passing through a youth bulge much like other parts of Pakistan.

Labour force participation for youth in Pakistan is currently 40 per cent. Among males the rate is 61 per cent, while for female youth, participation is just over 18 per cent. As of 2018, national youth unemployment stood at nearly 8 per cent [35]. The highest rates affect 20-24 year-olds, who exceeded 11 per cent unemployment between 2017 and 2018. In Sindh, the same trend is true, but more pronounced among young women. Within the same age demographic, 10.8 per cent of males and 22.5 per cent of females were unemployed [36]. Youth unemployment is concentrated in urban areas, but within Sindh, overall unemployment rates are lower than national averages.

Young men in Pakistan are also more active in education and/or training. To date, only 7.6 per cent of male youth in Pakistan between the ages of 15 and 24 are not engaged in employment, education or training (NEET). The NEET rate among females of the same age is far higher, with 55 per cent of young women falling into this category [37].

Agricultural greenhouse gas emissions

According to the Pakistan 2011-12 GHG inventory, total GHG emissions were 405.07 $MtCO_2e$ with 43.1 per cent of the total from the agriculture sector, and 2.6 per cent share of land use change for forestry sectors [38]. The energy and agriculture livestock sectors combined, account for 89 per cent of the total emissions and have remained the biggest emitters of GHGs since 1994.

Over the period 1990-2012, GHG emissions grew by 89 per cent, just under 3 per cent annually, whereas GDP increased by 136 per cent during the same time, averaging 4 per cent annually [39]. While Pakistan's carbon intensity remains at only 57 per cent of the global average, there is substantial mitigation potential through untapped efficiency measures [40].

The 2011-12 GHG inventory showed that roughly 54 per cent of agricultural emissions stem from enteric fermentation (emissions from the livestock sector), 18 per cent is from synthetic fertilisers, and 14 per cent is from manure left on pasture. These trends track livestock populations, which between 1990 and 2000 increased annually by 2.4 per cent, and about 3.5 per cent between 2001 and 2011 [38]. There is currently no province-level data on GHG emissions for Sindh. However, the livestock sector and rice cultivation are without a doubt key drivers of emissions given their importance in the province. It is therefore imperative that mitigation options be considered for the sector.

Natural hazards and disaster risk reduction

The Global Climate Risk Index 2019 published by GermanWatch, reports that Pakistan is repeatedly affected by disasters and continuously ranks among the most affected countries [41]. The Long-Term Climate Risk Index shows Pakistan ranks eighth among the ten countries most affected from 1998 to 2017 (annual averages) and is expected to be severely impacted by the adverse effects of future climate change. Much of Pakistan's vulnerability is linked to its dominant arid to semi-arid climate, a high dependency on a single river system, snow and glacial meltwater for the supply of water for agriculture [42].

Natural hazards, especially flooding and drought, directly impact agriculture and food security. Experience shows that the adverse and cumulative effects of disasters erode livelihoods and coping capacities over time. Disasters destroy crops and livestock, physical capital and livelihood assets, market infrastructure and productive inputs. To cope, rural families will often use their savings or increase borrowing to meet basic needs, depleting their resource base even further, rising levels of indebtedness and eroding livelihoods over time. Usually, disasters damage or contaminate productive land, destroy critical infrastructure and disrupt market access and trade [43].

Globally, DRR actions protect investments in the agriculture, livestock, fisheries/aquaculture and forestry sectors. These are aimed at preventing the creation of disaster risk, the reduction of current risk and the strengthening of economic, social, health and environmental resilience. Agricultural practices that increase farmers' resilience to natural hazards and extreme events, including but not limited to those considered CSA, contribute to DRR in the sector. The UN World Conference on Disaster Risk Reduction in 2015, agreed on four priorities for action in DRR. These four priorities form the basis of the Sendai framework, a voluntary agreement that recognises that governments have the leading role in reducing disaster risk, but that responsibility should be shared with local communities, the private sector, local governments, non-government organisations and other stakeholders [2].

Box 1: The four priorities of the Sendai Framework for Disaster Risk Reduction in the context of agriculture, livestock, fisheries/aquaculture, forestry and natural resource management [2]

Priority 1 Understanding disaster risk – Disaster risk management includes an understanding of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness and response.

Priority 2 Strengthening disaster risk governance to manage disaster risk – Disaster risk governance at the national, regional and global levels is essential for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

Priority 3 Investing in disaster reduction for resilience – Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance economic, social, health and cultural resilience. These initiatives are explored in more detail in Section 6 below.

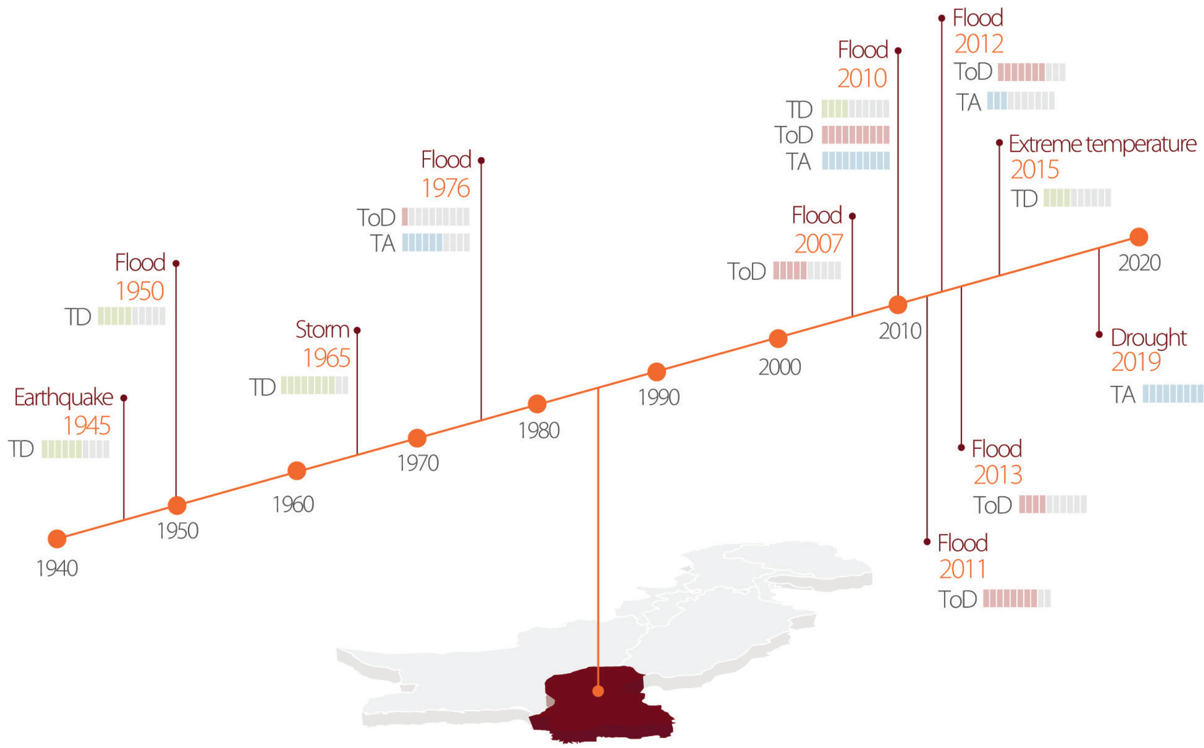
Priority 4 Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction. – The growth of disaster risk means there is a need to strengthen disaster preparedness for response, act in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase are critical opportunities to 'build back better', including through integrating DRR into development measures.

NB. The four priorities are inter-dependent and mutually reinforcing

Prevalent natural hazards and their Impacts

Sindh is in protracted crises with high levels of food insecurity characterised by recurrent disasters and prolonged food crises, the breakdown of livelihoods and insufficient institutional capacity to react to emergencies. Consecutive disasters have a severe long-term impact on livelihoods and food security, as well as contribute to reversing gains in alleviating poverty, agricultural development and reducing hunger. The yearly cost of natural resource losses and disasters in the province equals 4 to 6 per cent of estimated GSP, with crop losses resulting from salinity and waterlogging contributing about 46 percent of the total annual cost, disasters about 33 per cent, and the rest the result of different types of natural resource depletion [44]. The below timeline looks at the major natural hazard events that have struck Pakistan, considering total deaths (TD), total damage ($) (ToD) and total affected (TA), only including those that had a direct impact on Sindh.

Timeline of major hazards in Sindh [45]



TD: Totals deaths; ToD: Total damage; TA: Total affected

*The events identified are taken from the worst 10 events to hit Pakistan for the three indicators of total deaths, total damages ($) and total people affected, the ranking provided is for a national comparison but the events included are only those that impacted Sindh directly.

Floods

Flooding is the principal hazard in Sindh, as demonstrated by the devastating floods of 2010 and 2011 (see Box 2). The three consecutive years of flooding (2010-2012), coupled with a declining economic and security situation, constrained Sindh's progress towards achieving its MDGs, failing to attain them in their entirety by 2015. The most damaging floods in Sindh are those caused by heavy monsoon rains surpassing the capacity of the Indus river system and flooding the surrounding low lying areas.

Box 2: Historic flooding in 2010 and 2011 [46,47,48,49,50]

In late July 2010, record monsoon rains began in Khyber Pakhtunkhwa, Sindh, Punjab, and Baluchistan. The unprecedented volume of rainwater overwhelmed the Indus River flood defences, sweeping away roads and bridges and inundating an area of 38,600 square kilometres, leading to a humanitarian disaster considered to be one of the worse in Pakistan's history.

The floods affected approximately 20 million people, destroying homes, crops, and infrastructure. Between 1,200 to 2,200 people were estimated to have been killed, and about 1.6 million houses damaged or destroyed. An estimated 14 million people were left without homes.

The damage caused by the floods is estimated to be US$10 billion and has had a long-lasting impact on the country. Many hundreds of thousands of people stayed in temporary shelters, using makeshift tents along roads with inadequate sanitation and food supply months after the floods had subsided.

The following year, from August-September, severe flooding occurred in all 23 districts of Sindh due to record monsoon rains. The flood caused 434 deaths, damage to about 1.53 million houses and affected 4.8 million people. Over 2.7Mha of crops were affected. The flood was ranked as the second most devastating after those in 2010.

Drought and temperature extremes

Water scarcity in Sindh, especially in the face of rapid population growth, is a severe threat. Current estimates suggest that there are about 110–121 billion m^3 (cubic metres) of available water in Sindh, enough to meet yearly consumption. If the population continues to grow at its current rate, total water consumption will hit a critical point by 2040 [51]. Water consumption is only one factor affecting the province's water supply, additional conservation and environmental protection efforts are required to ensure the water supply for future generations [11]. Drought conditions in Sindh are further exacerbated by extreme high temperatures, which also directly impact crops and livestock.

The Himalaya-Karakorum-Hindukush contain the third largest ice reserves after the polar regions. Their glaciers hold a store of fresh water, gathering snow and ice in the winters and then feeding the Indus and other rivers in the summer. With climate change, temperature maximums have been increasing, and at the same time, the thinning of ice and the retreat of glaciers has taken place at an alarming rate. The decay estimates calculated by remote sensing techniques show that Siachen Glacier has reduced by 5.9km from 1989 to 2009, thinning the ice mass by approximately 17 per cent [52].

Drought is a major hazard for Sindh and one that is felt most acutely by the agricultural sector, particularly farmers in rain fed areas and those on the periphery of irrigated systems called 'tail-enders". In 2019, the Sindh Drought Needs Assessment surveyed 1,229 households in eight districts of the province. Compared to the 2016-2017 season, production losses were recorded for wheat (23 per cent), rice (35 per cent), cotton (18 per cent), cluster beans, millet and sesame (83 per cent) and pulses (95 per cent). A further 25 per cent of households reported the death of cattle in the last six months. As a result, as many as 71 per cent of households surveyed were moderately or severely food insecure [53].

Waterlogging and saline intrusion

A multitude of factors causing waterlogging and salinity include: the obstruction in natural water flow; a flat land topography; seepage from unlined irrigated channels; questionable performance of the Left Bank Outfall Drain and Right Bank Outfall Drain; overuse of irrigation water; reduced flow of freshwater (which leads to increasing seawater intrusion); high underground water extraction; rapid urbanisation; and lack of awareness among farmers [54]. It is estimated that 40 per cent of the irrigated lands in Sindh are salt affected. The extent of salinization in the province is expected to grow in years to come due to decreased river flows and the increased frequency and severity of droughts, with potentially devastating consequences for agricultural lands in the province. A recent study found that waterlogging in Sindh was increasing around newly developed areas, suggesting that urban drainage systems were poorly designed, creating an artificial sink [55]. To avoid the impacts of salinization, farmers use a mix of surface and groundwater to irrigate crops, however, if mismanaged this can result in upstream areas becoming waterlogged due to a rising water table, while tail-enders reliant on groundwater see the quality drop resulting in increased salinization [56].

Pest and Disease outbreaks

Changing weather patterns can increase the exposure of crops to pest and disease outbreaks. For sugarcane production in Pakistan, higher temperatures coupled with wet and humid conditions were found to favour diseases such as whip smut [57]. Losses from pest outbreaks were also found to be worse for cotton under increased temperatures, such attacks were particularly damaging during the flowering and fruit formation stages [58]. Work is continually being done by agricultural research in Pakistan and Sindh to identify new and improved crop varieties that are resilient to pest and disease outbreaks, however, under a changing climate, research may not be able to keep pace with the changes in the range and distribution of different pests and diseases.

Systemic challenges for the agricultural sector

Rapid population growth has led to dense settlements putting pressure on the land and other natural areas as families seek to meet their needs for sustenance. Intensive agricultural production results in soil degradation, erosion, and increased salinity, ensuing lower productivity. While this decline can occur in just a few years, it will take decades to restore land productivity [11].

Growth in population and food demand

Rapid growth and urbanisation are increasing pressure on Sindh's health, education, economic, and agricultural sectors to meet people's need for essential requirements [59]. Future fertility trends will largely influence Sindh's population in 2050, if the contraceptive prevalence rate (CPR) remains constant—at 29.5 per cent [60]—the population will grow from 47.8 million in 2017 [61] to 98.5 million by 2050 [62]—nearly doubling in just 29 years. Continued rapid population growth will have consequences for agriculture and other development sectors in Sindh. Creating a higher demand for food, thus increasing costs and lessening access to food for national consumption, which disproportionately affects the poorest people.

The rate of urbanisation in Sindh is putting pressure on surrounding agricultural lands, which are increasingly being converted due to urban sprawl and infrastructure projects, this has the potential to create land use and food conflicts, in the absence of effective land use policies [61]. Those migrating to urban areas end up living in illegal settlements. These settlements are highly vulnerable to floods, often being built along rivers or in areas that are prone to flooding. These populations are unregulated and, being illegal, receive less support from authorities in times of need. As a result, those migrating to urban areas cause other secondary hazards to unemployment, food insecurity and access to basic services health, nutrition and infrastructure.

Poverty and inequality

According to the 2015 Lahore University of Management Sciences/Oxfam GB research on inequality in Pakistan, Sindh is the most polarised province in Pakistan in terms of inequality, with the highest Gini index.[b] In other words, the divide between rich and poor in Sindh is more significant than any other province [62]. The Gini index increased in all four of Pakistan's provinces up until the mid-1990s, it registered a declining trend afterwards, suggesting households have become more equal within each province. Still, as a differential, in 2011–12 the Gini index for Sindh was 9.8 per cent higher than for Pakistan as a whole; inter-temporal income or consumption inequality is not only low but is also stable.

Investment in social infrastructure is generally concentrated in or around metropolitan districts, while districts located away from such centres, for example, in interior Sindh lag behind. Also, the human capital infrastructure gap between the most and the least developed districts is increasing over time [62].

Water management

The increasing frequency and severity of water shortages in Sindh can be attributed to factors other than climate change and natural variability, these include; poor storage capacity, losses at the field level, wastage, inequitable distribution and political influence that denies water supplies to tail-end farmers whose lands are fed by perennial canals like Nara and Rohri. Besides, farmers often lack support mechanisms, and capacities to use efficient irrigation systems involving drips, pivots and sprinklers that are the norm in developed countries.

Presently, irrigation water tariffs (abiana) are set too low to cover the costs of maintenance and repair of canal irrigation management and distribution systems (including drainage). There are inadequacies in how areas are assessed for water tariffs, and tariff collection is uneven, inefficient, and inequitable. Irrigation service delivery by the public sector is generally poor, with concerns on the equity and reliability of water distribution. Farmers in the tail end of the canals invariably do not receive their share of water because of the poor physical state of the waterways, water theft by farmers upstream, and rent-seeking by operators. Tail-enders are typically deemed to be at a disadvantage, receiving less water compared with farmers at the head of the canals, while paying more. The gap between operation and maintenance expenditures and revenue collection is about 70 per cent in Sindh.

State of mechanisation - an overview

The mechanisation of agriculture is playing a strategic role in improving agricultural production and productivity in Pakistan. The typical farm size in Pakistan is about 1 ha, and small and marginal land holdings (less than 2 ha) account for 85 per cent of land holdings. Small and non-contiguous groups of farms fail to achieve the 'economies of scale' required for them to make the substantial capital requirement for ownership of farm machinery. Over the past six decades, there has been a direct correlation between farm power availability and productivity. As an agrarian country, mechanisation is essential for Pakistan's economy optimising the use of biological, chemical and hydrological inputs. Up to now, the country has experienced 'selective farm mechanisation' limited to use of tractors – although over the past years the production of tractors increased significantly, experiencing a 37.6 per cent increase in 2018 compared with the previous year, with about 44,459 locally-made tractors sold.

The demand for tractors has increased. In part because the GoP lowered the Goods and Services Tax (GST) on tractors to 5 per cent [63]. There are approximately 0.94 million tractors in Pakistan, which provides 0.62kVA/0.41ha. Preparing the land is the only operation that is almost fully mechanised in the country for nearly all crops [64]. The uses of planting and spraying machinery have grown, and almost all cereal crops are threshed uses mechanised threshing. By increasing the available horsepower per hectare and through the proper management of agricultural machinery, the average crop yield can be enhanced.

Projected changes in climate

Owing to its aridity, the climate of Sindh is typically hot and variable. The average temperature during summer is 35°C, dropping to 16°C in winter. In summers, the temperature may rise to 45°C, and occasionally to 50°C, making the summer heat extremely variable. The highest temperature recorded in northern Sindh was 52°C. Sindh is projected to experience warming of 1.9 – 2.4 °C by 2050, with the largest increases seen inland away from the coast. A projected increase in maximum and minimum temperatures in winter will result in shorter winters and longer summers. The late onset and early ending of winter will reduce the length of the growing season. The premature end of winter means that temperatures will start rising in February just when the wheat crop reaches the grain formation stage. A sharp rise in temperature causes the forced maturity of grains, but they will not grow to a proper size and weight, nor accumulate

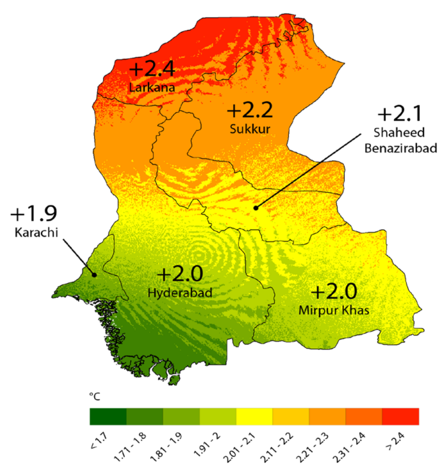
b The Gini index measures the degree of inequality in the distribution of family income in a country.

the optimum starch content; this will reduce the grain yield, as well as the economic return [65]. It is virtually certain there will be more frequent hot temperature extremes over most land areas during the next 50 years. Extreme heat is not only an agricultural threat, it is also a serious health risk, especially for elderly populations. The heat wave that struck Karachi in June 2015 led to the death of more than 1,200 people [66]. Although warming will not be uniform regionally in Sindh, the temperature increase will be slightly higher than the worldwide average.

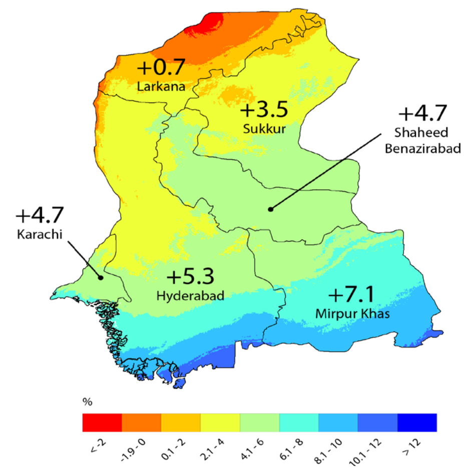
Climate change is altering the monsoon pattern in Pakistan and Sindh, driving changes in timing and intensity of rains. Climate change is also impacting water availability in Sindh through the melting of glaciers in the Himalayan and Hindu Kush mountain ranges which feed the Indus.[c] The result of which will interrupt seasonal flows in the Indus, requiring adjusted water management practices in the delta [67]. Crops are grown in both irrigated areas, and those under spate farming systems are highly sensitive to the amount of water available and temperature variability. It is estimated that with the rise of temperature (+0.50°C to 2°C), agricultural productivity will decrease by around 8 to 10 per cent by 2040 [68].

Projected change in Temperature and Precipitation in Sindh by 2050 [69, 70]

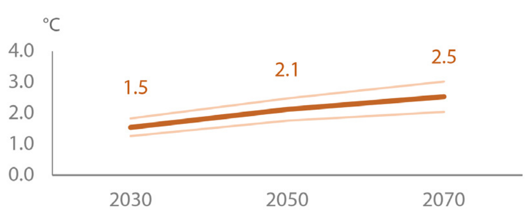
Changes in annual mean temperature (°C)



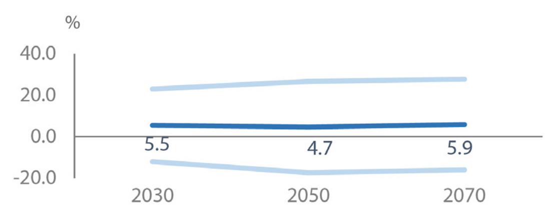
Changes in total precipitation (%)



Average temperature (°C)



Average precipitation (%)



Various simulation models project a decrease in yield of wheat and rice crops, and the length of growing season in the different agro-climatic zones of the country. For example, a 6 per cent reduction in wheat yield, and 15 to 18 per cent decrease for fine-grain aromatic basmati rice yield in all agroclimatic zones except northern areas [71].

According to the climate models, Sindh is expected to receive heavier than average rainfall during the monsoon season, but no significant change is foreseen for winter rainfall, which is low in this region of the country. The peak rainfall will occur in August, followed by July during the first half of the century. Future projections of precipitation also indicate that the rainy season in Sindh may extend towards autumn. In that case, it will be a challenge for wheat farmers to plant their crops on time since soils will not dry out sufficiently in the wet season to properly sow the fields. Drainage and soil reclamation should be a priority in the low-lying deltaic region. Surpluses and deficits of water will challenge food security in Sindh. An excess of water threatens agriculture by raising the water table, reducing soil drainage and increasing waterlogging and salinity. A deficit of water will cause drought, which will need canal or groundwater irrigation for crops [65].

c Around one-fifth of the world's population, mostly in South Asia, lives near these rivers.

Floods are expected to increase in the Indus delta, along with saline intrusion from sea level rise (SLR). Historic sea level rise for Pakistan is estimated at 1.1 mm per year from 1856–2000 along the Karachi coast. The IPCC AR5 notes a global mean SLR of 0.2–0.6 m by the end of this century, along the Arabian Sea border, an increase of 0.7 m SLR is projected by 2100, relative to the pre-industrial level. Future sea level rise will most likely affect the low-lying coastal areas south of Karachi towards Keti Bander and the Indus River delta. The vulnerability of Sindh's coastal region to SLR is probably higher than that of Baluchistan because of its flat topography and higher population concentration (with industrial activities along coastal areas, such as Karachi). Because of the increased frequency of storm surges combined with the SLR, saltwater intrusion has become an emerging challenge that, in time, will affect more of Sindh's land [72]. The saline and sodic content would rise to such a critical level that it would reduce the yield potential of fertile deltaic soils [73].

Overview of Climate-Smart Agriculture technologies and practices and their contribution to building resilience in the agricultural sector

Climate-Smart Agriculture technologies and practices present opportunities for addressing climate change challenges, as well as for economic growth and development of the agriculture sector. Hundreds of technologies and approaches around the world fall under the heading of CSA. For this profile, practices are considered as CSA if they improve food security as well as at least one of the other objectives of CSA (adaptation and/or mitigation) in the site-specific context of Sindh.

DRR actions and measures may be used to complement CSA techniques and practices to reduce the impacts of natural hazards and climate extremes. While these may vary from one crop to another and in different locations, some generic categories of DRR actions or measures–both on and off-farm – include:

- ***Preventive measures –*** land use regulations; seasonal crop planning; improved building codes (for example, for animal and food storage facilities); operation and maintenance (of irrigation systems); and public awareness and public education specifically targetting both male and female farmers;

- ***Emergency services –*** improved short-term natural hazard warnings and emergency response of local government authorities;

- ***Land and property protection –*** possibly structural relocation; elevation of growing beds; floodproofing; insurance; shrub removal; and emergency response planning;

- ***Structural projects –*** dams, levees, floodwalls, bridge and culvert modifications; firebreaks; measures to reduce soil erosion; and improving water source development;

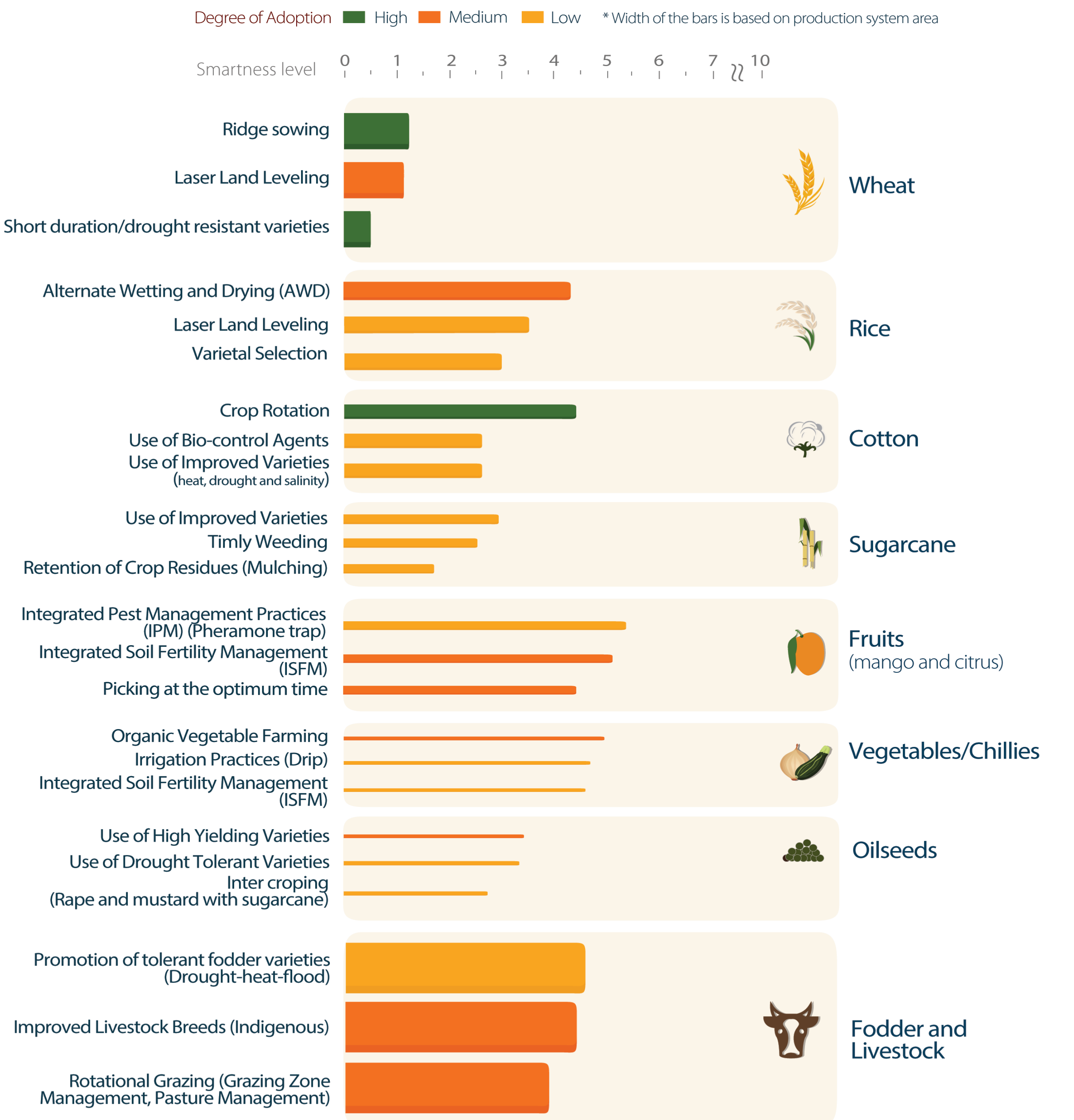
- ***Natural resource protection –*** preserving open spaces; wetland protection; identification and implementation of good management practices; and water resources management planning; and

- ***Public information –*** GIS map information; library resources; agricultural extension efforts; and environmental education.

Main practices identified and analysed in Sindh

The following graphics present a selection of CSA practices with high climate smartness scores according to expert evaluations. The average climate smartness score is calculated based on the practice's scores on eight climate smartness dimensions that relate to the CSA pillars: yield, income (productivity); water, soil, risks (adaptation); energy, carbon and nitrogen (mitigation). A practice can have a negative/positive/zero impact on a selected CSA indicator, with 10 (+/-) indicating a 100 per cent change (positive/negative) and 0 indicating no change. Practices in the graphics have been selected each of the production systems that are key for food security in Sindh.

Selected CSA practices and technologies for production systems key for food security in Sindh



** Unidentified production system area

For each of the above commodities, the prioritised practices were assessed for two separate regions in Sindh, reflecting the ability of the practice to meet the specific needs of the different regions. The identified regions were connected to the AEZ map which can be seen below. For wheat, rice, cotton, mango and oilseeds the two regions were identified as north Sindh (AEZ: I, II, III, IV, V, X) and south Sindh (AEZ: IV, V, VI, VII, VIII, IX, X), with north Sindh characterised by higher temperatures while the south is water stressed with greater impact from salinization and storm surges. For livestock, it was considered important to compare the effectiveness of the practice in the rain fed and irrigated (barrage) areas. Sugarcane was assessed for its ability to overcome the challenges faced in central and lower Sindh, namely limited water resources and higher salinity. The needs of vegetable production were seen to be different in southcentral and northwest Sindh.

Regions where the practices are implemented: **LS:** Lower Sindh ; **CS:** Central Sindh; **NW:** North West; **SC:** South Central; **BA:** Barrage Area; **RA:** Rainfed Area; **NS:** Northern Sindh; **SS:** Southern Sindh

The prioritised practices and those which received the highest smartness scores were often those which helped to mitigate the impacts of the major hazards facing agricultural production in Sindh. With only one of the prioritised practices considered to have no resilience building component. Figure 1 looks at the aggregate of the hazards mitigated by the different practices. What can be seen from the results is that the majority of the practices prioritised were focussed on mitigating the risks of droughts and pest and disease outbreaks, followed by heavy rains, high temperatures, flooding and salinization. This does not go to say that droughts and pest and disease outbreaks are the most severe hazards in Sindh, rather that they can be more effectively mitigated with on-farm CSA practices. While other hazards such as flooding and salinization are better managed through structural off-farm DRR measures.

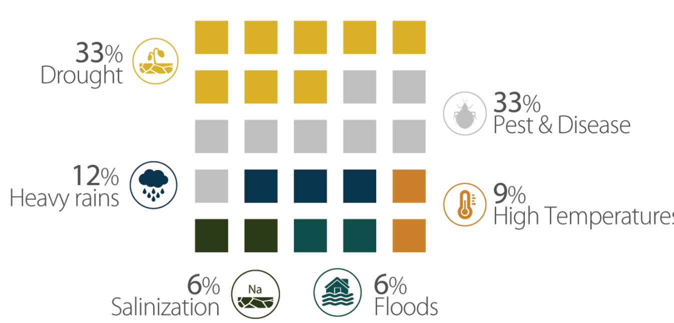


Figure 1: Provides an overview of the different hazards addressed by the prioritised CSA Practices

Practices and Technologies by Commodity

Wheat

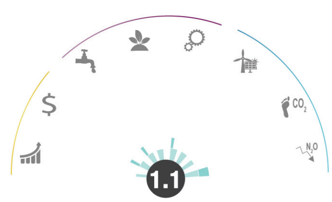
Wheat production in Sindh is constrained by multiple hazards including droughts, high temperatures and flooding. Laser land levelling and ridge sowing were prioritised as best practices, improving risk management, water and nutrient use efficiency.

Wheat is the major crop of Pakistan, accounting for 9.1 per cent of the value added in agriculture and contributing 1.7 per cent of the national GDP [63]. The production performance of wheat affects the overall growth rate of the economy, the import bill and the population's nutritional standards. Over the past few years, the country imported a million tonnes of wheat to meet the domestic needs of the growing population. Sindh is the second largest wheat producing province behind Punjab, with a planted area of 1.2 Mha (13 per cent of Pakistan's total planted area), producing 3.9 million tonnes (15 per cent of total). Of the four provinces in Pakistan, Sindh has the highest average wheat yields at 3.4 tonnes/ha; this is a fall from the average yields from 2010-15 [22]. The major wheat growing districts in Sindh are Khairpur, Ghotki, Shaheed Benazirabad, Naushero Feroze and Sanghar in AEZ's III, IV and X [74].

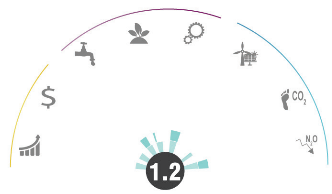
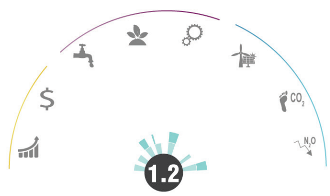
Wheat is a rabi crop, with sowing taking place from November-December and harvesting from March-April. The growing period for wheat in Sindh is temperature dependent, with southern Sindh experiencing a shorter growing period, restricting it to early maturing varieties. The time of sowing is an essential factor in obtaining an optimal return, with late planting resulting in a 12-16 kg daily reduction in the yield [75]. Rainfall is one of the most crucial factors impacting annual wheat production in Sindh, rainfall before sowing and shooting to the grain formation stage, is hugely beneficial. Conversely, rain after seeding, before germination and at the time of full maturity, negatively affects crop growth and yield. The plants have high water or soil moisture requirements during the flowering stage, followed by grain formation, and then vegetative stages [76]. Intermittent periods of high temperatures (>35°C), commonly experienced across Sindh, can significantly reduce yield and quality [77]. The development of heat-tolerant varieties is crucial to improving productivity in areas experiencing extremely high temperatures and variable rainfall [78].

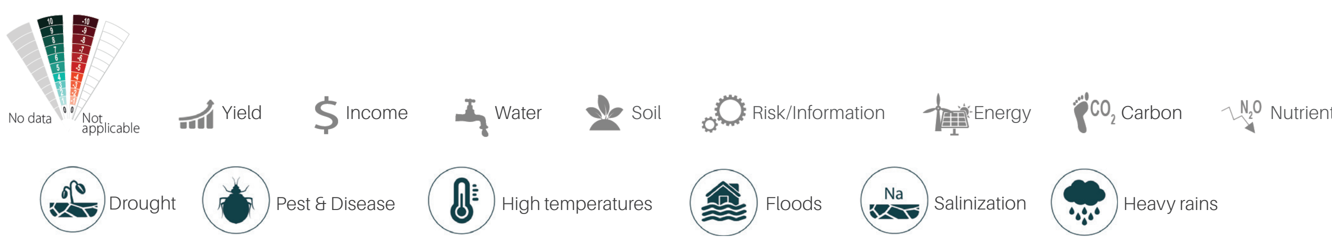
There remains a considerable gap between Pakistan's wheat yield and that of other advanced countries. The reasons for this include: delayed and prolonged harvesting of kharif crops (like cotton, sugarcane and rice) and consequent late planting of wheat; non-availability of inputs including seeds; the increase in input prices such as electricity, fertilisers, pesticides, and fuel; inefficient fertiliser use; weed infestation, soil degradation; acute shortages of irrigation water; climate change (causing drought in rainfed areas, heat stress, salinization and flooding), and weak extension services system [79].

Table 1. Detailed smartness assessment for selected wheat CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Wheat (23% of total harvested area)				
Laser Land Levelling ++ +	Northern Sindh <30%	M L		**Productivity** Increased yields and nutrient efficiency. **Adaptation** Improves water and nutrient use efficiency through even distribution across field. **Mitigation** Reduces emissions from pumping and excess inorganic fertiliser application.
	Southern Sindh <30%	M L		

12 Refer to Ayub Agriculture Research Institute https://aari.punjab.gov.pk/crop_varieties_wheat

CSA practice	Region and adoption rate (%)	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Wheat (23% of total harvested area)				
Ridge sowing + ++ +	Northern Sindh <30%	M L		**Productivity** 10-15% improvement in farmers incomes. Reduction in post harvest losses. **Adaptation** Improves irrigation water use efficiency, reduced losses under flooding and heavy rainfall, and reduces incidence of pest and disease. **Mitigation** Reduced energy use for pumping.
	Southern Sindh <30%	M L		



Laser land levelling is a suggested CSA practice for wheat. By employing this practice, farmers can achieve a uniform surface to their field, reducing pooling and the uneven distribution of water. The method relies on a laser beam situated at a fixed point at the side of the field, and a receiver fixed to the plough, regulating its height. High capital costs mean that agricultural service providers or government agencies primarily do this practice. Adopters of this practice have been found to save (10 per cent) on irrigation water, achieve uniformity in germination and timely maturity of the crop. The method is often encouraged in conjunction with short-duration or drought-resistant varieties. Some of the benefits of implementing this practice would be increased yields to ensure food security, proper use of irrigation water, and more effective use of fertilisers. Practices such as laser land levelling which promote gains in water use efficiency will become increasingly important in Sindh which is becoming increasingly exposed to droughts as growing water demand outstrips falling supply.

Other approaches include ridge-furrow planting, an efficient irrigation method in which water moves in a furrow and the wheat is planted on raised beds. Farmers have used this method for the last four years in Sindh. Through this practice, a 22 per cent saving of irrigation water and a 17 to 24 per cent increase in production has been achieved compared with the conventional method of broadcasting [80]. This approach thus increases yields, helping to improve food security, saves water to mitigate emissions associated with pumping, and reduces the incidence of disease and pests, while also lessening the need for pesticides.

To take a more sustainable approach, farmers must be trained to look beyond their over reliance on synthetic fertilizers. One approach proposed is that of integrated soil fertility management, where the application of macro nutrients is done at the correct time, with the correct placement and from the right source (preferably organic). Pursuing such practices has been found to have a restoring effect on both above and belowground biodiversity and microorganism dynamics, improving soil health and yields in the long term [69].

Rice

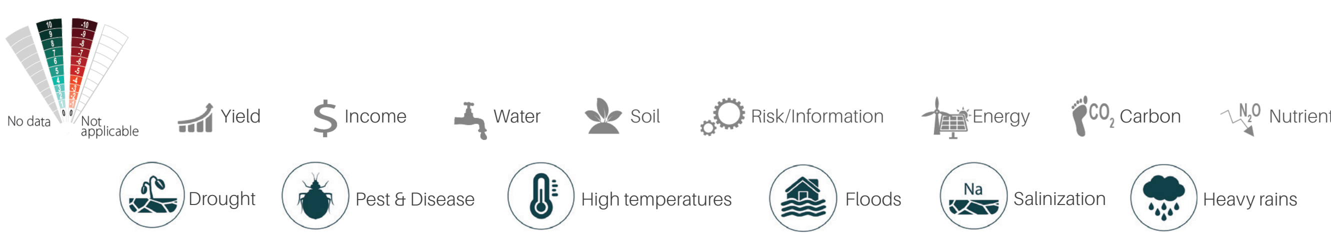
Rice yields in Sindh are negatively impacted by water scarcity, salinity, submergence and high temperatures. Prioritised practices of laser land levelling and alternate wetting and drying (AWD) were prioritised for their capacity to improve water use efficiency, ensuring high yields under drought conditions.

Pakistan is the world's eleventh largest rice producer and fifth largest exporter [81]. The domestic demand for rice is 2.2 million tonnes, leaving 4 million tons available for export, which amounts to almost US$2.0 billion, or 10 per cent of total exports. Sindh produces 35 per cent of the country's rice with annual production at around 2.6 million tonnes and an average yield of 3.5 tonnes/ha [22]. The rice-growing sector is estimated to employ about half a million people in Sindh.

In Sindh, rice is grown under diverse climatic and hydrological conditions with production concentrated in two distinct agro-ecological zones (AEZ), AEZ-3 which stretches down the west bank of the Indus, while AEZ-4 consists of large spill flats and basins which are generally irrigated. In Zone 3, the long, sweltering summers are well suited for growing coarse rice varieties, along with gram,

Table 2. Detailed smartness assessment for selected rice CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Rice (15% of total harvested area)				
Laser Land Levelling  ++  +	Northern Sindh 30-60%	M L	 3.4	**Productivity** Increased yields and nutrient efficiency. **Adaptation** Improves water and nutrient use efficiency through even distribution across field. **Mitigation** Reduces emissions from pumping and excess inorganic fertiliser application.
	Southern Sindh 30-60%	M L	 3.5	
Alternate Wetting and Drying (AWD)  ++  +  +	Northern Sindh <30%	M L	 4.3	**Productivity** Reduced water pumping costs increase farmers income. **Adaptation** Improves water use efficiency, increasing water availability in times of drought. **Mitigation** Reduced methane emissions compared to continuous flooding.
	Southern Sindh <30%	M L	 4.3	



wheat/barley, oilseed, Lathyrus, sarsoon, pulses, coriander and berseem/alfalfa. Rice farmers in Sindh face many challenges, with production highly sensitive to drought, salinity, high temperatures, and submergence/flood stress, forcing farmers to migrate (temporarily in many cases) to Karachi and other cities and towns to seek work. A total of 50 per cent of the province's irrigated area is waterlogged, while 56 per cent is affected by salinity [82]. The adoption of improved and certified rice varieties is essential for increasing rice productivity and profit. The adoption of such varieties has not been widely adopted due to high prices and a lack of availability. Productivity gains are held back by the absence of government subsidies, a shortage of credit facilities, a lack of awareness, poor infrastructure, rising costs of fertilisers, and a shortage of irrigation water [77]. Despite initiatives from the Sindh Seed Corporation, and the Rice Research Institute in Dokri, Larkana to promote certified seeds, only 10 per cent of rice growers adopt such practices, with the remainder relying on last year's seed due to high costs and a lack of availability. Replacement of conventional with improved varieties can significantly increase rice productivity [83]. In line with the strategic objectives of the Pakistan Agriculture Research Council (PARC), the best performing improved varieties should be identified and promoted by region. This process would be based on the specific soil, climate and hazard profiles of the different regions to promote varieties (drought, heat, flood or salinity tolerant, or short duration) that will achieve the highest returns while building resilience to natural hazards.

Laser land levelling was proposed as a CSA technology in response to water stress in Sindh. The creation of an even field surface improves the water use efficiency of rice production, increases germination rates and decreases losses. It is, however, a relatively expensive practice that farmers can only afford every three to four years with the help of a service provider.

Partial cost-benefit analysis of rice crop demonstration plot [84]

From 2015-2017, the Pakistan Red Crescent Society implemented a pilot programme to demonstrate CSA techniques for rice cultivation in Thatta district, Sindh. The profit in the demonstration plot was 51 per cent greater compared to the traditional farming plot. One of the most successful CSA techniques was to transplant seedlings, which increased yields; transplanting in rows meant that seedlings received uniform sunlight and aeration for better growth and fewer weeds. Another method was to shift to organic fertilisers since inorganic fertilisers negatively impact the soil, crops, and the environment. For example, the routine application of urea and DAP fertilisers increases soil pH, of already alkaline soils. Other CSA techniques to explore include adjusting the timing of planting, fertiliser application, and harvesting. Also, improved irrigation and weeding of the paddy can reduce disease and pest infestations. The demonstration plot showed farmers various options to improve crop management while minimising the use of pesticides for a safer environment. The rice cultivation with modern and progressive methods resulted in increased profits, which created a keen interest in CSA among local farmers.

Alternate wetting and drying (AWD) is another CSA practice with the potential to help rice growers in Sindh. AWD is a water management strategy which reduces the need for constant submergence of rice, which remains flooded during critical growing periods like flowering, but otherwise water levels can alternate between surface flooding and water levels falling below soil surface. The practice has proved to be an extremely effective water-saving technique, while reducing methane emission by nearly 70 per cent and maintaining rice yields [85]. Another associated benefit of AWD is reduced arsenic levels in the rice grain, as irrigation sources are often found to be contaminated with arsenic [86].

Cotton

Cotton cultivation in Sindh is heavily impacted by the pest and disease outbreaks along with extreme temperatures and flooding. Prioritised practices for cotton cultivation include the use of bio-control agents and crop rotation.

Cotton is one of the four major crops of Pakistan, accounting for for 8 per cent of the value-added in agriculture and contributes about 2 per cent to national GDP. Cotton is an essential input for the indigenous textile industry of Pakistan. In Sindh, cotton is cultivated on more than 404,686 ha [87]. The target for cotton production for 2018-19 was fixed by the Government at 4.2 million bales for Sindh from about 0.62 Mha. The main cotton growing districts in Sindh are Khairpur, Ghotki, Shaheed Benazirabad, Sanghar and Mirpurkhas, located in AEZ's III, IV, VII and X. The two most popular varieties of cotton grown are NIAB and the newly introduced Bt Cotton (a genetically modified variety containing toxins from Bacillus thuringiensis). The Better Cotton Initiative (BCI) introduced "better cotton" in Pakistan in 2009 as an effort to address the adverse socio-economic and environmental effects of conventional cotton production, using resources more efficiently and producing fewer environmental externalities.

Cotton requires sandy loam, silty loam and clay, with temperatures for optimum crop production ranging from a maximum 40°C to a minimum 26°C. The primary hazard impacting cotton production is the increased incidence of extremely high temperatures over 40°C, which result in fruit shedding, significantly reducing yields. Research has shown that a 1°C increase in temperatures during full picking can reduce yields by as much as 31 per cent, while higher temperatures earlier on in the lifecycle have a positive impact on returns [58]. According to the Pakistan Central Cotton Committee's (PCCC's) report, cotton quality is also deteriorating due to fake Bt Cotton seeds with high toxin levels, impacting both production and quality. Average contamination in Pakistan is 18g/bale against the international standard of 2.5g/bales, resulting in monetary losses of almost US$1.4 billion every year.

Another prominent threat to cotton production is water scarcity. Presently, farmers fear that because of severe water shortage the output of cotton may decline by 35 to 40 per cent compared to last year. The enormous increase in water, gas, fuel and electricity prices have also impacted the yield per hectare. According to the PCCC's report, over the last five years, cotton production has decreased from 13.86 million bales to 11.98 million bales (14 per cent) [88]. Total sowing of the country stands at about 2.5 Mha, seeing a decline over the last five years of 8.8 per cent. CSA has been proposed to mitigate the impacts of water scarcity, pest and disease outbreaks, salinity and extreme temperatures on cotton production, helping to build farmer's resilience to these common hazards. It has been observed that water-smart (planting in raised beds, laser land levelling, and the conjunctive use of water and drainage management), carbon-smart (reduced chemical use), and knowledge-smart (crop rotation and improved varieties, i.e. tolerant to drought, flood and heat stresses) practices are being adopted by cotton farmers in Sindh and elsewhere in the country.

Experts in Sindh prioritised crop rotation, bio-control agents and varietal selection as promising CSA practices for the province. Food security and health tend to increase with the introduction of crop rotation, specifically with pulses. Pulses and green manure crops are relatively input-efficient, enhancing spoil health, biodiversity and food security. Studies in Pakistan found that dual rows of cotton planted 120 cm apart with maize, sorghum, rice bean and cowpea fodders planted in-between provided higher economic returns than cotton monocrops [89]. This can be complemented with the use of organic fertilisers and applying a balanced mix of fertilisers to reduce GHG emissions while increasing productivity. The integration of biocontrol agents and forecasting systems for disease or pest can save on costs for pesticides, as well as bring environmental benefits. Farmers may use crop varieties that are tolerant to heat, drought, and salinity, which would reduce shedding and the need for irrigated water.

Another CSA practice currently being promoted for cotton in Sindh is the use of drip irrigation to improve water and nutrients use efficiency by delivering water slowly and directly to the roots of plants, either onto the soil surface or directly to the roots. Drip irrigation has been found to improve cotton yields while reducing water usage [90]. Planting cotton in raised ridges, is also used as it offers effective control over irrigation, water drainage and transport of nutrients. Sowing cotton on raised beds or ridges also enables larger plant populations due to better seed germination and seedling emergence even during heavy rains [91]. It further protects the crops from temporary waterlogging caused by flooding or heavy rains.

Table 4. Detailed smartness assessment for selected cotton CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 / 30-60 / 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Cotton (12% of total harvested area)				
Use of Bio-control Agents (Pest & Disease ++)	Northern Sindh <30%	S		**Productivity** Increased productivity and reduced expenditure on pesticides. **Adaptation** Reduced losses from pest attack. **Mitigation** Decreased pesticide use reduces GHG emissions.
	Southern Sindh <30%	S		
Crop Rotation (Pulses) (Pest & Disease +; Heavy rains +)	Northern Sindh <30%	L		**Productivity** Pulses act as green manure reducing input costs. **Adaptation** Pulses improve soil health. Income diversified. Reduced incidence of insect damage. **Mitigation** Falling fertiliser use reduces emissions.
	Southern Sindh <30%	L		

Yield · Income · Water · Soil · Risk/Information · Energy · CO_2 Carbon · N_2O Nutrient

Drought · Pest & Disease · High temperatures · Floods · Salinization · Heavy rains

Sugarcane

The practices promoted for sugarcane production targeted the primary hazards of pest and diseases, drought and high temperatures. Practices included the use of improved varieties and timely weeding.

The sugar industry is Pakistan's second largest agriculture-based industry after textiles. Sugarcane production for 2018-19 is forecast at 72 MMT, down 12 per cent from the revised 2017-18 estimate. The planting area has decreased 9 per cent compared to a year ago as farmers shifted to cotton. This is partly due to farmers' concerns about late payments from mills and lower prices [92]. Sindh accounts for 25 per cent of the total sugarcane production area in Pakistan, approximately 20.3 MMT, from about 333,000 ha. Sugarcane production is focussed in AEZ's III, IV, VII and IX in central and lower Sindh.

Sugarcane is a tropical crop, tolerating high temperatures, with an optimum growing temperature of 30°C. Sugarcane in Sindh has two planting seasons – the winter season with sowing from September to November, and the spring season with planting from February to March. Planting times should be carefully observed with late planting reducing yields by as much as 30 per cent. During the winter season sugarcane is often intercropped with onion. September planting gives robust growth but is most vulnerable to lodging if there are high winds or excessive rains [93].

The primary hazards impacting sugarcane production in Sindh are droughts and pest and disease outbreaks. Yields are further constrained by a lack of high yielding varieties and uneven fertiliser and pesticide application, resulting in a relatively low average yield of 57.5 tonnes/ha hectare, slightly below the 57.9 tonnes/ha in Pakistan, and well below its neighbour India with 69.7 tonnes/ha [22,94]. Like wheat, rice and maize, sugarcane is an exhaustive crop with an enormous nutrient requirement. Generally, fertiliser use in Pakistan is inadequately balanced, with most sugarcane producers using only nitrogenous (N) fertilisers or an imbalance of N and phosphorus (P); potassium (K) is almost neglected. Generally, water and fertiliser is applied simultaneously through an irrigation system ('fertigation'). Drought stress severely impacts sugarcane production, driving down yields.

The Seed Certification Department in Sindh promotes the adoption of improved varieties, increasing sugarcane yields under a changing climate. In Sindh, the leading early maturing varieties are GULABI-95, NIA-2004 and LARKANA-2001 with yields ranging from 150 to 170 tonnes per hectare, and mid-maturing varieties of NIA-98 and TH-10 with yields of 150 to 180 tonnes per hectare [95]. The majority of farmers however, still use seeds that are ill equipped to the conditions in Sindh, resulting in low yields and incomes [96]. Farmers need information on the most suitable varieties (drought, heat, pest and disease resistant, early maturing) for their region along with support in purchasing improved varieties through improved credit mechanisms. Timely weeding is encouraged as if left untended, weeds will compete with the crop for water, light and nutrients. These impacts will be magnified under climate change with warmer temperatures increasing weed populations and the pest and diseases that come with them [97]. Another example of a CSA practice for sugarcane is to retain crop residues or applying the remaining residues from previous crops. They are then incorporated into the soil, resulting in increased organic matter, water retention capacity, and soil fertility. These residues also increase microbial activity in the soil.

Seed rate and spacing are essential to ensure the optimal plant population, which is a crucial factor in sugarcane production. Planting sugarcane using a method of sowing called '2 in 1' means two sugarcane set rows in a single trench gives a much better crop stand and higher yield than traditional methods. Seed is often treated with hot water at 52°C for 30 minutes and with fungicide to improve germination and the control of many sugarcane diseases.

Table 5. Detailed smartness assessment for selected maize CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Sugarcane (6% of total harvested area)				
Use of Improved Varieties Drought ++ Pest & Disease ++ High temperatures ++	Lower Sindh 30-60%	M L		**Productivity** High yielding, resilient varieties reduce losses and increase productivity. **Adaptation** Improved varieties reduce losses under adverse climatic conditions along with pest and disease outbreaks. **Mitigation** Reduced requirement for pesticide and fungicide use reduces emissions and associated environmental degradation.
	Central Sindh 30-60%	M L		
Timely Weeding Drought + Pest & Disease ++	Central Sindh >60%	S		**Productivity** Improves nutrient use efficiency and yields, increasing productivity. **Adaptation** Eradication of weeds reduces incidence of pests and diseases. **Mitigation** Reduced fertiliser requirement reduces associated emissions.
	Lower Sindh >60%	S		

Yield · Income · Water · Soil · Risk/Information · Energy · CO_2 Carbon · N_2O Nutrient

Drought · Pest & Disease · High temperatures · Floods · Salinization · Heavy rains

Fruits (mango and citrus)

Fruit yields and quality in Sindh are below their potential due to the high incidence of pest attack and poor soil quality leaving orchards highly exposed to the effects of droughts and salinization. Practices of Integrated Pest Management and Integrated Soil Fertility Management were prioritised for their ability to reverse this trend.

Citrus production in Sindh is concentrated in Naushero Feroze, Mirpurkhas, Sanghar, Sukkur, Khairpur, and Shaheed Benazir Abad districts, corresponding to AEZ's II and IV. In 2016-17, about 42,000 ha were estimated to be growing citrus, producing approximately 26,300 tonnes. Most of the citrus produced is consumed locally without much value addition; however, 10-12 per cent of total production is exported. Citrus requires a critical low temperature for its ripening which if not achieved may lead to a decline in the production of fruit. The daily temperature fluctuations of Sindh are conducive to citrus production aiding flavour and sweetness, while the cooler climate of lower Sindh allows a virtually continuous harvest of lemons. Temperatures in Sindh rise a month earlier than Punjab, enabling the province to grow early varieties of mango, which start ripening from May to June. Sindhri is the leading variety grown in Sindh and considered one of the best.

Mangoes are the second largest fruit crop in the country after citrus, with a production of about 1.8 million tonnes grown on an area of about 170 Mha [98]. Sindh is second to Punjab, producing 24 per cent of total production. In 2016-17, Sindh grew mangoes on about 62,500 ha and produced 404,900 tonnes. Mangoes are grown mainly in Mirpurkhas, Tando Allah Yar, Hyderabad, Matiari and Sanghar districts, in AEZ IV [21]. In 2014-15, the country exported more than 4.6 million tonnes of mangoes, making a valuable contribution to foreign currency earning. Over the last couple of years, the production of quality mangoes has declined due in part to global warming and extreme weather events. While Sindh is comparatively less affected than Punjab, mango production in the south of the province has struggled under unforgiving weather (drought and heavy rains). Other factors contributing to decreased production include; use of unhealthy seeds forming diseased seedlings, insect attack (notably the mango mealy bug, fruit fly, mango weevil, scales, and mites), improper management practices during budding or grafting, timing of irrigation, pruning and application of fertilisers, which are contributing substantially to the decline of the industry. Adding to the ever-increasing problems are the post-harvest losses contributing almost 40 to 50 per cent. In 2016, 4.5 tonnes of mangoes were rejected by the European Union after discovering they were contaminated with fruit fly. Over five rejections will mean a complete ban on Pakistani fruit and vegetable imports in the European markets [99].

Table 6. Detailed smartness assessment for selected maize CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Fruits (3% of total harvested area)				
Integrated Soil Fertility Management (ISFM) + ++ ++	Northern Sindh 30-60%	S M L		**Productivity** Increased yields and nutrient efficiency. **Adaptation** Reduces soil degradation and associated erosion. Application timing adjusted to changing climate. **Mitigation** Improved nutrient use efficiency reduces emissions from excess inorganic fertiliser application.
	Southern Sindh 30-60%	S M L		

CSA practice	Region and adoption rate (%)	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Fruits (3% of total harvested area)				
Integrated Pest Management Practices (IPM) (Pheromone trap) ++	Northern Sindh 30-60%	S M		**Productivity** Improved yields and higher quality fruit fetch higher prices at market. **Adaptation** Reduce the impact of pest attack on fruit quality. **Mitigation** Reduced requirement for pesticide and fungicide use reduces emissions and associated environmental degradation.
	Southern Sindh 30-60%	S M		

CSA practices were proposed as a means to reverse the trend in climate related production losses for fruits in Sindh. To combat the impact of pests on fruit yields and quality, Integrated Pest Management (IPM) practices such as the use of pheromone traps were proposed. Pheromone (methyl eugenol) traps are hung from the branches of fruit trees during the mating season, attracting and trapping male flies, thus greatly reducing the population and its reproductive capacity. The placement of two to four traps per hectare can reduce infestation rates from 40 per cent down to 5 per cent [100].

Many fruit farmers are not achieving maximum yields due to the imbalanced use of fertiliser, reducing nutrient use efficiency. Farmers lack the knowledge of their soil to effectively balance the use of nitrogenous (N), phosphorus (P) and potassium (K) fertilisers to meet the plant needs, resulting in micronutrient deficiencies or excessive doses [101]. Improved information for farmers on the quantity and timing of fertiliser application will help improve yields. The implementation of integrated soil fertility management (ISFM) will positively impact soil health and structure, improving the resilience of fruit crops to drought, heavy rains and salinization.

Other proposed CSA practices are capacity building of farmers in fruit management training, comprising pruning and fertiliser application, improved mango varieties, manure and inorganic fertilisers and rain-water harvesting techniques to conserve water. These may include harvesting the road water run-off, micro-irrigation, or constructing terraces to increase water retention and reduce soil erosion.

Vegetables (tomatoes, chillies and onion)

The production of vegetables in Sindh is impacted by high temperatures, droughts, heavy rains and pests and disease outbreaks. Organic production and improved irrigation practices were proposed for their ability to improve soil health, water and nutrient use efficiency.

Vegetables comprise an essential component of the cropping pattern in Pakistan, but the increasing pressure on food and cash crops has limited the area under vegetables to roughly 2.3 per cent of the total cropped area (22.94 Mha). Of this, Sindh contributes about 26.2 per cent of the entire area under vegetable crops, producing a variety of vegetables including carrot, tomato, onion, chillies and potatoes. One of the most economically important vegetables in Sindh are tomatoes. The province is one of the main growing area of the country, with an output of about 141,586 tonnes, contributing a 25 per cent share of the total production. Next, in importance to tomatoes are onions. Sindh produced 666,764 MT of onion during 2014-15, on an area of 49,934 hectares according to Sindh Agriculture Department. After India, China and Mexico, Pakistan is the fourth largest producer of red chillies. The agro-ecological suitability of chilli production has resulted in an average yield of 1.7 tonnes/ha, contributing about 1.5 per cent of the national GDP. The three major types of chillies grown in Kunri are Maxi, Desi and Nageena [102].

In Pakistan, the per capita consumption of vegetables is currently low compared to other countries but the need for vegetables is expected to increase with the growing population and their changing diets. People in the upper-income strata consume well above the national average, while the bulk of the rural population and large percentage of poor among the urban population consume few vegetables [103]. As tomatoes are a relatively short duration crop with a three-month cropping cycle and give a high yield, the area under cultivation is increasing. Growers prepare nurseries in July for early sowing, and then harvest continues as late as February the following year with a few gaps [104]. October to December is the peak season for onion cultivation, although onions are grown throughout the year in the province. Chillies, being a warm-climate crop, are grown mostly in areas where the average temperature is 30°C for at least four to five months of the year. At lower temperatures growth becomes progressively weaker and despite being a warm season crop, at temperatures above 35°C coupled with dry winds, excessive flower drop may become a problem; therefore, increased regional temperatures propelled by climate change will negatively impact chillies production. Moreover, half the red chillies in the country are wasted due to contamination and aflatoxin. Aflatoxin is produced when chillies are dried on the ground. They should instead be dried on green sheets. Growers are being given 70 per cent subsidy on baskets used for collecting chillies while they receive Rs 1,000 extra as quality premium on their consignments under Sindh Growth Project funded by the World Bank [105]. Vegetables require specific post-harvest treatment, appropriate temperatures and relative humidity for their storage [106]. Post-harvest loss of vegetables produced in the country is about 35 per cent every year and estimated at US$ 800 million.

Table 7. Detailed smartness assessment for selected maize CSA practices implemented in Sindh

CSA practice	**Region and adoption rate (%)** **<30** **30-60** **60>**	**Predominant farm scale** **S: small scale** **M: medium scale** **L: large scale**	**Climate smartness**	**Impact on CSA Pillars**
Vegetables/Chillies (1% of total harvested area)				
Irrigation Practices (Drip) ++ +	North West <30%	M L		**Productivity** Plants receive exact water requirement, improving productivity and quality. **Adaptation** Improved water use efficiency, reducing requirement in times of drought. **Mitigation** Reduced pumping costs due to precision application.
	South Central <30%	S M L		
Organic Vegetable Farming + + +	North West <30%	M L		**Productivity** Farmers receive higher income for their produce and soil health is improved. **Adaptation** Maintains biodiversity and improves soil health. **Mitigation** Reduced emissions associated with inorganic fertiliser production.
	South Central <30%	M L		

Recommended CSA practices for vegetable production in Sindh include the introduction of organic vegetables and managing the chemical balance of fertilisers and pesticides through integrated soil fertility management. In line with the National Water Policy and Sindh Drought Mitigation and Management Policy (Draft), improved irrigation is another recommended CSA practice for vegetable farmers. Improved irrigation, such as drip irrigation, and land management help mitigate GHG emissions, waterlogging, and salinity through water-saving adaptive measures that follow the "More Crop Per Drop" concept. Salt- and drought-resistant genotypes can help to increase yields in saline soils while reducing poverty.[d] These practices would improve human health, income generation, and soil quality as well as the resilience of vegetable farmers to climate-induced drought and water stress.

Livestock and fodder

Livestock production is reliant on the availability of fodder for feed which can be greatly reduced during periods of drought. Cattle are also vulnerable to the effects of extreme temperatures and water scarcity. Tolerant fodder and livestock varieties were prioritised as CSA interventions.

The large-scale livestock sector plays a vital role in the agricultural-based economy of rural Pakistan and contributes about 58.9 per cent of the added value in agriculture and about 11.1 per cent to the national GDP. According to the 2017 livestock census, the total livestock population in Sindh was approximately 46.3 million animals. The livestock population had steadily increased as recent studies showed the Compound Annual Growth Rate for livestock population from 2006-2016 increased about 2.4 per cent for cattle, 2.7 per cent for buffaloes, 0.7 per cent for sheep, 2.6 per cent for goats, and 2.2 per cent for camels [107].

Pakistan's population growth, increased per capita income and export opportunities are fuelling the demand for livestock and livestock products in the country. However, dairy farmers face many problems including a shortage of veterinary facilities and access to loans or government subsidies. Many farmers require further training in modern dairy farming practice as recent studies of dairy farmers showed that only a few maintain farm records and use modern dairy techniques [107]. In addition, farmers also experience constraints in milk marketing. In 2013, the State Bank of Pakistan developed the Livestock Insurance Scheme (LLIS). As a collaborative undertaking with the Securities & Exchange Commission of Pakistan, other banks, insurance companies, and the provincial livestock and dairy departments, the LLIS aims to improve finance access for the livestock and dairy sector as well as risk mitigation for herd loss due to disease, natural calamities and accidents [108].

As livestock production intensifies the demand for fodder and the need to retain an uninterrupted supply increases. Therefore, fodder conservation is crucial in Sindh. Fodder crops in agriculture provide nutritious feed essential for the promotion and development of livestock, and supply over half of total animal feed [109]. However, the availability of fresh fodder fluctuates throughout the year. During the winter season, as well as between the two seasons (Kharif and Rabi), the non-availability of fodder leads to a drastic reduction in production performance of the livestock sector. Fodder includes pasture, hay, silage and roots that are used as animal feed.[e] In Sindh, challenges of water scarcity and increasing soil infertility have also disrupted fodder crop cultivation.

Haymaking[f] is used by many farmers in Sindh. Hay is high in dry matter and can help to control bloat and improve the milk quality by adding fibre and encouraging rumination. Throughout Sindh and elsewhere in Pakistan, Alfalfa (Lucerne) is the best animal feed available whereas the most important forage legume is berseem, a multi-cut, winter fodder crop grown under irrigated conditions which increases milk production and provides a good source of nutrition. Silage[g] is an integral part of animal feed rations that is economically cheaper than fresh fodder or hay and can supply feed any period of the year, which is especially useful during feed shortages.

CSA practices include promoting fodder varieties that are tolerant to drought, heat, and floods, as well as indigenous varieties. To address the winter-related feed shortage problems, seeds of rapid and multi-cut fodder types for quick production are needed to meet feed deficiencies which pose threats for the livestock population. More research is needed to identify appropriate fodder varieties, and extension departments have yet to design programmes to disseminate the approaches and seed varieties to climate-challenged areas, but good practices include cutting hay fodder to achieve the maximum nutritive value; drying the freshly cut fodder as quickly as possible; and appropriately storing to maintain quality. Similarly, for silage, good practices include cutting the fodder at the recommended growth stage; cutting into 2-3cm pieces; and repeatedly pressing the silage as much as possible to remove oxygen for anaerobic fermentation.

CSA practices for livestock include the introduction of new breeds through cross breeding and artificial insemination that are resilience to drought and diseases. Another practice is to promote rotational grazing, also referred to as grazing zone management or pasture management. New policies

d A geophyte is any plant that loses all its above-ground parts during winter.

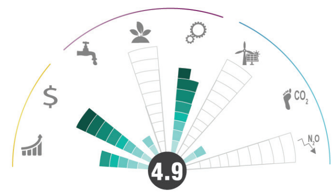
e Major fodder crops grown during winter include berseem, lucerne, oats, barley and mustard; while during summer these are maize, sorghum, S.S. Hybrids, millet guar and cowpeas.

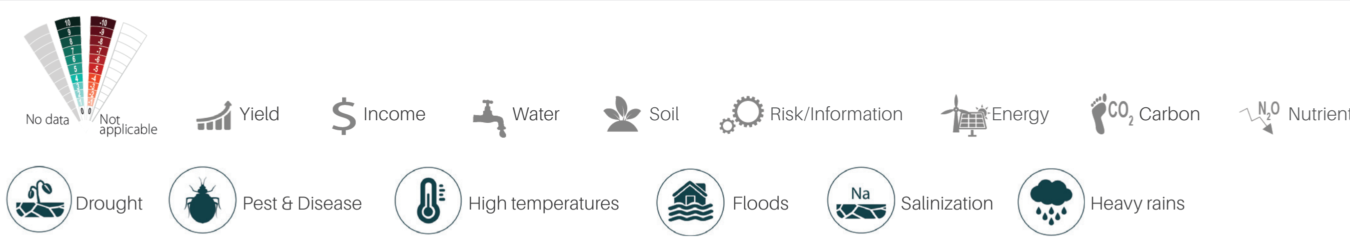
f Preserving dried fodder for easy storage, which is then made available to feed livestock, especially during periods of feed scarcity.

g Aims at preserving as much of the nutritional value of the original crop as possible by placing the fodder in an acidic environment whilst maintaining it as oxygen free (anaerobic) to prevent spoilage.

and better enforcement of existing policies on rotational practices would help to ensure that enough fodder is available for livestock during climate shocks. These CSA practices would likely have positive impacts by increasing the productivity of fodder inputs, along with an increase in yield in terms of the number of animals and milk production.

Table 8. Detailed smartness assessment for selected maize CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 / 30-60 / 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Livestock and fodder (NA)				
Improved Livestock Breeds (Indigenous + Exotic) + ++	Barrage Area <30%	L		**Productivity** Reduced losses in times of drought or extreme heat increase productivity. **Adaptation** Livestock breeds selected to be resilient to extreme conditions. **Mitigation** Varieties which produce fewer methane emissions can be selected.
	Southern Sindh <30%	L		
Promotion of tolerant fodder varieties (Drought-heat-flood) ++ ++ ++	Barrage Area <30%	S L		**Productivity** Improved varieties achieve higher yields and lower losses compared to conventional fodder crops. **Adaptation** Improved biodiversity. Tolerant varieties more resilient to adverse weather conditions. **Mitigation** Varieties can be selected which reduce the methane emissions from livestock.
	Rainfed Area <30%	S L		



Oilseeds

Oilseeds have a lower water requirement than other crops in Sindh but still suffer under drought conditions. The promotion of drought resistant and high yielding varieties was recommended by local experts.

In Pakistan, many oilseed crops are grown as a source of vegetable oil. Sindh contributes various oilseed crops, including mustard, sunflower, rapeseed and canola, but oilseed farming in general has fallen over the last decade due to low prices. In 2017, oilseeds were grown on about 26,300 ha in Sindh, while a decade earlier more than 121,400 ha of land was dedicated to oilseed production. The shortage of oilseed crop started in the 1970's with the rapid increase in population, per capita consumption, and stagnation of local oilseed crop production. An increase in the domestic production of oilseeds is needed to reduce the burden on the exchequer caused by edible oil imports. There is a considerable gap between consumption and local production of edible oils (1.6 million tonnes). The remaining areas of oilsseed production are located in Mirpurkhas, Sanghar, Larkana, Shaheed Benazirabad and Jacobabad districts in AEZ's I, II, IV, VII and X.

Among the Kharif oilseeds (sunflower, soybean, groundnut, sesame and caster), sunflower has gained popularity and hectarage among the new oilseed crops introduced to boost production yields. The essential features of this crop are a short growing period, high yield potential and a wide range of growing seasons (autumn, spring and winter). Sunflower fits well in different cropping patterns, has low irrigation water requirements, and wide adaptability to soil and moisture conditions. As oilseeds have low water requirements, it is feasible to increase the area of oilseeds in different AEZ's where it can compete with other crops; these potentially include coastal, barani, rod-kohi, and dobari lands in Sindh [110]. Despite needing less water than other crops, drought still poses a threat to oilseed crops. Sindh is classified as a region with high water scarcity, experiencing at least one major drought every five years, which could become more frequent and intense within a changing climate. Therefore, drought-resistant varieties of oilseed crops could be utilized to ensure sustainable yields and incomes. Another threat to production yields stem from disease incidence.

Oilseeds are prone to different diseases that can affect the quality and quantity of plants, some of which have the potential to destroy entire crops. Cultivation of disease resistant or tolerant varieties is alone a safe, economical and secure way to counter most infections. Crop rotation with non-host crops for two to three years is also reported as beneficial. Oilseed crops are also subject to various mechanical, physiological and biological stresses in all stages of growth. Primary factors affecting production include climate, toxicants, pollutants, insects, viruses, fungi, nematodes, and bacteria.

CSA practices for oilseed crops include the use of high yielding varieties, drought-tolerant varieties, and inter-cropping, for example, oilseed rape and mustard with sugarcane to diversify household incomes and decrease vulnerability to external stresses. These practices have the ability to sustain yields to meet rising demand as well as resistance to extreme weather events such as drought. Moreover, as a measure against disease incidence, crop rotation or intercropping with sugarcane provides oilseed farmers with alternate income while limiting vulnerabilities associated with monoculture systems.

Table 8. Detailed smartness assessment for selected maize CSA practices implemented in Sindh

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Oil Seeds (1% of total harvested area)				
Use of Drought Tolerant Varieties ++	Northern Sindh <30%	M L		**Productivity** Reduced losses due to drought improve productivity. **Adaptation** Increases yields under drought.
	Southern Sindh <30%	M L		
Use of High Yielding Varieties	Southern Sindh >60%	M L		**Productivity** Reduced losses due to drought improve productivity. **Adaptation** Increases yields under drought.
	Northern Sindh >60%	M L		

Yield Income Water Soil Risk/Information Energy CO_2 Carbon N_2O Nutrient

Drought Pest & Disease High temperatures Floods Salinization Heavy rains

Institutions and policies for CSA

Institutions

The Agriculture, Supply and Prices Department of the Government of Sindh is the lead entity responsible for provincial policy, planning and coordination in agriculture. The department has initiated development projects to improve farming methods, such as the Sindh Irrigated Agriculture Productivity Enhancement Project (SIAPEP) and the Sindh Agricultural Growth Project with financial assistance of World Bank. The department's activities include capacity building, adaptation and resilience strengthening to ensure climate-responsive agriculture to reduce poverty and food insecurity by half. Programmes also focus on managing natural resources sustainably, especially water resources and soil. Further, a sector-specific plan is to be devised in line with the agriculture policy adopted in April 2018, which will develop the capacity of relevant departments, adjust pertinent regulations and make appropriate technological changes aligned with the SDGs.

Within the Agriculture, Supply and Prices Department there are six wings; Research, Extension, Engineering and water management, Bureau of supply and prices, Planning and monitoring cell and the Cane commission. The wings are comprised of technical experts who support the creation and implementation of policies and activities within the department. Agriculture research has crop specific scientists located in field stations across the province conducting research on best practices. Agriculture extension uses a range of tools including radio, tv and smartphone apps to provide technical information and training to farmers on topics including CSA. Engineering and water management promote the transition to mechanisation in the province including the use of laser land levellers, and the management of irrigation systems and canals.

The Irrigation Department is the lead department for all activities concerning the irrigation network and barrage systems in Sindh. The department operates and maintains the irrigation and flood protection system, regulates flows of the River Indus and canal systems, covering Inter-Provincial and Intra Provincial Systems. This job will become increasingly challenging as demand for water outstrips supply, leading to difficult decisions on where water should be directed.

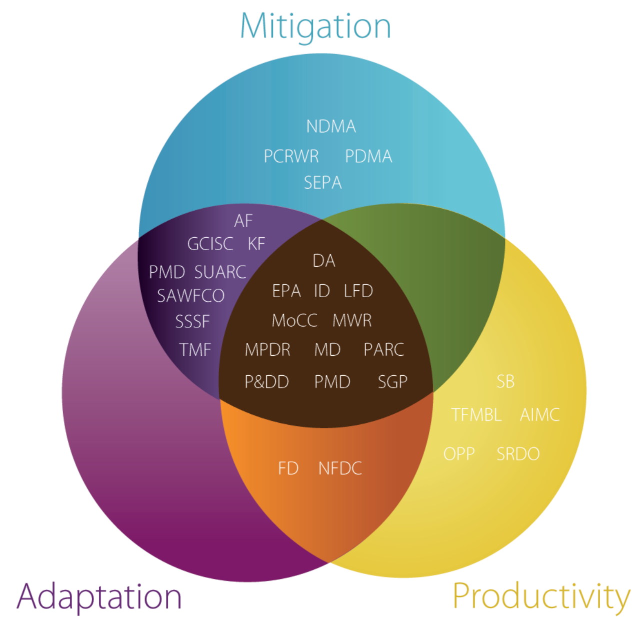
DRR activities in the province are headed by the Provincial Disaster Management Authority (PDMA) which is responsible for implementing policies and plans for disaster management. This includes the formulation of policies, assessment of vulnerabilities, establishment of disaster management plans, the evaluation of preparedness and increasing preparedness through education and outreach. The PDMA has presence within the districts in the form of District Disaster Management Authorities (DDMA) which work within the community to build resilience.

Several other departments and agencies, NGOs, development partners, research institutions and the private sector play critical roles in the agricultural sector, as described below:

- The Planning and Development Department focuses on rural and sustainable development and allocates funds for all three pillars. A SDGs Support Unit was set up in the Planning and Development Board, Sindh, with support from UNDP Pakistan to help implementation of the UN's Global Agenda 2030, including a focus on SDG 2 'End Hunger, achieve food security and improved nutrition and promote sustainable agriculture', in the province.

- The Meteorological Department works with agricultural extension services to disseminate weather advisories and improve farmers' planning for crops. For mitigation activities, the Sindh Environmental Protection Agency conducts environmental impact assessments (EIAs) and identifies measures to reduce GHG emissions that may be employed in Sindh's Annual Development Plan.

Enabling institutions for CSA in Sindh



AF AMARDO Foundation **AIMC** Akhuwat Islamic Microfinance Company **DA** Department of Agriculture **EPA** Environmental Protection Agency **FD** Food Department **GCISC** Global Change Impact Study Centre **ID** Irrigation Department **KF** Kashf Foundation **LFD** Livestock and Fisheries Department **MD** Metrological department Karachi **MoCC** Ministry of Climate Change **MPDR** Ministry of Planning, Development and Reform **MWR** Ministry of Water Resources **NDMA** National Disaster Management Authority **NFDC** National Fertilizer Development Centre **OPP** Orangi Pilot Project (OPP) **PARC** Pakistan Agricultural Research Council **PCRWR** Pakistan Council of Research in Water Resources (PCRWR) **PDMA** Provincial Disaster Management Authority **P&DD** Planning and Development Department **PMD** Pakistan Meteorological Department **SAWFCO** SAFCO Support Foundation **SB** Sindh Bank **SEPA** Sindh Environmental Protection Agency (SEPA) **SGP** Sindh GROWTH project **SRDO** Shadab Rural Development Organization **SSSF** Shah Sachal Sami Foundation **SUARC** Space and Upper Atmosphere Research Commission **TMF** Thardeep Microfinance Foundation **TFMBL** The First Microfinance Bank Ltd

- The Sindh Forest Department has mandated to protect, conserve and develop forestry resources in the province, which ultimately improves the environmental conditions in the province. The Department has introduced the Agro-Forestry Lease Policy wherein forestlands are leased out to individuals/corporate sector for five years extendable for another five years to raise forest trees in conjunction with agriculture crop.

- The Women Development Department, Sindh works on the formulation of public policies and laws to meet the individual needs of working women especially those engaged with agriculture. The department promotes of women's rights, gender equity and equality in the public sector and society in general.

- The Livestock Department, Sindh aims to impart training to livestock farmers on the problems of livestock management, animal breeding, animal nutrition and feeding, aquaculture and pond management.

- The Pakistani Red Crescents (PRC), supported by the German Red Cross run programmes throughout Pakistan and Sindh on risk reduction, preparedness and response. Their work includes Integrated Food Security Projects (IFSP) which recognise the importance of agricultural resilience as a component of DRR. Key areas covered were education on improved practices, access to finance, inputs and training.

While the presence of both local and international institutions is increasing, the sector remains fragmented with a lack of coordination among the different institutions. This results in gaps and overlaps in the implementation of policies and programmes focused on agricultural development, DRR and CSA adoption. International and local NGOs have implemented some CBDRM projects, mainly focusing on targeted areas, rather than the entire province. This includes structural and non-structural activities drawing on community-driven DRR measures; for example, infrastructure, land use planning, policies and regulations. Regarding early warning and information dissemination, the current mechanisms have not resulted in effective communication and exchange between institutions and communities. This has led to a lack of confidence in public institutions and causes delays in disaster responses, as well as the slow implementation of recommended climate forecast applications in the agriculture sector.

Policies

The graphic shows a selection of policies, strategies and programmes that relate to agriculture and climate change topics and are considered vital enablers of CSA and DRR in the country and province. The policy cycle classification aims to show gaps and opportunities in policy-making. Referring to the three main stages: policy formulation (relating to a policy that is in an initial formulation stage/consultation process), policy formalization (to indicate the presence of mechanisms for the policy to process at national level) and policy in active implementation (to show visible progress/ outcomes towards achieving broader policy goals, through concrete strategies and action plans).

The policy, implementation and financial responsibilities for climate change interventions and CSA rests with the provinces following the 18th amendment to the National Constitution in 2010. This amendment transferred many prerogatives of the Federal Government of Pakistan (GoP) to the provinces. However, the GoP remains the focal point for international commitments and setting the national climate agenda. Sindh has remained an active participant in climate activities through its endorsement of national policies. The National Climate Change Policy (2012) a multi-sectoral initiative provides policy guidance on climate change adaptation and mitigation for the country. The policy stresses the need for improvements in agriculture and disaster preparedness. The policy also emphasises on raising awareness, technology transfer and capacity building and institutional strengthening. Moreover, inter-ministerial coordination, regional and international cooperation are also proposed.

Pakistan ratified the 2015 Paris Accord in 2016 as part of its commitment to international climate action. The GoP engages in the UNFCCC through the Ministry of Climate Change, Pakistan's focal institution internationally on climate change. The Framework follows the NCCP policy for Implementation of the Climate Change Policy (2014-2030) and identifies vulnerabilities to climate change, outlining potential avenues for adaptation and mitigation. However, policy implementation both nationally and provincially has been slow due to the lack of resources from the provincial government.

The GoP framed Vision 2025: 2015-2025 with the 11th Five Year Plan (2013-18) to guide national economic development. The Vision 2025 aims to address the country's development through seven pillars, of which the fourth, Security: Energy, Water, and Food Security, sets objectives for water and food.[h] While specific activities conducted in Sindh are not explicitly stated, the overall importance of Vision 2025 and the Government of Sindh's commitment towards achieving these is recognised. CSA practices and DRR measures will contribute to the fulfilment of Vision 2025 goals.

The Sindh government developed several policies and acts to support agricultural growth, climate change adaptation and mitigation. Of these, some have already been implemented, while others are being formed or in the process of formalisation. The Sindh Environmental Protection Act (2014) provides regulations for the prevention and promotion of sustainable development through the establishment of procedures and systems for monitoring, research, and measures for environmental quality. It also established the Sindh Sustainable Development Fund,

h Water: increase water storage capacity to 90 days, improve efficiency of usage in agriculture by 20%, and ensure access to clean drinking water for all Pakistanis; Food: reduce food insecure population from 60% to 30%.

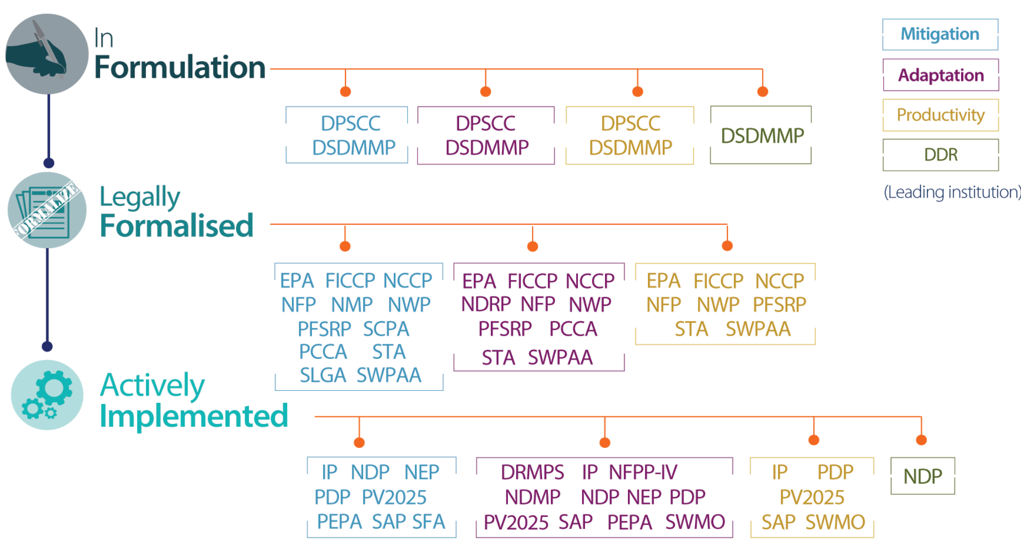
which can be used to provide financial assistance for environmental protection and improvement.

To help build resilience to climate change, and to reduce greenhouse gas emissions, the provincial Agriculture Policy (2018) identifies CSA practices and DRR measures as a priority. These include promoting new livestock breeds and seeds, as well as upgrading or building proper infrastructure, particularly at the farm level, to deal with higher and more variable rainfall and the ensuing floods and droughts. It will improve dissemination of up-to-date weather information and early warnings of disasters; launch agriculture and livestock insurance programmes; prepare contingency plans; set aside funds in case of major unforeseen disasters; and introduce improved crop storage and preservation techniques. The policy also lays the groundwork for implementing a certification system for organic crops, livestock, and fishery products.

In 2018, the provincial government produced a draft Sindh Climate Change Policy. The policy aims to build climate change resilience into Pakistan's agricultural system through improved irrigation and land management, enhanced institutional capacity to undertake research and development, and increased understanding of climate change issues by farmers, industry, and policymakers. The policy encourages precision farming, which is a farm management approach using information technology, GPS guidance, control systems, sensors, and other techniques to increase efficiency in growing crops and raising livestock. This approach can improve water efficiency and nutrient management, enabling the agriculture sector to better adapt to changing conditions.

The most recent legislation on disaster management in Pakistan is the 2013 National Disaster Risk Reduction Policy by the National Disaster Management Authority (NDMA) under the Ministry of Climate Change. The policy recognises that development in Pakistan is not risk conscious due to a low understanding of risk. The policy covers areas under each of the four DRR priorities according to the Sendai framework, the only mention of agriculture is the introduction of resilient rural insurance systems to protect vulnerable rural communities against extreme weather events. There

Enabling policy environment for CSA in Sindh



DPSCC Draft policy of Sindh Climate Change (2017) (Sindh Environment Protection Agency (SEPA)) **DRMPS** The Disaster Risk Management Plan Sindh (2008) (Provincial Disaster Management Authority) **DSDMMP** "Draft Sindh Drought Mitigation & Management Policy (2014) **EPA** Environment Protection act (2014) (Sindh Environment Protection Agency (SEPA)) **FICCP** Framework for implementation of Climate Change Policy (2014-2030) (2014) (Ministry of Climate Change) **IP** Irrigation policy (1996) (Water Management and Irregation Department) **NCCP** National Climate Change Policy (2012) (Ministry of Climate Change) **NDP** National DRR Policy (2013) (National Disaster Management Authority, Ministry of Climate Change) **NDMP** National Disaster Management Plan (2012) (National Disaster Management Authority, Ministry of Climate Change) **NDRP** National Disaster Response Plan (2019) (National Disaster Management Authority) **NEP** National Environmental Policy (2005) (Ministry of Environment) **NFP** National Forest Policy (2015) (Ministry of Climate Change) **NFPP-IV** National Flood Protection Plan (2016) (Ministry of Water and Power) **NMP** National Mineral Policy (2013) (Ministry of Petroleum & Natural Resources) **NWP** National Water Policy (2018) (Ministry of Water Resources) **PCCA** Pakistan Climate Change Act (2017) (Ministry Climate Change) **PDP** Poultry Development Policy (2007) **PEPA** Pakistan Environmental Protection Act (1997) (Environment Protection Agency) **PFSRP** Pakistan Food Security and Research Policy (2018) (Ministry of National Food Security and Research) **PV2025** Pakistan Vision 2025 2014 (Ministry of Planning, Development & Reform) **SAP** Sindh Agriculture Policy 2018-2030 (2018) (Agriculture, Supply and Prices Department, Gov of Sindh) **SFA** Sindh Forest Act (2012) (Sindh Forest Department) **SCPA** Sindh Consumer Protection Act (2014) **SLGA** Sindh Local Government Act 2013 (2013) (Local Government Department) **STA** Sindh Tenant Act and Sindh Tenancy (Amendment) Act (1950, 2013) **SWMO** Sindh Water Management Ordinance (2002) **SWPAA** Sindh Wildlife and Protected Areas Act, 2010 and ordinance 1972 (2010) (Wildlife Department) is however little coordination between DRR policies and the agricultural sector, this can be seen in the 2010 act on the establishment of a National Disaster Management Commission which included representation from a number of Ministries but with the Ministry of Agriculture absent.

Other policies and legislation related to water resources management are also linked to CSA. The Irrigation Act (1996) enables CSA strategies to improve productivity and risk mitigation. The Sindh Water Management Ordinance (2002) established the Sindh Irrigation and Drainage Authority, which is responsible for integrated water management for drinking water, flood protection and infrastructure maintenance. It also outlines the tasks of the water allocation committee, including the use of climate forecasts in determining water rights and distribution. The National Water Policy (2018) notes that climate change will impact water resources and, among other recommendations, calls for improved downscaling of climate information to better understand local conditions. This will support short and long-term adaptation measures, for example, improved water storage. The policy addresses adaptation through the "More Crop Per Drop" concept, which calls for improved irrigation methods, a modernised 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 Sindh Drought Mitigation and Management Policy Sindh (2018, draft) 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 recognises the importance of planning and capacity building, working with the agriculture and water resource sectors, to strengthen resilience to drought. The policy mentions several CSA opportunities, such as addressing soil degradation, modernising irrigation techniques, and new crops to increase soil fertility. The Sindh Forest Act (2012) recognises the role that forests play in providing vital ecosystem services such as soil and water conservation, reducing cyclone and flood impacts, and providing clean air and habitats. They can also support mitigation through carbon sequestration. The Disaster Risk Management Plan Sindh Province (2008) outlines strategies to improve DRR by ensuring that they are compatible with measures for poverty reduction, natural resources protection, and sustainable development. More specifically, food security and maintaining agricultural livelihoods are priorities for flood and drought prone areas.

The Disaster Risk Management Plan Sindh (2008) outlines the roles and responsibilities of the different departments in Sindh with regard to DRR in the province. The Agriculture Department is identified to play a key role in mitigation, preparedness and response. Identified mitigation activities include risk assessments, protection of areas faced with recurrent risks, insurance and credit schemes and land levelling. Preparedness activities are focussed around close coordination with the PDMA, response planning, contingency crop planning and awareness raising. Response activities involve minimising losses during disaster events, making inputs and equipment available after the event at a subsidised rate and surveying the damage.

The 'Building Disaster Resilience in Pakistan' is a UK/DFID funded programme aimed at supporting the implementation of the National Disaster Risk Reduction Policy and the National Disaster Management Plan, 2012 (NDMP). The goal of the programme is to increase Pakistan's capability to reduce disaster risk through better planning, preparedness, response, and resource allocation at the governmental and community levels. This includes work in Sindh on the revitalisation of farmers' groups in targeted areas. These groups play a significant role in the adoption of drought and flood resilient seeds and their multiplication, and in increasing awareness on crop diseases through regular farmer's meetings. Another policy focussed on disaster risk reduction is the National Flood Protection Plan, 2016 (NFPP-IV) which had been modified following the deviating floods of 2010-2012. The policy outlines numerous activities for risk reduction, both structural and non-structural. Measures promoted by the policy fall under all four priorities of the Sendai framework. The National Disaster Response Plan 2019 (NDRP) was updated to ensure it was aligned with the NDMP and the recommendations under the Sendai framework, focussing on priority 4.

Strategies and programmes that target climate action in the agriculture sector include the Sindh Resilience Project and the Sindh Agriculture Growth Project. Those projects focus on agricultural technologies, research and development, while modernisation efforts are often applied through private sector investment and partnerships. As part of the capitalise words (ADP), the Agriculture Department is providing skills training for provincial and District Government Departments. To meet this requirement, a development project, the 'Benazir Bhutto Shaheed Youth Development Programme' was started to train agriculture professionals in different fields. The project provides 'state-of-the-art' training in new development tools and agricultural skills to youth.

Financing CSA

Current finances

Domestic

Pakistan's various financial services play an essential role in determining the competitiveness and profitability of the agriculture sector and are vital in ensuring agriculture generates income for producers and other participants in the value chains which extend from input supplies to retail sales. Access to finance in rural areas has fallen behind the country's growth and development needs, and it is an essential limitation in the development of the agriculture sector.

Pakistan's current institutional structure of the financial system is elaborate, comprising the State Bank of Pakistan (SBP), specialised public sector banks, commercial banks,

Current and needed DRR and CSA activities mapped under the four priorities of the Sendai framework.

Priority 1: To improve the understanding of disaster risk and its impact on the agricultural sector in Sindh, various activities have been undertaken, including; a multi-threat assessment of risks and vulnerabilities, mapping and zoning exercises, forecasting and the establishment of early warning systems. These activities have found themselves constrained by a lack of technical capacity in Sindh, with the output failing to meet the needs of key stakeholders to make informed decisions based on risk. Agricultural practitioners require accurate and timely information on the different risks and vulnerabilities to identify the most suitable CSA practices. Therefore, activities under Priority 1 should be conducted through both a CSA and DRR lens. The Agricultural Extension Services (AES) in Sindh is already making risk information available to producers through innovative and accessible means, including a mobile application 'Agriculture for Nutrition'. Training and sensitisation in DRR of extension workers, field technicians and others providing direct assistance to producers is also considered important.

Priority 2: High levels of coordination are required between the different ministries and their departments to better mainstream DRR and CSA activities into legal frameworks, policies, strategies and plans. While the GoS have prioritised such work, the limited allocation of human and financial resource has constrained its success. Coordination mechanisms, the adoption of national strategies and plans, local level DRR action planning, and understanding and implementing DRR related laws strategies and plans are all viewed as areas requiring improvement.

Priority 3: Sees the most significant crossover between DRR and CSA activities, with the need to pursue both on-farm structural and non-structural measures to build the resilience of farmers and the agricultural sector to extreme events. Choices on production and the management practices employed by farmers will influence their vulnerability, the adoption of CSA practices with a strong adaptation component will help them build resilience, reducing their vulnerability to external shocks such as flooding and drought. The implementation of both on-farm and off-farm measures requires a system of risk retention and transfer (funds, insurance and social protection), adapted to the needs of different types of smallholders. The establishment of Public-Private Partnerships is proposed as a currently underutilised means to support disaster risk prevention.

Priority 4: The inclusion of different subsectors in the process of disaster preparedness and contingency planning are critical areas to be adopted. There is a growing need in Sindh for public awareness raising, carrying out scenarios and emergency drills, empowering women and marginalised groups, as well as building better in recovery, rehabilitation and reconstruction. Following a disaster, the agricultural sector becomes crucial in providing food and income security to rural households. This will, however, require awareness and preparedness of what farms need to become re-established.

microfinance institutions (MFIs), non-bank financial institutions (NBFIs), insurance companies, government saving institutions and stock exchanges. The SBP regulates and supervises commercial banks, microfinance banks (MFBs) and the financial services sector in general. The SBP also assists in the transformation of Rural Support Programmes (RSPs) and other MFIs into MFBs.

Specialised public sector institutions involved in rural finance include the Zarai Taraqiati Bank (ZTBL)[i] and Punjab Provincial Cooperative Bank Limited (PPCBL). The ZTBL mainly provides for the upper and middle segments of the rural financial markets, the rural elite and those farmers with sizeable landholdings, rather than to the small or marginalised farmer or the asset-poor. The ZTBL, commercial banks and agriculture cooperative societies disbursed about US$ 2.9 billion from 2014–2015 for agriculture [111].

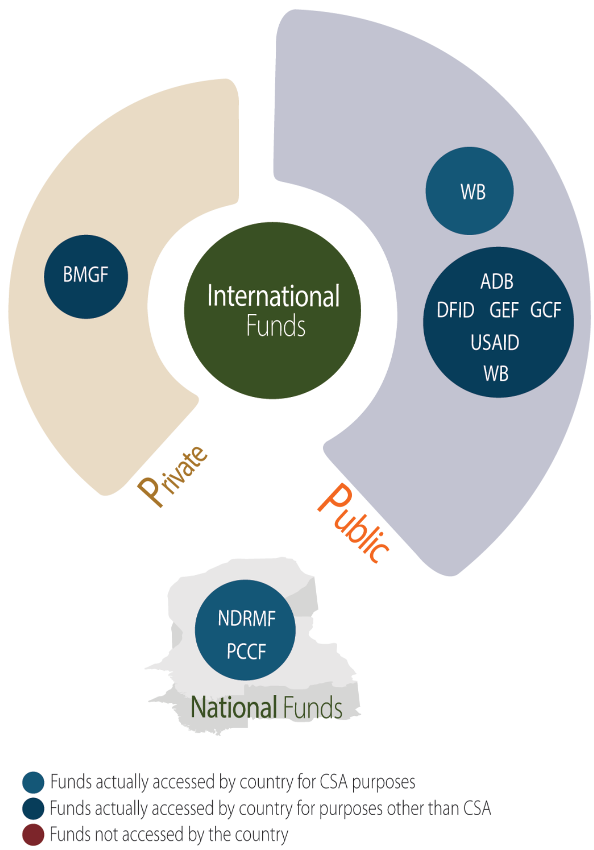
In the cooperative sector, loan terms and delivery methods typically exclude access by the poor. Credit components in government-sponsored programmes usually are not targeted at small farmers either by size, mode of delivery or terms of credit. The impact of these programmes has up to now been nominal as the services have been presented, promoted and delivered in a manner suggesting a politically-motivated grant facility, and this is the way it has been understood by those privileged to have access [112].

The financial sector is dominated by commercial banks, which usually have been urban-oriented and have avoided providing financial services to the rural poor. Commercial banks are neither structured nor geared to extend agricultural finance exposure nor organised to handle many small loans. They perceive making loans to small-scale farmers or the rural poor as a high cost/high-risk proposition offering uncertain returns.

i Formerly the Agricultural Development Bank of Pakistan.

There are several non-bank financial institutions (NBFIs) that provide a range of financial services. These include investment banks, leasing companies, mutual funds, housing finance, and Islamic financial institutions such as Modarabas. Like commercial banks, NBFIs generally do not target the lower end of the market, and their operations are concentrated in the larger urban centres of the country.

Financing opportunities for CSA in Sindh



ADB Asian Development Bank **BMGF** Bill and Melinda Gates Foundation **GCF** Gatsby Charitable Foundation **GEF** Global Environment Facility **NDRRMF** National Disaster Risk Management Fun **PCCF** Pakistan Climate Change Fund **USAID-DGP** United States Agency for International Development **WB** The World Bank Group

Microfinance Providers (MFPs), i.e., microfinance institutions (MFIs) and microfinance banks (MFBs) are considered a useful means for alleviating poverty, as they help to reduce risk and increase the income of poor households. However, the overall outreach of microfinance is still limited and MFIs in general do not usually provide agricultural lending. Their service coverage of marginal and small farmers is also restricted as they do not focus much on financing characterised by pronounced agricultural seasonality.

In 1999 the Pakistan Microfinance Network (PMN) was set-up as a network for organisations engaged in microfinance and was dedicated to improving the outreach and sustainability of microfinance in Pakistan. The PMN has made a significant contribution in helping to make the policy environment-friendly for the delivery of microfinance services by engaging policy-makers and highlighting some of the main issues, opportunities and challenges in the sector.

Sindh receives approximately 73 per cent of the taxes from the federal tax revenues as a provincial allocation on agriculture amounting to US$ 652 million [113]. In the provincial budget for the 2018-19 fiscal year, the Sindh government, following the federal government's lead, provides significant relief and subsidies to the agriculture sector. Revenue expenditure on agriculture was increased by 34 per cent to about US$74 million. The subsidy aims to promote mechanised farming through the purchase of tractors and agricultural implements including tillage, seedbed preparation, planting, inter-culture, fertiliser and chemical application equipment and machinery for reducing post-harvest losses.

According to the 2017 Climate Public Expenditure and Institutional Review (CPEIR) [114], total climate-relevant expenditure represents between 4.1 and 6.9 per cent of the total provincial budget. Between 5.6 and 10.0 per cent of Sindh's development budget is climate-related. The Annual Development Plans climate expenditure across the studied years is relatively stable in terms of average climate relevance of each department. However, the proportion of climate-related investment per department fluctuates in most of the departments. In most of the four years, Forestry, Irrigation and Social Welfare, spent 16–86 per cent of their budgets on climate-relevant investments. It is uncertain how much of this funding directly benefits the agriculture sector and CSA activities.

International

The international climate financing landscape in Sindh is at present complex and disjointed, with many stakeholders from both the public and private sector involved. Pakistan has been a major recipient of Official Development Aid (ODA), ranking in the top 10 for gross ODA received in 2017 [115]. Responding to Sindh's high vulnerability to climate change and exposure to natural hazards, numerous projects focus on these issues and the agriculture sector. There are currently ongoing projects from the World Bank, the Asian Development Bank (ADB), the Global Environment Facility (GEF), the Adaptation Fund, and Japan's Fast Start Finance Initiative.

Ongoing and recently completed projects in Sindh [42,116,117,118]

Project name	Value (US$ million)	Objectives	Pillars
World Bank: Sindh Agriculture Growth Project (2014-2019)	US$ 88.7 Loan	Aims to improve productivity and market access of small and medium producer's commodity value chains (onion, chilly, dates and rice). The project has three sub-components: (i) capacity building of producers; (ii) modernisation of extension services and agricultural research; and (iii) strategic planning for the agriculture sector.	- Productivity
World Bank: Sindh Irrigated Agriculture Productivity Enhancement Programme (2015-2021)	US$ 242.2 Loan	The project supports efficient management of scarce water resources at the tertiary and field level where water losses are highest. Besides promoting a high-efficiency irrigation system and improved agronomy, the project is designed to augment adaptation under different climate change scenarios. The project has four components: (i) to improve community watercourses – which includes strengthening of flood mitigation measures; (ii) introduce high-efficiency irrigation systems; (iii) improve agriculture practices; and (iv) improve project management, monitoring and evaluation.	- DRR - Adaptation - Productivity
World Bank: Sindh Barrages Improvement Project (2015-2024)	US$ 208 Loan	The project aims to iImprove the reliability and safety of the Guddu and Sukkur Barrages and strengthen the Sindh Irrigation Department's ability to operate and manage them. The rehabilitation and modernisation of the Sukkur Barrage will provide reliable water supply to 10 canals and reduce floods, under the oversight of a newly-established Barrage Monitoring Unit.	- DRR
World Bank: Sindh Resilience Project (SRP) (2016-2022)	US$ 120 Loan	Under the project, 15 small rainwater-fed recharge dams are being constructed in Tharparkar, Thatta, Dadu, Jamshoro, and Karachi districts. These dams will contribute to recharging underwater aquifers to provide water to nearby communities and help to improve local livelihoods. Under the SRP more than 5 million people living in areas affected by floods and drought will be direct beneficiaries. The infrastructure investments are expected to protect over 517,000 ha of land from floods and droughts.	- DRR - Adaptation - Productivity
Asian Development Bank: Sindh Coastal Community Development Project (2007-2014)	US$ 36 Loan	Increase access to ecologically sustainable income generating activities and government service for poor households in eight coastal talukas (sub-districts) of Thatta and Badin districts in Sindh. The services include planting of about 3,350 ha of mangroves at sites in the intertidal zones, which provide significant protection from storm-induced tidal surges and episodic cyclones.	- Productivity - Adaptation - DRR
European Union: Sindh Union Council and Community Economic Strengthening Support (2015-2021)	US$27.5 Grant	The Programme uses the Rural Support Programmes (RSP) social mobilisation approach for community-driven development, which is based on the idea that local people are the best agents of their progress once organised and trained to manage their resources and the financial support and services available. The programme focuses on poverty reduction, diversifying incomes, improved access and delivery of public services, stimulating community-driven local development initiatives, empowering women, as well as capacity development of the Government of Sindh.	- Productivity - Adaptation
Global Environmental Facility: Sustainable Land Management Programme to Combat Desertification in Pakistan (2013-2018)	US$ 20.4 Grant	The project included the rehabilitation of degraded rangelands, integrated water resource management, and the promotion of arid agriculture in Sindh.	- Productivity - Mitigation

Project name	Value (US$ million)	Objectives	Pillars
World Bank: Sindh Water Sector Improvement Project Phase I (SWSIP) (2007-2019)	US$ 175 Loan	The objective is to improve the efficiency and effectiveness of irrigation water distribution in Ghotki Area Water Board (AWB), Nara AWB, and Left Bank AWB, to improve reliability, equity and user satisfaction.	- Adaptation - DRR - Productivity
Asian Development Bank: National Disaster Risk Management Fund (NDRMF) (2019))	US$ 200 Loan	In 2019 the Asian Development Bank (ADB) supported by other international and bilateral donors observed a lack of financing for risk reduction in Pakistan, with current financing directed towards recovery. Responding to the apparent need for ex ante disaster financing in Pakistan, the National Disaster Risk Management Fund (NDRMF) was established. The focus of the fund was to finance projects that reduced existing risks or, disaster risk financing instruments which transferred residual risk that couldn't be mitigated, including insurance products and catastrophe bonds. The fund was established with $200 MIO USD from the ADB with counterpart financing of $25 MIO USD from the Pakistan Government, $3.4 MIO USD from the Australian Government and $1.5 MIO USD from the Swiss Government. The activities funded through the NDRMF will be implemented through the National Disaster Management Plan (NDMP) and the National Flood Protection Plan (NFPP-IV).	- DRR - Adaptation
GCF: Transforming the Indus Basin with Climate Resilient Agriculture and Climate-Smart Water Management (Draft)	US$55 Grant (Pending approval)	The project includes four components: i) climate-smart water management and information services, ii) building on-farm resilience to climate change, iii) creating an enabling environment, and iv) project management.	- Adaptation - DRR - Productivity

Potential Finances

Under the Annual Development Programme 2018-19, the Sindh government earmarked about US$36 million for ongoing agriculture development projects, with budget for 29 new or on-going schemes in research, extension, the Sindh Seed Corporation, mechanisation and water management [119].

Investments from the 'China-Pakistan Economic Corridor'(CPEC) are expected to trigger an extra GDP growth of 1.5 per cent from 2016 to 2020 and a further 1 per cent increase for the period 2020 to 2030 [120]. The CPEC projects will be located throughout Pakistan, including in some of the most vulnerable and impoverished districts of northern Sindh. Empirical evidence suggests a nexus between infrastructure development, agriculture output growth and poverty reduction. The agriculture sector would be a direct as well as indirect beneficiary of CPEC through increased access to markets, particularly in China [121]. Through the adoption and application of Chinese farming practices and technology to farms in Pakistan, the domestic yield and thus output for most crops can be increased significantly [122]. Critics argue China is planning to experiment with new agriculture techniques on Pakistan's land, which may not be taken up by farmers. Also, the Pakistan government has agreed to lease land to Chinese enterprises for agriculture, which by some, is viewed as a disadvantage for local farmers as Chinese enterprises are likely to sow crops on a mass scale and export them, potentially damaging opportunities for local people [123].

Increased private sector engagement through Public Private Partnership (PPP) is likely to play an increasingly important role in the agriculture sector. The ADB has several on-going loan and grant agreements providing support to strengthen the standards in the development and delivery of PPP projects and help bridge the infrastructure investment gap in Sindh province. Furthermore, the Sindh PPP Board has, for example, recently approved a proposal by the Sindh Agriculture Department to set up a large mango processing unit near Hyderabad.

Another novel financing technique with the potential to support the agricultural sector in mitigating the risk of natural disasters and extreme weather events is forecast based financing. The concept of forecast based financing is to use weather forecasts to enable the timely distribution of funds for preparedness activities before a potential disaster occurs, averting the worst of the impact. Such a system will become increasingly relevant in a world where international aid for disaster preparedness cannot keep pace with the increasing frequency and severity of extreme weather events, only distributing funds when and where they are needed. There are currently projects planned to look at the potential of forecast based financing in Pakistan by the German and British Red Cross [124].

Outlook

The agricultural sector in Sindh is increasingly under pressure from natural hazards, climatic extremes and various socio-economic factors. Collectively, these increase the vulnerability of the population, 39 per cent of whom rely on primary production agriculture for employment, with far reaching impacts on food and income security. The production of major crops such as wheat, rice, cotton and sugarcane is increasing threatened by adverse climatic conditions—Pakistan is one of the most effected countries globally—a situation which is projected to become more unpredictable under climate change.

Climate-Smart Agriculture practices and technologies have been identified as an important tool to increase the resilience of the agricultural sector, mitigating the impact of natural hazards on production. Those practices which were seen to be the most promising focused on the use of improved varieties (salinity, heat, drought, short duration), nutrient management (ISFM), pest and disease management (IPM), water saving techniques (laser land levelling, ridge sowing), and the diversification of livelihoods through crop rotation and intercropping.

There is a growing recognition amongst agriculturalists in Sindh that the health of the soils has been poorly managed or neglected, reducing the water and carbon storage capacity while increasing input costs through excessive and imbalanced input use. At the same time, water security issues are putting greater pressure on farmers to adopt water saving practices, this has been highlighted by the 2018-19 drought. Water security is projected to become an increasing issue for Sindh, with increasing consumption (population growth) expected to outstrip falling availability (reduced glacial melt) by 2050. The CSA practices proposed not only build resilience to the current threats facing agriculture and rural communities in Sindh but help to increase their preparedness for future events.

The recent mapping of the AEZ in Sindh, combined with climate projection models will be essential in developing context specific adaptation and mitigation strategies. Determining the most suitable cropping patterns for different AEZs will require further use of GIS mapping, remote sensing and other technologies. Combining these with appropriate CSA and DRR practices on the ground will help farmers to obtain the best yields from different crops within each AEZ.

More sustainable and productive agricultural practices are achievable in Sindh, through supporting pro-poor, disaster and climate risk-informed policies and strategies. There is potential to expand existing financing for agriculture and livestock and to seek new forms of finances, particularly from the private sector to develop CSA and DRR actions. Agricultural and financial institutions need to provide improved technical and financial support to smallholders to adopt CSA and DRR practices and encourage scaling up to ultimately improve the agriculture sector as a whole and the livelihoods of communities throughout Sindh.

List of Annexes

Annex 1: Characteristics of Agro-ecological Zones in Sindh

Zone ID	Max. Temp.(0C)	Min. Temp.(0C)	Rainfall (mm)	ETo (mm)	Soil Type
I	34.5-34.9	19.0-20.7	342-378	5.78	Loamy clay
II	34.0-35.2	19.2-20.9	20-126	4.39	Loam
III	34.1-34.6	20.6-20.9	55-162	3.74	Loam
IV	34.2-35.0	17.8-18.4	50-200	4.2-4.35	Loam
V	35.0-35.9	18.0-19.2	126-234	4.0-5.0	Clay Loam
VI	34.9- 35.8	18-19.0	120-250	4.01	Clay Loam
VII	34.01	18.5	150-197	4.3-5.37	Loam
VIII	34.3-34.7	17.8-18.4	157-230	4.03	Heavy and Silty Loam
IX	34.2-34.8	18.7	160-250	4.03-4.06	Sandy Loam
X	34.5	18.3-19.1	127-250	5.0-5.5	Sandy

Source: FAO. Agro-ecological Zones in Sindh, 2019.

Works cited

1. FAO. 2010. Climate-Smart Agriculture: Policies, practices and financing for food security, adaptation and mitigation. Rome: FAO. Available at http://www.fao.org/3/i1881e/i1881e00.pdf

2. UNISDR. 2015. Sendai Framework for Disaster Risk Reduction. Geneva. Available at https://www.unisdr.org/we/coordinate/sendai-framework

3. FAO. 2013. Climate-Smart Agriculture Sourcebook. Rome: FAO. Available at http://www.fao.org/docrep/018/i3325e/i3325e.pdf

4. FAO. 2019. Disaster risk reduction at farm level: Multiple benefits, no regrets Results from cost–benefit analyses conducted in a multi-country study, 2016–2018.

5. Pasha, H. A. 2015. Growth of the Provincial Economies. Institute for Policy Reforms (IPR), Pakistan. Available at https://ipr.org.pk/wp-content/uploads/2016/04/GROWTH-OF-PROVINCIAL-ECONOMICS-.pdf

6. Bureau of Statistics. 2017. Planning and Development Department, Government of Sindh. Available at http://sindhbos.gov.pk/

7. World Bank. 2019. Data bank. Available at: https://databank.worldbank.org

8. Husain, I. 2014. The Economy of Sindh 2012/13. Concluding Keynote Address at the 2nd International Seminar on Sindh through the Centuries held on 26 March 2014

9. Sher, F. 2018. Agriculture Sector Surpasses Target of 3.5 Per cent. Business Recorder, 27 April 2018. Available at https://fp.brecorder.com/2018/04/20180427365799/

10. Rasool A, Hassan MA. 2017. CPEC – Prospects and Challenges for Agriculture in Pakistan (Vision-2025). Faisalabad Chamber of Commerce & Industry. Available at http://fcci.com.pk/rte/Agriculture-Report.pdf

11. Government of Sindh. 2018. The Impact of Population Growth on Development in Sindh. Findings from the Resources for the Awareness of Population Impacts on Development Model. CIP Secretariat, Costed Implementation Plan, Population Welfare Department. Available at http://www.healthpolicyplus.com/ns/pubs/7194-8353_SindhPakistanRAPIDBooklet.pdf

12. Bureau of Statistics, 2017. District Wise Census Results 2017. Islamabad: Ministry of Statistics. Available at http://www.pbscensus.gov.pk/sites/default/files/DISTRICT_WISE_CENSUS_RESULTS_CENSUS_2017.pdf

13. Khan, A. B. 2017. Options for Reform: Tax the Privileged on Agriculture Income, The Express Tribune, 26 June 2017. Available at https://tribune.com.pk/story/1444769/options-reform-tax-privileged-agriculture-i/

14. Bureau of Statistics. 2014. Multiple Indicator Cluster Survey 2014 Available at: http://sindhbos.gov.pk/wp-content/uploads/2014/09/01-Sindh-MICS-2014-Final-Report.pdf

15. Bureau of Statistics. 2015. Labour Force Survey 2014-2015. Avaialable at: http://www.pbs.gov.pk/content/labour-force-survey-2014-15-annual-report

16. Bureau of Statistics. 2017. Sindh at a glance. Planning and Development Department, Government of Sindh. Available at: http://sindhbos.gov.pk/wp-content/uploads/2018/05/SAG-2017-1.pdf

17. UNDP-PK-Poverty-2 Income Inequality in Pakistan. 2009. Available at: https://www.undp.org/content/dam/pakistan/docs/Poverty%20Reduction/UNDP-PK-Poverty-2%20Income%20Inequality%20in%20Pakistan.pdf

18. Project, Planning & Development Department. 2016. The Irrigation Management Strategy for Irrigated Agriculture of Sindh Province (Pakistan), Project Coordination & Monitoring Unit, Sindh Water Sector Improvement. Available at http://metameta.nl/wp-content/uploads/2017/11/170323_Fourth-Draft-Irrigation-Managment-Strategy-for-Irrigated-Agriculture-of-Sindh-Province-Pakistan.pdf

19. FAO. 2016. Pakistan Agriculture Information System. Available at http://dwms.fao.org/~test/dat_crops_en.asp

20. FAO, UN, SUPARCO & Crop Reporting Service. 2012. Sindh CRS: Base Line Survey Agriculture Information System: Building Provincial Capacity for Crop Forecasting and Estimation. Islamabad: FAO Pakistan. Available at http://dwms.fao.org/~test/downs/publications/pak_sindh_bls_low.pdf

21. FAO. 2019. Agro-Ecological Zones Sindh (Draft). Available at: https://bdrp.pk/aez/

22. Bureau of Statistics, 2017. Agricultural statistics Pakistan 2016-17. Available at http://www.pbs.gov.pk/

23. Planning and Development Department. 2017. The Irrigation Management Strategy for Irrigated Agriculture of Sindh Province (Pakistan). Available at http://metameta.nl/wp-content/uploads/2017/11/170323_Fourth-Draft-Irrigation-Managment-Strategy-for-Irrigated-Agriculture-of-Sindh-Province-Pakistan.pdf

24. Pakistan Bureau of Statistics. 2014. Province wise fertiliser consumption. Available at: http://www.pbs.gov.pk/sites/default/files//tables/Table%2011%20%20Province-wise_consumption_of_fertilizer.pdf

25. UNDP. 2018. Human Development Index. Available at: http://hdr.undp.org/en/2018-update

26. Fan, S. 2015. How agriculture can improve health and nutrition. Geneva: World Economic Forum. Available at https://www.weforum.org/agenda/2015/04/how-agriculture-can-improve-health-and-nutrition/

27. Pakistan Climate Change Portal, 2018. Civil Society Coalition for Climate Change (CSCCC). Available at https://climateinfo.pk/impact

28. Bureau of Statistics. 2017. Statistics in demand. Planning and Development Department, Government of Sindh. Available at: http://sindhbos.gov.pk/stats-in-demand/

29. Government of Pakistan Finance Division. 2019. Pakistan Economic Survey 2018-19, Nutrition and Food Consumption Pg 217. Available at:http://www.finance.gov.pk/survey/chapters_19/Economic_Survey_2018_19.pdf

30. Bureau of Statistics. Housing units by source of drinking water, lighting and cooking fuel. Available at: http://www.pbs.gov.pk/content/housing-units-source-drinking-water-lighting-and-cooking-fuel

31. Pakistan Road Network. Road Class and Surface Condition. Available at: https://dlca.logcluster.org/display/public/DLCA/2.3+Pakistan+Road+Network

32. NoorMmemon, M. I., Noonari, S., Kalroo, M. A., Pathan, Z. M. A., Manzoor, A., & Pathan22, M. 2015. Women Labour Participation of Agricultural Production in Sindh Pakistan. Journal of Resources Development and Management, 10, 87-97.. Available at https://www.iiste.org/Journals/index.php/JCSD/article/viewFile/24242/24815

33. Ali, S. and Cheema, A. R. 2017. Counting the Uncounted: The economic contributions of women in rural Sindh. South Asia @ LSE blog. Available at http://blogs.lse.ac.uk/southasia/2017/06/01/counting-the-uncounted-the-economic.

34. CIAT; World Bank. 2017. Climate-Smart Agriculture in Pakistan. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); The World Bank. Washington, D.C. 28 p. Available at https://ccafs.cgiar.org/publications/climate-smart-agriculture-pakistan#.XF1UHlwzabg

35. ILO. 2018. ILOSTAT: Country Profile for Pakistan. Available at: https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:11110:0::NO::P11110_COUNTRY_ID:103166

36. Pakistan Bureau of Statistics. 2019. Labour force participation rates and un-employment rates by age, sex and area 2017-18. Available at: http://www.pbs.gov.pk/sites/default/files//Labour%20Force/publications/lfs2017_18/TABLE-15_perc_R.pdf

37. ILO. 2018. ILOSTAT: Youth NEET Rate. Available at: https://www.ilo.org/ilostat/faces/oracle/webcenter/portalapp/pagehierarchy/Page3.jspx?MBI_ID=20&_afrLoop=3957129685706231&_afrWindowMode=0&_afrWindowId=rpdvwzlu2_1#!%40%40%3F_afrWindowId%3Drpdvwzlu2_1%26_afrLoop%3D3957129685706231%26MBI_ID%3D20%26_afrWindowMode%3D0%26_adf.ctrl-state%3Drpdvwzlu2_57

38. Mir, K. A. Ijaz, M. 2015. Greenhouse Gas Emission Inventory of Pakistan for the Year 2011–2012. Islamabad: Global Change Impact Studies Centre (GCISC). Available at http://www.gcisc.org.pk/GHGINVENTORY2011-2012_FINAL_GCISCRR19.pdf

39. World Resources Institute. 2015. Climate Analysis Indicators Tool (WRI CAIT) 2.0. Available at https://cait.wri.org/

40. World bank. 2014. CO2 emissions. Available at: https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD?locations=PK-1W

41. German Watch. 2018. Global climate risk index. Available at https://germanwatch.org/en/cri

42. FAO. 2018. Concept Note. Transforming the Indus Basin with Climate Resilient Agriculture and Climate-Smart Water Management. Food and Agriculture Organization of the United Nations, Pakistan. 15 February 2018. Available at: https://www.greenclimate.fund/home

43. Amaral, C., Baas, S., Wabbes, S. 2012. The Urgency to Support Resilient Livelihoods: FAO Disaster, Risk Reduction for Food and Nutrition Security Framework Programme. FAO, Rome. Available at http://www.fao.org/docrep/017/i3084e/i3084e12.pdf

44. Sánchez-Triana, E., Enriquez, S., Larsen, B., Webster, P., Afzal, J. 2015. Natural Resource Degradation in Sindh Province. Sustainability and Poverty Alleviation: Confronting Environmental Threats in Sindh, Pakistan. July 2015, 79-126. Available at https://doi.org/10.1596/978-1-4648-0452-6_ch4

45. EM-DAT. 2017. The international disaster database. Centre for Research on the Epidemiology of Disasters. Available at: https://www.emdat.be/database

46. Ali, A. 2013. Indus Basin Floods: Mechanism, Impacts and Management. Manila: ADB; Pakistan Flood Victims - Alihamedhaghdoust.com , http://alihamedhaghdoust.com/pakistan-flood-victims.html

47. IFRC. 2011. Final Report Pakistan Flood 2011. International Federation of the Red Cross and Red Crescent Societies https://www.ifrc.org/docs/Appeals/11/MDRPK007FR.pdf

48. Government of Pakistan; World Bank; ADB. 2011. 2011 Pakistan Floods: Preliminary Damage and Needs Assessment. Available at http://documents.worldbank.org/curated/en/655781468058769881/pdf/846060WP0P09910Box0382140B00PUBLIC0.pdf

49. Ministry of Climate Change. 2016. Visiting Researcher Program – FY2016B. Country Report: Islamic Republic of Pakistan. Available at http://www.adrc.asia/countryreport/PAK/2016/Pakistan_CR2016B.pdf

50. Encyclopaedia Britannica. Pakistan Floods of 2010. https://www.britannica.com/event/Pakistan-Floods-of-2010

51. Avenir Health (RAPID Model). 2017. Available at https://www.avenirhealth.org/software-spectrummodels.php#rapid

52. Rasul, G. 2012. Climate Data Modelling and Analysis of the Indus Ecoregion. Islamabad: World Wide Fund for Nature. Available at http://www.indiaenvironmentportal.org.in/files/file/ccap_climatechange.pdf

53. Natural Disasters Consortium. 2019. Sindh Drought Needs Assessment (SDNA) Report, 2019. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/Sindh%20Drought%20Needs%20Assessment%20Report%20-%20January%2023%2C%202019.pdf

54. Arain, A. S. 2017. Senior Scientific Officer, Pakistan Council of Research in Water Resources (PCRWR).

55. Aslam, K., Rashid, S., Saleem, R., Aslam, R. 2015. Use of geospatial technology for assessment of waterlogging & salinity conditions in the Nara Canal Command area in Sindh, Pakistan. Journal of Geographic Information System, 7(4), 438.

56. Qureshi, A. S. 2011. Water management in the Indus basin in Pakistan: challenges and opportunities. Mountain Research and Development, 31(3), 252-261.

57. Mansoor, S., Khan, M. A. Khan, N. A. 2016. Screening of Sugarcane Varieties/Lines against Whip Smut Disease in Relation to Epidemiological Factors. J Plant Pathol Microbiol, 7(366), 2.

58. Raza, A., Ahmad, M. 2015. Analysing the Impact of Climate Change on Cotton Productivity in Punjab and Sindh, Pakistan.

59. Population Welfare Department. 2018. Available at http://pwdsindh.gov.pk/index.htm

60. National Institute of Population Studies and ICF International, 2013.

61. Peerzado, M. B., Magsi, H., Sheikh, M. J. 2018. Land use conflicts and urban sprawl: Conversion of agriculture lands into urbanization in Hyderabad, Pakistan. Journal of Saudi Society of Agricultural Sciences, 18 Feb 2018. Available at https://doi.org/10.1016/j.jssas.2018.02.002

62. Burki, A. A., Memon, R., Mir, K. 2015. Multiple Inequalities and Policies to Mitigate Inequality Traps in Pakistan. Oxfam Research Report, March 2015. Lahore University of Management Sciences (LUMS)/Oxfam GB. Available at https://www.oxfam.org/sites/www.oxfam.org/files/file_attachments/rr-multiple-inequalities-pakistan-110315-en.pdf

63. Ministry of Finance. 2018. Agriculture. Available at http://www.finance.gov.pk/survey/chapters_18/02-Agriculture.pdf

64. Rehman, T., Khan, M. U., Tayyab, M., Akram, M. W., Faheem, M. 2016. Current status and overview of farm mechanization in Pakistan – A review. Agricultural Engineering International: CIGR Journal. Available at http://www.cigrjournal.org/index.php/Ejounral/article/view/3650.

65. Rasul, G., Afzal, M., Zahid, M., Bukhari, S. A. A. 2012. Climate Change in Pakistan Focused on Sindh Province. Technical Report No. PMD-25/2012. Pakistan Meteorological Department. Available at http://www.pmd.gov.pk/report_rnd.pdf

66. Chaudhry, Q. Z., Rasul, G., Kamal, A., Mangrio, M. A., Mahmood, S. 2015. Technical Report on Karachi Heat Wave June 2015. Islamabad: Ministry of Climate Change Pakistan. Available at http://www.ndma.gov.pk/files/heatwave.pdf

67. Adnan, M., Nabi, G., Poomee, M. S., Ashraf, A. 2017. Snowmelt runoff prediction under changing climate in the Himalayan cryosphere: A case of Gilgit River Basin. Geoscience Frontiers, 8(5), 941-949.

68. Qamar Uz Zaman Chaudhry. Asian Development Bank. 2017. Climate Change Profile of Pakistan. Available at https://www.adb.org/publications/climate-change-profile-pakistan.

69. Ramírez-Villegas, J., Jarvis, A. 2008. High-resolution statistically downscaled future climate surfaces. Cali, Colombia: International Center for Tropical Agriculture (CIAT); CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

70. Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology: A Journal of the Royal Meteorological Society, 25(15), 1965-1978.

71. Iqbal, M. M. 2009. Climate Change Aspersions on Food Security of Pakistan. Science Vision, 2009. 15(1).

72. Ibrahim, Z., Ali, A., Ahmed, M., Zafar, H. 2015. Socio Economical Impact of Sea Water Intrusion in the Indus Deltaic Creek System. Presentation at the International Workshop on Sea Water Intrusion Affecting Coast Ecosystem and Livelihood, Karachi. Available at http://www.lead.org.pk/lead/pages/img/presentations_cohort19/SOCIO%20ECONOMICAL%

73. Bot, A., Nachtergaele, F., Young, A. 2000. Land resource potential and constraints at regional and country levels (No. 90). Rome: FAO.

74. Sindh Bureau of Statistics, Planning & Development Department. 2018. Sindh Development Statistics 2017. Available at: http://sindhbos.gov.pk/wp-content/uploads/2018/08/Development-Statistics-of-Sindh-2017.pdf

75. FAO. 2016. Importance of timely sowing of the wheat crop in Pakistan. Pakistan Agriculture Information System. Available at http://dwms.fao.org/~test/cas_wheatsowing_en.asp

76. Rashid, K., Rasul, G. 2011. Rainfall Variability and Wheat Production over the Potohar Plateau of Pakistan, Pakistan Journal of Meteorology, Vol 8, Issue 15.

77. Stone, P., Nicolas, M. 1995. Effect of Timing of Heat Stress During Grain Filling on Two Wheat Varieties Differing in Heat Tolerance. I. Grain Growth. Functional Plant Biology. 22(6): p. 927-934.

78. Rane, J., Nagarajan, S. 2004. High-temperature index—for field evaluation of heat tolerance in wheat varieties. Agricultural Systems, 2004. 79(2): p. 243-255.

79. Wheat productivity constraints (PARC). 2015. Available at http://www.parc.gov.pk/files/parc_pk/January-15/Statusper cent20Papers/statusper cent20paperper cent20Wheatper cent20inper cent20Pakistan.pdf

80. Hussain, I., Ali, A., Ahmed, A., Nasrullah, H., Iqbal, S., Aulakh, A. M., Ahmed, G. 2018. Impact of ridge-furrow planting in Pakistan: empirical evidence from the farmers field. International Journal of Agronomy, 2018. Available at https://doi.org/10.1155/2018/3798037

81. Usman, M. 2016. Contribution of agriculture sector in the GDP growth rate of Pakistan. J. Glob. Econ. 4, 184. Available at http://dx.doi.org/10.4172/2375-4389.1000184

82. Ilyas, F. 2017. "Sindh suffers 31pc crop loss annually due to waterlogging, salinity" Dawn, 12 Sep 2017. Accessed on 20 March 2019, https://www.dawn.com/news/1357033/sindh-suffers-31pc-crop-loss-annually-due-to-waterlogging-salinity

83. Lesk, C., Rowhani, P., Ramankutty, N. 2016. Influence of extreme weather disasters on global crop production. Nature. 529: p. 84.

84. Panhwar, Q. A. German Red Cross/ Pakistan Red Crescent Society.

85. Richards, M., Sander, B. O. 2014. Alternate wetting and drying in irrigated rice. Climate-Smart Agriculture Practice Brief. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: https://ccafs.cgiar.org/publications/alternate-wetting-and-drying-irrigated-rice#.XM52-o4zaM8

86. Setyanto, P., Pramono, A., Adriany, T., Susilawati, H., Tokida, T., Padre, A., & Minamikawa, K. 2018. Alternate wetting and drying reduces methane emission from a rice paddy in Central Java, Indonesia without yield loss, Soil Science and Plant Nutrition, 64:1, 23-30, DOI: 10.1080/00380768.2017.1409600

87. Sindh Board of Investment, Cotton Sector. Available at https://sedf.gos.pk/pdf/sectors/cotton.pdf

88. Sattar, S. 2018. Collapse of Pakistan cotton sector. 11 July 2018. Business Recorder. Available at https://fp.brecorder.com/2018/07/20180711389783/

89. Khan, M. B. & Khaliq, A. 2004. Studies on intercropping summer fodders in cotton. J. Res. Sci, 15(3), 325-331.

90. Dağdelen, N., Başal, H., Yılmaz, E., Gürbüz, T., Akcay, S. 2009. Different drip irrigation regimes affect cotton yield, water use efficiency and fibre quality in western Turkey. Agricultural Water Management, 96(1), 111-120.

91. Ali, M., Ali, L., Sattar, M., Ali, M. A. 2010. Response of seed cotton yield to various plant populations and planting methods. J. Agric. Res, 48(2).

92. USDA. 2018. Sugar Annual 2018. USDA Foreign Agricultural Service. Gain Report. Global Agriculture Information Network. Gain Report No. PK1812. 19 April 2018. Available at https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Sugar%20Annual_Islamabad_Pakistan_4-19-2018.pdf

93. Arain, G.N. 2012. Sugar Cane Cultivation In Pakistan. Rawalpindi: Valley Irrigation Pakistan (Private), Limited. Available at http://www.valleyirrigationpakistan.com/wp-content/uploads/2012/09/Sugar-cane-Cultivation-in-Pakistan.pdf

94. FAOSTAT. 2017. Available at: http://faostat.fao.org

95. Pakistan Agricultural Research. 2019. Sindh Sugarcane Varieties. https://par.com.pk/sugar/crop-management/seed-varieties/sindh

96. Memon, A., Khushk, A.M., Farooq, U. 2010. Adoption of sugarcane varieties in the sugarcane growing areas of Pakistan. Pakistan Journal of Agricultural Research, 23. Available at: http://pjar.org.pk/Issues/Vol23_2010No3_4/Vol23_2010No3_4P122.pdf

97. Hussain, S., Khaliq, A., Mehmood, U., Qadir, T., Saqib, M., Iqbal, M. A., Hussain, S. 2018. Sugarcane Production under Changing Climate: Effects of Environmental Vulnerabilities on Sugarcane Diseases, Insects and Weeds [Online First], IntechOpen, DOI: 10.5772/intechopen.81131. 5 November 2018. Available from: https://www.intechopen.com/online-first/sugarcane-production-under-changing-climate-effects-of-environmental-vulnerabilities-on-sugarcane-di

98. Ferozi, M. 2017. East or west, Pakistani mangoes are the best. Daily Times, 9 June 2017. Available at https://dailytimes.com.pk/7670/east-or-west-pakistani-mangoes-are-the-best/

99. Economic Advisor Wing. 2010. Economic Survey of Pakistan. Islamabad: Pakistan Finance Division.

100. Ishaq, M., Usman, M., Asif, M., Khan, I. A. 2004. Integrated pest management of mango against mealy bug and fruit fly. Int. J. Agric. Biol, 6(3), 452-454. Available at: https://www.researchgate.net/profile/Muhammad_Usman32/publication/228845400_Integrated_pest_management_of_mango_against_mealy_bug_and_fruit_fly/links/0fcfd50c9097b4a694000000.pdf

101. Khan, D., Shaukat S. S. 2006. The fruits of Pakistan: Diversity, Distribution, Trends of production and use. International Journal of Biology and Biotechnology, 3(3), 463-499. Available at: https://s3.amazonaws.com/academia.edu.documents/36425773/FRUITS_

of_PAKISTAN.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1554451183&Signature=hRCLtUjrmoChoEK2ASptdCvFvYw%3D&response-content-disposition=inline%3B%20file-name%3DTHE_FRUITS_OF_PAKISTAN_DIVERSITY_DISTRIB.pdf

102. Personal communication, Dr Fatah Mari, PC GROWTH Project, Sindh (2019).

103. Ministry of National Food Security and Research. 2012. Fruit, vegetable and condiments statistics of Pakistan 2011-12.

104. Sanaullah, N., Memon I. N., Solangi, S. U., Laghari, M. A., Wagan, S. A., Sethar, A. A., Kalwar, G. Y., Korejo, A. S., Jamro, A. S., Panhwar, G. M. 2016. Economic Implications of Tomato Production in Naushahro Feroze District of Sindh (2015-16). Research on Humanities and Social Sciences. Vol 5, No 7, 2015.

105. Sindh GROWTH Project. Available at http://sagp.gos.pk/

106. PARC. Available at http://www.parc.gov.pk/index.php/en/kitchen-home

107. Chandio, S., Talpur, M., Ilyas, R. M. 2018. Empirical Study of Livestock Population Growth and Dairy Farming in Sindh, Pakistan. Available at https://www.researchgate.net/publication/325035373_Empirical_Study_of_Livestock_Population_Growth_and_Dairy_Farming_in_Sindh_Pakistan/download

108. Livestock Insurance: SBP Teams Up with Banks, SECP - Dawn.com, Available at https://www.dawn.com/news/1053584

109. NARC, Fodder Research Program, Islamabad. Available at http://www.parc.gov.pk/index.php/en/csi/137-narc/crop-sciences-institue/714-fodder-program

110. Amin, J. Nd. Potential areas for oil seeds production. AgriHunt. Available at https://agrihunt.com/articles/major-crops/potential-areas-for-oil-seeds-production/

111. Bureau of Statistics. 2017. Punjab Development Statistics 2017. Planning & Development Department. Government of Punjab Lahore. Available at http://bos.gop.pk/developmentstat

112. Burton, M., Fileccia, T., Gulliver, A., Qamar, M. K., Tayyab, A. 2012. Priority Areas for Investment in the Agricultural Sector. Country Highlights. Prepared Under The FAO/World Bank Cooperative Programme. Available at http://www.fao.org/fileadmin/user_upload/rust/docs/Pakistan_inside%20pages.pdf

113. Ministry of Finance. 2017. Pakistan Economic Survey 2016-2017. Islamabad: Ministry of Finance. Available at: http://www.finance.gov.pk/survey/chapters_17/02-Agriculture.pdf

114. UNDP Pakistan. 2017. Climate Public Expenditure and Institutional Review (CPEIR) at a Glance and Next Steps. Available at https://www.climatefinance-developmenteffectiveness.org/sites/default/files/publication/attach/Pakistan-CPEIR-2017-Overview.pdf

115. OECD, Development Assistance Committee. 2018. Gross bilateral ODA 2016-2017. Available at: https://public.tableau.com/views/AidAtAGlance/DACmembers?:embed=y&:display_count=no?&:showVizHome=no#1

116. World Bank. Sindh Agricultural Growth Project. Available at http://projects.worldbank.org/P128307?lang=en

117. Sindh Union Council and Community Economic Strengthening Support (SUCCESS). Available at https://eeas.europa.eu/delegations/pakistan_en/47396/Sindh%20Union%20Council%20a

118. Global Environment Facility, Sustainable Land Management Programme to Combat Desertification. 2019. Available at https://www.thegef.org/project/sustainable-land-management-programme-combat-desertification

119. Government of Sindh, Finance Department. 2018. Budget 2018-2019. Authorisation of Expenditure of 1st Quarter of Financial Year 2018-2019 from 1st July to 30th September 2018. Volume V. Available at https://fdsindh.gov.pk/site/userfiles/Budget%202017-18/VOLUME%20V%202017-18/Volume%20V%20Complete.pdf

120. Ministry of Climate Change. 2016. Pakistan's Intended Nationally Determined Contribution (Pak-INDC) Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Pakistan%20First/Pak-INDC.pdf

121. Ahmed, R., Mustafa, U. 2016. Impact of CPEC Projects on Agriculture Sector of Pakistan: Infrastructure and Agricultural Output Linkages. Available at https://www.pide.org.pk/psde/pdf/AGM32/papers/Impact%20of%20CPEC%20Projects%20on%20Agriculture%20Sector%20on%20Pakistan.pdf

122. Faisalabad Chamber of Commerce & Industry. 2017. CPEC: Prospects and Challenges for Agriculture in Pakistan (Vision-2025). Available at http://fcci.com.pk/rte/Agriculture-Report.pdf

123. En Mass Energy. Impact of CPEC On Pakistan's Agriculture. Available at https://www.enmassenergy.com/sites/default/files/Impact%20Of%20CPEC%20On%20Pakistan%20agriculture.pdf

124. Lagdameo, D. 2017. Forecast-based Financing: Towards Forecast-based Value Add. IFRC. Available at: http://www.climate.gov.ph/images/CCCWeek2017/DAY2-RiskFinancing/Forecast-based-Financing--Towards-Forecast-based-Value-Ad

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