

Climate-Smart Agriculture for Punjab, Pakistan

Climate-smart agriculture (CSA) highlights

A Pakistan is ranked among the top ten most climate vulnerable countries in the world in the Global Climate Risk Index. In the past decade Punjab has experienced severe droughts, followed by devastating floods. This unpredictable cycle of climatic extremes has severely impacted agriculture production and the supporting irrigation systems. Proactive Climate-Smart Agriculture (CSA) is needed to counter many of these adverse climatic threats.

A Punjab houses over half of the country's population with 110 million inhabitants. With a population growth rate of over 2%, this number is set to rise. The current production systems will have to shift from over dependence on cash crops to higher value and more nutritious crops, to meet the nutrition needs of its people.

P Agriculture is important to the Punjab economy, contributing approximately one-quarter of provincial GDP. The province also accounts for two-thirds of the total national agriculture output. The sector employs over 16 million people or 45% of the Punjab labour force and is the main employment source of nearly three-quarter of the female labour force. Agriculture offers significant opportunities for economic growth.

A Of the total agricultural area in Punjab 90% is dedicated to five major cash crops (cotton, wheat, rice, sugarcane and maize) and fodder, leaving the remaining 10% available for horticulture and high value crops such as oil seeds, lentils and vegetables, important for food and nutrition security. Agricultural diversification might therefore help balance the economic, social, and health needs of the province.

A Punjab covers arid to semi-arid plains region of Pakistan. It is water stressed. Roughly 94% of the total water in Pakistan (mainly in Punjab) is directed towards agriculture, of which half goes to waste. Investment is urgently needed to improve water management strategies, increase irrigation efficiency and reduce water wastage.

A The province has developed a comprehensive agriculture policy that recognizes climate change as a threat to agriculture production and water use. It promotes research-based approaches in agriculture to reduce poverty and malnutrition through improved markets, land and water management, focusing on food security and empowerment of women and youth. However, implementation of the policy is weak and requires stronger integration with other policies, institutions and funding to support uptake of CSA practices.

A Adaptation **M** Mitigation **P** Productivity **I** Institutions **\$** Finance

The climate-smart agriculture (CSA) concept reflects an ambition to improve integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), planning is required to address tradeoffs and synergies between these three pillars: productivity, adaptation, and mitigation [1]. The priorities of different countries and stakeholders are reflected to achieve more efficient, effective, and equitable food systems that

address environmental, social, and economic challenges 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 [2]. Mainstreaming CSA requires critical stocktaking of established and promising practices for the future, and of institutional and financial enablers for CSA adoption. This profile provides a snapshot of a developing baseline created to initiate discussion, both within Punjab and globally, about entry points for investing in CSA at scale



Provincial context

Economic relevance of agriculture

Punjab is the second largest of Pakistan's four provinces comprising one-fourth (205,344 km²) of the total area. Hosting the five main rivers of Pakistan – Indus, Chenab, Sutlej, Jhelum, and Ravi—Punjab is known as the 'grain basket' of the country for its rich fertile alluvial soils and irrigated plains. It contributes to over half of Pakistan's Gross Domestic Product (GDP) [3] and is home to half of its population [4]. Over the last 15 years (2000-2015) Punjab's Gross State Product (GSP) has grown at an annual rate of 4.1% [3], backed by strong expansion of services and agriculture. However, the province has experienced periods of inconsistent economic development due to political, environmental, and social challenges, leading to inconsistent growth in the province and specifically agriculture.

Agriculture is the mainstay of Punjab economy, contributing approximately 27% to the provincial GSP [3, 5], while its share in national GDP is only 19% [6]. As a result, the province accounts for two-thirds of the national agriculture production. Agriculture constitutes three quarters of national exports, of which 60% is from Punjab. The province represents a significant share of national production of key cash crop; wheat (77%), cotton (74%), sugarcane (65%), rice (52%) and cattle (55%) [7]. But also, significant national

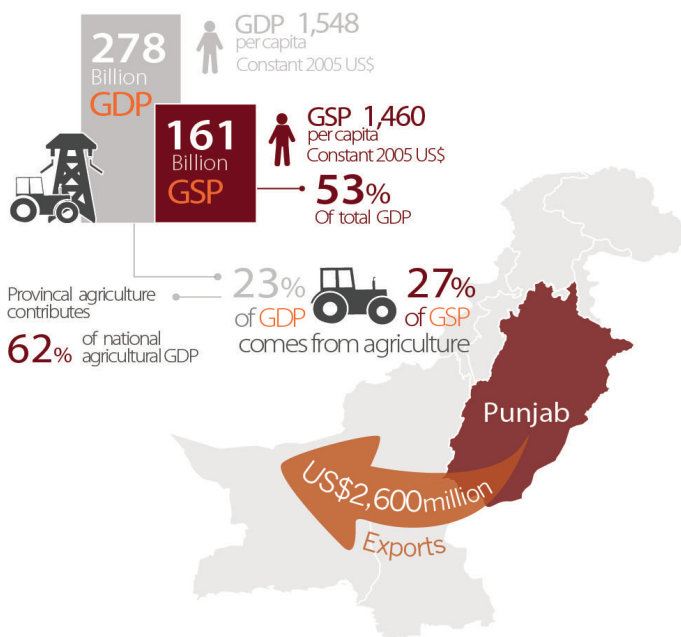
share in horticulture, including mango (77%) and citrus (97%) [7]. Agriculture not only offers vital raw materials for key exports as textiles and agro-food products (including rice and horticulture), but also contributes significantly to the social, economic and cultural activities of its citizens.

Punjab has 12.5 million hectares (ha) of cultivable farm land [7]. The average farm size is 2.26 ha, with approximately 42% of the farmers categorised as smallholders with holdings of less than one ha. Only 21% of farmers own more than 3 ha of land [7]. In 2018, the country's agriculture sector recorded a growth of 3.8% [10], a turnaround compared to the dismal negative growth rate of 0.2% in 2016 (the first negative growth in 15 years) due to the impact of extreme events (floods and droughts) on key crops, a lack of access to essential inputs, and a global downturn in commodity prices [11]. 2016-2017 witnessed a turnaround, with agriculture growing 4.2% [5]. The recovery was backed by higher commodity prices and support from the government to improve the availability of certified seeds, pesticides and agriculture credit, along with enhance subsidy's for fertilizer [10].

Agriculture is critically important for food security, livelihoods, economic growth and export revenues in the province. Yet agricultural productivity remains low in the country and province, with significant yield loss compared to global averages in crops like wheat, rice and cotton [12]. Increasing water shortage, decreasing soil fertility, degradation in water quality and constraints on expanding agriculture area contribute to lower yields and production [13]. Higher productivity in the short and medium term must come from improved utilization of existing agricultural land and resources. Almost 90% of the cultivated agricultural land in Punjab is dedicated to major cash crops (cotton, wheat, rice, sugarcane and maize) and fodder leaving the remaining 10% available for horticulture and high value crops such as oil seeds, lentils and vegetables [9]. With limited policy and financial support, the transition from cash crops with low crop diversification to the production of high value commodities is challenging.

With an estimated population of 208 million, Pakistan is the sixth most populous country in the world. It is also one the youngest countries, with youth (15-29 years) comprising just under half of the country's total workforce [14]. Punjab is home to more than half of the country's population at 110 million [4]¹ with a density of 536 persons/km², more than twice the national average. Over 60% of Punjab's population continues to reside in rural areas [15] despite rapid recent urbanization². Using pro-poor policies, the country has significantly reduced the incidence of poverty, from 64% in 2001 to 29.5% in 2013 [6]. Life expectancy in the province has improved over the last decade from 64 to 68 years. Nationally, 40% of the population is still deprived of some basic necessities, which is known as multidimensional poverty [16]. Although Punjab has the lowest incidence of multidimensional poverty among all provinces [16], it is home to the highest number of poor people in the

Economic relevance of agriculture in Punjab [3, 6, 8, 9]



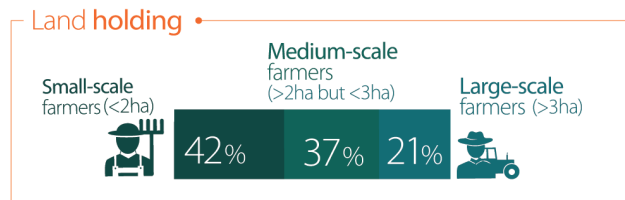
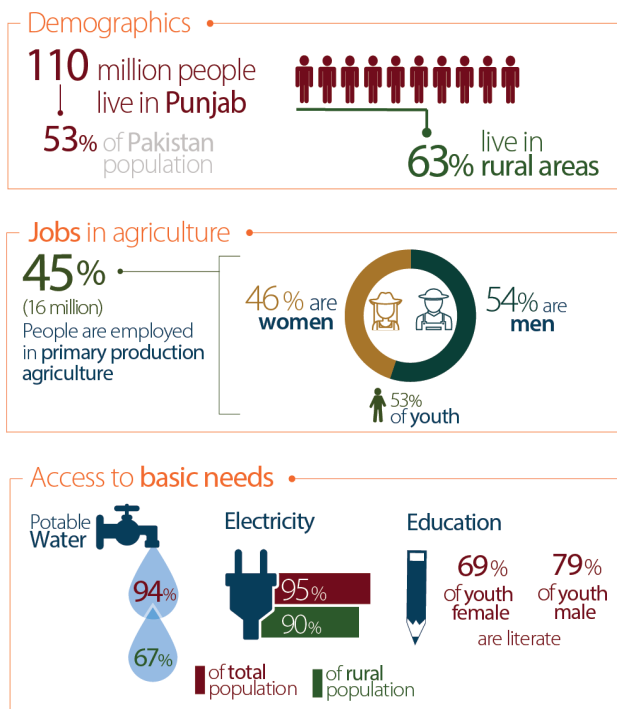
1. According to the latest population census carried out by the Pakistan Bureau of Statistics in 2017
 2. 4 out of the top 5 most populated cities in Pakistan are in Punjab, namely Lahore, Faisalabad, Rawalpindi, and Gujranwala.

country due to its large and growing population [9]. Income disparity is significant across production zones; households in cotton/wheat zones tend to be worse off than those in mixed cropping production systems [9].

Agriculture provides employment to over 16 million people in Punjab or 45% of the labour force, comprised of 54% male and 46% female. It is the main income source for 35% and 73% of the economically active male and female labour force respectively [7], yet the sector's value addition in the province stands at only 27% [9]. When compared with other sectors, such as services that contribute 60% to the economy whilst accounting for only 39% of the labour force [17], agriculture's contribution is much lower. This is indicative of higher poverty levels within the agriculture sector.

Youth unemployment continues to be another growing challenge in the country, up from 6.5% in 2007 to 9.1% in 2015 [14]. This is especially significant for the rural agriculture-based economy that employs more than half (around 53%) of Pakistan's young adults [14]. The informal nature of this sector offers low prospects for upward social and economic mobility, with most workers either self-employed or receiving low pay. The youth's minimal participation in agricultural studies at higher education level coupled with few structured programs, reflects this expectation gap and is a serious concern for Punjab's agriculture-based economy [14].

People, agriculture, and livelihoods in the Punjab [4, 7, 14, 15, 21]



Women farmers are major contributors to agriculture yet own a fraction³ of the land in Punjab, with exact ownership estimates unknown [18]. Their contribution to agriculture often goes unrecognized (50% are engaged as farm and family labour) and unpaid (75% receive no payment) [19]. Even where women are paid, their wages are less than half of that of their male counterparts [20]. Women also have limited access and control over productive resources (e.g. land, irrigation infrastructure, and agricultural inputs), are less aware of novel technologies and skills to add value and improve marketing. They also have less access to extension and financial services [19]. The growing and uncertain impact of climate change and extreme events further exacerbates the vulnerability of women farmers to cope with consequent economic, social and environmental shocks.

Land use

Punjab comprises around 25% of Pakistan's geographical area, 57% of the cultivated area and 73% of the cropped area [7]. Approximately 72% of the reported land⁴ in Punjab (12.5 million ha) is available for cropping, with the balance land either infertile or under infrastructure [7]. The province's forested area is only 2.3% of total land and is declining at a rate of 0.2-0.5% per year nationally [23]. Deforestation is driven by urbanization, a rural reliance on fuel wood, and poor land planning. Effective policy and monitoring mechanisms are needed urgently to protect forests. The province has recently launched initiatives⁵ to encourage private investment in afforestation.

The area of land under production has remained relatively stable over the last four decades. Since most of the arable land in Punjab is already cultivated, agricultural growth is achieved through intensification and higher use of fertilizers and pesticides, with longer term implications for human health and wellbeing, soil degradation and ecological damage.

3 The exact percentage of women farm ownership is uncertain. Estimates range from 2%-7% ownership and largely unsubstantiated
 4 Land utilization status is assessable for 86% of the aggregate territory, while 14% remains unreported
 5 The provincial government has set-up the South Punjab Forest Company to lease out close to 40,400 ha of forest land to private sector in district of Southern Punjab <http://spfc.org.pk>

Land use in Punjab [7, 22]

Total land area Punjab

20,630,000 ha

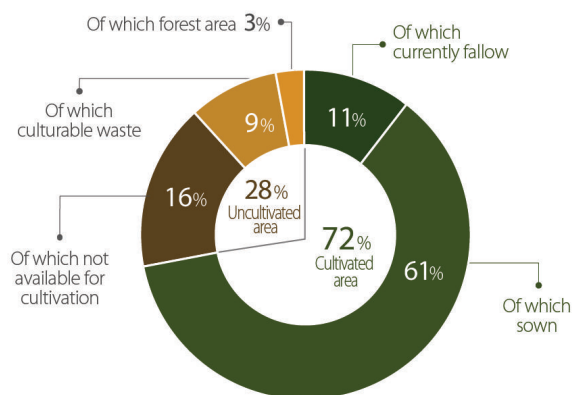
= 26% of national land area

Agricultural area

17,449,107 ha

= 85% of total land area

Cultivated and uncultivated area



Agricultural production systems

The upper Indus plain is the lifeline of Punjab's agriculture system and its people. The Indus is the longest of the five rivers which run through Punjab, depositing rich soil and creating a fertile landscape suitable for agriculture. The province is broadly divided into two key production areas (1) Barani and (2) Irrigated areas. The irrigated area employs canals, wells and tube-wells, while the Barani areas are entirely reliant on rainfall. Most agricultural production in Punjab is irrigated. The province's irrigation system is based on rivers, dams, barrages and canals. Roughly 94% of the agricultural area in Pakistan is equipped for irrigation [24], with the lion's share of water directed towards Punjab. Over 80% of Punjab's cropped area is irrigated by the Indus Basin Water System served through over 59,000 watercourse commands [25]. Despite this extensive network and favorable growing conditions, productivity remains a challenge. Water availability at farms is inadequate due to wastage and inefficient use, caused by a lack of modern water distribution infrastructure. This results in low productivity in the province despite the potentially favourable soils [25].

Punjab contains diverse Agro-Ecological Zones (AEZ) with considerable variations in topography, altitude, climate, and seasons. The AEZs are defined on the basis of combinations of soil, landform and climatic characteristics. It informs the type and location of the crops and how they are produced [27]. The Pakistan Agriculture Research Council in 1980 delineated the Country into ten broad AEZs. They further divided Punjab into four broad categories with 11 subzones. However, with the rapid changes in land use and water resources of the country, along with changing climatic

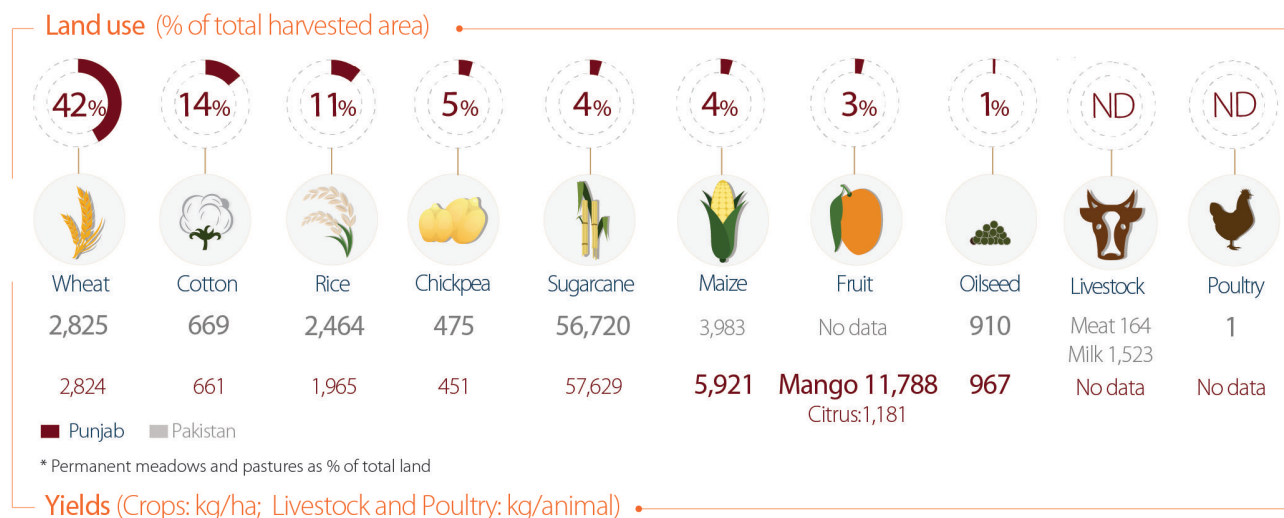
patterns, these AEZs are now obsolete as they do not accurately represent the current realities. A two-year project commissioned by the Food and Agriculture Organization (FAO) and prepared by several partner institutions has recently expanded the AEZs into 14 zones in Punjab alone (Annex 1) to match the soil, water and environmental characteristics with the production patterns [28]. The updated AEZs will help farmers, government departments and other stakeholders, setup appropriate practices and policies for sustainable use of natural resources and to optimize production.

Two types of soil dominate Punjab, sand and loam that are favourable for growing many different types of crops [28]. Although most crops are grown across the province, some are dominant in particular AEZs. For example, the main crops such as cotton, sugar cane, rice and wheat are cultivated along the Indus River, the Indus Basin and Delta, and northern and southern irrigated plains. Punjab sits at the convergence of these key ecological zones.

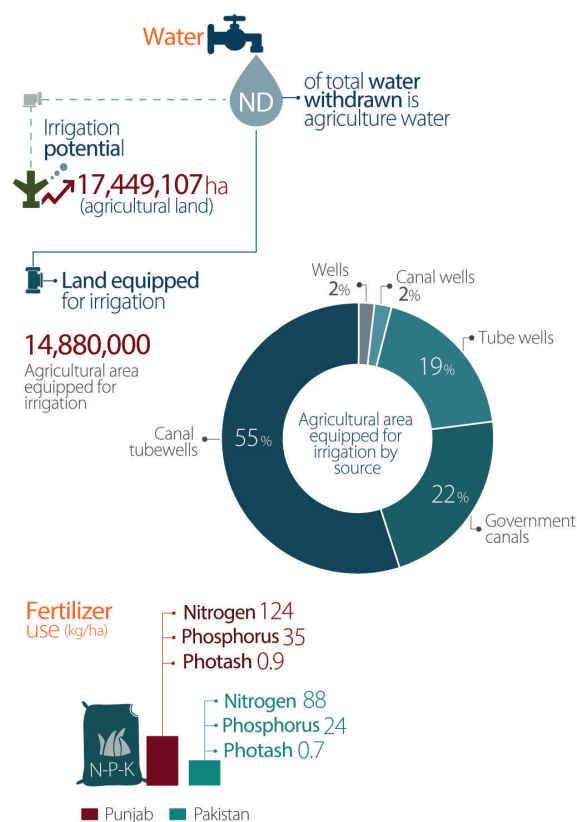
Pakistan receives monsoon rainfall in the summer, while in winter it often receives rainfall from moist western systems, originating in the Mediterranean region [29]. These two forces broadly determine the two main cropping seasons in Punjab. 'Kharif' (April-June) is suitable for summer cultivation of rice, cotton, maize, pulses, sesame and groundnut, and 'Rabi' (October-December) is when wheat, lentil, oilseeds, barley, mustard and vegetables such as turnip, spinach, peas, garlic and lettuce are grown. During the spring and autumn seasons maize, sunflower, potato, tomato, onion and soybean are grown. Punjab also produces sugarcane, moringa, and fodder crops.

The following infographic shows a selection of agriculture production systems key for Punjab food security. The production systems have been chosen through a participatory method involving the government of Punjab and local stakeholders, considering economic, productivity, nutrition and environmental factors.

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



Agricultural input use in Punjab [5, 7]



mortality rates in Pakistan and Punjab. Despite producing over two-thirds of national agricultural output, more than one quarter of Punjab households remain food insecure [7]. A recent study of the Punjab districts shows that smallholders produce meagre amount of surplus food as compared to large farmers [31]. The structure of the agricultural sector in Punjab with many small farms of less than 1 ha, exacerbates food insecurity, especially amongst families with small children [7].

According to Punjab Multiple Indicator Cluster Survey in 2014, 34% of children under 5 are moderately or severely underweight, 33.5% are moderately or severely stunted (i.e. too short for their age) and 17.5% are moderately or severely wasted (i.e. too thin for their height) [21]. Although people in Punjab are slightly better nourished than those in other provinces, there is wide disparity across the province [21]. According to some estimates over one-third of households consume less than the recommended average daily calories [9]. Low nutritional quality is associated with high mortality, hardship, poor child development, reduced productivity and reduced immunity to diseases [26, 32]. Furthermore, only half the women in Punjab have normal body mass index, while 18% are underweight and 30% are overweight or obese⁶ [19, 33]. Obesity also stems from diets rich in sugar and fat but low in healthy nutrients.

In the Pakistani diet, cereals (predominantly wheat) remain the main staple food, accounting for 62% of total energy [20]. Wheat is followed by milk and vegetables in terms of calories consumed. The consumption of meat, and seasonal fruits and vegetables is limited due to socioeconomic conditions and lack of organized marketing facilities. On average, households in Pakistan spend 37% of their income on food, higher than any other commodity group [20]. The expenditure is higher in rural areas at 42%, where two-thirds of the population resides and 80% of the poor are concentrated. Expenditure on milk accounts for over 20% of the household food budget, followed by wheat at 13%

Food security, nutrition, and health

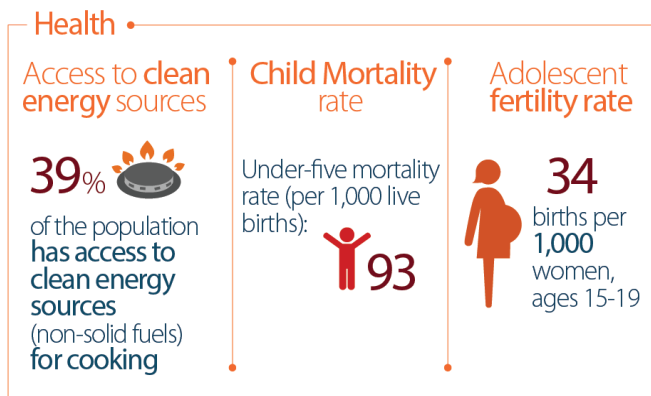
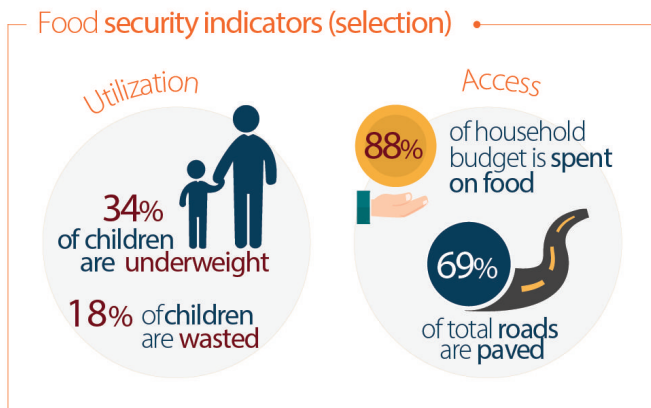
Despite steady economic progress, food insecurity and under-nutrition remain recognized health challenges in Pakistan and Punjab. According to FAO, food insecurity is often exacerbated by climatic shocks [30]. Under-nutrition has resulted in high maternal and child morbidity and

6 Overweight and obese women are disproportionately concentrated in higher income and education group (NNS, 2011)

[20]. Pakistan is one of world's largest milk producer and consumer. According to an earlier study with limited sample, prevalence of adult lactose mal-absorption was found in 60% of the subjects [34]. This can significantly impact nutritional planning in Punjab and needs to be researched further. Limited access to credit, markets and government services further contribute to widespread chronic poverty and food insecurity among rural populations.

To reduce the incidence of under-nutrition, the Punjab government in 2015 launched the Multi Sectoral Nutrition Strategy (MSNS)⁷. The programme envisions reducing the stunting rate to 20% by 2027. Achieving this ambitious target will require a broad approach with concerted effort and support from health, agriculture, education, food and social protection sectors.

Food security, nutrition, and health in Punjab [20, 21]



Agricultural greenhouse gas emissions

To date there are no direct studies on the contribution of Punjab to global greenhouse gas (GHG) emissions, however such studies have been conducted on a national scale. These find Pakistan's contributions to represent only 0.8% of global emissions, estimated at 405 million tons of carbon

dioxide equivalent (MtCO₂e) annually⁸ [35]. Consequently, the country is ranked 148th in the world on the list of global emitters, based on a per capita GHG emission of 1.96 tons of CO₂e[36].

Of the total GHG emissions in Pakistan, energy is the single largest contributor representing approximately 46% (186 MtCO₂e) of the emissions, followed by agriculture at 43% (175 MtCO₂e) mainly through livestock rearing and cropland [35]. These systems represent 78% and 22% of total agriculture emissions, respectively [6]. Punjab, with over two-thirds contribution to national agriculture production, is responsible for a significant portion of the GHG emissions in the sector, covering livestock enteric fermentation, soil quality measures, manure management, use of synthetic fertilizers, rice cultivation and burning of crop residues [37]. Although, by 2030 agriculture's share in GHG is projected to decrease to 30% of the total emissions, due to expected growth in the energy sector, agriculture will continue to remain a significant emissions contributor [35].

With a growing population and evolving dietary preferences, including increasing meat consumption, food demand is expected to increase significantly in to the future, driving commensurate increases in agricultural sector emissions.

Challenges for the agricultural sector

Agriculture is the economic, social and cultural lifeline for the people of Punjab. The sector holds the key to drawing millions out of poverty, but faces tremendous social, technological and environmental challenges. These include rapid population growth, urbanization, child malnutrition, gender inequality, low mechanization, lack of access to credit, poor water availability and quality. Soil degradation, and an increasingly animal-based diet are additional threats. A changing climate adds yet another layer of threat, especially to smallholder farmers that rely on agriculture and lack the capacity to adapt to the climate challenges [38].

Population growth

Punjab's population is the fourth largest subnational entity globally, and compared as a country it would be the 12th most populated country [39]. The province has been growing at over 2%⁹ annually [15]. The current per capita caloric availability in Pakistan, 2,440 kcal/day [40] is likely to fall unless food production and availability keeps the pace with the projected population growth. The current production systems will also have to shift from over dependence on cash crops to higher value and more nutritious crops, to meet the nutrition requirements of the people and ensure future food security. The transition would require financial, infrastructure, input and policy support from the government, private sector and institutions.

⁷ Refer to <https://msnc.punjab.gov.pk>

⁸ Based on National GHG Inventory 2014- 2015 data

⁹ Punjab's population has grown at the slowest rate among all provinces, but the absolute yearly population number remains high

Water availability and usage

Water availability and usage is crucial for Punjab. Most of the province's territory is arid or semi-arid relying on an extensive irrigation system. Much of the irrigation water from the Indus river is from glacial melt, snowmelt, rainfall and runoff. Erratic monsoons, rising average temperature, increased glacial melt and cross border water disputes increase the uncertainty and vulnerability of agriculture [24, 41].

Approximately 94% of Pakistan's water (mainly in Punjab) is for agriculture, out of which an estimated 50% is wasted during distribution and application [42]. Over-irrigation from lack of knowledge on optimal timing and quantity is common. Rapid urbanization, population growth, inadequate water storage, sedimentation of reservoirs and overall low system efficiency are an increasing strain on supplies [43]. Investment is therefore urgently needed to improve efficiency, reduce wastage, and regulate irrigation, along with robust water accounting and measurement mechanisms [44].

Increased demand and erratic availability has increased the reliance on and extraction of ground water, with an exponential growth in the number of tube wells over the last 4 decades, with 1 million tube wells in Punjab alone [7]. This strain on groundwater by agriculture and industry has dramatically dropped the water table and aquifers have become contaminated by unregulated discharge [45, 46]. Aquifer pumping is mainly for rice production, which adds stress on the groundwater during droughts because of rice's high demand for water compared to most other crops. Adoption of On Farm Water Management (OFWM) system to optimise water use for cropping along with appropriate legislation are important [47]. Strategies including laser levelling of fields, sprinklers, drip irrigation and irrigation schedules could improve salinity, help conserve 30-50% of water and reduce yields by over 25% [25].

Mechanization, technology, infrastructure and financing

The rural population, the backbone of agriculture sector, is comprised mainly of smallholding, poor farmers who lack access to modern farming methods, machinery, transportation, storage facilities, electricity, inputs, and improved seeds [48]. Smallholders are disproportionately vulnerable to climate impacts and shocks due to their lower socioeconomic conditions that limits their capacity to adapt to change [38]. The high price of seeds and a lack of government support inhibits farmers from adopting novel techniques. Small farm size and persistent poverty denies farmers capitalizing on economies of scale or increased mechanisation, reducing risk taking and diversification. Extension services are weak, as such, many farmers are unaware of modern methods including information on agrochemicals, crop varieties and fertilizer use. In 2014,

only 27% of the total households surveyed in Punjab had interacted with an extension agent [49]. Moreover minimal asset ownership and lack of collateral limit farmers access to credit markets [5]. Despite the introduction of several agricultural credit initiatives by commercial, microfinance banks, and rural support programmes, knowledge of these initiatives is limited among smallholders. These smallholders have to rely on middlemen¹⁰ that offer credit at exploitative rates.

Research and capacity building

Despite continuous progress in agricultural production, there are significant yield gaps in major crops from the province compared with developed countries and the region as a whole. Research in Punjab focuses on growth strategies around intensification of production (improving efficiency) and expansion of the production base (increasing capacity). Intensification may lead to increased production but often comes with the added risk of soil degradation that can curtail gains while adding to production costs [50]. Expansion of the production base is also impractical as cropping area in Punjab is saturated by growing pressures of population and urbanization.

Agriculture research, although inherently complex, is needed to develop robust evidence-based policies, plans and farmer training strategies in a changing socio-ecological environment. The Punjab government has recently released the Punjab Agriculture Policy 2017 [9] to direct attention on improving research by strengthening capacity of the existing research units and departments, including the Punjab Agriculture Research Board. The policy focus needs to cater for the needs and rights of smallholder farmers, who are the backbone of the sector.

Gender

Gender inequality and discrimination is another important characteristic of Punjab's agricultural sector. While 73% of employed women in Punjab depend on agriculture, women are less likely to own income-generating assets such as land, machinery or equipment, nor do they have equal power in financial or economic decision making [19]. Women participation in non-agricultural income generating activities is very low. Less than 5% of women aged 16 and above had worked as non-agricultural employees (including business enterprise) [49].

The lack of access to the latest technologies and farming techniques, weak extension support, and high illiteracy creates further challenges for women in agriculture [19].

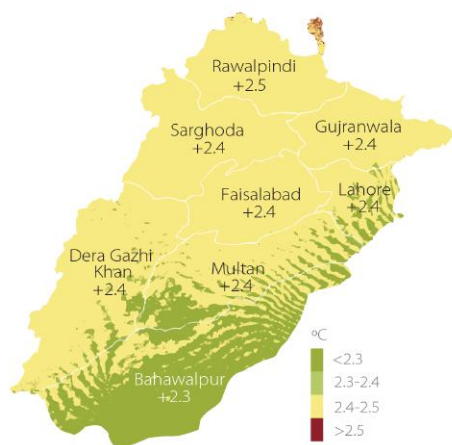
Key investments in improved infrastructure, extension support, credit availability, storage, seeds, farming methods, gender inclusive approaches, research and development, and water infrastructure are needed to tackle the emerging challenges to the sector's development, especially in the context of serious threats to water security and climate change impacts.

¹⁰ Agriculture middlemen in Pakistan are referred to 'Artis' who control significant portion of the agriculture supply chain and financing for smallholder farmers

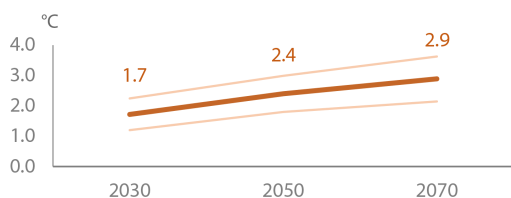
Agriculture and climate change

Projected change in Temperature and Precipitation in Punjab by 2050^[53, 54]

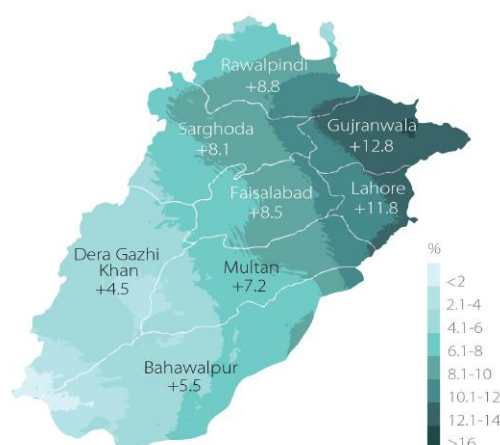
Changes in annual mean temperature (°C)



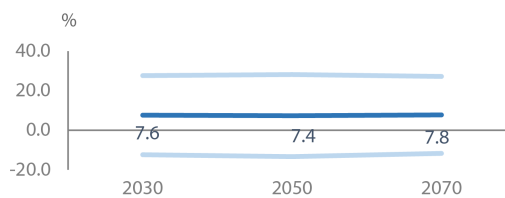
Average temperature (°C)



Changes in total precipitation (%)



Average precipitation (%)



Projected changes in climate

Pakistan, is ranked among the top ten most climate vulnerable countries in the world in the Global Climate Risk Index [54]¹¹. Climate change poses a serious threat to agriculture in Punjab, exacerbating the vulnerability of its growing population [55].

Punjab lies in arid to semi-arid region of Pakistan and has three climatic seasons. Extremely hot summers from May to July where temperatures reach 45°C–50°C. This is followed by monsoons from the Bay of Bengal from August to September, when average annual rainfall can range between 1140–1270 mm in sub-mountain region and 508–630 mm in the plains. October to March are cooler with mildly foggy winters, but some areas experience temperatures below 0°C. The monsoons bring rains to the northern parts of the province, while the southern regions receive rainfall from southwest winds from over the Arabian Sea [56].

In the past decade Punjab has experienced severe droughts, followed by devastating floods in 2010, 2011, and 2014.

This vicious and unpredictable cycle of climatic extremes have severely impacted agricultural production and the supporting irrigation systems. The average temperatures in Punjab have risen by 0.5°C in the past century from 1901 to 2000 [56] and expected to rise by a further 1°C–3°C by 2060 [57]. A recent study shows that each degree-Celsius increase in global mean temperature would, on average, reduce global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4% [58]. The impact on yields may vary across the AEZ's in Pakistan and Punjab, but are likely to be significant without adequate adaptation strategies [59].

A rise in the temperature will increase the glacial melt in the Himalayas, that feed the river system, followed by unpredictable monsoons patterns. Results will be severe cycles of too much or too little water [60]. As a result, the surface water availability in the province through the Indus basin will likely become unpredictable, severely constraining the ability of farmers and policy makers to plan and produce effectively.

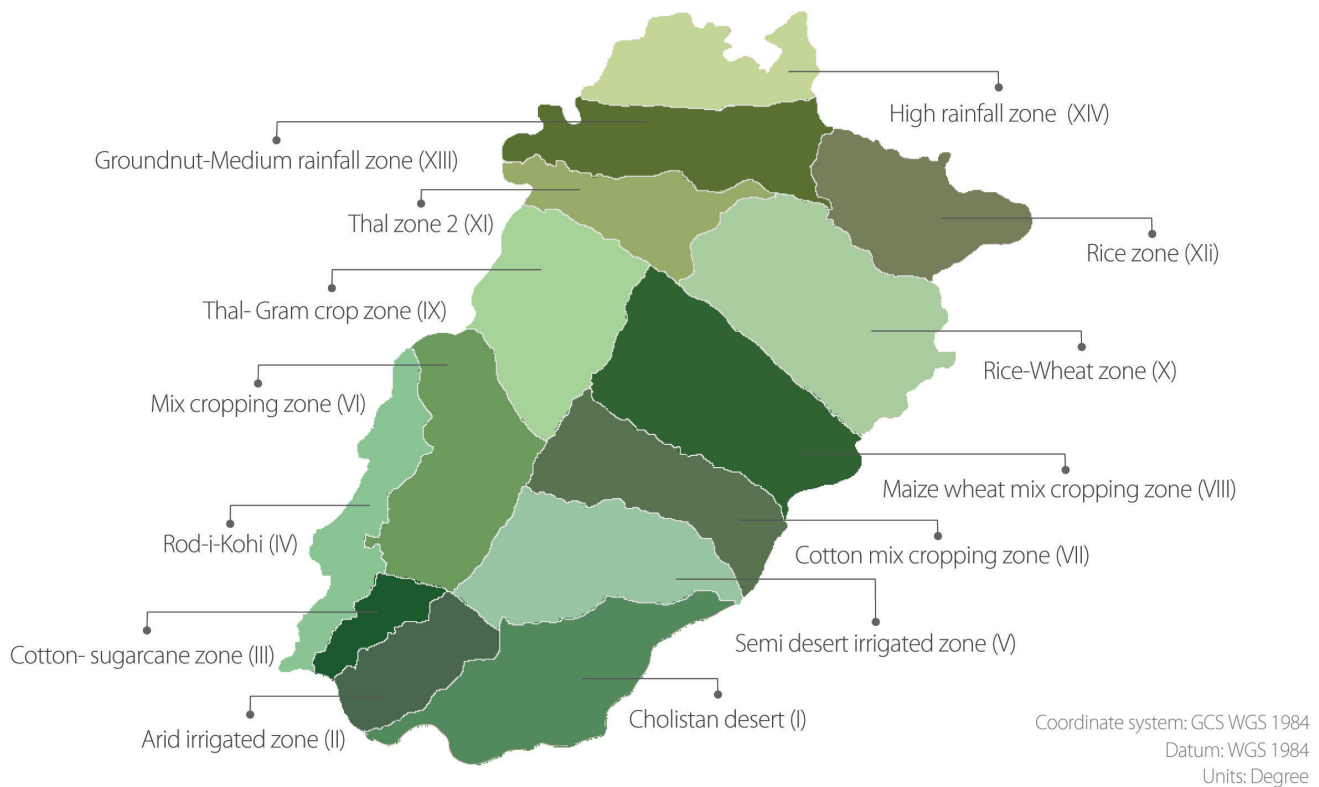
11 According to annual averages (1996 to 2015) of the Long-Term Climate Risk Index

Overview of CSA technologies and practices

CSA technologies and practices present opportunities for addressing climate change challenges, as well as for economic growth and development. Practices are considered CSA if they enhance food security as well as at least one of the other objectives of CSA (adaptation and/or mitigation). Hundreds of technologies and approaches around the world fall under the heading of CSA.

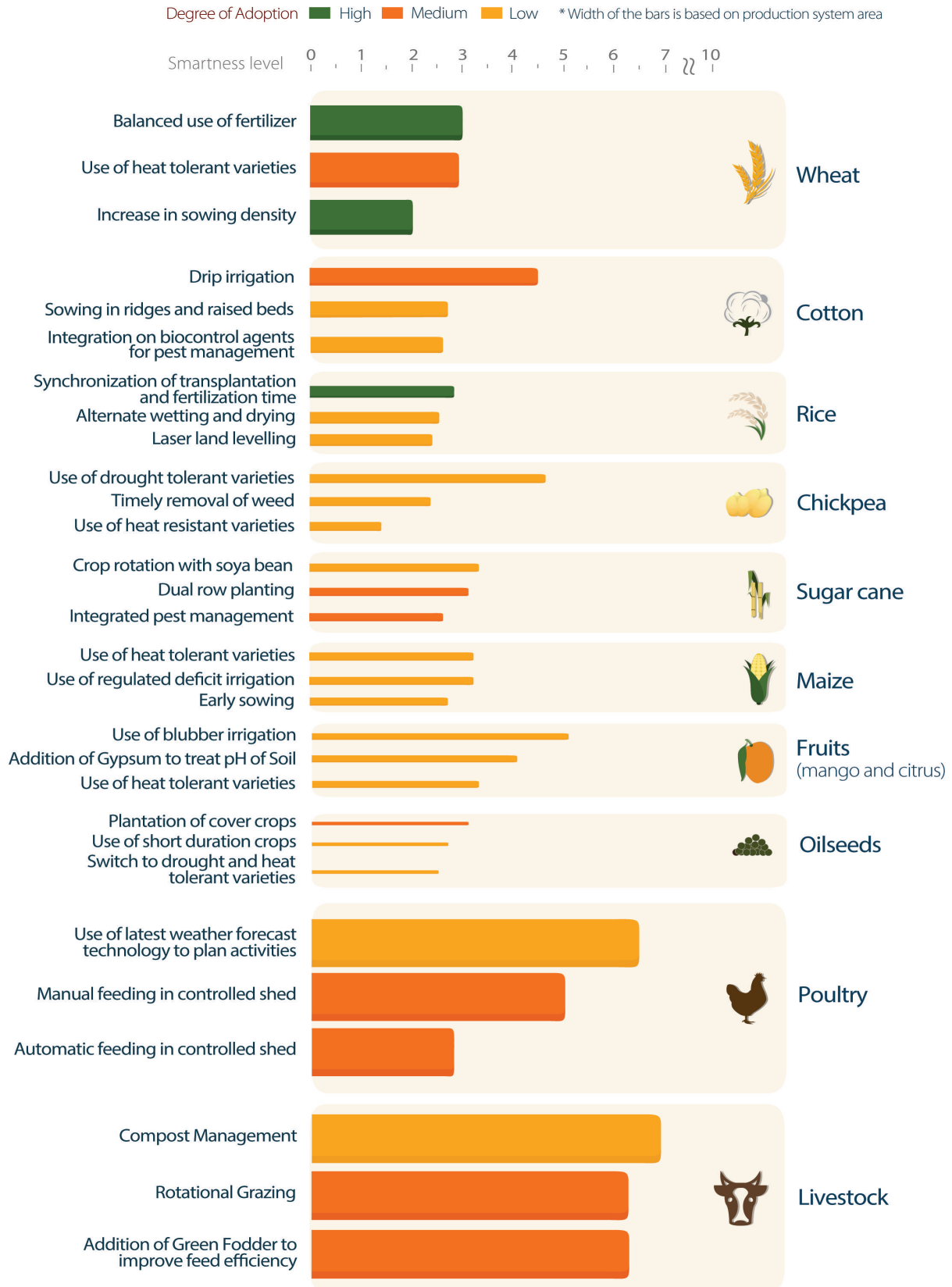
Most CSA practices identified in this study address chronic challenges to Punjab's agricultural sector, namely drought, flood, and intense heat. These practices include water management strategies, improved crop and livestock varieties, integrated pest management, manure management, and renewable energy.

Map detailing the different Agro-Ecological Zones in Punjab^[23]



Map of Punjab's updated Agro-Ecological Zones AEZ's, prepared by the University of Agriculture Faisalabad, PMAS Arid Agriculture University, Agriculture Department Punjab and the Food and Agriculture Organisation (FAO).

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



** Unidentified production system area

Practices and Technologies by Commodity

Wheat

Wheat, a winter crop, is the most widely planted in Punjab. Roughly 6.9 million ha were cropped during the Rabi (winter) season of 2015–16 [22]. It is the single most important starchy staple in the Pakistani diet accounting for an estimated 37% of both food energy and protein intake [61]. The crop has the potential of addressing the high prevalence of zinc deficiency in the population, especially amongst women and children, by fortifying wheat varieties with high zinc content [62, 63]. Variations in production can have serious implications for food security, nutrition and health of the country, especially for poor rural populations.

Around 90% of the crop is grown in irrigated areas, concentrated in AEZ VIII (Maize Wheat Mix Cropping Zone) and X (Rice Wheat Zone). The crop requires fertile loam to clay loam soils with good drainage for better yields, good soil moisture level and with maximum temperature of 28°C and minimum temperature of 6°C [28, 64]. The average yield of the wheat crop in 2016 marginally increased by 1.3% to 19.5 million tons compared to the previous year [22], because of timely sowing, favourable rains, cool temperatures and availability of inputs. According to the Pakistan Agriculture Research Council (PARC) significant yield gaps exist between farmers in irrigated areas (2.5–3 tons per ha) and those reliant on rain (0.5–1.3 tons per ha). Wheat production in the country has historically been highly variable and well

below potential, due to non-availability of improved inputs like seed, inefficient fertilizer use, weed infestation, shortage of irrigation water, drought and terminal heat stress, soil degradation and inefficient extension services [22].

Intermittent periods of very high temperature (>35°C), common in many of the world’s wheat growing areas, can significantly reduce yield and quality [65]. High temperatures cause an array of physiological and biochemical changes in plants, which affect growth and development and may lead to a significant reduction in yield [66]. The development of heat tolerant varieties is crucial to improving productivity in areas experiencing extreme high temperatures and variable rainfalls [67]. The Wheat Research Institute, Faisalabad¹² has periodically been releasing improved varieties of wheat with higher protein content, yield potential and food quality over the last several decades. Recently researchers from the Punjab Seed Council have released an improved heat and drought tolerant variety of wheat (Gold-16) for southern Punjab with better genetic potential, heat tolerance and disease resistance that could also resist lodging.

For integrated soil fertility management, it is important that plants receive the correct balance of macro nutrients (N,P,K) and micronutrients, given the soil conditions. Imbalanced application results in the inefficient uptake of nutrients, reducing potential yield gains and representing a miss use of farmers scarce resources. Farmers in Pakistan were found to lack sufficient knowledge of the nutritional crop requirements and the soil fertility status to effectively balance the use of their inputs, often resulting in nutrient leaching, nutrient imbalances in the soil and the eutrophication/pollution of water bodies [68].

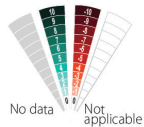
Table 1. Detailed smartness assessment for selected wheat CSA practices implemented in Punjab

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 (42% of total harvested area)				
Irrigated	<30%	S	3.6	<p>Productivity Right source (organic), right application time, amount and place promote sustainable increase in productivity and income with minimal impact on the environment.</p> <p>Adaptation Right source (organic), right application time, amount and place promote efficient use of local inputs. Reduces runoff and risk of nutrients leaching into groundwater or surface water.</p> <p>Mitigation Balanced organic fertilization reduces GHG carbon foot print and emissions associated to synthetic fertilizers use.</p>
Balanced use of fertilizer	30-60%	L	2.7	

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
	<30 30-60 60>			

Wheat (42% of total harvested area)



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 (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

Pakistan is the 11th largest rice producer globally [70]. Rice in Punjab is primarily grown in the 'Kalar' bowl, located between the Ravi and Chenab rivers and irrigated areas. These areas correspond to AEZs X (Rice Zone) and XII (Rice-Wheat Zone) [28]. The soils required are a mixture of clay and silt, and clay loam, with optimum temperatures between 20°C to 36°C. Favourable climate and soils enable Punjab to produce 100% of Pakistan's fine grain Basmati rice (for premium export) from the "Kalar" area. Basmati is roughly 65% of the rice produced by the province. In 2016, rice was planted on 1,789 million ha, 5.2% lower than the previous year due to reduced returns and a shift to fodder and other competitive crops [22]. As a result, the total production also fell by 4% to 3.5 million tons. Farmers in the two AEZs historically grow rice in the Kharif (wet summer season) and wheat in the Rabi (dry winter season). The soil conditions and crop management practices undergo drastic changes during these two distinct seasons, requiring careful action to optimise yield and soil conservation.

Among the factors that influence rice yield substantially, the most important are less number of plants per unit planting area, transplanting of aged rice nursery and imbalanced use of fertilizer in the field [71]. Scarcity of skilled labour and careless transplanting results in low density of rice plantation and hence low yields. This is further exacerbated by reliance of farmers on outdated production practices. Recent studies encourage that by demonstrating and setting up experiments for different improved methods of transplanting and use of alternative sources of fertilizers, knowledge gap among farmers can be improved resulting in improved production cycles and higher yields [71].

Water management strategies have become more important in recent years, especially for rice production given the increased intensity and unpredictability of both drought and flood as well as the growing unreliability of glacier melt leading to variability in the river flows. Excessive pumping of ground water for irrigation through diesel tube wells adds to GHG emissions and costs of production [37]. Historically, irrigation has been inefficient because of poor field design and uneven surfaces leading to water pooling and wastage that cause uneven germination and growth. Punjab already employs laser land leveling to overcome this wastage [25]. A laser beam situated at a fixed point at the edge of the field with a receiver box on a plough allow farmers to achieve field uniformity. This practice is promoted by the Directorate General Agriculture (Water Management) Punjab and is estimated to save irrigation time by 30%, improve yields by 12% and save energy by 31% [25, 72]. The government has offered 6,000 laser leveling units to farmers in all irrigated areas of Punjab from 2015 to 2018, which should increase

adoption and in turn enhance productivity by improving water efficiency. However, poor promotion of the benefits and limited access to credit inhibits wider adoption of laser leveling by farmers.

Another technique of growing importance is alternate wet and drying (AWD) of paddies. AWD is a management strategy where close monitoring of soil saturation is used to reduce the need for constant submergence of rice paddies. Rice remains flooded during critical growing periods like flowering, but otherwise water levels can alternate between surface flooding and water level falling below soil surface. A 'field water tube' is inserted in the soil to monitor the water

depth on the field. AWD has proved to be an extremely effective water-saving irrigation technology, while reducing methane emission by nearly 70% and maintaining rice yields [37, 73]. Another associated benefit of AWD is reduced arsenic levels in the rice grain, as irrigation sources are often found to be contaminated with arsenic [74]. Its adoption by farmers in Punjab, however, remains limited. Key knowledge gaps, weak extension support and low incentive to reduce water usage are some of the barriers to adoption. Increasing the involvement of farmers in AWD research through participatory and interdisciplinary methods will improve uptake of these and other water-saving techniques including laser leveling.

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

CSA practice	Region and adoption rate (%)			Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
	<30	30-60	60>			
Rice (11% of total harvested area)						
Alternate wetting and drying (AWD)	Irrigated Areas <30%			S M L		<p>Productivity Increases yields by promoting more effective tillering and stronger root growth. Reduces irrigation costs</p> <p>Adaptation Increases water use efficiency by intermittent water application (reducing permanent flood). Allows crop production under water scarce conditions.</p> <p>Mitigation Reduces GHG emissions/carbon footprint related to the use of synthetic fertilizers. Reduces methane emissions from permanent flooding.</p>
	Kallar Tract <30%			S M L		
Synchronization of transplantation and fertilization time	Kallar Tract >60%			S M L		<p>Productivity Enhances production per unit area due to the higher grain yield, reduced losses and better harvest quality.</p> <p>Adaptation Reduces water demand, thus reducing pressure on natural resources. Increases resilience to drought.</p> <p>Mitigation Increases in production efficiency potentially reduce energy use and GHG emissions per unit of product.</p>
	Irrigated Areas >60%			S M L		



Alternate Wet and Dry Method (AWD) - Rice

Allah Ditta, 35 years lives in a small village, Chabotra Adha, 20 km from the small town of Salarwahin, in district Muzaffargarh. He has 7 children including 4 sons and 3 daughters. He has been a Food-secure Future Farming (FFS) member since June 2018.

He recalls his experience, “before participation in FFS sessions, we practiced continuous flooding of rice due to unawareness of the Alternate Wetting and Drying method (AWD)”. “During this training, I learned about innovative ways of growing different crops including rice in nearby cultivable land. I also came to know that pesticides, which are normally used in food crops have toxic effects on human health. Knowledge about different methods of growing rice including AWD was a fruitful learning of the FFS sessions. I also learnt how to control harmful insect’s through integrated manners”.

During regular weekly FFS sessions, beneficiary farmers were selected to establish trial sites for AWD. Allah was selected as host farmer for the job. He established the site and applied AWD, using an AWD water tube throughout the season, maintaining records of the process. He saved 3 irrigations as compared to the continuous flooding method. The members of the FFS also found that there was less attack of pest in this field as pests were controlled through the addition of Integrated Pest Management (IPM) techniques. This method has proved not only helpful for reducing emission of methane gas as compare to continuous flooding method but also benefitted economically by reducing the cost of irrigation water.

Allah Ditta says, “I wish to educate and mobilize my relatives and neighbours to join hands with my FFS group to learn innovative practices of agriculture production on different major crops. I want to see my village chemical free and healthy food at my own home, and land which could lead to a sustainable prosperity.”

He further continued, “I have participated in many trainings but found this one different which address our basic needs and guided us to achieve them by our own sources. The practical and participatory nature of the training developed our interest in post training activities as the actual principle of learning by doing was applied during the whole training. It was really a life changing project which seems small in its volume but huge in its objective and goals”.



(Information source and pictures courtesy of FAO Pakistan)

Table 3. CBA analysis for AWD in rice (1 acre)

CBA tool summary Farm (1 acre) results	Change in yield	Incremental net present value (NPV)	Internal rate of return (IRR)	Payback period	Initial investment	Scenario in the analysis (10 years)	
Unit	%	US\$	%	Years	US\$	Before	After
Value	+ 7	400	NA	NA	-28.4	Continuous flooding of rice	AWD
Aggregate analysis CBA tool summary	Total area of Rice (acre)	Current adoption rate (%)	Adoption rate (%)	Aggregated NPV (US\$)	Period (years)		
	4,418,000	10	49	286,827,000	10		

Adoption of the AWD method will reduce the cost for irrigation by 25% compared to continuous flooding of rice. The cost of implementation is lower than that of current practice, resulting in a negative initial investment cost. The profitability of AWD is significantly higher than that of continuous flooding with a NPV of US\$ 978 per acre in 10 years compared to US\$ 578 for continuous flooding. According to the projection, if the adopted rate of AWD moves from 10% to 49% in Punjab over the next 10 years, the aggregate benefit would be \$ 286,827,000.

Cotton

Cotton, known as ‘white gold’, is an important cash crop in both Pakistan and Punjab. The cotton textile sector is the largest manufacturing industry, accounting for approximately 60% of the country’s exports and 25% of the industrial GDP [10]. Punjab alone produces over 70% of the total cotton crop. Cotton production, however, has been variable over the years due a changing climate, low awareness of farmers of such climatic threats and policy challenges including changing subsidies [75, 76]. In 2016 production was roughly 38% lower than the previous year at 6.3 million bales compared to 10.3 million bales in 2015 [22]. Permanent waterlogging/flooding hampers nutrient uptake and increases the incidence of pests and disease [75]. In 2017 production partially recovered by 10%, which is still substantially lower than 2015. The highest yield areas are in the cotton belt, now AEZs II (Arid Irrigated Zone), III (Cotton-Sugarcane Zone) and VII (Cotton Mix Cropping Zone) with the best soil and climatic conditions [28]. The soil required is sandy loam, silty loam and clay and the temperature for optimum crop production ranges from maximum 40°C to minimum 26°C.

The development of cotton varieties and the realization of their potential are subject to many limitations imposed by weather, water availability, crop management and pest control. Research shows that farmers in Punjab are adopting CSA practices and technologies in cotton to counter the challenges of decreasing water supply, climate change and increasing soil salinity. These practices include planting in raised ridges, laser levelling, reduced chemical input and

the use of improved varieties, helping farmers improve yields and resource use efficiency [77].

Drip irrigation as a CSA practice has the potential to save water (minimize evaporation) and nutrients by delivering water slowly and directly to the roots of plants, either onto the soil surface or directly to roots. Drip irrigation has been found to improve cotton yields, while reducing the water usage [78]. Studies in the region show improved plant height and bolls per plant in plots where drip irrigation is used [79]. Although, installing drip irrigation is expensive, a case study of five farms by Punjab agriculture department showed water savings of 33%, reduced fertilizer use of 41% and improved yields by 32% compared to conventional methods [80]. Further detailed economic analysis is required to test the viability of the practice.

Another CSA technique is planting cotton crop in raised ridges. This 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 unusual rains [81]. It further protects the crops from temporary water logging. To improve yield, the Punjab Government announced a subsidy of PKR 100 billion (USD 800 million)¹³ for approved varieties of cotton seed to farmers operating in the relevant AEZs under the ‘Khadim-e-Punjab Kissan Package in 2016’.

13 All currency conversions from PKR to USD are done using the exchange rate of 0.008 (on Sept 22nd 2018)

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

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 (14% of total harvested area)				
Drip irrigation	South Punjab <30%	M		<p>Productivity Higher profits due to increased crop yield and decreased input costs for fertilizer.</p> <p>Adaptation Reduces soil erosion and improves nutrient and water use efficiency in drought prone areas.</p> <p>Mitigation Reduces energy use compared to conventional irrigation. Provides moderate reduction in GHG emissions in the medium and long term per unit of food produced.</p>
	Central Punjab <30%	S		
Sowing in ridges and raised beds	South Punjab <30%	M		<p>Productivity Reduces crop losses from pests and diseases. Potential increases in profits due to increased crop yield and quality.</p> <p>Adaptation Improved water use efficiency and lower risk of rot due to heavy rain.</p> <p>Mitigation Reduced emissions from the use of synthetic fertilizer.</p>
	Central Punjab <30%	S		



Yield

Income

Water

Soil

Risk/Information

Energy

CO₂ Carbon

N₂O Nutrient

Maize

Maize is the third most widely grown food crop after wheat and rice in Punjab. It is a vital source of nutrition for the rapidly growing population. Maize is a two season crop grown in spring and autumn. Punjab contributes approximately 38% of the acreage and 30% of the total maize grain production in the country [22]. The planted area in 2016 was 0.48 million ha, which marginally increased from the preceding year by 2.5% [22]. Successful maize production depends on the optimum application of inputs, fertile well-drained soils, considerable moisture and warmth from germination to flowering. The Central Punjab region corresponding to AEZ VIII (Maize Wheat Mix Cropping Zone) dominates the maize production in the province [28]. The soil required is silty loam, loamy and medium clay and the temperature for

optimum crop production ranges from maximum 38°C to minimum 20°C.

Maize is drought sensitive and requires frequent irrigation for successful germination and growth, especially in arid and semi-arid regions. Droughts reduce yields by about 10–15%, which can increase to 40% under severe droughts [82]. On the other hand, water logged soil is also very harmful. Adequate and timely irrigation is important to ensure good yields. Regulated Deficit Irrigation (RDI) is an optimization approach of delivering water at the drought sensitive stage of the crop and relying on rainfall outside this period. Studies shows that RDI combined with ridge plantation can improve yields by over 20% [83]. Further by optimising the combination of irrigation and nitrogen fertilization, water consumption can be reduced by 20% without significantly

impacting the crop yield [84]. Adoption of RDI is currently low in the province due to low knowledge and awareness.

The most suitable temperature of germination and growth of Maize is between 21°C to 32°C. A modelling study in Punjab on climate variability showed that maize yield would be reduced by 43% by an increase in maximum and minimum temperatures of 4.4°C and 2.3°C, respectively [85]. Extremely high temperature reaching 40°C–50°C in summers in Punjab damage the crop resulting in low yields and loss to farmers. The temperatures in Pakistan

and Punjab are expected to rise further by an average 1°C–3°C by 2060 [57], adding uncertainty to the production patterns. Use of heat-tolerant varieties with timely sowing could reduce yield loss compared to current varieties by as much as 90 % in 2030 with irrigation [86]. A number of local hybrid seeds have been bred and tested in Punjab in high temperatures that have shown increased tolerance to high temperatures [87]. Encouraging heat-tolerant maize varieties as a potential CSA practice could shield farmers from severe loss and help overcome weather extremes from a changing climate.

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

CSA practice	Region and adoption rate (%)			Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
	<30	30-60	60>			
Maize (4 % of total harvested area)						
Use of regulated deficit irrigation	Pothar Region	<30%		M		<p>Productivity Improves or maintains yield per unit of water.</p> <p>Adaptation In combination with standardized irrigation designs/schemes leads to water use efficiency reducing the water demand in drought prone areas. Minimizes erosion.</p> <p>Mitigation Reduces energy requirements for irrigation hence associated GHG emissions per unit of produce.</p>
	Central Punjab	<30%		M		
Use of heat-resistant and pest-tolerant varieties	Pothar Region	30-60%		M		<p>Productivity Reduces crop failure risk. Enables production and yield stability even when there is water scarcity, hence increases food availability and access. Contributes to reductions in production costs.</p> <p>Adaptation Increases farmers' capacity to limit crop exposure to damage caused by pests and climate hazards.</p> <p>Mitigation Reduces use of synthetic pesticides and fungicides, thus reducing related GHG emissions and carbon footprint.</p>
	Central Punjab	<30%		S		



Yield

Income

Water

Soil

Risk/Information

Energy

CO₂ Carbon

N₂O Nutrient

Cost Benefit Analysis

CRA Practice: Improved maize varieties (higher yield and drought tolerant)

Extremely high temperature reaching 40°C–45°C in summers in Punjab damage the crop resulting in low yields and loss to farmers. Therefore, there is a great need to develop and promote maize varieties that are more tolerant to water and heat stress. The current CBA analysis is based on hybrids maize variety with higher yield and tolerance to drought.



Table 6. CBA analysis for high-yielding and drought tolerant Maize varieties (1 acre)

CBA tool summary Farm (1 acre) results	Change in yield	Incremental net present value (NPV)	Internal rate of return (IRR)	Payback period	Initial investment	Scenario in the analysis (10 years)	
Unit	%	US\$	%	Years	US\$	Before	After
Value	+ 58	617	89	3	121	Conventional varieties	High-yielding and drought tolerant
Aggregate analysis CBA tool summary	Total area of Maize (acre)	Current adoption rate (%)	Adoption rate (%)	Aggregated NPV (US\$)	Period (years)		
	1,200,000	35	62	88,000,000	10		

To assess the financial viability for farmers in adopting improved maize varieties a Cost Benefit Analysis (CBA) was conducted. The current adoption of improved Maize varieties remains low (35%). This could in part be explained by the higher costs for seeds and increased fertilizer requirement. The CBA result reveals a clear financial gain from adopting improved varieties. The net incremental benefit largely compensates the additional investment costs and the IRR of the practice is 89%, presenting a wide range of profit potential. If the practice is adopted and implemented on 69% of land currently cultivated with maize in Punjab, this would generate an aggregate benefit of \$ 88,000,000 after 10 years.

Sugarcane



Sugarcane is one of the main cash crops of Pakistan, with Punjab's share at 62% of the national total. Roughly 85% of the production is used by commercial mills to produce sugar. After textiles, the sugar industry is the country's second largest agriculture-based industry. In 2015-16 season sugarcane covered over 0.7 million ha, a decrease of 0.7% on the previous year [22]. The total production was 42 million tons: an increase of 2.2% [22]. The average yield in the country and province is much lower at 56 tons/ha compared to the world average of 70 tons/ha [26]. Conventional planting practices including improper row spacing and seeding density are the most critical factors for reducing sugarcane yield in the country [88]. The yield per hectare also varies across the province with differences in weather conditions. Sugarcane is a tropical crop that tolerates hot and humid conditions. It is usually planted from stem cuttings rather than from seed. The optimum crop production temperature is between 20°C to 40°C. Production of sugarcane dominates in AEZ III (Cotton – Sugarcane Zone) where the soil is heavy loam and clay loam [28]. Chronic delays in payments to farmers by the sugar mills has been a long standing political and social challenge in Pakistan and Punjab [89]. Recently the government has devised a new pricing mechanism for crops linked to

wholesale prices to offer a level playing field with other crops.

Sugarcane is a water-intensive semi-perennial crop. As one of the world's thirstiest crops, sugarcane production has a negative environmental impact on the water scarce areas of Punjab. Yields have been effected by the use of unsuitable land, low fertility rates, poor fertilizer provision, using exhausted plants and less resistant varieties, poor management, poorly timed harvesting and planting. Nurseries have been established to keep the growing stalks safer from diseases and pests. Rotating sugar cane with soybeans can raise cane yields trapping nitrogen and reducing soil degradation to increase profitability [90].

Dual row planting of the sugar cane crop is another effective CSA practice. This method of sowing is called "2 in 1" meaning two sugarcane rows in a single trench with about 9 inches space between them. Dual row planting gives much better crop stand and ultimately up to 25%-28% more yield than traditional methods in some trials [91, 92]. With wider rowing space the plant is exposed to more light, inducing higher rates of photosynthesis leading to faster growth and higher sugar recovery [93]. The wider space allows for inter-row hoeing by tractor, thus saving costs and improving efficiency [93].

Table 7. Detailed smartness assessment for selected sugarcane CSA practices implemented in Punjab

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 (4% of total harvested area)				
River belt	<30%	L		<p>Productivity Increases total production and productivity per unit area. Increases in income stability and food security due to harvest of multiple crops.</p> <p>Adaptation Minimizes the incidence of pests and diseases. Reduces the risk of total crop failure under market and climatic shocks due to crop diversification. Improves soil fertility.</p> <p>Mitigation When combined with nitrogen fixation species (leguminous) reduces the use of synthetic fertilizers. Increases soil organic matter.</p>
Crop rotation with soya bean	<30%	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
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Sugarcane (21% of total harvested area)



Productivity

Increases production per unit area hence income due to denser planting.

Adaptation

Improves moisture conservation, reduces soil erosion, and enhances efficient fertilizer and water use.

Mitigation

Long term benefits on soil carbon sequestration due to greater above- and below-ground biomass accumulation.

Fruits (mango and citrus)

Mango and citrus production use almost 3% of the total agricultural area of Punjab. Around 97% of total citrus produced in Pakistan comes from Punjab. The citrus orchards are located in Sargodha, Rahim Yar Khan and Toba Tek Singh Districts that fall under AEZs II (Cotton Mix Cropping Zone), VIII (Maize Wheat Mix Cropping Zone), and X (Rice-Wheat Zone). District Sargodha is the largest citrus producer in the country. Punjab also produced 1.3 million tons of mango in 2015 which accounted for 77% of the national production [22]. Mango production is clustered in the southern districts of Punjab – AEZ VII (Cotton Mix Cropping Zone) [28]. District Multan is the largest mango producer accounting for 45% of the total provincial production area in 2016.

In the fruit growing areas of Punjab, low quality irrigation water, loaded with salt, causes deposition of sodium on good quality soils [94]. Use of brackish water and lack of good quality irrigation increases salinity, which is further aggravated by poor soil management and inadequate drainage [95]. Excessive sodium in soil lowers the yield of mangos. Gypsum (calcium sulphate) is an excellent source of sulphur used in the reclamation of highly alkaline soils. Applying Gypsum to the soil improves mango crop yield and enhances plant nutrition by exchanging Sodium for Calcium allowing the Sodium to leach out of the soil [96].

Most fruit growing areas in Punjab face constraints on irrigation and water availability. Substantial improvement in fruit size and quality can be achieved by irrigation¹³. Bubbler irrigation system, along with drip irrigation is a potentially useful method for irrigating fruit tree orchards [96]. (Under the bubbler system a low pressure solid permanent installation mechanism is installed near the tree groves. Each tree is flooded with water during irrigation. The water infiltrates into the soil and wets the root zone. Bubbler irrigation is useful for regions where conventional irrigation is inefficient, especially in sandy areas as it offers high irrigation efficiency with up to 75% water savings [97]. However, the bubbler system is expensive limiting its uptake in the province. Government support is needed to promote its use.

Pulses (chickpeas)

Punjab dominates national pulses production. In 2016, the province's total production of chickpeas was 0.43 million tons, accounting for 82% of national production [22]. The cultivation is mostly concentrated in the western districts of Punjab, corresponding to AEZ XI (Thal-Gram Crop Zone). The crop requires silty loam to sandy loam soils with good drainage for better yields, good soil moisture level and with maximum temperature of 28°C and minimum temperature of 8°C [28, 64]. The Thal desert area is the hub for chickpeas production as it cannot deliver major

13 ARefer to <http://www.nda.agric.za/docs/Infopaks/mango.htm>

Table 8. Detailed smartness assessment for selected fruits CSA practices implemented in Punjab

CSA practice	Region and adoption rate (%)	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
	<30 30-60 60>			
Fruits (Mango and Citrus) (3% of total harvested area)				
Addition of lime to treat pH of soil	Citrus - Sargodha, Jhang, Faisalabad <30%	L	4.3	<p>Productivity Allows production in soils with adverse chemical characteristics (low pH). Increases income per unit of area or produce.</p> <p>Adaptation Progressive reduction of lime application can be achieved through inclusion of organic matter/fertilizers, enhancing biological activity and subsequently soil fertility.</p> <p>Mitigation In combination with organic fertilizers improves soil carbon stocks and organic matter content, hence reducing gradually the use of synthetic fertilizers and associated GHG emissions.</p>
	Mango - Khanewal, Rahim Yar Khan <30%	L	3.8	
Use of sprinkler irrigation	Citrus - Sargodha, Jhang, Faisalabad <30%	S M L	5.3	<p>Productivity Potential increases in crop yield and quality, hence greater farmer profits. Allows continuous production throughout the year.</p> <p>Adaptation Improves water use efficiency compared to conventional methods. Benefits water stressed areas increasing farmers' capacity to limit crop exposure to climate shocks (drought or flooding).</p> <p>Mitigation Saves energy compared to conventional irrigation methods. Implies moderated GHG emissions due to fuels used for pumping, however increases in productivity reduces GHG emissions per unit of food produced.</p>
	Mango - Khanewal, Rahim Yar Khan <30%	S M L	4.9	



cash crops due to the low fertility of its soils and a lack of irrigation. Chickpea performs well under water stressed conditions in marginal soils. Bhakkar is the largest chickpea producing district that contributed 43%; whereas Khushab and Layyah respectively accounted for 30% and 11% of the total provincial production [22].

The chickpea and pulses growing areas face high temperatures and heat waves during summers. Over time, the limited irrigation system in the area has also become less efficient from silting and water losses [25]. Drought and heat stress limits growth and yield. Heat tolerant varieties are important for improving chickpea yields [98]. Wilt, drought

and moisture stress are parallel problems that emerge together. Heat and drought tolerant varieties are especially essential for dry production areas¹⁴ of Punjab.

Chickpeas are out competed by weeds due to their slow germination and emergence, thus rendering them highly vulnerable. This can cause severe yield losses and harvesting problems, by reducing the number of secondary branches of the crop [99]. A promising CSA practice is timely removal of weeds as this enhances the growth of pulses and chickpeas. Studies show that flat sowing as opposed to ridge sowing along with hand weeding can increase the crop yield by up to 15% against chemical spraying for weed removal [100].

14 Refer to <http://www.parc.gov.pk/index.php/en/csi/137-narc/crop-sciences-institute/712-national-coordinated-pulses-programme>

Table 9. Detailed smartness assessment for selected pulses CSA practices implemented in Punjab

CSA practice	Region and adoption rate (%)			Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
	<30	30-60	60>			
Pulses (Chickpea) (21% of total harvested area)						
Barani	<30%			L	2.9	<p>Productivity Maintains or improves yields and therefore profits in dry years. Improves food security and farmers income.</p> <p>Adaptation Reduces crop losses and increases yields during drought. Reduces the demand on water resources.</p> <p>Mitigation Provides moderate reduction in energy use and GHG emissions per unit of food produced.</p>
Timely removal of weed	<30%			L		
Irrigated	<30%			L	2.9	<p>Productivity Overall agro-ecosystem productivity is maintained, thus improving productivity and profit.</p> <p>Adaptation Reduces crop losses and increases yields during drought. Reduces the demand on water resources.</p> <p>Mitigation Maintains or improves soil above- and below-ground carbon stocks and organic matter content in the medium and long term.</p>
Use of drought tolerant varieties	<30%			L		
Barani	<30%			L	3.4	<p>Productivity Overall agro-ecosystem productivity is maintained, thus improving productivity and profit.</p> <p>Adaptation Reduces crop losses and increases yields during drought. Reduces the demand on water resources.</p> <p>Mitigation Maintains or improves soil above- and below-ground carbon stocks and organic matter content in the medium and long term.</p>
	<30%			L		



Yield
 Income
 Water
 Soil
 Risk/Information
 Energy
 CO₂ Carbon
 N₂O Nutrient

Livestock

Pakistan's livestock population is one of the largest in the world. It contributes approximately 56% of the added value in agriculture and nearly 11% to the national GDP [101]. Punjab is a major livestock producer [7]¹⁵. Small ruminants and other animals form part of rural households' food basket and provide security in times of crisis to meet household expenses.

Historically, smallholder farmers dominate livestock ownership with 88% possessing six animals or less [22], which helps smallholders meet their needs of milk, meat

and cash through the sale of animals. In Punjab, livestock farming is mainly practiced in Chiniot, Kasur, Khanewal, Khushab, Nankanasab, Rajanpur and Sargodha districts.

To improve the feed efficiency of livestock, addition of green fodder (such as barley) to feed is a common practice in the region. Barley is abundantly available in the province. The practice decreases the cost of feed by decreasing dependence on imported feed ingredients. This also enhances sustainability and resilience. Addition of fodder also helps reduce livestock carbon footprint. Green fodder supplements lactating cows, producing a considerable weight gain in calves [102].

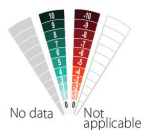
15 According to the latest Agriculture Census of 2010 Punjab houses Cattle (13m), Buffalos (16m), Sheep (5m), Goats (17m) and Camels (0.2m)

Planned grazing, such as rotational grazing is a potential CSA practice being piloted¹⁶ in Punjab for sheep. It is the technique of using animals to regenerate pastures. This involves putting a large herd of animals on a small area of land for a few days at a time (mob grazing). The animals are removed, and the land is allowed to recover before returning the animals again. The technique can increase productivity of rangelands and improve the land's ability to

withstand negative seasonal and climatic changes. Reduced grazing pressure improves carbon sequestration and helps rehabilitate poor land and stops degradation [103]. Moving livestock significantly improves resilience of livestock systems to climate change, although more research is needed to understand impact on socio-ecological aspects of the practice [104].

Table 10. Detailed smartness assessment for selected livestock CSA practices implemented in Punjab

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 (NA)				
Compost management	North Punjab <30%	M L		<p>Productivity Increases in productivity per unit of area and produce quality. Increases profits as farmers can use compost to offset inorganic fertilizer costs.</p> <p>Adaptation Promotes the use of local inputs. Contributes to soil health by improving physical, chemical and biological characteristics. Reduces runoff and erosion. Increases soil moisture conservation.</p> <p>Mitigation Maintains or improves soil carbon stocks. Reduces use of synthetic fertilizers and related GHG emissions (carbon footprint) when managed correctly.</p>
	South Punjab <30%	M L		
Rotational grazing	South Punjab <30%	S		<p>Productivity Increases productivity and income through equitable, efficient, and effective use of pasturelands. Reduces cost from supplemental feed per unit of product.</p> <p>Adaptation Improves soil quality and land carrying capacity. Prevents pasture degradation and biodiversity loss. Limits soil erosion. Facilitates manure collection and management.</p> <p>Mitigation Enhances vegetation cover and facilitates carbon storage in soils. Reduces use of synthetic fertilizers and related GHG emissions (carbon footprint).</p>
	North Punjab 30-60%	S		



Yield

Income

Water

Soil

Risk/Information

Energy

CO₂ Carbon

N₂O Nutrient

16 Pilot conducted by University of Veterinary and Animal Sciences and Combating Poverty and Climate Change Foundation. See case study

Holistic Planned Grazing (HPG)

The HPG project was piloted by the University of Veterinary and Animal Sciences in Lahore (UVAS) and the Combating Poverty and Climate Change Foundation (CPCCF) on a 5-acre grazing pasture within UVAS campus. The purpose was to determine whether HPG can raise land productivity and enhance profitability of livestock farming in central Punjab. HPG principles were developed by the Savory Institute for regenerative, organic agriculture to counter the threat of climate change.

50 sheep of different ages chosen at random from the UVAS flock in December 2016 were set to graze a 5-acre field that had been sub-divided into 30 equal paddocks of 1/6 acre each. The entire flock grazed one paddock at a time for 35 days before being moved to the next paddock. No fertilizer or insecticides were applied to the pasture and no additional feed was provided. Each paddock was grazed in sequence to start again after 30 changes.

The preliminary results show that land productivity increased by 100% by supporting twice the stock of 100 animals mostly through natural births, mortality rate dropped to below 3% per annum versus expected rate of 8%-10% per year, daily weight gain of lambs was 20% higher and conception rate was 85% against 60% target rate. These results suggest that properly managed animal impact on land, which is the central feature of HPG, is a powerful tool for enrichment of soil through revival of its natural microbial content. This enhances soil organic matter and in turn raises fertility and water-holding capacity of land, while improving overall animal health and productivity.



(Information source and pictures courtesy of CPCCF)

Poultry

Poultry is important in Punjab, accounting for over 70% of national poultry farming, 80% of egg production, 85% of the feed production and 100% of the poultry processing units [105]. Poultry farming is spread out across the northern and southern regions of Punjab. In the south it is mainly practiced in Bahawalpur, Multan, D.G Khan and Bahawalnagar Districts, which fall in AEZ I, V, VI AND VI. The Northern Punjab areas include Sargodha, Mianwali, Gujrat and Attock Districts, that fall in AEZ X, XI, XII and XIV. Due to the growing significance of poultry production in the provincial agriculture system, the government has

enacted legislation for the registration of poultry farms and production, housing and health management of the birds [106].

High temperatures combined with humidity are serious problems for commercial poultry production [107]. Heat stress causes death of birds, reduced growth and egg production, reducing profits [108]. Weather forecasting can help the farmer manage heat by optimizing stocking rate and improving shed design, ventilation and insulation [107]. With improvements in technology, long-range weather forecasts are becoming more reliable and accessible and hence are a promising CSA practice in Punjab.

Poultry farming in Punjab is intensive and concentrated in controlled sheds in or near large cities. Controlled sheds counter the problems of extreme summer conditions and provide an optimal environment for broilers to grow quickly and stay healthy. Feeding, watering, ventilation, and temperature control are automated that make the

environment conducive for poultry production by getting continuous production. A recent study showed significant difference between the cost of production and net revenue of open shed and controlled shed farms due to improved environment and feeding systems in control sheds [109].

Table 11. Detailed smartness assessment for selected poultry CSA practices implemented in Punjab

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
Poultry (NA)				
Manual feeding in controlled shed	South Punjab 30-60%	M		<p>Productivity Increases animal yield due to conducive environment for feeding and growth.</p> <p>Adaptation Controlled shed provides temperature regulation during extreme weather conditions such as heat waves or extreme cold.</p> <p>Mitigation Enhances manure management hence reduced emissions. Reduces emissions intensity per bird.</p>
	North Punjab >60%	L		
Use of latest weather forecast technology to plan activities	South Punjab <30%	M L		<p>Productivity Efficient running of facility according to weather conditions improves efficiency and profitability.</p> <p>Adaptation Increases farmers' capacity to be prepared and limit crop exposure to climate risks.</p> <p>Mitigation Optimum planning increases efficiency in resources management (e.g. water) indirectly reducing carbon footprint from operational activities/use of fossil fuels.</p>
	North Punjab <30%	M L		



No data Not applicable

Yield

Income

Water

Soil

Risk/Information

Energy

CO₂ Carbon

N₂O Nutrient

Oilseeds

Edible oil is an important staple in Punjab. Pakistan's production has not met demand, with some 70% of domestic requirements being imported [110]. Since early 1970s imports have increased 12.5% annually a trend that is likely to continue with increases in population.

In Punjab two main types of oilseed crops are grown i.e. traditional Rabi crops (rapeseed and mustard) and non-traditional crops (sunflower, safflower, soybean) [110]. The area under rapeseed and mustard was 0.1 million ha in 2015-2016, a 10% decrease over the previous year [22] with a yield reduction of 9% to 0.127 million tons. The main cultivation area is in Bahawalpur district, corresponding to

AEZ I (Cholistan Desert) and AEZ II (Arid Irrigated Zone). The crop requires silt clay loam and sandy clay loam soils with maximum temperature of 30°C and minimum temperature of 10°C [28]. There are both major and minor constraints that affect the oilseed production in the province. The constraints that directly discourage and deter the farmers are climatic threats, low returns and inadequate support of essential production elements including credit, quality seed, production technology and appropriate farm machinery.

Regions cultivating oilseeds face high summer temperatures, therefore using of heat tolerant varieties is an important CSA practice. Moisture stress results in uneven crop growth and poor yield. Maintenance of moisture and temperature improves oil quality and seed weight. Heat tolerant varieties

Table 12. Detailed smartness assessment for selected oilseeds CSA practices implemented in Punjab

CSA practice	Region and adoption rate (%)	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
	<30 30-60 60>			
Oilseeds (1% of total harvested area)				
Use of short duration crops	Winter Crop Region <30%	S		<p>Productivity Promotes high yields per unit area and allows farm diversification, hence potential increase in income.</p> <p>Adaptation Prevents soil erosion. Promotes soil Reduces vulnerability to climate hazards through shorter exposure. Easier to replant in response to disaster. Enhances water use efficiency.</p> <p>Mitigation Provides moderate reduction in GHG emissions per unit of food produced.</p>
	Summer Crop Region <30%	S		
Plantation of cover crops	Summer Crop Region 30-60%	S M L		<p>Productivity Reduces production cost by reducing synthetic fertilizer requirements when leguminous crops are used. Increases income per unit of produce.</p> <p>Adaptation In combination with other conservation agriculture practices, improves soil health and structure (e.g., porosity), hence water retention capacity. Reduces runoff and erosion.</p> <p>Mitigation Cover with leguminous crops reduces the need for nitrogen-based synthetic fertilizers. Maintains soil structure and improves soil carbon stocks.</p>
	Winter Crop Region 30-60%	S M L		



can withstand higher temperatures without impacts on growth and yield¹⁷. Oilseeds with their short duration are also planted as cover crops for others such as wheat. This improves the structure of the soil while increasing organic matter and enhancing soil nutrients. The technique also improves erosion control and suppresses weeds and pests. Weeds are controlled by cultivation of cover crops and minimum till before planting. This also helps reduce the use of harmful herbicides.

Barriers to adopting CSA Practices

While in certain areas steps have been taken to prepare for the adverse impacts of climate change, the widespread adoption of CSA practices and other strategies remains low. This is in part due to a raft of barriers that persist in reducing the capacity of the agricultural sector in Punjab taking all necessary actions. These barriers can be divided broadly into technical, social, environmental, financial and management challenges.

There is insufficient information for farmers on local climate conditions and the application of appropriate practices. A lack of certified heat and drought tolerant varieties, the inefficient use of fertilizers and pesticides and the inefficient use of irrigation water further adds to production challenges [111]. Extension services must be strengthened to disseminate information to farmers about new varieties and their availability as well as on improved farming practices. Furthermore, the extension process could be strengthened with the promotion of farmer to farmer extension, for a more inclusive process with greater buy in and participation from farmers.

Research funding is a low priority in the country (roughly 0.2 per cent of the agricultural GDP) inhibiting improvements in farming. More critically, there is a lack of holistic strategy and direction in setting research priorities, cooperation across provinces and coordination among the many relevant agencies. Funds for research institutes and universities are needed urgently.

A tradition of monoculture and widespread dependence on inorganic fertilizers, herbicides and pesticides damage soils, destroying above- and below-ground biodiversity. There is a mismatch between the demand for high value crops for exports, such as mangoes, and citrus and their production. Strong policy, technical and financial support are needed to encourage farm diversification, with a move to high value crops.

Development and implementation of quality standards for agricultural inputs backed by sustainable practices are urgently needed. Centralized chemical treatment facilities should be encouraged. Efficient use of water needs promotion and government should intervene actively through credit schemes and appropriate training for farmers. Finally marketing support should be provided to export high value crops. Finally marketing support should be provided to export high value crops, through the strengthening of farmers associations.

17 <https://www.dawn.com/news/968368/boosting-canola-cultivation>

CSA case study: Solar Coupled Drip Irrigation

It was 2011 when Mustafa Yousaf, a young banker in the UAE decided to quit his job to pursue farming as a business. On his return to Punjab, he explored different farming options on his land at Saikhum, a village an hour-and-a-half's drive from provincial headquarters Lahore. His first year of farming was not encouraging because the cost of growing spices and vegetables with flood irrigation was more than he earned from their sale. He ceased conventional flood irrigation and switched to drip irrigation on six acres to grow vegetables under the World Bank funded PIPIP program during 2013-14 from On Farm Water Management (OFWM).

60% Less Water
50% Less Fertilizers
40% More Yield

He explained that the vegetables grown under drip irrigation are less prone to fungal diseases and require less fungicides. Another benefit is 35% less weeds because the water is applied directly to the crop's roots, while most of the soil remains too dry for weeds to germinate. Mr. Mustafa found that drip irrigation enabled them to compete in the international market with better quality produce of uniform size because water and fertilizer was delivered to the plants as required.

Mr. Mustafa has taken a step further by installing solar power, funded by the Punjab Government, to operate the drip irrigation system, reducing operational and labor costs. Mr. Mustafa says that "solar power for operating the drip irrigation system allows us to automate the entire system and further cut down labour cost" as they are no longer dependent on the unreliable and insufficient power supply from the grid in the area.

He acknowledged that increasing adoption of drip irrigation, especially in canal irrigated areas of the Punjab is due to the strenuous efforts of OFWM staff. Mr. Mustafa has also signed an agreement with an international food firm to grow Chilies, Fenugreek (Kasuri Methi) and Coriander according to GAP (Good Agriculture Practices) standards. He has also grown gladiolus successfully on drip irrigation. "Growing these crops according to international standards is only possible with drip irrigation technology", he said.

While sharing his experience of solar operated drip irrigation system, Mr. Mustafa reported that this is an ideal combination of two climate smart technologies enabling the farmers to cut down their input costs drastically and at the same time enhance productivity.

(Information source courtesy of Directorate General Agriculture (Water Management) Punjab, Pakistan)



Institutions and policies for CSA

Institutions

The Agriculture Department of the Government of Punjab is the lead entity responsible for provincial policy, planning, and coordination in agriculture. The department has planned several initiatives for the coming year to improve farming methods. These include facilitating access to high quality seeds and crop insurance, enhancing soil health, improving market access, upgrading research institutions, and encouraging public/private partnerships, amongst others.

Several other departments and agencies, non-governmental organizations (NGOs), development agencies, research institutions and the private sector play key roles in the agricultural sector. These include the Livestock & Dairy Development Department (LDDD), Punjab Agriculture Research Board (PARB), Ayub Agriculture Research Institute (AARI), University of Agriculture Faisalabad (UAF), Punjab Seed Corporation (PSC), Zarai Taraqiati Bank Ltd. (ZTBL) to name a few. Strategies and programs that target climate action in the agriculture sector include the 'Natural Resource Management Program' by the National Rural Support Program (NRSP). The program trains farmers on increasing crop yields in a sustainable manner and reducing environmental impacts.

The Punjab Agricultural Research Board is also revising and restructuring its mandate to develop a strong evidence-based approach to agriculture. A World Bank-supported review of agricultural research and extension in Punjab started in August 2017 with financial support from the Australian government.

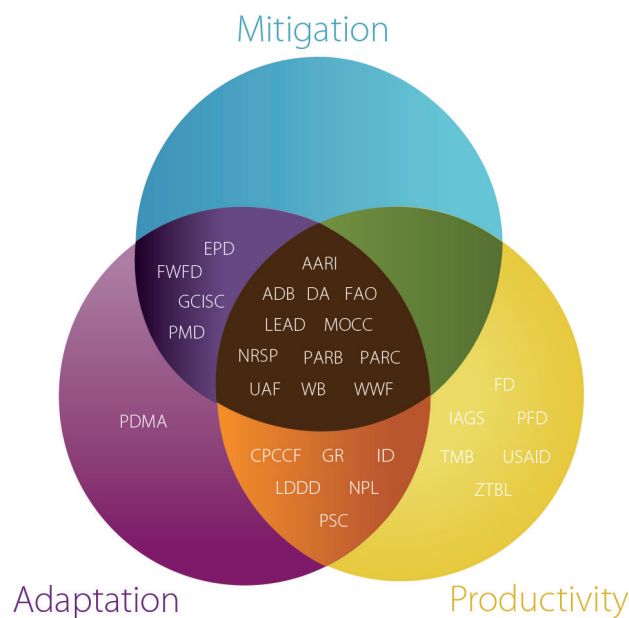
While the presence of both local and international institutions is increasing, the sector remains fragmented with a lack of coordination among the different institutions. This results in gaps and overlaps in the implementation of policies and programmes focused on agricultural development and CSA adoption. The following graphic highlights the key institutions whose main activities relate to one, two, or three CSA pillars (adaptation, productivity, and mitigation).

Policies

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. Punjab has remained an active participant in climate activities through its endorsement of national policies.

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 with regard to climate change. The GOP has developed the

Enabling institutions for CSA in Punjab



AARI Ayub Agriculture Research Institute ADB Asian Development Bank CCCC Combating Poverty and Climate Change Foundation DA Agriculture Department - Punjab EPD Environment Protection Department - Punjab FAO Food and Agriculture Organisation of the United Nations FD Farm Dynamics FWFD Forest, Wildlife & Fisheries Department - Punjab GCISC Global Change Impact Studies Centre GR Guard Rice Limited IAGS Institute of Agricultural Sciences, Punjab University ID Irrigation Department - Punjab LEAD Leadership for Environment and Development LDDD Livestock and Dairy Development Department MOCC Ministry of Climate Change NPL Nestle Pakistan Limited NRSP National Rural Support Program PARB Punjab Agriculture Research Board PARC Pakistan Agricultural Research Council PDMA Provincial Disaster Management Authority PFD Punjab Food Department PMD Pakistan Meteorological Department PSC Punjab Seed Corporation TMB Telenor Microfinance Bank UAF University of Agriculture Faisalabad USAID United States Agency for International Development WB The World Bank WWF World Wide Fund ZTBL Zarai Taraqiati Bank Ltd

National Climate Change Policy (NCCP), a multi-sectorial initiative that provides policy guidance on climate change mitigation and adaptation for the country [112]. The NCCP was followed by the Framework for Implementation of the Climate Change Policy (2014–2030), which identifies vulnerabilities to climate change and outlines potential avenues for adaptation and mitigation. However, policy implementation both nationally and provincially has been slow due to the lack of resources from government. In 2015, the Lahore High Court, in a landmark judgement, constituted a "Climate Change Commission" with representatives from key government agencies, NGOs, research institutes and lawyers, to expedite implementation of NCCP in Punjab.

The Punjab government has developed several policies and acts to support agricultural growth, climate change adaptation and mitigation. Of these, some have already been implemented, whilst others are either in formulation or formalized.

While there are several enabling policies for CSA adoption in Punjab, their implementation remains a challenge. Translating policies into meaningful support for smallholders is key for sustainably growing the agriculture sector and the overall economy as well as helping millions of farmers escape the poverty trap and prosper.

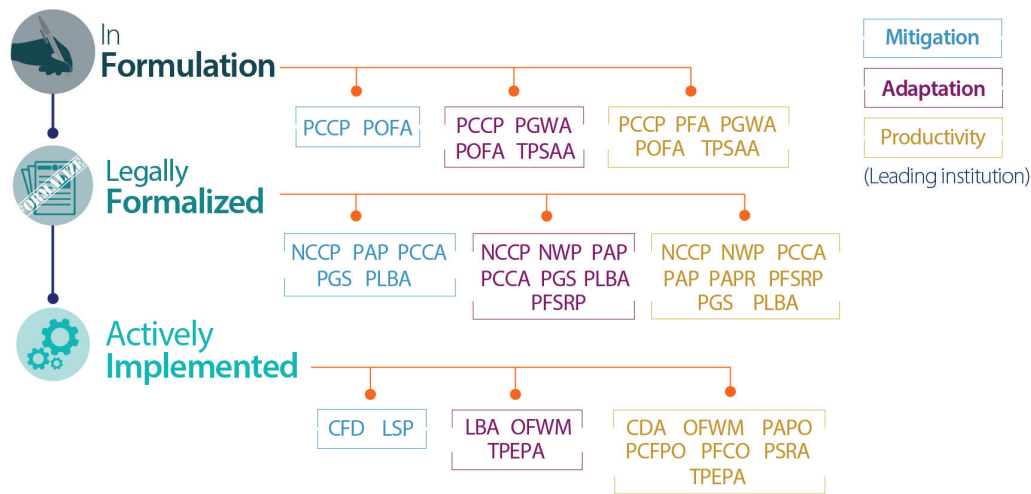
The province has formulated the first comprehensive 'Punjab Agricultural Policy, 2017' which was approved in June 2018 and received technical input from farmers, agricultural officials and academics [9]. The policy sets out the ambition of transforming agriculture into a sustainable, modern and market driven sector supported by technology. This is a major effort by the province to offer structure and guidelines for agriculture since the devolution of food and farming to provinces under the 18th Amendment.

The Punjab Agricultural Policy, 2017, identifies climate change as a threat for agriculture and water availability. It promotes a research based approach to reduce poverty and malnutrition through improved agricultural markets and resource management by focusing on food security and empowerment of women and youth. The policy envisions the creation of the Institute for Climate Smart Agriculture (ICSA), The ICSA will promote CSA practices and technologies and practices among farmers to address food security, mitigation and adaptation. These include efficient

water management, improved crop varieties and livestock breeds, integrated manure management, integrated pest management, and the adoption of renewable energy sources. The institute will coordinate government, public and private sector institutions to address climate change in agriculture.

Several other policies also link with CSA activities though not explicitly. The Punjab Fertilizer Act encourages the use, testing and availability of quality and environmentally friendly fertilizers. The Punjab Organic Farming Act promotes soil health improvement by combining traditional practices, innovation and science to benefit the environment, through measures, such as cover crops, composting crop residues, and crop rotation. The Punjab Seed (Amendment) Act provides control and regulation for seeds of various crop varieties. The development of improved varieties and locally adapted seeds are important CSA interventions, along with certification. The Punjab Agriculture Food and Drug Authority Act, 2016 describes the establishment and role of the institution in the testing and examination of pesticides, fertilizers, foods and medicines. This is vital in establishing CSA as it ensures provision of high quality and safe agriculture inputs. The proposed acts and new policies are supplemented by several older acts and ordinances. Under the On Farm Water Management and Users Associations Ordinance 1981, more than 11,000

Enabling policy environment for CSA in Punjab



CDA Canal and Drainage (1873) (Punjab Irrigation Department) **NCCP** National Climate Change Policy (2012) (Ministry of Climate Change) **NWP** National Water Policy (2018) (Ministry of Water) **OFWM** On-Farm Water Management and Water Users Associations Ordinance (1981) (Punjab Agriculture Department) **PAP** Punjab Agricultural Policy (2018) (Punjab Agriculture Department) **PAPO** Punjab Agricultural Pests Ordinance (1959) (Punjab Agriculture Department) **PAPR** Punjab Agricultural Pesticides Rules (2018) (Punjab Agriculture Department) **PCCA** Pakistan Climate Change (2017) (Ministry of Climate Change) **PCCP** Punjab Climate Change Policy (2017) (Environmental Protection Department, Punjab) **PCFPO** Punjab Seeds & Fruit Plants Ordinance (1965) (Punjab Agriculture Department) **PFA** Punjab Fertilizer (2018) (Punjab Agriculture Department) **PFCO** Punjab Fertilizers (Control) Order (1973) (Punjab Agriculture Department) **PFSRP** Pakistan Food Security and Research Policy (2018) **PGS** Punjab Growth Strategy (2015) (Government of Punjab) **PGWA** Punjab Groundwater Preservation (2014) (Punjab Irrigation Department) **PLBA** Punjab Livestock Breeding (2014) (Punjab Livestock and Dairy Development Department) **POFA** Punjab Organic Farming (2017) (Punjab Agriculture Department) **PSRA** Punjab Soil Reclamation (1952) (Punjab Agriculture Department) **TPEPA** The Punjab Environmental Protection (2012) (Environmental Protection Department, Punjab) **TPSAA** The Punjab Seed (2017) (Punjab Agriculture Department)

watercourses have been renovated for irrigation. These associations play a pivotal role in watercourse renovation and maintenance. They control distribution of water to fields while the underground reservoirs and water pockets are allowed to refill and retain their capacity naturally.

With the growing importance of livestock and limited direction on livestock policies prior to devolution, the Punjab government has initiated the next generation of reforms in the sector [113]. Major challenges include the lack of public policy framework, knowledge deficit on improved breeds and animal care. In addition, with weak marketing and funding constraints plagued by middleman profit capture, the livestock sector operates well below its potential [113]. Serious support from the government and private sector is needed to encourage and promote CSA practices to develop the sector sustainably.

To counter the growing threat of climate change and encourage sustainable growth, the Punjab government has developed the Punjab Growth Strategy, 2018 [114]. The strategy encourages 'better use of energy in agriculture' and explores means of harnessing renewable and alternate energy, to supplement conventional sources that are limited and expensive. The use of these new technologies and practices are complementary by reducing GHG emissions. The government also plans to phase out the wheat procurement program and directly subsidise smallholders, focus spending on CSA innovation, high-value agriculture, agri-businesses, and crop insurance. These measures envision reducing the fiscal burden on the Punjab government and the agriculture department while enhancing the effectiveness of public resources.

Financing CSA

Current finances

There are several local and global financing organisations active in Punjab to support agriculture. Yet access to finance remains a serious challenge, especially for smallholder farmers that represent the backbone of the sector. Access to finance is constrained by a variety of factors that include lack of bankable collateral by farmers, lack of expertise of financial institutions in managing agriculture loan portfolios, low levels of demand due to fragmentation of agriculture value chain and high transaction cost to reach rural communities.

According to the 2017 Climate Public Expenditure and Institutional Review (CPEIR), total climate-relevant spending in Punjab increased from PKR 54.4 billion (USD 435 million) in 2011/12 to PKR 112.7 billion (USD 902 billion) in 2014/15, an increase of nearly 107% [115]. Climate-relevant expenditure represented between 6.2% and 9.3 % of the total provincial budget for the period 2011–2015 and

13.7% in 2015–2016. However, it is unclear how much of this funding directly benefited agriculture and CSA activities.

Based on the official data, ZTBL, commercial banks and agriculture cooperative societies disbursed roughly PKR 361 billion (USD 2.9 billion) in 2014–2015 for agriculture activities [7]. Agriculture taxes also play an important role in financing agriculture activities. Agriculture is subject to direct and indirect taxes on inputs and services. However, the government continues to collect land-based agriculture taxes rather than collect income taxes due to the lack of an appropriate tax system¹⁸. Although agriculture contributes 27% to the provincial GDP, the tax collected from agriculture is discretionally lower than taxes on non-agriculture income [116]. In the 2017–2018 budget, the total amount of agriculture income tax and land revenue was PKR 16 billion (USD 128 million). The province also receives approximately 70% of the taxes from the federal tax revenues as provincial allocation on agriculture amounting to PKR 81.5 billion (USD 652 million) [9]. However, non-compliance of law (land-based tax vs. income taxes) produces a loss of tax revenue estimated to several billions Pakistani rupees [116].

Punjab also offered direct agriculture subsidies of PKR 55 billion (USD 440 million) in 2018 on wheat procurement, seeds, tube-wells, and electric pumps, including offering interest free loans and subsidised crop insurance. In 2016 the Punjab government announced a finance package worth roughly PKR 100 billion (USD 800 million) to support farmers. This investment aimed to improve technology and inputs to enhance on-farm productivity.

The Punjab government has also recently launched the Connected Agriculture Punjab Package (CAPP) in partnership with Telenor Pakistan and Tameer Bank. The CAPP offers wide-ranging support to farmers through a digital platform in the form of interest free loans, subsidies, advisory services for cropping. In addition, 125,000 smartphones have been distributed to farmers to access the digital platform. Several technological projects are in process of registering farmers, offering access to key agriculture information and collecting farm level data on production and resource use.

Private sector financial institutions and microfinance institutions also offer vital micro loans to farmers ranging from PKR 25,000 to PKR 1.5 million (USD 200 to 12,000). The loans are for agricultural inputs, working capital and other financing requirements. However, these are usually collateral based, restricting access to the most vulnerable farmers who don't own land or lack formal credit records. Institutions include ZTBL, Khushali Bank, Mobilink Bank and Finca Bank, amongst others.

International donor-funded projects focusing on agriculture that support climate change make up a considerable portion of the climate financing currently available in Pakistan and Punjab.

¹⁸ Refer to <https://fp.brecorder.com/2017/02/20170213141041/>

In 2017, the World Bank approved USD 300 million financing programme to Strengthen Markets for Agriculture and Rural Transformation (SMART) to modernize agriculture in Punjab. The project envisages creating 350,000 jobs and lifting 1.7 million people from poverty by helping farmers grow high value crops. The resources provided by the World Bank will form part of a larger program by the government to promote agriculture and support much-needed reforms to improve agriculture and livestock productivity. The agriculture, livestock & dairy development, food, and irrigation departments will implement the programme. The project will also develop agriculture's resilience to climate change and foster agribusiness in Punjab over the next five years. Targeting reduced inequality through expanding the opportunities for women and youth. It intends to shift PKR 55 billion (USD 440 million) per year that is currently spent on subsidies, towards 'SMART' input subsidies for smallholders, agricultural research, farmer training and support for high-value and climate-smart agriculture. Additionally, SMART will help improve the sustainability by strengthening the management of irrigation water and help tackle ground water depletion.

The Southern Punjab Poverty Alleviation Project is another example of an international funded project. The International Fund for Agricultural Development (IFAD) is funding, through a USD 40 million concessional loan, projects that increase the income of 80,000 poor households through enhanced employment and increased agriculture production.

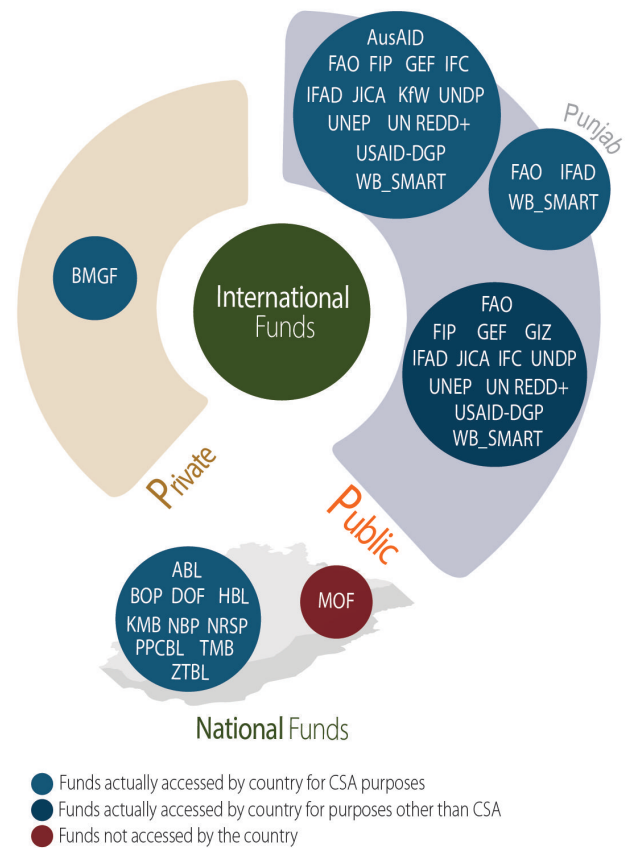
Potential Finances

To promote and create potential CSA activities across the Province, public, private, and international finances need to be actively mobilized. Pakistan's Climate Change Act sets the stage to establish the Pakistan Climate Change Authority and Pakistan Climate Change Fund, which are expected to help mobilize domestic and international funds for mitigation and adaptation measures in the country and province.

Public Private Partnerships (PPP) will be instrumental in the development of programmes which achieve long term sustainability. A few interventions with various private sector partners such as Nestle, or NGOs such as World Wide Fund for Nature and CAB International can support agricultural sector development and resilience. Partnership between Pakistan and China on China Pakistan Economic Corridor (CPEC) is a potential game changer in Pakistan's economy with implications for agriculture. More research is however needed to understand the actual impacts of the CPEC investments in agriculture production and the allied value chains.

International development partners such as the World Bank, IFAD, DFID, and UN-FAO play a key role in research, development and scaling of CSA in Punjab. New international climate funds such as the Green Climate Fund (GCF) likewise offer opportunities to leverage funds for scaling-up CSA throughout the country. A recent project proposal¹⁹, to the

Financing opportunities for CSA in Punjab



AusAID Australian Agency for International Development BMGF Bill and Melinda Gates Foundation FAO Food and Agriculture Organization of the United Nations FIP Forest Investment Program GEF Global Environment Facility GIZ German Society for International Cooperation IFAD International Fund for Agricultural Development IFC International Finance Corporation JICA Japan International Cooperation Agency KfW German Development Bank International Climate Initiative UNDP United Nations Development Programme UNEP United Nations Environmental Programme UN REDD United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation USAID-DGP United States Agency for International Development – Development Grants Program WB-SMART The World Bank Group - supported Strengthening Markets for Agriculture and Rural Transformation project

tune of USD 55 million, envisioned by FAO and submitted to the to the GCF, focuses on transforming the Indus basin with climate resilient agriculture and climate-smart water management. Dedicated domestic agricultural finance organizations can be set-up to access direct financing from the GCF and other funds. This can be supplemented with local funds as envisioned under the Punjab Agriculture Policy.

National financial institutions such as ZTBL and National Bank are vital in establishing research and development in the agriculture sector of the Province. These funders are also collaborating with regional universities to enhance CSA through scientific and technical research.

19 Concept note submitted by FAO to GCF. Available at <https://www.greenclimate.fund/library/-/docs/list/874832/page/2>

Outlook

In Punjab, where agriculture holds strong social, economic and cultural significance, CSA offers attractive opportunities for strengthening the sector in a changing climate. Climate change is an imminent threat to the livelihoods of millions of families in Pakistan and Punjab that rely on agriculture. Climate impacts may slow the economic progress of the country and roll-back advances of the last decades.

By leveraging existing financing, unlocking new sources of financing, promoting pro-poor policies, and empowering institutions to take action, transformational change towards more sustainable and productive agricultural systems can be achieved.

CSA can play a significant role in Punjab's economy. Adoptable interventions range from innovative, technological practices like laser land levelling and drip irrigation systems to management changes like crop diversification, proper cropping patterns and timely weeding of crops. Investing in research to develop high yielding heat resistant, drought tolerant, and pest resistant crop varieties and livestock breeds is especially critical. Finally, agroforestry and large-

scale country-wide tree plantation programmes²⁰ are necessary to counter emissions from rapid land use change and deforestation in Punjab, while positively impacting ecosystem services.

Developing data driven models to simulate the likely impact of climate change on the different agricultural production systems across the AEZ will be critical to ensure the adaptation and mitigation strategies are context specific. This may include the use of information technology, GIS techniques and remote sensing for precision farming that optimize input use and generates quality data on crop, soil and climate related parameters to identify ideal cropping patterns for different AEZs.

Along with use of technology, offering financing through local and international sources especially to smallholder farmers is important for widespread adoption of CSA. Implementing and aligning climate conscious policies across different sectors and recognizing the threat of climate change in provincial planning agendas as well as training farmers in latest technologies and practices through farmer programs would further encourage CSA adoption in Punjab.

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²⁰ Plant for Pakistan campaign launched by the Government across the country

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This publication is a product of the collaborative effort by the International Center for Tropical Agriculture (CIAT), the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), FAO, the UK Government's Department for International Development (DFID) and HCC (Pakistan) to identify province-specific baselines on CSA in Punjab, Pakistan. The document complements the CSA Profiles series developed between 2014 and 2016 by CIAT, CCAFS, the World Bank, and USAID for countries in Latin America, Asia and Africa.

The document was prepared under the co-leadership of Godefroy Grosjean (CIAT) and Andrew Jarvis (CIAT, CCAFS); It is based on a methodology prepared by CIAT, the World Bank and the Tropical Agricultural Research and Higher Education Center (CATIE) in 2014 and revisited in 2015, 2017 and 2018 by Andreea Nowak, Caitlin Corner-Dolloff, Miguel Lizarazo, Andy Jarvis, Evan Girvetz, Godefroy Grosjean, James, Giles, Felicitas Roehrig, Jennifer Twyman, Julian Ramirez, Carlos Navarro, Jaime Tarapues, Steve Prager, Carlos Eduardo Gonzalez (CIAT/CCAFS), Charles Spillane, Colm Duffy and Una Murray (National University Ireland Galway)

Main authors: Abrar Chaudhury, Nadia Ayub, James Giles, Sekou Traore, Ishfaq Ahmad, Miguel Lizarazo, Godefroy Grosjean.
 Project leader for Asia: Godefroy Grosjean (CIAT)
 Original graphics: Fernanda Rubiano (independent consultant)
 Design and layout: CIAT and Fernanda Rubiano (independent consultant)

This document should be cited as:
 CIAT; FAO. 2018. Climate-Smart Agriculture in Punjab, Pakistan. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT), FAO, Rome, 36p.

Acknowledgements

The authors thank Humera Qasim (ADU) and Banaras Khan (FAO) for their valuable comments on the document and support to the project. The project benefitted greatly from the logistical support provided by Waleed Khan and Mishkat Awan.