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Knowledge Brief

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Advancing Climate-Smart Agriculture (CSA) in Pakistan
Building Resilience for Food Security and Rural Livelihoods

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Executive Summary

Pakistan's agriculture sector, which serves as the country's economic backbone, is facing an unprecedented crisis due to worsening climate change. Frequent natural disasters such as severe floods, intense heatwaves, and changing rainfall patterns are devastating crops, livestock, and rural livelihoods. The situation is aggravated by inefficient agricultural practices and a heavy reliance on water-intensive crops like sugarcane and rice. Furthermore, a lack of consistent government investment in research, disaster preparedness, and climate adaptation leaves smallholder farmers highly vulnerable to continuous climate shocks and growing food insecurity.

Climate-Smart Agriculture (CSA)

Climate-Smart Agriculture (CSA) represents a strategic effort to align agricultural development with climate action. Its primary goal is to secure food supplies and support wider development objectives in the face of rising food demand and climate uncertainty. It precisely has three pillars i.e., food security, adaptation and mitigation.

To secure food supplies and protect rural communities, the document advocates for adopting Climate-Smart Agriculture (CSA)—an approach that combines higher productivity with climate resilience and reduced emissions. Key practical solutions include transitioning to water-efficient irrigation technologies (such as drip and sprinkler systems), introducing heat and drought-tolerant seed varieties, and encouraging farmers to diversify into higher-value crops. To scale these practices effectively, Pakistan needs strategic policy reforms that redirect subsidies toward modern technology, expand access to microcredit and crop insurance, and strengthen agricultural research and extension services for farmers across the country.

1. Introduction

Pakistan's agriculture sector remains the nation's economic backbone, but is also standing at a perilous crossroads of climate change. Rising temperature, unexpected rainfall pattern, heavy floods, and declining water availability threaten the agriculture sector with variability in food pro-

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duction. The rural livelihood is dependent on agriculture is also at stake because of these severe climate changes. It is worth stressing that this is not simply a story of shifting rainfall: Pakistan's average temperature has climbed by roughly 0.6–1.0°C over the past century, part of the same build-up of global greenhouse gases that is altering monsoon behaviour, glacial melt, and the frequency of compound heat-flood events across the Indus Basin (Waseem and Rana, 2023).
This year 2.4 million people have been affected due to 2025 floods and 0.9 million evacuated across 23 districts of Punjab. In Khyber Pakhtunkhwa[2], flash floods have impacted 1.57 million people, while in Sindh about 1.6 million residents across 15 districts are at risk (WFP, 1-7 September, 2025). These figures are a quantitative manifestation of a brewing crisis rooted in environmental degradation and it is threatening the livelihoods of millions of people. The 2025 flood has inflicted severe damage across multiple sectors of the economy, with particularly devastating effects on crops, livestock, housing, and other vital assets. The extent of this destruction is not uniform across districts. Within districts the severity also differs from village to village and from locality to locality. Alongside, heat waves are huge threat as it effecting the size and quality of the produce along with more vulnerability to pests' attacks.

Compounding this environmental onslaught is a persistent lack of strategic fiscal prioritization by the government. Critical areas like agricultural research and development (R&D), climate adaptation, and water management infrastructure receive a fraction of the required investment. Recent budget trends further underscore this imbalance. Allocations for climate mitigation have increased from PKR 133 billion in 2023–24 to over PKR 600 billion in 2025–26 but funding for adaptation and disaster preparedness remains inconsistent and comparatively modest. This skewed spending pattern reflects a reactive rather than preventive approach to climate resilience, leaving the agriculture sector highly vulnerable to future shocks.

Keeping this background under consideration, this Knowledge Brief aims to highlight key issues in Pakistan's agriculture through the lens of CSAs three pillars i.e., food security, adaptation and mitigation and propose the CSA solutions organized in the same way. Such CSA solutions has the potential to reduce risks while enhancing agricultural productivity. In section 2, the issues have been discussed with a tag to the pillar it speaks to and at the end of document table 1 synthesis the issues and its CSA solutions along with policy recommendations.

2. Agricultural Challenges in Pakistan Necessitating Climate-Smart Solutions

2.1. Direct and Indirect Agricultural Losses Due to Climate Hazards (Adaptation)

Climate change is a risk to agriculture sector along with environmental degradation. With growing number of floods, heatwaves and droughts, not only the productivity is reduced but it also intensified rural poverty and food insecurity. Pakistan has experienced 26 major floods in its history, each causing widespread devastation to lives, property, and the environment. Between 1950 and 2013, the cumulative economic losses amounted to $37.55 billion (Government of Pakistan, 2018), with an additional $30 billion in damages and loss of GDP recorded in 2022 alone[3] . The Global Climate Risk Index 2025 identifies Pakistan as the most climate-vulnerable countries worldwide as per 2022 estimates, with agriculture bearing a disproportionate share of the impact (Germanwatch, 2025)[4]. Furthermore, the climate change could cost $38 trillion per annum, this cost is mainly associated with agriculture, infrastructure and public health (Kotz et al., 2024). This cost figure is not Pakistan-specific but it shows the magnitude of climate-related vulnerabilities.

2.Particularly in the district of Swat, Buner, Shangla

3.https://www.worldbank.org/en/news/press-release/2022/10/28/pakistan-flood-damages-and-economic-losses-over-usd-30-billion-and-reconstruction-needs-over-usd-16-billion-new-assessme

4.https://www.germanwatch.org/sites/default/files/2025-02/Climate%20Risk%20Index%202025.pdf

Direct losses stem from crop and livestock destruction during climate-related disasters. Indirect losses accrue from damaged infrastructure—canals, storage facilities, and farm-to-market roads—which cripples supply chains (Government of Pakistan, 2022). Furthermore, there are significant macroeconomic repercussions as well. For example, the devastation of the cotton crop directly impacts the textile industry, leading to reduced foreign exchange earnings from a largest export sector of Pakistan. Simultaneously, crop failures necessitate massive import bills for essential commodities like wheat and edible oils, draining precious foreign reserves and fueling food inflation that disproportionately harms the urban poor. The loss of high-value export crops like the Chaunsa mango or Kinnow orange due to climate vagaries further erodes the sector's profitability.

2.2. Water Scarcity and Canal Losses (Adaptation + Mitigation)

Pakistan's agriculture sector consumes nearly 90% of the nation's water resources (The Nation, 2024)[5], and is under mounting pressure due to rising food demands, climate change, and evolving cropping patterns. The Indus Basin Irrigation System (IBIS) is the main source of water for irrigation in Pakistan that irrigates nearly 80% of cultivated land but nearly 50% of the water diverted from the Indus system does not reach the fields due to inefficient irrigation systems. Pakistan Meteorological Department (PMD) reported that there is 1.5°C increase in average temperature since last six decades which is projected to rise even more in coming years[6]. On the one hand water is susceptible to climate change and on the other hand it is being wasted and used inefficiently. Therefore, it is important to adopt modern and efficient irrigation practices that consume less water and provide more crop per drop of water. The most viable solution to the wastage of water due to inefficiency of irrigation practices is the adoption of water-saving irrigation techniques or High Efficiency Irrigation Technologies (HEIT). Transitioning from flood irrigation to drip, sprinkler, and laser land levelling can reduce water use by 30–50% while improving yields (Van der Kooji et al, 2013). Uptake of such technologies is still partial. Recent evidence suggests only about 17–30% of Pakistani farmers have adopted at least one climate-smart irrigation practice. The adoption is usually on part of their landholding rather than farm-wide, which is well below adoption levels reported for Nepal (Shahzad et al., 2021). High installation costs, weak extension outreach, and fragmented landholdings remain the binding constraints, and the parallel spread of subsidized solar tube wells (useful as it is for cutting energy costs) has begun to accelerate groundwater depletion in the absence of withdrawal regulation (Balasubramanya et al., 2024) Such inefficiency has a direct fiscal cost not only the environmental. Every unit of water lost due to canal seepage of over-irrigation is equivalent to yield foregone which ultimately pushes up the import bill.

2.3. Dependence on Water-intensive Crops (Food Security and Adaptation)

More than 80% of the water is consumed by four major crops i.e., wheat, rice, sugarcane and cotton (Young et al., 2019), but the contribution of these crops to GDP is less than 5% (Government of Pakistan, 2025). A heavy reliance on water-intensive crops such as rice and sugarcane not only depletes Pakistan's already scarce water resources but also exposes farmers to higher climate risks. Shifting towards diverse, less water-demanding, and higher-value crops like fruits, vegetables, pulses, oilseeds, and climate-resilient fodder can help stabilize farm incomes and reduce vulnerability to crop failures. Diversification helps smallholders reduce crop dependency, manage climate-related risks, and benefit from markets where demand and returns are stronger. However, scaling up requires strong policy support such as credit facilities, crop insurance, extension services, and guaranteed market linkages in order to encourage farmers to transition away from traditional water-intensive crops. Field research from the University of Agriculture

5.Pakistan's agriculture sector consumes nearly 90% of the nation's water resources

6.https://www.agrieconomist.com/climate-resilience-in-pakistans-agriculture-sector

Faisalabad shows that the household surveys across Punjab's rice-wheat and cotton-wheat systems find that farmers who combine crop diversification with soil and water conservation measures report better adaptation and food-security outcomes than those who do not (Usman et al., 2023; Haq et al., 2021). A province-wide review of climate-smart practices similarly finds diversification into pulses, oilseeds, and fodder among the more consistently tested and resilient options for central and southern Punjab, while diversification into horticulture such as mango and citrus remains far less advanced and would need dedicated extension support before it can be scaled (Ullah et al., 2026).

2.4. Limited use of Climate-Resilient Seeds and Practices (Adaptation and Food Security)

The erratic monsoon is a challenge and vulnerable for crops like in 2022 floods destroyed 4.4 million acre of cropland (The Agricultural Economist, 2025)[7]. Globally, heatwaves stress crops by reducing their productivity particularly of cereal crops (Singh et al., 2023). One of the most effective ways to adapt agriculture to climate change is through the use of research-based, climate-resilient crop varieties. Drought and heat-tolerant strains of wheat & maize (Punjab-2011 and Sahiwal-2017, which require 30% less water) and cotton (FH-142 and MNH-886) are being developed and released by the Pakistan Agricultural Research Council (PARC), the National Agricultural Research Centre (NARC), and provincial research institutes like AARI Faisalabad (The Agricultural Economist, 2025)[8]. These varieties are designed to withstand temperature extremes, prolonged dry spells, and erratic rainfall patterns, making them particularly important for arid and semi-arid regions. Wheat Rice Institute (WRI) Faisalabad has developed high yielding and high-zinc wheat variety Akbar-2019, which is successfully adopted and replacing the traditional seeds (Ahmad et al., 2024). This seed has the tendency to handle tough climatic conditions. The need is to boast the adoption of these climate resilient seed varieties. The National Seed Development and Regulatory Authority (NSDRA) is aiming to transform the agriculture through the development of sustainable and competitive seed systems. It has the mission to upgrade the crop productivity through germplasm improvement, R&D and through provision of high quality seeds.

2.5. GHG Emissions and Mitigation Potential in Agriculture Sector (Mitigation)

Amidst these immediate climate challenges, it is quite notable that the agriculture sector itself is also a significant contributor to the country's greenhouse gas emissions. Agriculture is contributing 43% of Pakistan's total GHG emissions, mainly from livestock (78%) and croplands (22%) (International Monetary Fund, 2022; Zubair et al., 2022). It reinforces that mitigation cannot be treated as an afterthought to adaptation in Pakistan's CSA agenda rather it needs to be a central priority for the country's climate change adaptation and mitigation efforts. Improving irrigation and water management carries high abatement potential at moderate cost, since it cuts both methane from flooded rice paddies and the energy used for groundwater pumping. Manure management and biogas conversion also offer real abatement potential too, but need higher upfront investment. That is why a large part of uptake stayed limited to scattered pilot projects. NDC 3.0 names climate-smart agriculture as a mitigation co-benefit sector within its broader target of cutting projected 2035 emissions by 50%, but agriculture is given far less specific detail than energy.

By integrating productivity, resilience, and emission reduction, these approaches offer a pathway to safeguard livelihoods and ensure food security. With over 60% of the rural population dependent on agriculture (Mehmood,2021), closing it is not optional.

7.https://www.agrieconomist.com/climate-change-and-agriculture-in-pakistan

8.https://www.agrieconomist.com/climate-change-and-agriculture-in-pakistan

2.6. Vulnerabilities and Policy Gaps in Promoting Climate-Smart Agriculture (Cross-cutting: Food Security, Adaptation and Mitigation)

It is now well established that agriculture sector is vulnerable to climate change and solution lies in the integration of policies of food security, adaptation and mitigation under the CSA. But there exist policy gaps in Pakistan in promotion and adoption of CSA policies. The National Climate Change Policy 2021 though recognizes the vulnerability of this sector and acknowledged the need for CSA solutions. It calls for the framework to handle the climate risks, however it lacks the details implementation guidelines, and provides insufficient technical and financial support required for farmers. Moreover, coordination between federal and provincial authorities remains weak, and awareness among smallholder farmers about CSA practices is still limited. These gaps hinder the effective scaling of climate-smart interventions across the country. The financing numbers also illustrate the gap: Pakistan's National Adaptation Plan (2023) puts total climate and development investment needs at roughly $348 billion through 2030, of which adaptation and resilience alone account for about $152 billion. Yet actual climate finance remains skewed heavily towards mitigation (close to 79% in recent years) leaving agricultural adaptation chronically under-resourced (Government of Pakistan, 2023). The updated Nationally Determined Contribution (NDC 3.0) reaffirms commitments on irrigation efficiency and emission reduction, but without a mechanism such as climate-smart budget tagging in federal and provincial development budgets, CSA risks remaining a set of scattered pilot projects rather than a funded national programme.

Part of the problem is political economy, not just capacity. Flat tariff rates for tube-wells and subsidies for fertilizers are quite popular and easy to administer instead of HEIS or performance-based incentives. Provincial governments often lack the fiscal space or the electoral incentive to prioritize CSA over more visible infrastructure spending.

2.7. Interlinkages Between Farm Practices, Ecosystems, and Socio-Economic Systems (Cross-cutting)

CSA cannot be reduced to a checklist of on-farm techniques; its practices are only as effective as the ecosystems and social systems they sit within. Drip irrigation or laser levelling improves water-use efficiency at the farm gate, but its long-term payoff depends on aquifer recharge and canal governance, and the same technology that helps one farmer can accelerate groundwater depletion for a neighbour if adopted without regulation (Balasubramanya et al., 2024). Similarly, crop diversification only reduces climate risk where markets, credit, and extension services exist to absorb new crops; without them it simply shifts risk from one commodity to another (Ahmad et al., 2020). A recent systematic review of CSA in Punjab frames this as socio-ecological resilience, in which ecological integrity—soil, water, biodiversity—and social capacity—income diversification, institutions, gender-inclusive extension—reinforce each other, so that CSA interventions ignoring one side tend to produce short-lived or inequitable gains (Ullah et al., 2026). For Pakistan, this means CSA planning has to move beyond a practice-by-practice list towards coordinated investment across irrigation governance, seed systems, rural finance, and land tenure—precisely the interdependence that CSA discussions in the country tend to underplay.

Conclusion

Pakistan's agriculture sector stands at the frontline of climate vulnerability, but it also holds immense potential to drive climate adaptation and mitigation if guided by the right policies and practices. CSA offer a viable solution but such solution does not necessarily frame around productivity-enhancing practices only rather it needs due attention to supporting ecosystems, markets and institutions otherwise it will have limited impact. Without urgent reforms, the costs of inaction will continue to escalate in the form of lost productivity, and deepening rural poverty. Climate smart practices such as water efficient irrigation, crop diversification, climate resilient seeds, advanced technologies etc., offer a viable pathway to safeguard food security and rural livelihoods. Targeted investment in agricultural R&D, equitable access to farm credit, and well-designed subsidies that reach smallholders will be critical for scaling these solutions. The challenge is no longer about identifying what works, but about mobilizing the political will, institutional capacity, and financial resources to implement these strategies at scale. With agriculture contributing significantly to both the economy and emissions, Pakistan's transition towards climate-smart agriculture is not just an environmental necessity but also an economic imperative for long-term resilience and sustainable growth. Below is the short brief of issues, CSA solutions and policy recommendations for that.

Table 1: Key Issues in Pakistan's Agriculture and CSA solution

Key Issue in Pakistan's Agriculture	CSA Solution	CSA Pillar	Policy Recommendation
Water Scarcity & Canal Losses (50%)	Drip, sprinkler irrigation, laser land levelling, digital water scheduling	Adaptation + Food Security	Redirect subsidies to HEIS; promote solar pumps; farmer training via extension
Dependence on Wheat–Rice–Sugarcane (Water-intensive)	Crop diversification into pulses, oilseeds, vegetables, fodder	Food Security + Adaptation	Credit & offtake contracts for HVC growers; mandatory crop insurance bundled with input credit; agro-processing zones near diversification hubs
Frequent Floods, Heatwaves, Droughts	Climate-resilient seeds (heat/drought/flood tolerant), raised beds, zero tillage	Adaptation	Fund PARC, AARI & NSDRA; strengthen seed certification; regional seed banks
High GHG Emissions (43% from agriculture)	Zero tillage, residue management (no burning), biogas plants, agroforestry	Mitigation + Adaptation	Carbon credit incentives; ban residue burning + subsidize Super Seeder machines
Livestock Methane Emissions & Feed Inefficiency	Improved animal feed, biogas units, manure management	Mitigation	Livestock methane reduction program; subsidize farm-level biogas & silage units
Limited Credit, Insurance & Financing	Weather-indexed crop insurance, green financing, microcredit for CSA tech	Food Security + Adaptation	Through State Bank interventions; make insurance mandatory with Kissan Card

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