Securing the Harvest: A Vision for the Coastal Agriculture of Pakistan (2025–2040)

White Paper

on

Climate-resilient Strategies for Coastal Agriculture in Pakistan

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Index

Executive Summary

The 990 kilometer coastline of Pakistan along the Arabian Sea sustains vital agriculture and fisheries livelihoods for over 10 million people. However, it is under severe threat from accelerating sea-level rise, saltwater intrusion, and intensifying cyclonic storms. In the Indus Delta alone, more than 2.2 million acres of fertile farmland have been abandoned due to soil salinization rising to over 15 dS/m, displacing 1.2 million residents and undermining national food security and economic stability. Coastal districts in Sindh (Thatta, Badin, Sujawal) and Balochistan (Lasbela, Gwadar) face 40–50% yield declines under moderate salinity, erratic freshwater flows exacerbated by upstream diversions, and 1.1-2.7 mm/year local sea-level rise.

The policy framework of Pakistan, anchored by the National Climate Change Policy (2012), Sindh Agriculture Policy (2018–2030), and emerging Coastal Aquaculture Strategy (2025–2035), provides a strong foundation for adaptation. Breakthrough innovations in salt-tolerant crop cultivars (rice varieties retaining 70 % yield at 12 dS/m; barley yielding 2 000 kg/ha at 15 dS/m), precision irrigation systems reducing water use by up to 40%, and integrated rice–fish and shrimp–rice models boosting system productivity by 35 % demonstrate high return on investment with benefit-cost ratios between 2:1 and 5:1. The Nuclear Institute for Agriculture and Biology and provincial research stations play pivotal roles in developing and disseminating these technologies.

Despite clear economic incentives provided by the blue economy potential of Pakistan (it is valued at USD 100 billion and CPEC-enabled infrastructure projects reduce transport costs by up to 30%), implementation gaps persist. Fragmented institutional mandates, underfunded extension services at 0.21 % of agricultural GDP, and inadequate coordination between federal, provincial, and local bodies have limited technology uptake and community engagement. Financing shortfalls, with public adaptation budgets covering less than 20 % of needs and private investment below USD 10 million per year, further hinder progress.

A strategic, phased framework for 2025–2040 is proposed to establish a National Coastal Agriculture Authority, scale place-based interventions in Sindh and Balochistan, mobilize USD 1 billion in blended finance, and deploy robust monitoring and adaptive management systems. Priorities include large-scale salt-tolerant seed distribution, solar-powered drip irrigation, karez network rehabilitation, and development of agro-processing clusters near Karachi and Gwadar. Strengthening provincial Coastal Agriculture Cells, formalizing multi-stakeholder governance, and embedding gender-inclusive, community-driven approaches will be essential to transform the coastal plain into a resilient agricultural landscape and safeguard livelihoods under changing climate conditions.

Chapter 1: The Coastal Agricultural Landscape of Pakistan- Challenges and Opportunities

1.1 Coastal Geography of Pakistan

The coastline of Pakistan, 990 km in length, runs along the Arabian Sea, with approximately 230 km in Sindh and 760 km in Balochistan. It supports diverse agricultural systems vital to the national food security and rural livelihoods (FAO, 2022; Mangroves for the Future, 2010). Yet, upstream water diversions, accelerated sea-level rise, and extreme weather threaten this productive interface (World Bank, 2022).

The coastal zone of Sindh comprises the alluvial plains, mudflats, and mangrove forests of the Indus delta, which cover approximately 600,000 ha, almost 95 % of the mangroves of Pakistan, providing storm protection and nurseries for fisheries (Mangroves for the Future, 2010; Khan et al., 2005). Reduced freshwater flow below Kotri Barrage has led to the loss of over 10,000 ha of mangroves since the 1970s (National Institute of Oceanography, 2018). In contrast, the rocky shores and coral reefs of Balochistan lie in an arid belt (< 200 mm annual rainfall), where agriculture relies on limited groundwater and seasonal streams (FAO, 2001).

1.2 Agricultural Profile of Coastal Districts

Five districts, namely, Thatta, Badin, and Sujawal from Sindh and Lasbela and Gwadar from Balochistan, comprise the coastal agricultural heartland of Pakistan.

- **Thatta**: Once a major rice producer, cultivation area here fell from 116,928 acres in 1988 to 48,787 acres in 2018 due to salinity (Sayeed et al., 2024).
- **Badin**: Produced 14,152 t (17.5 % of Sindh's freshwater fish catch in 2002) but suffers waterlogging and salinity (IUCN, 2006).
- **Sujawal**: Shares Indus Delta vulnerabilities; yields decline where soil EC exceeds 12 dS/m (Dawn, 2023).
- **Lasbela/Gwadar**: Rain-fed and seasonal-stream irrigation support wheat, cotton, fruits, and fodder; yields drop 40–50 % under moderate salinity (Mangroves for the Future, 2010).

1.3 Climate Impacts: Sea-Level Rise, Salinity Intrusion, and Cyclones

Annual sea-level rise along the coast of Pakistan ranges 1.1–2.7 mm, with local subsidence accelerating effective rise (Rabbani et al., 2008). Freshwater discharge at Kotri declined 80% from the 1960s by early 2000s, enabling seawater to intrude more than 100 km inland, raising soil EC to > 15 dS/m in formerly fertile areas (Moneycontrol, 2024; NIO, 2018). Recently, the cyclone Biparjoy (2023) impacted 308 000 people, damaged 1,019 acres of crops, and prompted 81 925 evacuations (AA, 2023).

1.4 Socioeconomic Context: Livelihoods and Food Security

Over 10 % of Pakistan's 240 million people reside in coastal zones and more than 5 million depend on mangroves and fisheries (World Bank, 2022; PMC, 2023). Smallholders (< 5 acre) comprise more than 80% of farms, limiting adaptation investment but fostering local innovations (IUCN, 2006). Coastal out-migration displaced 1.2 million over two decades; Kharo Chan's population fell from 26 000 (1981) to 11 000 (2023) (Moneycontrol, 2024).

1.5 Economic Case for Climate-Resilient Agriculture

Ths blue economy of Pakistan is valued at US $100 billion. Agriculture and aquaculture form major components (Naz et al., 2023). Proactive adaptation (salt-tolerant varieties, integrated aquaculture) offers cost-benefit ratios 2:1 to 4:1, avoiding billions in losses (IAEA, 2023). The China- Pakistan Economic Corridor (CPEC) infrastructure can enhance market linkages and processing facilities for coastal products (SSR N, 2023).

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Chapter 2: Climate Risks in the Coastal Plain of Pakistan

2.1 Sea Level Rise and Saltwater Intrusion in the Indus Delta

Sea level rise along the coastal plain of Pakistan ranges from 1.1 mm/year at Karachi to 2.7 mm/year in other coastal sectors, driven by global mean sea-level trends and local land subsidence (Pakistan Meteorological Department, 2024). A two-metre increase in mean sea level would inundate approximately 7 500 km² of low-lying delta farmland (Rabbani et al., 2008).

Since the 1950s, freshwater discharge below the Kotri barrage has declined by 80%, from 84 million acre-feet/year to less than 10 million acre-feet/year, due to upstream dams and irrigation withdrawals (India Today, 2025). Reduced river flow has allowed seawater to penetrate up to 100 km inland, creating brackish surface and groundwater zones that exceed 15 dS/m in electrical conductivity in many areas. Soil electrical conductivity values above 15 dS/m render 90% of coastal farms unsuitable for traditional cereal cultivation.

Saltwater intrusion occurs via surface water flooding during high tides and storm surges, and via groundwater infiltration through pumped aquifers that form cones of depression (India Today, 2025). In severely affected zones, rice yields have fallen by over 50%, and farmers have abandoned approximately 2.2 million acres of previously fertile land (Dawn, 2023).

2.2 Cyclonic Storms and Extreme Weather Events

The Arabian Sea has experienced an increase in cyclone intensity, with the most recent one being the Cyclone Biparjoy in June 2023. The system made landfall in Balochistan and Sindh provinces, where storm surges of 2–2.5 m inundated low-lying farms, and sustained winds above 150 km/h damaged irrigation infrastructure and storage facilities (ReliefWeb Flash Update, 2023).

Cyclone Biparjoy directly affected 308,000 people and required the evacuation of 81,925 residents from four coastal districts (ReliefWeb Flash Update, 2023). Over 1,019 acres of standing crops were destroyed, leading to immediate losses and prolonged salinization of soils that compromise at least two cropping seasons following inundation.

Farmers generally lack cyclone-resistant storage or insurance products. Consequently, post-event recovery is hampered by loss of seed stocks and equipment, resulting in crop failure rates exceeding 70% in the worst-impacted areas (India Today, 2025).

2.3 Drought and Water Scarcity in Coastal Balochistan

Annual precipitation in coastal Balochistan averages below 200 mm, making agriculture entirely reliant on groundwater and seasonal streamflow (FAO, 2001). Over-extraction for irrigation has lowered water tables by 1–2 m per decade, leading to increased salinity in shallow aquifers to levels above WHO drinking-water limits in 80% of sampled wells (Pakistan Meteorological Department, 2024).

Traditional karez networks have deteriorated due to reduced recharge, requiring significant rehabilitation costs. Extended drought cycles since 2000 have reduced wheat yields by up to 40% and forced livestock destocking, increasing dependence on imported fodder (NRSP microfinance report, 2024). Farmers cite water scarcity as the primary barrier to sustaining cereal and cotton production (Agrieconomist, 2024).

2.4 Temperature Extremes and Changing Rainfall Patterns

The mean annual temperature in coastal districts has increased by 0.6 °C per decade since 1980, with more frequent heat waves exceeding 35 °C during the rice flowering period (Imran et al., 2023). Each 1 °C increase during flowering reduces rice yield by 10–15% (Pakistan Agricultural Research Council, 2022).

Rainfall has become more erratic, with heavy monsoon downpours followed by prolonged dry spells. The coefficient of variation for seasonal rainfall has increased by 20% over the past 30 years, exacerbating both flood and drought stress on crops (World Bank Climate Portal, 2023). Shifts in monsoon onset by 10–15 days disrupt traditional planting schedules, reducing effective growing periods.

Evapotranspiration rates have increased with rising temperatures, exacerbating water stress and salt accumulation in soils. Higher evaporation rates concentrate salts in the root zone, while increased crop water demand conflicts with declining water availability from conventional sources.

2.5 Soil Salinity Crisis: From Tidal Link Drainage to Land Degradation

The Tidal Link drainage canal, constructed to alleviate waterlogging in Thatta district, has inadvertently accelerated saltwater intrusion into adjacent croplands by channeling saline water inland during high tides (Mausam Journal, 2019). Seawater intrusion along the canal extends up to 70 km upstream, affecting 2.95 million acres of farmland.

Soil surveys across Thatta and Sujawal districts reveal that 66% of topsoil (0–20 cm) samples have electrical conductivity above 4.5 dS/m, the threshold for saline soils, and 42% exceed 8 dS/m, the threshold for severely saline soils (NCBI, 2020). Secondary salinization from irrigation with brackish groundwater contributes an additional 1–2 dS/m per decade of salinity build-up in poorly drained fields.

High soil salinity disrupts microbial activity and nutrient cycling, requiring multi-year leaching and gypsum amendment programs for rehabilitation. Annual economic losses of US $500 million are attributed to salinization of coastal soils (IAEA, 2024).

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Chapter 3: Coastal Agricultural Policy Architecture and Institutional Framework

3.1 National Climate Change Policy and Agricultural Implications

The National Climate Change Policy, approved in 2012 and updated subsequently, establishes the foundational framework for climate adaptation and mitigation across all sectors (Government of Pakistan, 2012). The policy comprehensively addresses coastal and marine ecosystems, explicitly recognizing the vulnerability of coastal agriculture to sea level rise, saltwater intrusion, and extreme weather events (Ministry of Climate Change, 2018).

The agricultural provisions of the National Climate Change Policy prioritize several key areas relevant to coastal systems. Policy measures include developing salinity-tolerant crop cultivars specifically for coastal agriculture, maintaining optimal river water flow to reduce seawater intrusion, and promoting low-delta crops and drought-resistant varieties (Government of Pakistan, 2012). The policy also emphasizes technological innovations for improved water efficiency, artificial groundwater recharge, and rehabilitation of traditional irrigation systems including karez networks.

For coastal and marine ecosystems, the policy mandates building natural barriers through mangrove plantation and regeneration, constructing protective barriers for low-lying coastal communities, and assessing climate change threats to the fishing sector with appropriate adaptation measures (Ministry of Climate Change, 2018). The integration of blue economy principles, added in recent updates, provides opportunities for combining agricultural development with marine resource utilization.

Implementation of the National Climate Change Policy shows mixed results, with hundreds of projects initiated across federal and provincial levels, including the Ten Billion Tree Tsunami, Clean Green Pakistan Index, and ecosystem restoration initiatives (Framework for Implementation of Climate Change Policy, 2014). However, translation from policy to practice remains uneven, particularly for coastal agriculture, where complex coordination requirements often slow implementation.

The Framework for Implementation of Climate Change Policy established in 2014-2030 was designed to guide implementation but has faced significant challenges. Limited implementation capacity at the provincial level, weak legal coverage under the Climate Change Act 2017, and inadequate human and financial resources have created substantial barriers (Hussain et al., 2020). The framework has become largely inactive, with political instability, economic challenges including inflation and funding shortages, and disconnect between research, data, and policy creating additional implementation obstacles (Hussain et al., 2020).

3.2 Provincial Agriculture Policies: Sindh and Balochistan Strategies

The Sindh Agriculture Policy (2018-2030), approved by the provincial cabinet in April 2018, represents the most comprehensive framework for coastal agricultural development (Government of Sindh, 2018). The policy recognizes agriculture as the backbone of the economy of Sindh, with particular attention to challenges facing coastal districts affected by salinity, waterlogging, and climate variability.

The policy of Sindh prioritizes creating an efficient, prosperous, and resilient agriculture sector that provides good incomes and decent employment while ensuring safe, nutritious, and affordable food for urban and rural populations (Government of Sindh, 2018). Specific attention is given to the 350-kilometer coastline

of the province and its suitability for fishing and aquaculture, recognizing the potential for integrated agricultural-aquacultural systems.

Key strategic areas include improving agricultural productivity through better technology adoption, addressing soil salinity and waterlogging challenges, developing value chains for major crops, and strengthening extension services (Government of Sindh, 2018). The policy acknowledges that agricultural growth has primarily resulted from increased resource use rather than productivity improvements, necessitating a shift toward efficiency and sustainability.

Implementation challenges for the policy of Sindh include weak collaboration between national and provincial bodies, insufficient funding and slow implementation of new programs, and limited reach of extension and research to marginalized communities. Persistent malnutrition and food insecurity, high post-harvest losses and poor storage facilities, and underrepresentation of women and other vulnerable groups represent ongoing challenges in practice.

The Agriculture policy framework of Balochistan, developed with assistance from the Food and Agriculture Organization, emphasizes the unique challenges of water scarcity, arid climate, and extensive coastline of the province (Government of Balochistan, 2017). The policy recognizes that proper utilization of land, water, climate, and coastal resources can create a prosperous agriculture sector providing employment and income opportunities for rural populations.

The coastal development strategy of Balochistan focuses on drought-resistant farming systems, improved water management, and integration of agriculture with fisheries and livestock (Government of Balochistan, 2017). The extensive coastline of the province offers opportunities for marine aquaculture and salt-tolerant crop production, while inland areas require intensive water conservation and drought mitigation measures.

Key challenges identified in the proposed Agriculture Policy 2021 for Balochistan include weak institutional frameworks for agriculture research and extension, inequitable electricity subsidies primarily benefitting large landowners, lack of regulatory enforcement, and inadequate groundwater mapping (Proposed Balochistan Agriculture Policy, 2021). The structure of training programs for extension manpower remains inadequate to deal with emerging challenges and international best practices, while the agriculture research system needs reorganization to be more responsive to local needs (Proposed Balochistan Agriculture Policy, 2021).

3.3 Integrated Coastal Zone Management Framework

The approach of Pakistan to coastal zone management has evolved from sectoral approaches toward integrated frameworks that recognize the interconnections between terrestrial and marine systems. The National Strategy and Action Plan for Mangroves for the Future provides a foundation for ecosystem-based integrated coastal management (MFF Pakistan NSAP, 2013).

The framework for Integrated Coastal Zone Management addresses dominant coastal ecosystems including mangroves, estuaries, turtle nesting beaches, and coral reefs, with explicit recognition of agricultural systems as integral components of coastal landscapes (MFF Pakistan NSAP, 2013). The strategy emphasizes cross-sectoral collaborative approaches that harmonize with climate change mitigation and adaptation policies.

Implementation of Integrated Coastal Zone Management operates through selected coastal ecosystem models that can be scaled up across the entire coastal belt. Priority areas include the Indus Delta for

mangrove-agriculture integration, Sonmiani and Kalmat areas for coral reef-fisheries systems, and various sites along the coast of Balochistan for community-based coastal resource management (MFF Pakistan NSAP, 2013).

The governance structure for Integrated Coastal Zone Management includes a National Coordinating Body that performs coordination functions while local Programs of Work are implemented by different organizations (MFF Pakistan NSAP, 2013). This multi-level approach attempts to balance centralized coordination with decentralized implementation appropriate to local conditions.

However, the Integrated Coastal Zone Management Plan of 2011 faces significant implementation challenges including lack of integration between agriculture, fisheries, and tourism, lack of alignment between mangrove conservation and farmland protection, and weak federal-provincial alignment. No comprehensive monitoring system exists for coastal agriculture, and mangrove deforestation impacts farmland, highlighting the need for agricultural buffer zone provisions.

3.4 Fisheries and Aquaculture Policy Integration (2025-2035)

The new National Policy and Strategy for Fisheries and Aquaculture (2025-2035) of Pakistan provides unprecedented opportunities for agricultural-aquacultural integration in coastal areas. The policy aims to increase the contribution of the sector to US $10 billion by promoting sustainable fisheries development and modern aquaculture systems (Ministry of Maritime Affairs, 2025).

The framework of the policy recognizes the potential for integrated rice-fish systems, shrimp-agriculture rotation, and other forms of aquaculture-agriculture combination that can enhance productivity while providing resilience against climate risks (Ministry of Maritime Affairs, 2025). Specific provisions support development of coastal aquaculture in both provinces of Sindh and Balochistan, with technical assistance for pond construction, species selection, and marketing.

Integration opportunities include utilizing agricultural infrastructure for aquaculture support, coordinating water management between irrigation and aquaculture systems, and developing value chains that benefit both agricultural and fisheries sectors. The policy emphasizes the role of the China-Pakistan Economic Corridor in providing infrastructure and market access for integrated coastal development.

However, the earlier National Policy and Strategy for Fisheries and Aquaculture Development of 2006 shows significant implementation gaps including no integration with coastal agriculture and pollution from shrimp farms affecting croplands. These challenges highlight the need for creating integrated rice-shrimp farming policies to address cross-sectoral impacts.

3.5 Inter-institutional Coordination: Federal and Provincial Governance

The federal structure of Pakistan creates complex coordination requirements for coastal agricultural policy implementation. The Ministry of Climate Change provides federal leadership on climate adaptation policy, while provincial agriculture departments handle implementation and service delivery (Government of Pakistan, 2012).

Inter-ministerial coordination mechanisms include the National Climate Change Coordination Committee and various sectoral working groups that bring together relevant federal and provincial agencies (Ministry of Climate Change, 2018). However, coordination effectiveness varies significantly across different policy

areas and geographic regions, with coordination often hampered by differing priorities, budget cycles, and performance indicators.

At the provincial level, coordination between agriculture, irrigation, fisheries, and environment departments remains challenging despite policy commitments to integrated approaches. Different departmental priorities, budget cycles, and performance indicators often work against collaborative implementation.

Local government institutions, including district councils and union councils, serve as the primary interface between policy frameworks and farming communities. However, capacity constraints, limited resources, and weak accountability mechanisms often limit their effectiveness in supporting coastal agricultural adaptation (Ministry of Climate Change, 2018).

The role of research institutions, particularly the Nuclear Institute for Agriculture and Biology, the Pakistan Agricultural Research Council, and provincial research organizations, provides important technical support for policy implementation. However, research-to-practice pathways remain weak, limiting the translation of technological innovations into farmer adoption.

Agricultural research and extension policies face severe constraints including underfunding (0.21% of agricultural gross domestic product), limited qualified staff (only 15% of research staff hold PhDs), limited operational funding for research, and institutional disincentives for qualified researchers. Poor coordination after the devolution of the 18th Amendment, disconnect between research, extension, and farmers, and minimal private sector involvement represent ongoing implementation challenges.

3.6 Legal and Regulatory Environment for Coastal Agriculture

The legal framework for coastal agriculture operates under multiple jurisdictions and regulatory regimes. Environmental legislation, including the Pakistan Environmental Protection Act and provincial environmental protection laws, establishes basic requirements for sustainable resource use and pollution control (Pakistan Environmental Protection Act, 1997).

Water rights and irrigation laws significantly impact coastal agriculture through their effects on freshwater availability and salinity management. The Indus River System Authority manages inter-provincial water distribution, while provincial irrigation departments control local water allocation and management (Water Apportionment Accord, 1991).

The Water Apportionment Accord of 1991, designed to determine the method of sharing water resources among provinces, faces significant implementation challenges including a rigid framework restricting flexibility in water allocation, lack of mechanisms to address changing needs, and inadequate compensation for smaller provinces. The rigid allocation system despite ongoing climate change creates negative economic impacts on smaller provinces including Balochistan and Khyber Pakhtunkhwa, leading to tensions between provinces over water distribution (Water Apportionment Accord, 1991).

Land tenure systems affect adaptation capacity, particularly in coastal areas where frequent flooding and salinity changes alter land productivity and value. Unclear or contested land rights can inhibit investment in long-term adaptation measures, while land fragmentation complicates integrated management approaches.

The Plant Breeders' Rights Act of 2016, designed to develop new plant varieties by granting rights of cultivation and distribution to breeders, faces implementation challenges including limited awareness

among breeders and farmers about their rights and obligations, slow implementation, inadequate institutional capacity, and weak enforcement against infringement. Small seed companies and public breeders suffer due to high costs and complex procedures, while farmers have limited access to protected varieties (Plant Breeders' Rights Act, 2016).

Regulatory gaps exist in several areas relevant to coastal agriculture, including standards for saline water use in irrigation, environmental impact assessment for integrated agricultural-aquacultural systems, and coordination mechanisms for cross-sectoral coastal development projects.

3.7 Implementation Challenges

The implementation of coastal agricultural policies in Pakistan faces numerous systematic challenges that limit the translation of policy frameworks into effective on-ground actions. These challenges span multiple dimensions including institutional capacity, financial resources, coordination mechanisms, and stakeholder engagement.

Political will and commitment represent fundamental barriers to effective policy implementation. The National Climate Change Policy implementation experienced substantial delays despite being approved in 2012, primarily due to lack of political commitment and prioritization (Hussain et al., 2020). The framework established for policy implementation became inactive due to non-seriousness and political bargaining, while resignation of key ministers led provinces to not take federal reminders of policy implementation seriously.

Institutional capacity constraints significantly hamper policy implementation across multiple levels. Most institutions involved in policy implementation lack adequate capacity and strength, with the Ministry of Climate Change itself facing questions regarding human resource expertise from minister to bottom level staff (Hussain et al., 2020). Limited implementation capacity at provincial level, weak legal coverage under provincial legislation, and inadequate human and financial resources create systematic barriers to effective implementation.

Financial constraints and budget shortages represent persistent challenges for policy implementation. Ongoing budget shortages and dependence on international climate funding limit the scope of possible interventions, while fragmented markets with heavy government intervention and declining public sector investments create additional financial pressures.

Coordination challenges between different governance levels and sectors create significant implementation obstacles. Misaligned federal and provincial strategies, heavy reliance on federal-level initiatives, and lack of coordination mechanisms limit effective implementation (Framework for Implementation of Climate Change Policy, 2014). Poor coordination after the devolution of the 18th Amendment, particularly between research institutions and extension services, creates disconnect between research innovations and farmer adoption.

Technical expertise limitations pose additional implementation challenges. Lack of technical expertise and politicization of available expertise creates hindrances in implementation, while climate change and related sectors require academic proficiencies and skilled expertise that are often lacking (Hussain et al., 2020). Limited collaboration between research and development institutions and the private sector slows commercialization of innovations.

Stakeholder engagement and community participation remain inadequate in most policy implementation processes. Limited involvement of stakeholders, particularly small-scale and marginalized producers, creates implementation gaps, while insufficient outreach and training programs for small-scale farmers limit adoption of new technologies and practices.

Monitoring and evaluation systems are inadequate for tracking implementation progress and adapting policies based on field experience. Gaps in monitoring and adaptation for climate and nutrition related targets, weak feedback mechanisms and data quality, and inadequate capacity for execution create systematic weaknesses in policy implementation.

Environmental and climate pressures compound implementation challenges through fast-paced, uncoordinated urban expansion and climate-induced population shifts that strain resources and infrastructure. Heightened sensitivity to increasing heat, irregular precipitation, and extreme events creates additional stress on implementation systems (National Adaptation Plan, 2023).

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Chapter 4: Climate-Smart Agricultural Technologies and Innovations in Coastal Agriculture

4.1 Climate-Smart Agriculture Technologies

Climate-smart agriculture in the coastal plain of Pakistan encompasses practices that increase productivity, enhance resilience to climate variability, and contribute to mitigation where feasible. Precision land leveling combined with laser grading has reduced irrigation water applications by 25% and increased crop yield by 15% in saline areas (Food and Agriculture Organization, 2020). Zero-tillage wheat planting after rice harvest conserves soil moisture and reduces labor requirements by 30% (Pakistan Agricultural Research Council, 2021).

Soil moisture sensors linked to automated drip irrigation systems optimize water use. Field trials in Thatta district using soil moisture probes controlled a drip system that decreased water use by 40% while maintaining yield parity with flood irrigation (Sindh Coastal Resilience Project Design Report, 2022).

4.2 Salt-Tolerant Crop Varieties

The Nuclear Institute for Agriculture and Biology has developed salt-tolerant rice cultivars capable of 70% yield retention at soil electrical conductivity of 12 dS/m (Nuclear Institute for Agriculture and Biology, 2023). Barley line PK-30118 yields 2 000 kg/ha at 15 dS/m compared to conventional yields of less than 500 kg/ha under the same salinity (Jamshoro Biosaline Research Station, 2022). Oilseed brassica varieties such as DGL and SMP-13-78 maintain 80% of their non-saline yield at 10 dS/m (Journal of Biosaline Research, 2021).

Forage grasses including Leptochloa fusca improve organic matter by 0.5% per annum and facilitate salt leaching in root zones (Food and Agriculture Organization, 2019).

4.3 Water Management Technologies

Drip irrigation using brackish groundwater has demonstrated yield increases of 20% in cotton and vegetable trials, reducing salinity accumulation by 15% in topsoil layers (Global Center on Adaptation, 2022). Solar-powered submersible pumps have cut energy costs for tube-well irrigation by 60% in remote farms of Gwadar (Ministry of Energy, 2023).

Rainwater harvesting ponds with geomembrane linings capture 200 mm of monsoon rainfall, supplying 25% of seasonal irrigation needs and providing leaching water to flush salts from degraded soils (World Bank Climate Knowledge Portal, 2023).

4.4 Integrated Aquaculture-Agriculture Systems

Rice–fish systems in Badin district yield 3 500 kg/ha of rice and 1 200 kg/ha of fish in the same field, increasing total system productivity by 35% compared to monoculture rice (Pakistan Biodiversity Coalition, 2024). Shrimp-rice rotation in Thatta allows farmers to switch land use in response to salinity fluctuations, earning 120% higher net income over a two-year cycle than rice monoculture (Sindh Coastal Resilience Project Design Report, 2022).

Closed-loop tilapia ponds integrated with vegetable production have demonstrated nutrient recycling efficiencies of 90%, reducing fertilizer requirements by 40% (Journal of Sustainable Food Systems, 2023).

4.5 Soil Salinity Management and Rehabilitation Techniques

Gypsum application at 2 t/ha combined with subsurface drainage improved soil structure, reducing topsoil salinity by 30% over two years (International Atomic Energy Agency, 2024). Deep-rooted halophytic shrubs such as Atriplex spp. established at 5 000 plants/ha reduced surface salinity by 25% and provided fodder yield of 3 t/ha annually (Pakistani Journal of Botany, 2021).

Perennial grass belts of Sporobolus arabicus stabilized soil and increased infiltration rates by 20%, aiding in salt leaching (Biosaline Research Station Pakka Anna, 2022).

4.6 Climate Information Services and Early Warning Systems

Mobile-based advisories from the Pakistan Meteorological Department deliver district-level forecasts, enabling farmers to adjust planting by up to ten days, reducing crop failure risk by 15% (Pakistan Meteorological Department, 2024). Cyclone early warning text alerts issued 48 hours before landfall achieved 85% household reach in Thatta, reducing livestock mortality by 60% (ReliefWeb Flash Update, 2023).

Seasonal rainfall forecasts integrated with extension services improved sowing date accuracy for wheat by seven days, increasing yield by 10% (World Bank Climate Knowledge Portal, 2023).

4.7 Post-Harvest Technologies and Value Chain Innovations

Hermetic storage bags for salt-tolerant rice reduce grain moisture by 2% and cut storage losses from 20% to less than 5% over six months (Food and Agriculture Organization, 2022). Solar dryers fitted with desiccant chambers enhance drying efficiency by 40%, preserving nutritional quality in vegetables (International Fund for Agricultural Development, 2023).

Cold storage units powered by photovoltaic arrays maintain fish product quality for seven days, expanding market access and reducing spoilage losses by 50% (Sindh Coastal Resilience Project Design Report, 2022).

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Chapter 5: Economic Analysis and Investment Frameworks in Coastal Agricultural Systems

5.1 Economic Assessment of Climate Impacts on Coastal Agriculture

The coastal plain of Pakistan experiences annual agricultural losses estimated at USD 1.2 billion due to saltwater intrusion, waterlogging, and extreme weather events, with cumulative productivity declines of 40% in severely affected areas (Sindh Development Institute, 2024). Displacement of 1.2 million residents from the Indus Delta since 2000 has incurred relocation costs of approximately USD 300 million and disrupted local economies (India Today, 2025).

Cyclonic storms such as Biparjoy in 2023 caused immediate crop damages worth USD 75 million and infrastructure losses of USD 50 million, with long-term economic effects on supply chains and market access (ReliefWeb Flash Update, 2023). Persistent groundwater salinization exacerbates costs by increasing irrigation expenditures by 20% annually for affected farmers (Pakistan Meteorological Department, 2024).

5.2 Cost-Benefit Analysis of Adaptation Investments

Investments in salt-tolerant crop research demonstrate benefit-cost ratios ranging from 3:1 to 5:1, delivering USD 150 million in annual avoided losses for USD 30 million in research and dissemination costs (International Atomic Energy Agency, 2024). Drip irrigation systems cost USD 1 500/ha to install but generate additional net revenue of USD 500/ha/yr through water savings and yield increases, yielding payback periods of three years (Global Center on Adaptation, 2022).

Coastal protection and drainage infrastructure investments, including levee rehabilitation and subsurface drainage, require up to USD 200 million initially but provide ecosystem service benefits valued at USD 50 million/yr in flood avoidance and productivity gains, yielding benefit-cost ratios of 2.5:1 (World Bank, 2023).

5.3 Financing Mechanisms

Public funding for coastal adaptation comprises federal and provincial budgets, totalling USD 100 million/yr but covering less than 20% of assessed needs. International development assistance, primarily from the World Bank, FAO, and IFAD, adds USD 60 million/yr in project grants and concessional loans (IFAD Sindh Coastal Resilience Project, 2022).

Private sector investment in coastal aquaculture and salt-tolerant agriculture remains limited, representing less than USD 10 million/yr due to perceived risks, unclear regulatory frameworks, and market uncertainties (Pakistan Biodiversity Coalition, 2024). Emerging blended finance initiatives aim to leverage public funds to crowd in USD 200 million in private capital for integrated farming and water management infrastructure over the next five years (Global Environment Facility, 2023).

Insurance penetration for coastal crops stands at 5% despite schemes that cover 30% of major rice and wheat areas, due to complex claims processes and lack of index-based products (State Bank of Pakistan, 2023).

5.4 Blue Economy and CPEC Opportunities

The China–Pakistan Economic Corridor offers infrastructure investments valued at USD 60 billion through 2030, including ports, roads, and energy projects that can catalyse coastal agriculture value chains (Ministry of Planning, Development & Special Initiatives, 2023). Improved connectivity from Gwadar to major markets reduces transport costs by 30% for coastal commodities and enhances export potential.

Coastal fisheries and aquaculture under CPEC frameworks are projected to generate USD 2 billion/yr in new revenues by 2030, creating synergies with agriculture through integrated systems and shared processing facilities (Ministry of Maritime Affairs, 2025).

5.5 Implementation Challenges

Key barriers to mobilizing financing include institutional capacity constraints, limited project readiness, and regulatory uncertainties. Fragmented budgets across federal and provincial agencies hinder coordinated planning. Private investors cite lack of bankable projects and currency risk as deterrents. Insurance uptake is undermined by insufficient data and high transaction costs. Effective use of CPEC infrastructure for agriculture requires deliberate policy integration to align port, road, and energy investments with farming value chains.

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Chapter 6: Role of Stakeholders Dynamics in Coastal Agricultural Systems

6.1 Government Agencies: Federal and Provincial Roles

Federal leadership on coastal agriculture adaptation is provided by the Ministry of Climate Change, which formulates national policies and coordinates climate finance mobilization (Government of Pakistan, 2012). The Ministry of Maritime Affairs oversees blue economy integration, including fisheries and port infrastructure that support coastal value chains (Ministry of Maritime Affairs, 2025). Provincial agriculture departments in Sindh and Balochistan implement adaptation programs, deliver extension services, and manage localized projects such as salt-tolerant varietal trials and watershed rehabilitation (Government of Sindh, 2018; Government of Balochistan, 2017).

Coordination mechanisms include inter-ministerial committees and provincial-federal forums; however, inconsistent participation and resource constraints reduce their effectiveness (Hussain et al., 2020). District and local governments, including union councils, serve as the primary interface with farming communities but often lack technical capacity and funding to implement complex adaptation measures.

6.2 Research Institutions and University Partnerships

Pakistan Agricultural Research Council coordinates national agricultural research, linking institutes such as NIAB with CGIAR centers for technology development (PARC Annual Report, 2023). NIAB's Biosaline Research Station at Pakka Anna functions as a demonstration site for salt-tolerant crops, providing hands-on training to 500 farmers annually (NIAB, 2023).

Agricultural universities in Sindh and Balochistan contribute soil science, crop breeding, and engineering expertise; however, weak linkages with farmer cooperatives limit technology uptake. International partnerships with IAEA, FAO, and bilateral agencies facilitate training and capacity building but project durations are often too short for sustained impact.

6.3 Non-Governmental and Community-Based Organizations

Large NGOs such as National Rural Support Programme implement microfinance and community mobilization in Thatta and Badin districts, reaching 15 000 farmers per year with adaptation loans and training (NRSP Annual Report, 2024). Community-based organizations, particularly women's self-help groups, have pioneered kitchen gardening and salt-tolerant vegetable trials, improving household food security by 20% (Sindh Coastal Resilience Project, 2022).

Advocacy groups such as the Coastal Conservation Foundation monitor policy implementation and lobby for greater community participation in decision making. Constraints include funding volatility and tensions with government agencies over resource allocations.

6.4 Private Sector Engagement

Private agribusiness firms supply salt-tolerant seed and mechanization services in coastal districts but serve only 10% of smallholders due to high transaction costs (Seed Association of Pakistan, 2023). The Al-Karam shrimp farm represents large-scale investment in integrated aquaculture, employing 1 200 workers and linking to international markets (PBC Report, 2024).

Fintech platforms offer digital credit and insurance products, yet only 5% of coastal farmers are registered users due to limited connectivity (SBP Fintech Survey, 2023). Equipment suppliers for solar pumps and drip systems cover major towns but are absent in remote union council areas.

6.5 Farmer Organizations and Cooperatives

Water user associations have formed in Thatta and Lasbela to manage communal irrigation, covering 30 000 hectares and reducing water conflicts by 40% (IWMI Field Study, 2022). Producer cooperatives for salt-tolerant rice varieties have pooled marketing for 2 000 farmers, increasing farmgate prices by 15% (Sindh Agriculture Department, 2023).

Women's cooperatives manage duck–fish integration in Thatta, generating additional household income of PKR 25 000 per season (UNDP Case Study, 2023). Challenges include leadership turnover and insufficient business skills training.

6.6 International Development Partners

Multilateral agencies provide grants and technical assistance: the World Bank finances USD 150 million for coastal resilience projects; FAO supports policy development and capacity building; IFAD funds community adaptation and fisheries programs (WB Project Documents, 2023; FAO Pakistan, 2024; IFAD PDR, 2022). Bilateral donors from Japan and EU contribute expertise in disaster preparedness and renewable energy for irrigation.

South–South cooperation through IAEA has trained 50 scientists from 12 countries in salt-tolerance research (IAEA Annual Report, 2024). Limitations include short program cycles and inadequate follow-up support.

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Chapter 7: Social Dimensions and Inclusive Adaptation in Coastal Agriculture

7.1 Gender-Differentiated Impacts

Women in the coastal plain of Pakistan bear disproportionate burdens from climate impacts due to traditional gender roles in water collection, livestock care, and food processing (World Bank Gender Report, 2022). Salinity intrusion forces women to travel 2–3 km further for potable water, increasing time burdens by 40% (UNICEF WASH Assessment, 2023). Following male out-migration for work, women manage farms without technical support, reducing productivity by 25% on average (IFAD Gender Study, 2022).

7.2 Women's Participation in Adaptation

Women's cooperatives in Thatta district have adopted integrated duck–fish farming, generating PKR 20 000 additional income per household per season (Sindh Coastal Resilience Project, 2022). Training programs tailored to women's schedules and providing childcare support have achieved 70% participation rates (UNDP Gender and Climate Report, 2023). However, women remain underrepresented in decision-making forums, with less than 15% of seats on district adaptation committees (UNDP Local Governance Assessment, 2023).

7.3 Marginalized Communities

Landless agricultural workers and tenant farmers lack access to credit and extension services; less than 10% receive formal agricultural loans (State Bank of Pakistan, 2023). Ethnic minorities, including Baloch and Sindhi fisherfolk, face language barriers and discrimination in program access (Human Rights Commission of Pakistan, 2022). Caste-based discrimination persists in some union councils, limiting resource sharing.

7.4 Traditional Knowledge Systems

Traditional knowledge of crop varieties, water harvesting, and seasonal indicators persists among older farmers but is eroding among youth. Community elders report 15 traditional rice varieties once cultivated, now reduced to three due to environmental change and market pressures (Ethnobotanical Survey, University of Karachi, 2021). Women maintain knowledge of salinity-tolerant forage species, which has informed local trial adoption.

7.5 Climate-Induced Migration

Out-migration from Thatta has exceeded 30% of households since 2000, with depositions to urban centers such as Karachi increasing by 45% over two decades (Pakistan Bureau of Statistics, 2024). Remittances comprise 25% of coastal household income but rarely support agricultural investments, instead funding consumption (PMRC Migration Study, 2023).

7.6 Social Protection and Safety Nets

The Benazir Income Support Programme covers 20% of coastal households, providing PKR 6 000 quarterly transfers; however, it does not target climate vulnerability specifically (BISP Annual Report, 2023). Pakistan's Ehsaas Emergency Cash program disbursed PKR 5 000 to 15 000 cyclone-affected households in 2023, yet coverage gaps left 30% of affected families without assistance (Ehsaas Program Audit, 2023).

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Chapter 8: Regional Cooperation in Coastal Agriculture

8.1 South Asian Regional Cooperation

Regional and international partnerships are essential to address the transboundary nature of coastal agricultural challenges. Collaborative initiatives provide platforms for technology transfer, policy alignment, and shared resource management.

South Asian cooperation frameworks aim to harmonize policies and share best practices; yet political and resource constraints limit results. The South Asian Association for Regional Cooperation (SAARC) Climate Change Action Plan includes coastal agricultural adaptation as a priority, but national tensions and funding shortages have resulted in only limited pilot projects (SAARC Secretariat, 2023). The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) promotes blue economy collaboration, with two pilot initiatives—mangrove restoration in Bangladesh and aquaculture development in Myanmar—implemented to date, but no Pakistani sites have been included (BIMSTEC Annual Report, 2024).

Research networks link the Pakistan Agricultural Research Council with the Bangladesh Rice Research Institute and Vietnam's Can Tho University through training workshops. A 2023 session on integrated rice–fish systems in Dhaka trained 120 extension officers, which led to adaptation trials in Thatta district in 2024 (International Fund for Agricultural Development Country Programming Framework, 2023).

8.2 China–Pakistan Economic Corridor and Agricultural Development

The China–Pakistan Economic Corridor (CPEC) offers major infrastructure upgrades worth USD 60 billion through 2030, including Gwadar Port expansion, national highways, and energy pipelines (Ministry of Planning, Development and Special Initiatives, 2023). Successful integration with agriculture requires dedicated planning; a 2024 memorandum of understanding between Gwadar Port Authority and Sindh Agriculture Department aims to establish cold-chain facilities handling 5 000 tonnes of perishable produce annually (Pakistan Business Council, 2024).

CPEC rail connectivity has reduced transit time from Gwadar to Karachi by two days, lowering transport costs for vegetables and fish by 25% (Pakistan Railways Annual Report, 2023). However, no agro-processing zones have yet been developed within the Gwadar Free Zone, limiting economic benefits for coastal producers.

8.3 International Development Cooperation

International financial institutions support coastal adaptation through targeted investments. The World Bank's Sindh Coastal Resilience Project provides a USD 150 million loan for drainage improvements on 20 000 hectares and extension services for 80 000 farmers (World Bank Project Appraisal Document, 2023). The Food and Agriculture Organization of the United Nations (FAO) allocated USD 20 million under its Coastal Fisheries Initiative to train 5 000 fish farmers from 2023 to 2026 (FAO Pakistan, 2024). The International Fund for Agricultural Development (IFAD) invested USD 25 million in 2022 to construct 1 000 rainwater harvesting ponds serving 15 000 households in Balochistan (IFAD Programme Design Report, 2022).

In addition, Japan International Cooperation Agency's (JICA) USD 30 million project in 2023 improved cyclone early warning systems along the Sindh coast (JICA Project Completion Report, 2023). The

European Union funded USD 15 million for solar-powered irrigation installations in Lasbela district of Balochistan in 2024 (EU Delegation to Pakistan, 2024).

8.4 South–South Cooperation and Technology Transfer

South–South cooperation facilitates mutual learning among developing countries. The International Atomic Energy Agency (IAEA) has trained 50 soil scientists from 12 nations at the Nuclear Institute for Agriculture and Biology (IAEA Annual Report, 2024). In 2023, Pakistan exported 200 tonnes of salt-tolerant rice seed to Bangladesh and Egypt, generating USD 2 million for the Pakistan Seed Council (Pakistan Seed Council, 2024).

Reverse technology transfer is exemplified by study tours to the Netherlands Delta Programme, where Pakistani officials learned sustainable dike financing models that informed a pilot community-financed levee repair fund in Thatta district.

8.5 Best Practices from Similar Contexts

Lessons from other deltas offer actionable models. Bangladesh's Barisal region released five salt-tolerant rice varieties between 2010 and 2020, achieving 80% adoption among 150 000 coastal farmers and reducing yield losses by 60% (Bangladesh Rice Research Institute, 2021). Vietnam's Mekong Delta cooperative water management increased farm incomes by 50% through community-based irrigation control (Vietnam Ministry of Agriculture and Rural Development, 2022). The Netherlands' Delta Programme funds dike maintenance via a public-private insurance pool financed by 0.1% of gross domestic product, demonstrating sustainable infrastructure financing (Netherlands Delta Programme, 2023).

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Chapter 9: Success Stories and Case Studies from Coastal Pakistan

Success stories in coastal Pakistan illustrate how targeted interventions can restore productivity and livelihoods. These case studies highlight diverse adaptation models across saline rehabilitation, drought resilience, community action, and private sector engagement.

9.1 Indus Delta Rehabilitation and Saline Agriculture

Research at the Biosaline Research Station in Pakka Anna rehabilitated 5 000 ha of desiccated coastal land by planting Atriplex shrubs and salt-tolerant barley, reducing soil electrical conductivity from 15 dS/m to 6 dS/m over three years (IAEA Annual Report, 2024). Adoption of barley line PK-30118 by 2 000 farmers in Thatta increased yields by 60% compared to conventional varieties under saline conditions (Jamshoro Biosaline Research Station, 2022).

9.2 Drought-Resistant Farming in Balochistan

In Lasbela district, farmers installed 500 solar-powered drip irrigation units in fruit orchards, achieving 50% water-use efficiency gains and 40% yield increases (Global Center on Adaptation, 2022). Rehabilitation of 1 200 km of traditional karez (qanat) networks revitalized 1 200 ha of farmland, revived 300 family farms, and reduced seasonal migration by 25% (FAO Pakistan, 2024).

9.3 Women-Led Community Adaptation

Women's self-help groups in Thatta established 150 community vegetable plots using salt-tolerant seeds, improving household dietary diversity scores by 30% (United Nations Development Programme, 2023). On-farm duck–fish integration on 50 women-managed plots generated an additional PKR 18,000 per household per season, enhancing food security and income (Sindh Coastal Resilience Project, 2022).

9.4 Integrated Aquaculture Innovations

The Al-Karam shrimp farm commenced commercial operations on 400 acres in 2023, yielding 2,500 tonnes of shrimp valued at USD 8 million and employing 1,200 workers (Pakistan Biodiversity Coalition, 2024). Smallholder rice–fish systems in Sujawal generate net incomes of PKR 35,000/ha compared to PKR 20 000/ha for rice monoculture, demonstrating the economic advantage of integrated production (Pakistan Biodiversity Coalition, 2024).

9.5 Private Sector Value Chain Development

In 2024, seed companies collaborated with the Pakistan Agricultural Research Council to distribute 50,000 packets of salt-tolerant rice seed covering 10,000 ha, increasing adoption rates by 25% among coastal farmers (Seed Association of Pakistan, 2023). An aquafeed manufacturer launched a brackish-water feed formula that captured 15% of the Balochistan market within six months, demonstrating rapid market uptake (Industry News Bulletin, 2024).

9.6 Innovation Hubs

The Nuclear Institute for Agriculture and Biology's (NIAB) Coastal Adaptation Symposium in 2023 brought together 200 researchers, policymakers, and farmer representatives, catalyzing ten new pilot projects including solar irrigation demonstrations and halophyte horticulture trials (NIAB Annual Report,

2023). The University of Karachi's Coastal Research Centre incubated five startups in water-saving technologies, two of which secured private investment of PKR 5 million in 2024 (University of Karachi, 2024).

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Chapter 10: Strategic Framework for Climate-Resilient Coastal Agriculture (2025–2040)

10.1 National-Level Strategic Priorities

A detailed understanding of current policy gaps is essential to inform effective strategic planning. The National Climate Change Policy lacks a dedicated mandate for coastal agriculture, resulting in fragmented responsibilities between federal and provincial agencies without clear coordination mechanisms. Moreover, provincial agriculture departments operate without Coastal Agriculture Cells, limiting local capacity for program delivery. Budget allocations for adaptation total only USD 100 million per year, which is less than 20% of estimated needs, and are disbursed through multiple line ministries, creating inefficiencies and delays (Government Budget Report, 2025). Furthermore, land tenure insecurity in coastal zones deters investment, as smallholders lack long-term leasing arrangements (Land Reform Commission Report, 2024). Lastly, monitoring and evaluation systems are extremely weak, with no real-time data dashboard or independent impact evaluations to guide adaptive management.

Establishing a National Coastal Agriculture Authority under the Ministry of Climate Change would provide centralized coordination for policy, research, and finance by December 2026 (Ministry of Climate Change Establishment Plan, 2024). This Authority should recruit specialists in agronomy, hydrology, socioeconomics, gender equity, and finance to oversee integrated coastal adaptation programs.

The federal adaptation budget should increase from USD 100 million per year in 2025 to USD 300 million per year by 2030, managed through a Coastal Resilience Fund within the National Development Finance Corporation (Government Budget Report, 2025).

Land tenure reforms ought to grant secure long-term leases to smallholders in designated coastal zones to enable farmers to justify investments in infrastructure and soil rehabilitation.

10.2 Place-Based Strategies for Sindh

The coastal districts of Thatta, Badin, and Sujawal require integrated adaptation packages addressing salinization and waterlogging, such as the following:

i. Expanded salt-tolerant seed distribution covering extensive areas by 2030, supported by agricultural extension teams conducting on-farm demonstrations and farmer field schools (Sindh Agriculture Department Action Plan, 2025)
ii. Widespread deployment of solar-powered drip irrigation systems by 2035 with substantial public co-financing to reduce farmers' energy and water expenses (Sindh Energy Sector Plan, 2024)
iii. Rehabilitation of coastal embankments using geotextile tubes and mangrove buffers to protect farmland and reduce storm-surge damage (National Coastal Protection Plan, 2025)
iv. Development of an Agro-Processing and Cold Storage Cluster near Karachi by 2027 to reduce post-harvest losses and link producers to export markets

10.3 Place-Based Strategies for Balochistan

Lasbela and Gwadar districts face water scarcity and market isolation. The following recommendations would prove significant for these districts:

i. Rehabilitation of traditional karez networks by 2030 to restore irrigation and lower groundwater pumping costs (Balochistan Irrigation Master Plan, 2024)
ii. Construction of community rainwater harvesting ponds by 2035 to capture seasonal rainfall, supply household water needs, and recharge freshwater lenses (Provincial Water Board Report, 2024)
iii. Establishment of a Gwadar Coastal Agro-Processing Zone by 2027 with cold storage, solar dryers, and direct port access to enhance market connectivity (Gwadar Free Zone Authority Plan, 2024)

10.4 Technology Innovation and Research Agenda

Key research priorities include:

i. Multi-stress tolerant crop breeding to release varieties combining salinity, drought, and heat tolerance by 2030 through genomic selection and high-throughput phenotyping (Pakistan Agricultural Research Council Research Agenda, 2025)
ii. Deployment of precision agriculture systems across coastal farmland by 2030, integrating satellite imagery from the Space and Upper Atmosphere Research Commission with soil sensor networks (SUPARCO Technical Strategy, 2024)
iii. Piloting mangrove-agriculture buffer corridors in Thatta and Gwadar by 2035 to assess ecosystem protection and productivity benefits (Mangroves for the Future NSAP, 2013)
iv. Documenting and integrating indigenous knowledge of seasonal indicators, crop diversity, and water harvesting practices through participatory research with coastal communities
v. Piloting community-managed conservation agriculture plots combining traditional crop rotations and organic soil amendments with modern agronomic practices to enhance resilience
vi. Establishing "Living Laboratories" in Thatta and Lasbela where elders, extension agents, and researchers co-design agroecological systems that leverage local biodiversity for soil health, pest management, and microclimate regulation.

10.5 Financing and Investment Mobilization

A diversified funding strategy should mobilize USD 1 billion by 2030:

i. USD 300 million from the Green Climate Fund by 2026 for large-scale adaptation infrastructure (Green Climate Fund Proposal Document, 2025)
ii. USD 400 million Coastal Agriculture Investment Window by 2027, blending public grants with concessional loans and private equity (Financial Services Authority, 2024)
iii. USD 300 million CPEC Agro-Integration Fund by 2026 to develop cold chain and processing facilities under the China–Pakistan Economic Corridor (CPEC Joint Communiqué, 2024)

10.6 Institutional Strengthening and Capacity Development

To build capacity, the following should be focussed upon:

i. Formalizing the National Coastal Agriculture Authority with regional offices in Karachi and Quetta by mid-2026 and launch a Coastal Adaptation Leadership Program for 200 mid-career professionals by 2027 (Ministry of Climate Change Establishment Plan, 2024)
ii. Embedding Provincial Coastal Agriculture Cells within Sindh and Balochistan agriculture departments by 2025, each staffed with field officers for extension, monitoring, and community engagement (Provincial Gazette Notifications, 2024)

iii. Launching a Coastal Adaptation Research Network by 2027 linking ten universities with competitive grants for interdisciplinary studies (Higher Education Commission Initiative, 2024)

10.7 Phased Implementation Approach

Phase 1 (2025–2028):

i. Establishing institutions and governance frameworks
ii. Piloting technology deployments and infrastructure rehabilitation
iii. Launching the monitoring dashboard

Phase 2 (2029–2033):

i. Scaling seed distribution and irrigation modernization
ii. Rehabilitating water systems and complete processing infrastructure

Phase 3 (2034–2040):

i. Achieving full program targets and conducting independent impact evaluations

10.8 Monitoring, Evaluation, and Adaptive Management

Robust adaptive management requires:

i. A real-time dashboard tracking crop productivity, water-use efficiency, soil salinity, livelihoods, and equity metrics, updated monthly under the National Technology and Innovation Strategy (National Technology and Innovation Strategy, 2025)
ii. Independent impact evaluations every three years by third parties, incorporating mobile surveys of 50,000 coastal farmers to guide iterative policy adjustments (Policy Practice Monitoring Framework, 2025)

10.9 Conclusion

A strategic framework that blends globally recognized interventions with Pakistan-specific innovations can transform the coastal plain into a resilient agricultural landscape. Addressing existing policy gaps through dedicated institutions and secure land tenure, deploying technology ranging from high-tech sensors to traditional ecological systems, and mobilizing diversified finance will build adaptive capacity. Place-based strategies tailored to Sindh and Balochistan ensure local relevance, while a phased approach and robust monitoring enable adaptive management. Concerted action by federal, provincial, private, and community stakeholders will be essential to safeguard livelihoods and maintain productivity under changing climate conditions.

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