Securing the Harvest: A Vision for the Coastal Agriculture of Pakistan

White Paper

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Executive Summary

The coastline of Pakistan stretches for 990 kilometers along the Arabian Sea, supporting critical farming and fisheries livelihoods for more than 10 million individuals. This zone is under increasing stress from rapid sea-level rise, saltwater encroachment, and stronger cyclonic events. Within the Indus Delta, over 2.2 million acres of once-productive farmland have been abandoned as soil salinity surpassed 15 dS/m. This has forced 1.2 million people to relocate, threatening national food supplies and undermining economic resilience. Agricultural districts situated in Sindh (Thatta, Badin, Sujawal) and Balochistan (Lasbela, Gwadar) experience yield reductions of 40 to 50 percent under moderate salinity, highly variable freshwater flows worsened by upstream diversions, and localized sea-level rise of 1.1 to 2.7 millimeters annually.

The policy structure of Pakistan, based on the National Climate Change Policy of 2012, the Sindh Agriculture Policy for 2018–2030, and the forthcoming Coastal Aquaculture Strategy for 2025–2035, forms a strong platform for adaptation. Significant technological advances demonstrate promise: salt-tolerant rice lines that retain 70 percent yield under 12 dS/m salinity, barley producing 2,000 kilograms per hectare at 15 dS/m, precision irrigation that reduces water demand by up to 40 percent, and integrated rice–fish or shrimp–rice systems that enhance system productivity by 35 percent. These approaches deliver strong financial returns, with benefit-cost ratios ranging from 2:1 to 5:1. Institutions such as the Nuclear Institute for Agriculture and Biology together with provincial research stations are central to developing and distributing these innovations.

Despite strong economic incentives linked to the blue economy, which is valued at 100 billion US dollars, and transport efficiencies from CPEC infrastructure that reduce costs by nearly 30 percent, serious gaps in practice remain. Overlapping institutional responsibilities, very low funding for extension services at only 0.21 percent of agricultural GDP, and limited cooperation between federal, provincial, and local agencies restrict widespread adoption. Financing also falls short, with government adaptation budgets covering less than one-fifth of requirements and private sector contributions staying below 10 million US dollars per year.

A phased action plan for 2025 to 2040 is recommended. This involves establishing a National Coastal Agriculture Authority, expanding tailored interventions across Sindh and Balochistan, mobilizing one billion US dollars in blended financing, and deploying comprehensive monitoring and adaptive management systems. Key priorities are large-scale distribution of salt-tolerant seed, expansion of solar-powered drip irrigation, rehabilitation of karez networks, and creation of agro-processing clusters near Karachi and Gwadar. Strengthening provincial Coastal Agriculture Cells, formalizing inclusive multi-stakeholder governance mechanisms, and embedding gender-sensitive, community-based approaches will be essential to transform the coastal plains into resilient agricultural landscapes and secure livelihoods under the pressures of climate change.

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

1.1 Coastal Geography of Pakistan

The shoreline of Pakistan extends for 990 kilometres along the Arabian Sea, including nearly 230 kilometres in Sindh and 760 kilometres in Balochistan. It supports diverse farming systems that are crucial for food security of the country and for sustaining rural livelihoods (FAO, 2022; Mangroves for the Future, 2010). However, upstream water withdrawals, rising sea levels, and more frequent extreme weather are putting this productive zone at serious risk (World Bank, 2022).

The coastal landscape of Sindh contains alluvial plains, tidal flats, and mangrove forests of the Indus delta. Covering about 600,000 hectares, this delta represents almost 95 percent of Pakistan's mangroves, providing natural storm barriers and critical nursery grounds for fisheries (Mangroves for the Future, 2010; Khan et al., 2005). Declining freshwater flow below Kotri Barrage has already caused the disappearance of more than 10,000 hectares of mangroves since the 1970s (National Institute of Oceanography, 2018). In contrast, the coastal belt of Balochistan, characterized by rocky shorelines and coral reefs, lies within an arid region receiving less than 200 millimetres of rainfall each year. Farming here depends mainly on limited aquifers and seasonal streams (FAO, 2001).

1.2 Agricultural Profile of Coastal Districts

Five key districts make up the core agricultural region along the coast: Thatta, Badin, and Sujawal in Sindh, together with Lasbela and Gwadar in Balochistan.

- **Thatta**: Once considered a major rice-growing area, the cultivated land declined from 116,928 acres in 1988 to 48,787 acres in 2018 as a result of salinity (Sayeed et al., 2024).
- **Badin**: Accounted for 14,152 tonnes, or 17.5 percent of Sindh freshwater fish production in 2002, but today suffers from waterlogging and salinity problems (IUCN, 2006).
- **Sujawal**: Shares vulnerabilities of the Indus Delta, with sharp yield losses where soil electrical conductivity is above 12 dS/m (Dawn, 2023).
- **Lasbela and Gwadar**: Rely on rain-fed and ephemeral stream irrigation to grow wheat, cotton, fodder, and fruits. Output declines by 40 to 50 percent under moderate salinity conditions (Mangroves for the Future, 2010).

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

Observed sea-level rise along Pakistan's coastline ranges from 1.1 to 2.7 millimetres annually, and land subsidence intensifies effective rise (Rabbani et al., 2008). Flow of freshwater at Kotri Barrage fell by nearly 80 percent between the 1960s and early 2000s, allowing seawater to penetrate more than 100 kilometres inland. As a result, soil electrical conductivity in previously fertile fields has risen above 15 dS/m (Moneycontrol, 2024; NIO, 2018). Recently, Cyclone Biparjoy in 2023 impacted 308,000 people, destroyed 1,019 acres of crops, and forced evacuation of 81,925 residents (AA, 2023).

1.4 Socioeconomic Context: Livelihoods and Food Security

Around 10 percent of the total population of Pakistan, estimated at 240 million, live in coastal areas, and over 5 million people rely directly on mangrove ecosystems and fisheries (World Bank, 2022; PMC, 2023). Smallholder farms below 5 acres account for more than 80 percent of holdings. This scale limits investments for adaptation but also encourages local innovation (IUCN, 2006). Out-migration from coastal regions has displaced about 1.2 million people in two decades. In Kharo Chan, population declined from 26,000 in 1981 to only 11,000 in 2023 (Moneycontrol, 2024).

1.5 Economic Case for Climate-Resilient Agriculture

The blue economy of Pakistan has been valued at approximately 100 billion US dollars, with farming and aquaculture making up major contributions (Naz et al., 2023). Early adoption of resilience measures, such as salt-tolerant seed varieties and integrated aquaculture systems, delivers cost-benefit ratios of 2:1 to 4:1, helping avoid billions in potential losses (IAEA, 2023). Infrastructure under the China Pakistan Economic Corridor (CPEC) is expected to strengthen market connectivity and establish processing facilities for coastal agricultural outputs (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

Rates of sea level rise along the coastal belt of Pakistan range between 1.1 millimetres per year at Karachi and up to 2.7 millimetres annually in other locations, driven by global averages as well as local ground subsidence (Pakistan Meteorological Department, 2024). A rise of two metres in mean sea level would submerge around 7,500 square kilometres of deltaic farmland (Rabbani et al., 2008).

Since the mid twentieth century, freshwater outflow below Kotri Barrage has reduced by nearly 80 percent, declining from 84-million-acre feet per year to under 10-million-acre feet annually, mainly due to upstream storage and irrigation withdrawals (India Today, 2025). The loss of discharge has enabled seawater movement up to 100 kilometres inland, creating brackish conditions in both surface water and aquifers, where electrical conductivity exceeds 15 dS per metre. At values above 15 dS per metre, about 90 percent of farms are rendered unsuitable for conventional cereal cultivation.

Saltwater reaches farmland through tidal flooding during surges and high tides, as well as through aquifer intrusion linked to groundwater pumping that forms depressions (India Today, 2025). In the most degraded zones, rice harvests have fallen by over half, and nearly 2.2 million acres of once fertile fields have been abandoned (Dawn, 2023).

2.2 Cyclonic Storms and Extreme Weather Events

The Arabian Sea has witnessed rising cyclone intensity. A recent case was Cyclone Biparjoy in June 2023, which struck Balochistan and Sindh. Surges of 2 to 2.5 metres flooded farmlands, while sustained winds above 150 kilometres per hour destroyed irrigation systems and storage structures (ReliefWeb Flash Update, 2023).

Biparjoy impacted more than 308,000 people and required evacuation of 81,925 residents in four coastal districts (ReliefWeb Flash Update, 2023). More than 1,019 acres of crops were wiped out, creating immediate financial damage and leaving behind saline deposits that compromise at least two cropping cycles.

Most farmers lack storm-resistant storage or agricultural insurance. As a result, recovery is obstructed by the destruction of seed reserves and farming tools, causing crop failure rates higher than 70 percent in areas most exposed (India Today, 2025).

2.3 Drought and Water Scarcity in Coastal Balochistan

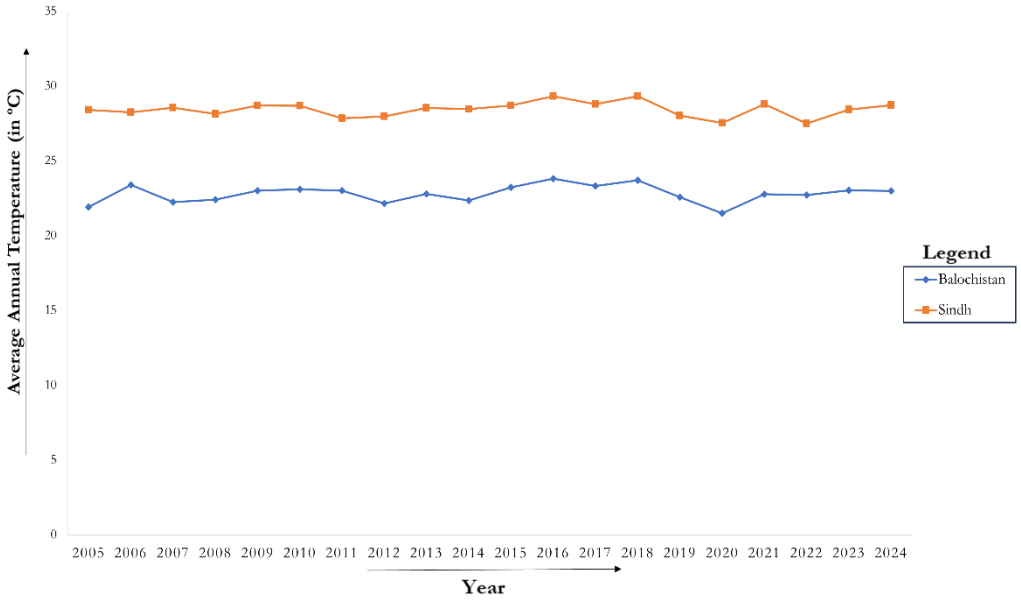
Average rainfall in the coastal tracts of Balochistan is below 200 millimetres annually, which makes crop cultivation dependent entirely on aquifers and temporary streams (FAO, 2001). Excessive groundwater withdrawal has lowered water tables by one to two metres per decade, and shallow aquifers now exceed World Health Organization drinking water standards in 80 percent of sampled wells (Pakistan Meteorological Department, 2024).

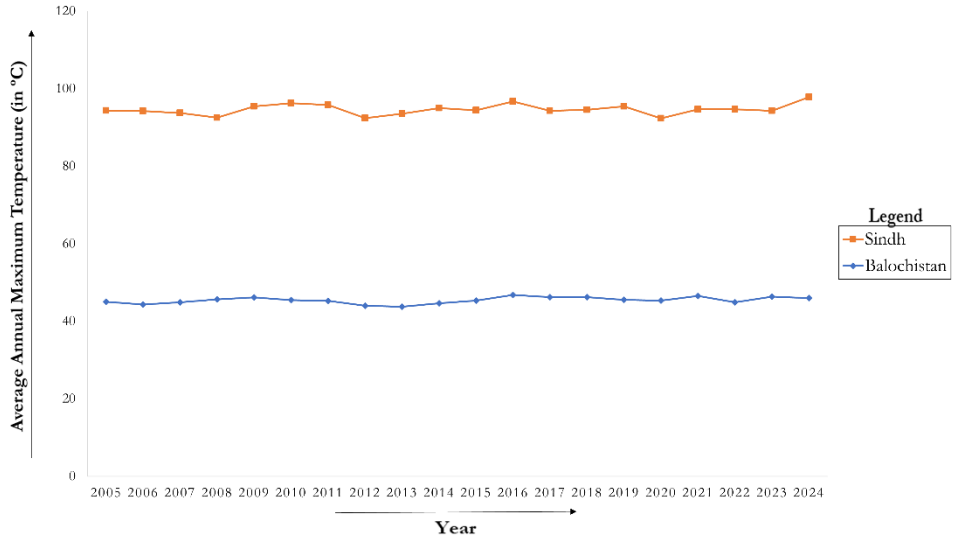
Traditional karez irrigation systems have deteriorated due to lower recharge, requiring heavy investments for rehabilitation. Prolonged drought periods since 2000 have reduced wheat harvests by up to 40 percent

and forced herders to reduce livestock, increasing reliance on imported fodder (NRSP microfinance report, 2024). Local farmers consistently report lack of water as the principal obstacle for sustaining production of cereals and cotton (Agrieconomist, 2024).

2.4 Temperature Extremes and Changing Rainfall Patterns

The mean temperature in coastal districts has increased by 0.6 degrees Celsius each decade since 1980. More frequent heat waves now exceed 35 degrees Celsius during the flowering stage of rice (Imran et al., 2023). Every 1 degree Celsius rise at flowering reduces rice yield by between 10 and 15 percent (Pakistan Agricultural Research Council, 2022).





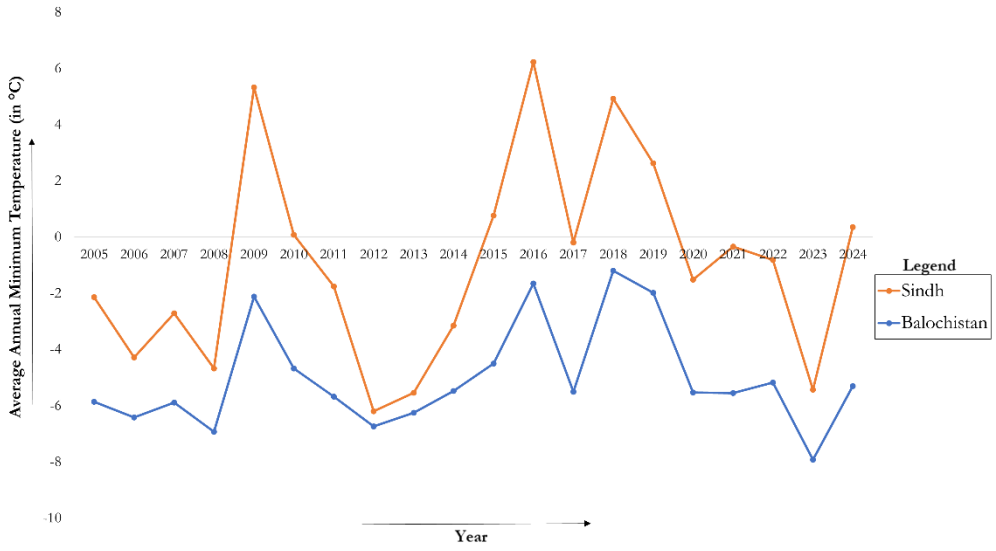


Figure 1: Temperature trends across coastal Pakistan

Rainfall patterns have become less predictable, with intense monsoon storms followed by long dry spells. The variability coefficient of seasonal rainfall has risen by 20 percent during the past three decades, aggravating both flood and drought stresses (World Bank Climate Portal, 2023). Changes in monsoon onset of 10 to 15 days shorten effective cropping periods and disrupt traditional planting schedules.

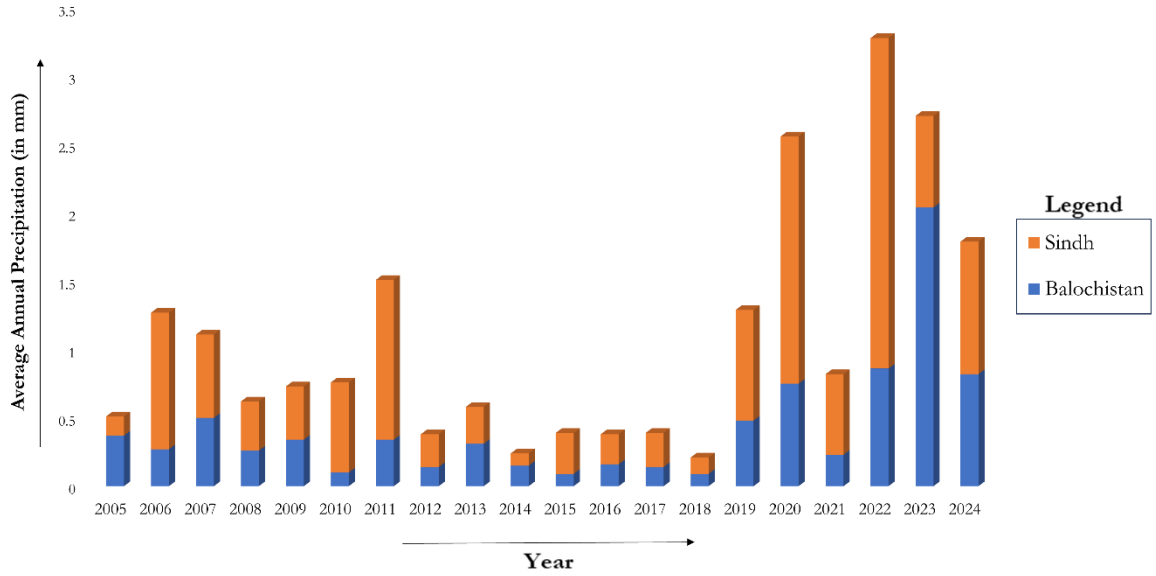


Figure 2: Precipitation trends across coastal Pakistan

Higher evapotranspiration caused by rising heat intensifies water stress and increases salt concentrations in soils. Greater water demand from crops conflicts with declining water supply, while evaporation accumulates salts in the root zone.

2.5 Soil Salinity Crisis: Tidal Link Drainage and Land Degradation

The Tidal Link drainage canal, constructed to address waterlogging in Thatta district, has unintentionally worsened salinity by transporting seawater inland during tidal surges (Mausam Journal, 2019). Saline intrusion along the canal extends nearly 70 kilometres upstream, degrading about 2.95 million acres of farmland.

Soil sampling in Thatta and Sujawal districts indicates that 66 percent of surface soils (0 to 20 cm depth) record electrical conductivity above 4.5 dS per metre, marking salinity, and 42 percent exceed 8 dS per metre, classed as severe salinity (NCBI, 2020). Secondary salinization caused by irrigation with brackish groundwater contributes a further 1 to 2 dS per metre increase per decade in poorly drained fields.

Excessive salinity disrupts soil microorganisms and nutrient cycles, demanding long-term reclamation through leaching and gypsum application. Economic losses of roughly 500 million US dollars annually are attributed to salinity in the coastal farmlands (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, first adopted in 2012 and later updated, forms the central framework guiding adaptation and mitigation strategies across multiple sectors (Government of Pakistan, 2012). The document highlights coastal and marine systems, noting the vulnerability of coastal agriculture to rising seas, saline water intrusion, and increasingly frequent storms (Ministry of Climate Change, 2018).

Agricultural provisions within the policy focus on several priorities. These include developing crop lines tolerant to salinity, maintaining adequate river flow to reduce seawater penetration, and promoting cultivation of low-water-use and drought-resistant varieties (Government of Pakistan, 2012). The policy further encourages technological solutions for water conservation, artificial recharge of groundwater, and restoration of traditional irrigation systems such as karez.

For marine and coastal ecosystems, the policy calls for establishing natural barriers through regeneration of mangroves, constructing protective infrastructure for low-lying coastal communities, and assessing climate risks for the fisheries sector alongside targeted adaptation responses (Ministry of Climate Change, 2018). More recent updates added blue economy perspectives, creating opportunities for integration of agricultural development with sustainable marine resource utilization.

Although numerous projects have been launched under this policy framework, including the Ten Billion Tree Tsunami, the Clean Green Pakistan Index, and ecosystem restoration efforts, progress on coastal agriculture has remained inconsistent. Complex coordination requirements often delay implementation and reduce effectiveness (Framework for Implementation of Climate Change Policy, 2014).

The Implementation Framework for Climate Change Policy (2014–2030) was designed to facilitate action, yet it has faced multiple obstacles. Limited provincial-level capacity, weak enforcement under the Climate Change Act of 2017, and shortage of financial and technical resources have hindered results (Hussain et al., 2020). The framework is now largely inactive, with political instability, inflation, and gaps between research evidence and policy practice adding to the difficulties.

3.2 Provincial Agriculture Policies: Sindh and Balochistan Strategies

The Agriculture Policy of Sindh (2018–2030), approved by the cabinet in 2018, provides the most comprehensive framework for coastal agricultural development (Government of Sindh, 2018). The document recognizes agriculture as the backbone of the economy of Sindh, with particular focus on coastal zones challenged by salinity, waterlogging, and climate stress.

The Sindh policy aims to build an efficient, resilient, and profitable agriculture sector that ensures decent incomes, employment opportunities, and food security for both rural and urban citizens (Government of Sindh, 2018). It emphasizes the 350-kilometre shoreline of Sindh, noting its importance for fishing and aquaculture, and explores opportunities for integrating agriculture with aquacultural systems.

Strategic priorities include boosting productivity through adoption of technology, addressing soil salinity and waterlogging, developing crop value chains, and improving extension services. However, the policy

also recognizes that past growth relied heavily on greater input use rather than efficiency gains, underscoring the need for sustainable approaches.

Challenges for Sindh include limited cooperation between national and provincial levels, inadequate funding, slow progress of programs, and weak reach of extension to marginalized groups. Malnutrition, high post-harvest losses, poor storage, and limited inclusion of women and vulnerable households remain persistent obstacles.

The Agriculture Policy of Balochistan, developed with FAO assistance, focuses on the distinctive challenges of water scarcity, arid conditions, and an extended coastline (Government of Balochistan, 2017). The document stresses the potential of land, water, and climate resources to create a prosperous agriculture sector offering rural employment and income.

Balochistan's coastal development strategy emphasizes drought-resilient systems, water management improvements, and integration of agriculture with fisheries and livestock (Government of Balochistan, 2017). Marine aquaculture and salt-tolerant crops represent coastal opportunities, while inland regions require conservation of water and drought mitigation.

The draft Agriculture Policy 2021 for Balochistan highlights challenges such as weak agricultural research and extension systems, inequitable electricity subsidies favouring large landholders, poor regulatory enforcement, and insufficient groundwater data (Proposed Balochistan Agriculture Policy, 2021). Training structures for extension remain inadequate, and the research framework needs restructuring to meet local priorities and align with global best practices.

3.3 Integrated Coastal Zone Management Framework

Pakistan has shifted from sector-specific approaches to a more integrated model of coastal management that recognizes linkages between land and sea. The National Strategy and Action Plan for Mangroves for the Future offer a base for ecosystem-oriented coastal planning (MFF Pakistan NSAP, 2013).

The Integrated Coastal Zone Management Framework covers major ecosystems such as mangroves, estuaries, coral reefs, and turtle nesting beaches, while identifying agriculture as an integral part of the coastal mosaic (MFF Pakistan NSAP, 2013). The framework stresses collaborative approaches that complement national climate adaptation and mitigation strategies.

Implementation takes place through demonstration sites that can be scaled up. These include the Indus Delta for mangrove-agriculture integration, Sonmiani and Kalmat for coral reef–fisheries models, and multiple Balochistan sites for community-managed resources.

A National Coordinating Body provides high-level oversight, while local institutions implement specific programs (MFF Pakistan NSAP, 2013). This structure attempts to balance central direction with locally tailored action.

Yet, the 2011 plan faces serious challenges. Integration between farming, fisheries, and tourism remains weak. Coordination between mangrove conservation and farmland protection is limited, and federal–provincial alignment is inconsistent. No monitoring system currently tracks coastal agriculture, while mangrove loss continues to affect farmland, emphasizing the need for protective buffer zones.

3.4 Fisheries and Aquaculture Policy Integration (2025–2035)

The new National Fisheries and Aquaculture Policy (2025–2035) introduces major opportunities for integration of agriculture and aquaculture in coastal provinces. The policy envisions sectoral contribution reaching 10 billion US dollars by expanding sustainable fisheries and aquaculture systems (Ministry of Maritime Affairs, 2025).

The framework highlights potential for integrated systems such as rice–fish farming and shrimp–rice rotations that simultaneously enhance yields and strengthen climate resilience (Ministry of Maritime Affairs, 2025). The document provides for technical support to Sindh and Balochistan in pond construction, species diversification, and marketing infrastructure.

Integration opportunities also extend to use of agricultural infrastructure for aquaculture, joint water management, and combined value chains. The China–Pakistan Economic Corridor is highlighted as a driver for infrastructure and market access.

Experience with the earlier National Fisheries and Aquaculture Policy of 2006 shows gaps, particularly lack of integration with farming and environmental damage from shrimp farming on croplands. These issues underline the importance of cross-sectoral regulations such as rice–shrimp integration policies.

3.5 Inter-Institutional Coordination: Federal and Provincial Governance

Pakistan's federal system creates complex coordination challenges for coastal agriculture. The Ministry of Climate Change leads on adaptation policy at the national level, while provincial agriculture departments implement programs (Government of Pakistan, 2012).

Mechanisms such as the National Climate Change Coordination Committee and other sectoral working groups bring together provincial and federal agencies (Ministry of Climate Change, 2018). However, effectiveness varies depending on priorities, budget schedules, and performance measures.

Provincial coordination between agriculture, irrigation, fisheries, and environment departments remains limited despite commitments to integration. Differences in priorities and cycles create further gaps.

Local governance bodies, including union councils and district councils, represent the key interface between farmers and policies. Nevertheless, limited resources, poor accountability, and capacity shortages often reduce their effectiveness in delivering adaptation measures (Ministry of Climate Change, 2018).

Research institutions such as the Pakistan Agricultural Research Council, Nuclear Institute for Agriculture and Biology, and provincial stations offer technical expertise but struggle with weak pathways to farmer adoption.

Research and extension face problems including underfunding (0.21 percent of agricultural GDP), shortage of qualified researchers (only 15 percent with doctoral degrees), and lack of incentives. Devolution under the 18th Amendment added further disconnects between research and extension. Private sector involvement remains minimal.

3.6 Legal and Regulatory Environment for Coastal Agriculture

Coastal agriculture is governed by several overlapping laws and regulations. Environmental legislation, including the Pakistan Environmental Protection Act and provincial environmental statutes, sets the framework for sustainable resource use (Pakistan Environmental Protection Act, 1997).

Irrigation and water laws strongly affect coastal systems by shaping freshwater flows and salinity management. The Indus River System Authority oversees provincial allocation, while provincial irrigation agencies manage distribution at local levels (Water Apportionment Accord, 1991).

The 1991 Accord faces significant problems. The framework is rigid, limiting flexibility in water allocation. No mechanisms exist for addressing new challenges, and smaller provinces receive inadequate compensation. Climate variability has worsened tensions over distribution, with provinces such as Balochistan and Khyber Pakhtunkhwa facing economic losses.

Land tenure also influences adaptation. Frequent flooding and rising salinity affect land quality, while unclear ownership reduces willingness to invest in long-term measures. Land fragmentation makes integrated approaches more difficult.

The Plant Breeders Rights Act of 2016 created rights for new varieties, but uptake remains weak. Challenges include poor awareness, lack of enforcement, high costs for small companies, and limited farmer access to protected seed varieties.

Regulatory gaps exist for key areas such as standards for irrigation with saline water, environmental assessments for combined aquaculture-agriculture projects, and coordination rules for cross-sectoral coastal initiatives.

3.7 Implementation Challenges

Translation of policies into practice faces barriers across multiple dimensions.

Political commitment remains weak. The National Climate Change Policy, despite adoption in 2012, experienced long delays in implementation (Hussain et al., 2020). The Implementation Framework became inactive due to limited seriousness, political instability, and ministerial turnover.

Institutional capacity is low at both federal and provincial levels. The Ministry of Climate Change has insufficient staff and expertise, while provincial units face similar weaknesses (Hussain et al., 2020). Gaps in provincial legal frameworks and limited resources reinforce these problems.

Budget shortages further constrain implementation. Limited public resources and reliance on international climate finance restrict the scale of interventions. Fragmented markets, government interference, and declining investments add financial pressure.

Coordination problems between national and provincial bodies also hinder progress. Misalignment of strategies and dependence on federal projects limit local ownership (Framework for Implementation of Climate Change Policy, 2014). Devolution has widened the disconnect between research, extension, and farmer communities.

Technical capacity is another obstacle. Expertise shortages, politicization, and lack of collaboration between public and private research institutions slow uptake of innovations.

Stakeholder participation remains insufficient. Marginalized groups and small producers often remain excluded from planning and implementation. Training programs are limited, and outreach is inadequate.

Monitoring and evaluation are poorly developed. Gaps in data, feedback loops, and institutional monitoring capacity weaken progress tracking and limit learning from field experience.

Finally, climate and environmental pressures add further difficulties. Urban expansion, population shifts, rising temperatures, and erratic rainfall create added stress on already weak 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 agricultural practices in the coastal belt of Pakistan aim to raise productivity, strengthen resilience to variable climate, and contribute to mitigation where applicable. Precision levelling of land with laser tools has lowered irrigation demand by 25 percent and lifted yields by 15 percent in saline tracts (Food and Agriculture Organization, 2020). Direct seeding of wheat without tillage after rice harvest conserves soil moisture and reduces labour input by 30 percent (Pakistan Agricultural Research Council, 2021).

Soil moisture sensors linked to automated drip systems enhance water use efficiency. Field experiments in Thatta district showed that probes managing drip irrigation cut water use by 40 percent while maintaining yields equal to conventional flood irrigation (Sindh Coastal Resilience Project Design Report, 2022).

4.2 Salt Tolerant Crop Varieties

The Nuclear Institute for Agriculture and Biology created rice cultivars that retain 70 percent of yield potential at soil salinity of 12 dS/m (Nuclear Institute for Agriculture and Biology, 2023). Barley line PK 30118 provides 2 000 kilograms per hectare at 15 dS/m, compared with under 500 kilograms for conventional cultivars in the same conditions (Jamshoro Biosaline Research Station, 2022). Oilseed brassica types like DGL and SMP 13 78 deliver 80 percent of their non saline yield at 10 dS/m (Journal of Biosaline Research, 2021).

Forage grasses including Leptochloa fusca increase organic matter by 0.5 percent each year while assisting salt leaching in the root zone (Food and Agriculture Organization, 2019).

4.3 Water Management Technologies

Use of drip systems with brackish groundwater raised cotton and vegetable yields by 20 percent and reduced topsoil salt accumulation by 15 percent (Global Center on Adaptation, 2022). Solar powered submersible pumps lowered energy costs of tube wells by 60 percent in farms of Gwadar (Ministry of Energy, 2023).

Rainwater harvesting ponds lined with geomembrane stored about 200 millimetres of monsoon rainfall, covering nearly 25 percent of seasonal irrigation demand and supplying leaching water to flush salts from degraded soils (World Bank Climate Knowledge Portal, 2023).

4.4 Integrated Aquaculture Agriculture Systems

Rice fish farming in Badin produced 3 500 kilograms of rice and 1 200 kilograms of fish per hectare, increasing total productivity by 35 percent compared with rice only (Pakistan Biodiversity Coalition, 2024). Rotational shrimp rice systems in Thatta allow farmers to switch land use with changing salinity, generating 120 percent higher net returns across a two year cycle compared with rice monoculture (Sindh Coastal Resilience Project Design Report, 2022).

Closed loop tilapia ponds combined with vegetable beds achieved nutrient recycling efficiency of 90 percent, lowering fertilizer needs by 40 percent (Journal of Sustainable Food Systems, 2023).

4.5 Soil Salinity Management and Rehabilitation

Applying gypsum at two tonnes per hectare along with subsurface drainage improved soil condition, lowering salinity in the top layer by 30 percent over two years (International Atomic Energy Agency, 2024). Planting halophytic shrubs such as Atriplex at 5 000 plants per hectare reduced surface salinity by 25 percent and supplied three tonnes of fodder per hectare annually (Pakistani Journal of Botany, 2021).

Belts of Sporobolus arabicus stabilized the soil, raised infiltration by 20 percent, and supported natural leaching of salts (Biosaline Research Station Pakka Anna, 2022).

4.6 Climate Information Services and Early Warning

Mobile phone-based advisories from the Pakistan Meteorological Department deliver local forecasts, enabling adjustments in sowing dates by up to ten days and lowering crop loss risks by 15 percent (Pakistan Meteorological Department, 2024). Text message cyclone alerts sent 48 hours before landfall reached 85 percent of households in Thatta, cutting livestock mortality by 60 percent (ReliefWeb Flash Update, 2023).

Integration of seasonal rainfall forecasts with extension services improved accuracy of wheat sowing by about seven days, increasing yields by 10 percent (World Bank Climate Knowledge Portal, 2023).

4.7 Post Harvest and Value Chain Innovations

Hermetic storage bags for salt tolerant rice reduce grain moisture content by 2 percent and lower storage losses from 20 percent to below 5 percent across six months (Food and Agriculture Organization, 2022). Solar powered dryers equipped with desiccant chambers enhanced drying efficiency by 40 percent, retaining nutrient quality of vegetables (International Fund for Agricultural Development, 2023).

Cold storage facilities powered by solar photovoltaic systems-maintained fish quality for seven days, extending market access and reducing spoilage losses by 50 percent (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 region of Pakistan suffers agricultural losses valued at nearly USD 1.2 billion annually as a result of salinity intrusion, waterlogging, and climate extremes, with productivity reductions of up to 40 percent in heavily impacted zones (Sindh Development Institute, 2024). Since 2000, the displacement of approximately 1.2 million inhabitants from the Indus Delta has generated resettlement costs of USD 300 million while severely disrupting local economies (India Today, 2025).

Cyclones such as Biparjoy in 2023 caused crop destruction worth USD 75 million along with infrastructure damages of USD 50 million, while long term effects continue to undermine supply chains and restrict market access (ReliefWeb Flash Update, 2023). Ongoing groundwater salinization has further increased farmer expenses, adding nearly 20 percent annually to irrigation costs (Pakistan Meteorological Department, 2024).

5.2 Cost Benefit Analysis of Adaptation Investments

Research on salinity tolerant crop varieties provides benefit cost ratios between 3 to 1 and 5 to 1, avoiding approximately USD 150 million in losses each year with research and dissemination costs of only USD 30 million (International Atomic Energy Agency, 2024). Drip irrigation requires an initial investment of USD 1 500 per hectare but delivers USD 500 per hectare annually through yield gains and water savings, achieving payback in about three years (Global Center on Adaptation, 2022).

Expenditure on coastal protection and drainage measures such as levee reinforcement and subsurface drains may reach USD 200 million at the outset, yet annual ecosystem service benefits of USD 50 million in reduced flooding and higher crop productivity provide benefit cost ratios near 2.5 to 1 (World Bank, 2023).

5.3 Financing Mechanisms

Government allocations for coastal climate adaptation, drawn from federal and provincial sources, total around USD 100 million each year but meet less than one fifth of the actual requirement. International assistance from multilateral agencies including the World Bank, FAO, and IFAD contributes an additional USD 60 million annually in grants and concessional credit (IFAD Sindh Coastal Resilience Project, 2022).

Private sector participation in aquaculture and salinity tolerant farming systems remains minimal, with annual flows below USD 10 million due to perceived risks, regulatory ambiguities, and market volatility (Pakistan Biodiversity Coalition, 2024). Blended finance models are being developed to leverage public capital and mobilize USD 200 million of private funding for integrated farming and irrigation systems during the next five years (Global Environment Facility, 2023).

Crop insurance coverage in coastal farming remains very limited at around 5 percent, although available schemes nominally cover 30 percent of major rice and wheat areas. Uptake remains weak due to complex claims processes and the absence of reliable index-based products (State Bank of Pakistan, 2023).

5.4 Blue Economy and CPEC Opportunities

The China Pakistan Economic Corridor is expected to deliver USD 60 billion of infrastructure by 2030, including port facilities, road connectivity, and energy investments that can stimulate coastal agricultural value chains (Ministry of Planning, Development and Special Initiatives, 2023). Enhanced transport from Gwadar to key domestic and international markets could reduce logistics costs by about 30 percent for farm commodities and strengthen export prospects.

Coastal fisheries and aquaculture initiatives under CPEC are projected to yield USD 2 billion annually by 2030, creating complementarities with farming through integrated systems and common processing facilities (Ministry of Maritime Affairs, 2025).

5.5 Implementation Challenges

Major constraints in mobilizing resources include weak institutional capacity, limited preparation of projects, and uncertain regulatory conditions. Disaggregated budgets between federal and provincial authorities reduce planning efficiency. Private investors highlight scarcity of bankable projects and currency related risks as key deterrents. Insurance adoption remains poor because of limited data availability and high administrative costs. To ensure that CPEC infrastructure contributes effectively to agriculture, deliberate alignment of port, road, and energy developments with farm value chains will be required.

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Chapter 6: Role of Stakeholders Dynamics in Coastal Agricultural Systems

6.1 Government Agencies: Federal and Provincial Roles

The Ministry of Climate Change provides overall federal leadership for adaptation in coastal agriculture, preparing national strategies and coordinating climate finance mobilization (Government of Pakistan, 2012). Oversight of blue economy integration, including fisheries and port infrastructure supporting coastal supply chains, is carried out by the Ministry of Maritime Affairs (Ministry of Maritime Affairs, 2025). Provincial agriculture departments in Sindh and Balochistan handle practical program implementation, extension delivery, and site-specific projects such as varietal testing for salinity tolerance and rehabilitation of watersheds (Government of Sindh, 2018; Government of Balochistan, 2017).

Existing coordination arrangements include inter ministerial committees and forums linking provinces and federal agencies, but limited participation and resource shortages undermine their functioning (Hussain et al., 2020). District administrations and union councils act as the main contact point with local farmers, yet these units often lack the technical knowledge and adequate financial resources to undertake complex adaptation projects.

6.2 Research Institutions and University Partnerships

The Pakistan Agricultural Research Council leads agricultural research nationally and links institutes like NIAB with CGIAR centers for technology innovation (PARC Annual Report, 2023). The Biosaline Research Station at Pakka Anna, managed by NIAB, demonstrates salt tolerant crops and trains nearly 500 farmers each year through practical sessions (NIAB, 2023).

Universities in Sindh and Balochistan provide expertise in crop breeding, engineering, and soil science, although weak collaboration with farmer cooperatives slows adoption of innovations. International collaborations with IAEA, FAO, and bilateral agencies support training and capacity development, but the limited duration of projects reduces continuity and long-term impact.

6.3 Non-Governmental and Community Based Organizations

Major non-governmental actors such as the National Rural Support Programme deliver microfinance and community mobilization services across Thatta and Badin, reaching about 15 000 farmers annually with loans and training for adaptation (NRSP Annual Report, 2024). Local community organizations, especially women led self-help groups, have advanced kitchen gardening and trials of salt tolerant vegetables, which improved household food availability by 20 percent (Sindh Coastal Resilience Project, 2022).

Advocacy based organizations like the Coastal Conservation Foundation monitor execution of policies and promote stronger participation of communities in decision making processes. Constraints to their work include unpredictable funding streams and disagreements with government over resource distribution.

6.4 Private Sector Engagement

Private agribusiness companies supply salt tolerant seeds and mechanization services in coastal districts, yet their outreach extends to only 10 percent of small farmers because of high costs of delivery (Seed Association of Pakistan, 2023). The Al Karam shrimp enterprise represents a major commercial investment in aquaculture, employing 1 200 individuals and connecting to international supply chains (PBC Report, 2024).

South Asian Forum for Environment (SAFE)

Financial technology platforms provide credit and crop insurance digitally, although just 5 percent of farmers in coastal areas have registered accounts due to connectivity barriers (SBP Fintech Survey, 2023). Suppliers of solar pumping systems and drip irrigation equipment maintain presence in larger towns but remain absent in remote union council regions.

6.5 Farmer Organizations and Cooperatives

Associations of water users have emerged in Thatta and Lasbela to manage shared irrigation networks, covering around 30 000 hectares and reducing disputes over water by 40 percent (IWMI Field Study, 2022). Marketing cooperatives formed around salt tolerant rice cultivation now represent 2 000 farmers and have increased producer prices at farmgate level by 15 percent (Sindh Agriculture Department, 2023).

Women led cooperatives operate duck and fish integration projects in Thatta, producing seasonal household income increases of nearly PKR 25 000 (UNDP Case Study, 2023). Persistent difficulties include changes in leadership and gaps in training for management and business planning.

6.6 International Development Partners

Multilateral institutions contribute both funding and technical inputs: the World Bank has allocated USD 150 million for coastal resilience; FAO assists with policy formulation and training; IFAD finances fisheries and local adaptation initiatives (WB Project Documents, 2023; FAO Pakistan, 2024; IFAD PDR, 2022). Bilateral donors from Japan and the European Union provide expertise in disaster response and renewable energy for irrigation.

South South cooperation facilitated by IAEA has trained 50 scientists from 12 nations on salinity tolerance research (IAEA Annual Report, 2024). However, short cycles of program funding and weak follow up mechanisms reduce overall continuity and depth of results.

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Chapter 7: Social Dimensions and Inclusive Adaptation in Coastal Agriculture

7.1 Gender Differentiated Impacts

Women living in the coastal plain of Pakistan carry disproportionate burdens from climate pressures because of their traditional responsibilities in water collection, livestock care, and household food preparation (World Bank Gender Report, 2022). When salinity intrusion spreads, women are forced to travel an additional 2–3 km to find safe drinking water, raising time burdens by nearly 40 percent (UNICEF WASH Assessment, 2023). As men migrate for employment, women often assume full farm management without access to technical guidance, which results in average yield declines of 25 percent (IFAD Gender Study, 2022).

7.2 Participation of Women in Adaptation

Cooperatives run by women in Thatta district have introduced integrated duck and fish farming, generating seasonal household income increases of PKR 20 000 (Sindh Coastal Resilience Project, 2022). Training sessions scheduled around women's availability and complemented by childcare services have reached 70 percent participation rates (UNDP Gender and Climate Report, 2023). Despite these successes, women continue to be underrepresented in decision making structures, occupying fewer than 15 percent of positions on district level adaptation committees (UNDP Local Governance Assessment, 2023).

7.3 Marginalized Communities

Tenant farmers and landless laborers experience limited access to both credit and extension programs, with fewer than 10 percent receiving formal agricultural loans (State Bank of Pakistan, 2023). Ethnic minority groups, including Sindhi and Baloch fisherfolk, face exclusion through language gaps and discriminatory practices that restrict their participation in adaptation initiatives (Human Rights Commission of Pakistan, 2022). In certain union councils, caste-based discrimination continues to affect equitable access to resources.

7.4 Traditional Knowledge Systems

Local knowledge about crop types, water harvesting methods, and seasonal indicators is still maintained among older generations but is being lost among younger farmers. Community elders recall that fifteen rice varieties were cultivated historically, yet only three remain in practice because of market pressures and environmental stress (Ethnobotanical Survey, University of Karachi, 2021). Women continue to preserve awareness of forage species tolerant to salinity, and this knowledge has supported adoption of local crop trials.

7.5 Migration Driven by Climate Stress

Out migration from Thatta has surpassed 30 percent of households since 2000, with movement toward urban centers such as Karachi increasing by 45 percent during the last two decades (Pakistan Bureau of Statistics, 2024). Remittances now account for roughly 25 percent of household earnings in coastal zones, although most funds are used for daily consumption rather than reinvestment in agriculture (PMRC Migration Study, 2023).

7.6 Social Protection and Safety Nets

The Benazir Income Support Programme currently provides quarterly transfers of PKR 6 000 to 20 percent of households in coastal areas, though targeting is not designed specifically for climate risk (BISP Annual Report, 2023). The Ehsaas Emergency Cash initiative disbursed PKR 5 000 to 15 000 families affected by cyclones during 2023, but nearly 30 percent of impacted households were not covered due to program gaps (Ehsaas Program Audit, 2023).

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Chapter 8: Regional Cooperation in Coastal Agriculture

8.1 South Asian Regional Cooperation

Regional as well as international collaborations are vital for addressing the cross-boundary nature of coastal agricultural challenges. Joint initiatives create opportunities for technology sharing, policy harmonization, and coordinated resource governance.
South Asian cooperative frameworks have the stated goal of aligning policies and exchanging successful practices; however, political frictions and limited resources restrict outcomes. The South Asian Association for Regional Cooperation (SAARC) Climate Change Action Plan lists coastal agricultural adaptation among its priorities, yet ongoing national disputes and financial shortages have allowed only small-scale pilot projects (SAARC Secretariat, 2023). The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) encourages collaboration on the blue economy, with two pilot undertakings implemented so far mangrove rehabilitation in Bangladesh and aquaculture expansion in Myanmar but no sites within Pakistan have yet been chosen (BIMSTEC Annual Report, 2024). Research linkages have connected the Pakistan Agricultural Research Council with the Bangladesh Rice Research Institute and Can Tho University in Vietnam through regional workshops. One such training session held in Dhaka in 2023 on integrated rice–fish systems involved 120 extension staff, later leading to field trials in Thatta district during 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) provides large-scale infrastructure investments valued at USD 60 billion through 2030, including development of Gwadar Port, construction of national highways, and establishment of energy pipelines (Ministry of Planning, Development and Special Initiatives, 2023). To ensure benefits for agriculture, careful integration is required. A memorandum signed in 2024 between the Gwadar Port Authority and Sindh Agriculture Department seeks to create cold chain facilities with the capacity to handle 5 000 tonnes of perishable crops every year (Pakistan Business Council, 2024). Rail connectivity under CPEC has shortened transport time between Gwadar and Karachi by two days, reducing vegetable and fish transport costs by 25 percent (Pakistan Railways Annual Report, 2023). Yet agro-processing facilities inside the Gwadar Free Zone are not developed, which restricts broader economic benefits for coastal farmers and producers.

8.3 International Development Cooperation

Global financial institutions continue to fund coastal adaptation through targeted programs. The World Bank has provided a USD 150 million loan under the Sindh Coastal Resilience Project to finance drainage for 20 000 hectares and extension outreach for 80 000 farmers (World Bank Project Appraisal Document, 2023). The Food and Agriculture Organization (FAO) allocated USD 20 million through its Coastal Fisheries Initiative to train 5 000 aquaculture farmers during 2023–2026 (FAO Pakistan, 2024). In 2022, the International Fund for Agricultural Development (IFAD) committed USD 25 million to build 1 000 rainwater harvesting ponds, serving nearly 15 000 households across Balochistan (IFAD Programme Design Report, 2022).
In addition, Japan International Cooperation Agency (JICA) supported a USD 30 million project in 2023 that strengthened cyclone early warning capacity on the Sindh coast (JICA Project Completion Report,

2023). The European Union invested USD 15 million in 2024 for solar irrigation systems across Lasbela district in Balochistan (EU Delegation to Pakistan, 2024).

8.4 South–South Cooperation and Technology Transfer

South–South partnerships enable shared learning across developing nations. The International Atomic Energy Agency (IAEA) trained 50 soil experts from 12 countries at the Nuclear Institute for Agriculture and Biology (IAEA Annual Report, 2024). During 2023, Pakistan exported 200 tonnes of salinity-resistant rice seed to Bangladesh and Egypt, generating export earnings of USD 2 million for the Pakistan Seed Council (Pakistan Seed Council, 2024).
An example of reverse transfer occurred through exposure visits to the Netherlands Delta Programme, where Pakistani representatives studied dike financing mechanisms. Insights from these visits inspired a pilot fund for levee repairs in Thatta district, financed collectively by local communities.

8.5 Best Practices from Comparable Contexts

Experiences from other deltas offer lessons relevant for Pakistan. In the Barisal region of Bangladesh, five salinity-resistant rice cultivars released between 2010 and 2020 achieved adoption by 80 percent of 150 000 coastal farmers, cutting yield losses by 60 percent (Bangladesh Rice Research Institute, 2021). Vietnam's Mekong Delta introduced community-managed irrigation that improved household farm earnings by 50 percent (Vietnam Ministry of Agriculture and Rural Development, 2022). The Netherlands Delta Programme finances dike upkeep through a public-private insurance pool, funded by 0.1 percent of gross domestic product, illustrating a durable model for infrastructure sustainability (Netherlands Delta Programme, 2023).

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Chapter 9: Success Stories and Case Studies from Coastal Pakistan

9.1 Indus Delta Rehabilitation and Saline Agriculture

Work conducted at the Biosaline Research Station in Pakka Anna restored 5 000 hectares of degraded coastal land through the planting of Atriplex shrubs together with salt-tolerant barley. Soil electrical conductivity declined from 15 dS/m to 6 dS/m within three years (IAEA Annual Report, 2024). The introduction of barley line PK-30118 among 2 000 cultivators in Thatta raised harvests by 60 percent compared with conventional crops under saline stress (Jamshoro Biosaline Research Station, 2022).

9.2 Drought-Resistant Farming in Balochistan

In Lasbela district, orchard farmers adopted 500 solar-powered drip irrigation systems, which produced 50 percent efficiency gains in water use and 40 percent higher yields (Global Center on Adaptation, 2022). Restoration of 1 200 kilometers of traditional karez (qanat) water networks rejuvenated 1 200 hectares of farmland, revived 300 family-based holdings, and lowered seasonal outward migration by 25 percent (FAO Pakistan, 2024).

9.3 Women-Led Community Adaptation

Women's self-help groups in Thatta introduced 150 shared vegetable plots using saline-tolerant seed varieties, raising household dietary diversity scores by 30 percent (United Nations Development Programme, 2023). On-farm duck–fish integration across 50 women-managed fields generated an additional PKR 18 000 for each household per growing season, strengthening both nutrition and earnings (Sindh Coastal Resilience Project, 2022).

9.4 Integrated Aquaculture Innovations

The Al-Karam shrimp enterprise began operations on 400 acres in 2023, producing 2 500 tonnes of shrimp valued at USD 8 million and employing 1 200 staff members (Pakistan Biodiversity Coalition, 2024). At the same time, smallholder rice–fish production systems in Sujawal yielded net incomes of PKR 35 000 per hectare in contrast to PKR 20 000 per hectare under rice alone, proving the financial advantage of diversified farming (Pakistan Biodiversity Coalition, 2024).

9.5 Private Sector Value Chain Development

During 2024, seed firms worked with the Pakistan Agricultural Research Council to distribute 50 000 packets of saline-tolerant rice seed across 10 000 hectares, which lifted adoption levels by 25 percent among coastal cultivators (Seed Association of Pakistan, 2023). Additionally, an aquafeed producer released a new formula suitable for brackish water that secured 15 percent of the Balochistan market in only six months, highlighting quick market absorption (Industry News Bulletin, 2024).

9.6 Innovation Hubs

The Coastal Adaptation Symposium hosted by the Nuclear Institute for Agriculture and Biology in 2023 convened 200 experts, decision-makers, and farming representatives. This initiative spurred ten fresh pilot projects that included solar irrigation applications and halophyte horticulture testing (NIAB Annual Report, 2023). Meanwhile, the Coastal Research Centre at the University of Karachi incubated five technology

startups in water-saving methods, two of which attracted private funding worth 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 clear understanding of policy shortcomings is necessary to guide effective planning. The National Climate Change Policy does not include a specific mandate for coastal agriculture, leading to divided responsibilities between federal and provincial institutions with limited coordination. Provincial agriculture departments also function without dedicated Coastal Agriculture Cells, reducing their ability to deliver programs locally. Current budget allocations for adaptation reach only USD 100 million annually, covering less than 20 percent of estimated requirements, and are distributed through several ministries, creating duplication and delays (Government Budget Report, 2025). In addition, insecure land tenure in coastal areas discourages investment, as small farmers lack secure long-term leasing arrangements (Land Reform Commission Report, 2024). Monitoring and evaluation mechanisms are also weak, with no real-time dashboard or external impact evaluations to guide adaptive management.

Creation of a National Coastal Agriculture Authority within the Ministry of Climate Change would establish centralized oversight for finance, research, and policy by December 2026 (Ministry of Climate Change Establishment Plan, 2024). This body should employ experts in agronomy, hydrology, economics, gender, and financial management to lead integrated coastal adaptation programs.

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

Land tenure reform should provide long-term secure leases in designated coastal zones so that smallholders can invest in infrastructure and soil improvement.

10.2 Place-Based Strategies for Sindh

Thatta, Badin, and Sujawal require adaptation strategies that address salinity and waterlogging, including:

i. Expansion of salt-tolerant seed distribution across large areas by 2030, supported by farmer field schools and demonstration plots (Sindh Agriculture Department Action Plan, 2025).
ii. Widespread use of solar-powered drip irrigation by 2035, with public subsidies to reduce farmer energy and water costs (Sindh Energy Sector Plan, 2024).
iii. Strengthening of coastal embankments through geotextile tubes and mangrove barriers to protect farmland from storm surges (National Coastal Protection Plan, 2025).
iv. Creation of an Agro-Processing and Cold Storage Cluster near Karachi by 2027 to reduce post-harvest losses and connect producers with export markets.

10.3 Place-Based Strategies for Balochistan

Lasbela and Gwadar face challenges of scarce water and weak market access. Recommended actions include:

i. Rehabilitation of traditional karez systems by 2030 to restore irrigation and lower groundwater extraction costs (Balochistan Irrigation Master Plan, 2024).
ii. Construction of community-scale rainwater ponds by 2035 to capture rainfall, provide household supply, and recharge aquifers (Provincial Water Board Report, 2024).
iii. Development of a Gwadar Coastal Agro-Processing Zone by 2027 equipped with cold storage, solar dryers, and direct port access (Gwadar Free Zone Authority Plan, 2024).

10.4 Technology Innovation and Research Agenda

Priority areas for research and innovation are as follows:

i. Development of crop varieties with tolerance to salinity, drought, and heat through genomic selection and high-throughput screening, releasing multi-stress cultivars by 2030 (Pakistan Agricultural Research Council Research Agenda, 2025).
ii. Deployment of precision agriculture across coastal farms by 2030, integrating satellite monitoring from SUPARCO with soil-sensor networks (SUPARCO Technical Strategy, 2024).
iii. Pilots of mangrove-agriculture buffer corridors in Thatta and Gwadar by 2035 to evaluate protective and productivity benefits (Mangroves for the Future NSAP, 2013).
iv. Documentation and integration of indigenous ecological knowledge of crops, water systems, and seasonal indicators through participatory research.
v. Community-managed conservation agriculture plots combining crop rotation, organic amendments, and improved agronomic techniques.
vi. Establishment of Living Laboratories in Thatta and Lasbela where local farmers, elders, and researchers co-design agroecological systems based on local biodiversity for soil fertility, pest control, and microclimate regulation.

10.5 Financing and Investment Mobilization

A diverse financing plan should mobilize USD 1 billion by 2030:

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

10.6 Institutional Strengthening and Capacity Development

Key steps for institutional development include:

i. Formalization of the National Coastal Agriculture Authority with regional offices in Karachi and Quetta by 2026, and launch of a Coastal Adaptation Leadership Program for 200 mid-career professionals by 2027 (Ministry of Climate Change Establishment Plan, 2024).
ii. Embedding of Provincial Coastal Agriculture Cells in Sindh and Balochistan departments by 2025, staffed with field officers for extension, monitoring, and engagement (Provincial Gazette Notifications, 2024).
iii. Creation of a Coastal Adaptation Research Network by 2027 linking ten universities with competitive grants for cross-disciplinary research (Higher Education Commission Initiative, 2024).

10.7 Phased Implementation Approach

Phase 1 (2025–2028):

i. Institutional and governance structures established.
ii. Pilot technology deployments and infrastructure restoration initiated.
iii. Monitoring dashboard launched.

Phase 2 (2029–2033):

i. Scaling of seed distribution and irrigation modernization.
ii. Expansion of water rehabilitation systems and completion of processing zones.

Phase 3 (2034–2040):

i. Fulfilment of all program targets and execution of independent evaluations.

10.8 Monitoring, Evaluation, and Adaptive Management

Adaptive governance requires:

i. A real-time monitoring dashboard covering crop yields, water efficiency, soil salinity, equity indicators, and household livelihood outcomes, updated monthly (National Technology and Innovation Strategy, 2025).
ii. Independent evaluations every three years by third-party organizations using mobile surveys of 50 000 farmers, feeding into adaptive adjustments (Policy Practice Monitoring Framework, 2025).

10.9 Conclusion

A comprehensive framework that combines globally recognized practices with Pakistan-specific innovations can transform the coastal plain into a resilient agricultural system. Addressing gaps through strong institutions and secure tenure, scaling technologies from advanced sensors to traditional methods, and mobilizing varied financing will build long-term resilience. Tailored place-based interventions for Sindh and Balochistan ensure local effectiveness, while phased implementation with robust monitoring provides adaptive flexibility. Success will require collaboration among federal, provincial, private, and community stakeholders to safeguard livelihoods and maintain productivity under shifting climate conditions.

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