

ADVANCE SOCIAL SCIENCE ARCHIVE JOURNAL
Available Online: https://assajournal.com
Vol. 05 No. 01. Jan-March 2026.Page# 8511-8520
Print ISSN: 3006-2497 Online ISSN: 3006-2500
Platform & Workflow by: Open Journal Systems
https://doi.org/10.5281/zenodo.23671591

Agricultural Vulnerability and Food Security in Coastal Sindh

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Abstract
Coastal Sindh, comprising the Indus Delta districts of Badin, Thatta, and Sujawal, faces compounding pressure from collapsing freshwater flows, seawater intrusion, and recurrent floods and cyclones. This paper combines published studies, Integrated Food Security Phase Classification (IPC) district tables, and official records reported in the national press to assess how these pressures translate into food insecurity. Flow below Kotri Barrage fell from 155.36 billion cubic metres in 1959 to 0.32 in 2002, and cultivable land in Thatta shrank by about 58 percent between 1988 and 2018. In a survey of household heads in Badin and Thatta, 90.5 percent cultivated less land than in the previous season. IPC data show that 25 percent of Badin's and 20 percent of Sujawal's analysed population were in Phase 3 (Crisis) or worse in December 2025–March 2026. A Coastal Concentration Ratio, introduced here, shows that the delta districts hold about 15 percent of Sindh's analysed population but 28–32 percent of its current Phase 4 (Emergency) population and about 58 percent of its projected Phase 4 population; the ratio stays above one even at the lower edge of IPC's rounding band. A district vulnerability matrix exposes evidence gaps, notably Thatta's absence from the 2025–26 IPC analysis. The paper proposes a four-pillar resilience agenda: restoring environmental flows, adapting agriculture to salinity, targeting nutrition-sensitive social protection, and building early-warning systems.

Keywords: *Coastal Sindh, Food Security, Indus Delta, Agricultural Vulnerability, Climate Resilience.*

1. Introduction

In a river delta, food security depends on a single physical boundary: the interface between freshwater and the sea. When that boundary moves inland, arable land turns saline, groundwater

becomes undrinkable, mangroves and fisheries decline, and households lose the farm, fishing, and livestock incomes through which they command food (FAO, 1996; Sen, 1981). The Indus Delta shows this process clearly. Annual flow below Kotri Barrage fell from 155.36 billion cubic metres (BCM) in 1959 to 0.32 BCM in 2002, and the active delta is now about one-tenth of its original extent (Kalhoro et al., 2016). Cultivable land in Thatta fell from 116,928 acres in 1988 to 48,787 acres in 2018, a decline of about 58 percent (Mahar & Zaighiam, 2019, as cited in Sayeed, Adil, & Mallah, 2024).

These slow losses are compounded by acute shocks: about 23 percent of Badin was inundated in the 2022 floods (Qamer et al., 2023), and Cyclone Biparjoy led to the evacuation of 84,610 people in 2023 (Provincial Disaster Management Authority [PDMA], as cited in Sayeed et al., 2024). Yet national and provincial studies of household food insecurity report results at larger scales (Aziz, Iqbal, & Butt, 2016; Ullah et al., 2023), and studies of the delta focus on hydrology and land rather than food outcomes. As a result, the food-security burden of the delta districts has not been measured against the rest of Sindh. This paper is a secondary-data synthesis that addresses this gap with three objectives:

- To document how hydrological change and recurrent floods and cyclones have affected agriculture and livelihoods in Badin, Thatta, and Sujawal.
- To measure the burden of acute food insecurity and malnutrition in these districts and test whether severe food insecurity is concentrated in the coastal belt relative to the rest of Sindh.
- To reconcile the reported estimates of land lost to seawater intrusion across sources and talukas, and to establish a plausible range for the loss.

2. Background

The FAO's four pillars (availability, access, utilization, and stability) and Sen's (1981) entitlement approach both apply in the delta: salinity removes land from production, falling farm and fishing incomes weaken access, poor water quality undermines utilization, and repeated floods and storms erode stability. Household studies in Pakistan find that economic capacity rather than national food supply is the binding constraint (Iram & Butt, 2004), and that large families, high dependency ratios, low education, and single-income dependence raise vulnerability, with Sindh the most food-insecure province studied (Aziz et al., 2016).

Evidence specific to the delta is concentrated in a few sources. Kalhoro et al. (2016), using a literature review and field surveys in 2013–14, report dry-season salinity reaching 84 km upstream, erosion of about 0.179 km per year at the delta mouth, and a decline of mangroves from 650,000 to about 400,000 acres, of which only about 125,000 acres were healthy (Asian Development Bank, 2005, as cited in Kalhoro et al., 2016). Jagirani, Guriro, and Lakho (2021) surveyed 200 household heads in 20 villages of Badin and Thatta and linked seawater intrusion to lower income in a regression with $R^2 = 0.756$. Fatima, Alamgir, Khan, and Owais (2022) built climate–conflict vulnerability indices for the three districts, and Qamer et al. (2023) estimated 2022 flood losses from satellite data. Evidence on adaptation is thinner: Mobeen et al. (2025) surveyed 400 farmers in five Sindh districts, including Badin, and found that tree plantation (75 percent), canal dredging (74 percent), and agroforestry (72 percent) were the commonest measures, while rainwater harvesting (34 percent) was among the least adopted.

3. Data and Methods

The study is a desk-based synthesis. Evidence was assembled in October 2026 and ranked by reliability: peer-reviewed studies; IPC acute food insecurity analyses (published 21 February 2025 and 18 February 2026) and the IPC acute malnutrition analysis (published 17 April 2026); the technical report by Sayeed et al. (2024); and newspaper reports of official records, used only

where no stronger source exists and labelled as reported figures. Discrepancies between sources are reported rather than silently resolved.

Two indicators are computed from IPC district tables. Phase 3+ prevalence is the population in Phase 3 or worse divided by the population analysed. The Coastal Concentration Ratio (CCR) is the coastal districts' share of Sindh's population in a given phase divided by their share of Sindh's population analysed; values above 1 indicate over-representation. The coastal group is Badin, Thatta, and Sujawal in the November 2024–July 2025 cycle (IPC, 2025) and Badin and Sujawal in the December 2025–September 2026 cycle (IPC, 2026a), because Thatta was not re-analysed. Sindh totals are those of the districts analysed in each cycle, and shares use published population counts. Because IPC reports district percentages in 5-point steps, CCR is tested for sensitivity to rounding (Section 4.4). Projected figures are IPC expectations, not observed outcomes.

4. Findings

4.1 The delta has lost its water, land, and mangroves

Key finding: the delta has moved from a perennial to an episodic water supply, and reported land loss ranges from 1.2 to 2.2 million acres. Figure 1 shows that flow below Kotri fell to 0.32 BCM in 2002, only 0.2 percent of the 1959 value, and that flood years (112.50 BCM in 1994; 67.02 BCM in 2010) deliver water in short pulses rather than as dependable irrigation (Kalhoro et al., 2016). The 1991 Water Accord stipulates 12 BCM below Kotri. Seawater advances in the intervals between pulses, and the pulses themselves arrive as floods that damage standing crops.

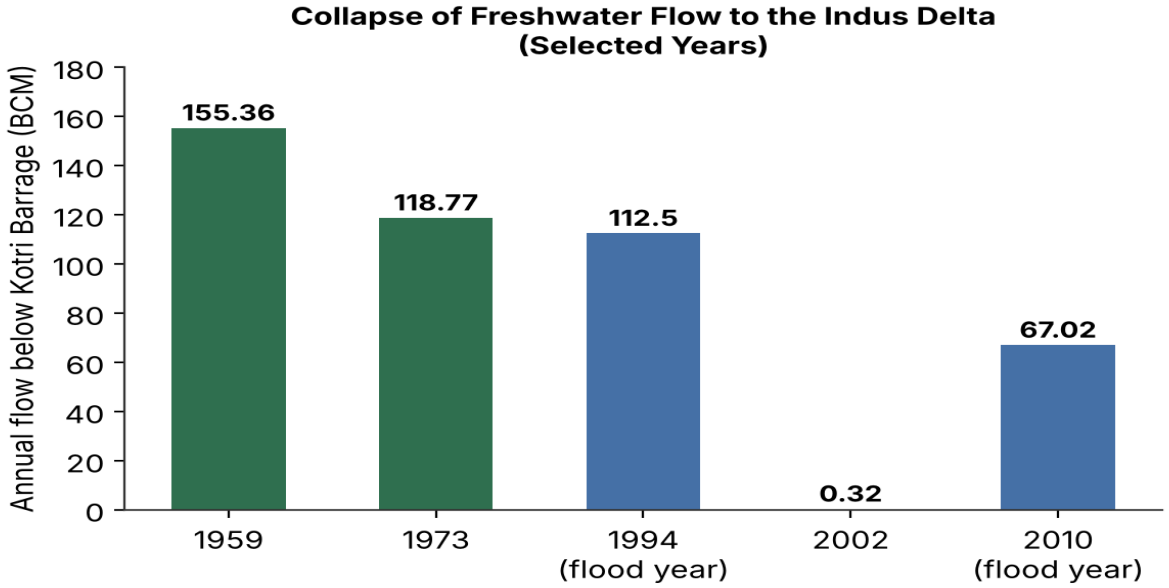


Figure 1. Annual freshwater flow below Kotri Barrage, selected years (BCM). Source: constructed from Kalhoro et al. (2016).

Two series estimate the resulting land loss (Table 1): IUCN estimates for 2003 summarized by Kalhoro et al. (2016) and Sindh revenue-department records reported by Khawaja (2025). The revenue records place about 1.32 million acres in three Sujawal talukas (about 60 percent of their area) and about 170,000 acres in three Thatta talukas, a total of about 1.49 million acres. A 2019 estimate by the Pakistan Council of Research in Water Resources of about 2.2 million acres, relayed by Memon and Soomro (2025), has no stated geographic scope. Taken together the estimates bracket the loss at 1.2–2.2 million acres. Within Sujawal the geography of loss appears to have shifted toward Kharo Chhan and Jati, while Keti Bunder and Ghorabari show almost identical figures across two decades, which may indicate stabilization or reliance on legacy records.

Table 1. Sea-encroached land by taluka in two reported series

Taluka (district)	IUCN (2003), acres	Revenue records (2025 report), acres	Share of taluka area (computed)
Shah Bandar / Bunder (Sujawal)	590,000	518,895	70.5%
Jati (Sujawal)	226,663	405,000	46.1%
Kharochhan / Kharo Chhan (Sujawal)	117,823	400,000	67.2%
Keti Bandar / Bunder (Thatta)	113,900	114,208	—
Mirpur Sakro (Thatta)	60,178	about 23,930	—
Ghorabari (Thatta)	31,490	32,060	—
Total	**1,219,858 (eight talukas)**	**1,494,093 (six talukas)**	—

Sources: Kalhoro et al. (2016), citing IUCN (2003); Khawaja (2025). Shares are computed from the acreage and taluka areas reported by Khawaja (2025). The IUCN total includes Badin (49,179 acres) and Golarchi (30,625 acres). Khawaja (2025) states 46% for Shah Bunder, which matches its share of submerged dehs (43 of 92, or 46.7%) rather than of land; the land share implied by its acreage is 70.5%. The report's headline of 1.2 million acres is below the sum of its own taluka figures, which are used here.

4.2 Livelihoods and shocks are eroding the income base

Key finding: households lose both principal income sources at once. In the Badin–Thatta survey, agriculture (51.5 percent) and fishing (34.5 percent) supplied 86 percent of main income, while 90.5 percent of respondents reported less cultivated land, 95 percent lower farm produce, 82.5 percent smaller fish catches, and 87 percent lower income; wage labour (3 percent) offered little offset (Jagirani et al., 2021). The sample is small and self-reported, but it agrees with the hydrological evidence. Fatima et al. (2022) rank Badin highest on overall climate–water conflict vulnerability and sensitivity, Thatta highest on climate–agriculture conflict vulnerability, and Sujawal weakest in adaptive capacity.

Floods add acute losses. Sindh's expected 2022 production losses were 80 percent for rice, 88 percent for cotton, and 61 percent for sugarcane (Qamer et al., 2023). Badin alone had 23.41 percent of its area inundated and expected losses of 320,844 tonnes of rice, 94,432 bales of cotton, and 1,156,688 tonnes of sugarcane, equal to about 17, 3, and 11 percent of the Sindh totals; Thatta's expected losses were 49,470 tonnes, 16,942 bales, and 424,746 tonnes, and Sujawal has no published values. Cyclone Biparjoy caused far smaller crop damage (over 1,000 acres) but required 84,610 evacuations, showing that large-scale pre-emptive evacuation is feasible in the delta (PDMA, as cited in Sayeed et al., 2024).

4.3 Food insecurity is higher and more persistent in the delta

Key finding: Phase 3+ prevalence in the delta districts is at or above the Sindh average in every period, and Badin shows no improvement. Table 2 and Figure 2 show Badin at 25 percent in both cycles, Sujawal improving from 25 to 20 percent, and Thatta at 20 percent when last analysed. Badin and Sujawal retain 5 percent of their populations in Phase 4 even in the projected periods, when the Sindh-wide share is projected to fall to 1 percent. IPC attributes conditions in Sindh to high food and fuel prices, limited market access, damaged infrastructure, livestock losses, new household debt, and the lingering effects of the 2022 floods and 2024 monsoon rains (IPC, 2025), with the 2025 monsoon floods and drought added in the later cycle (IPC, 2026a).

Table 2. IPC acute food insecurity classification of the delta districts and Sindh totals (people; percentage of population analysed)

District	Population analysed	Phase 3+ (current)	Phase 4 (current)	Phase 3+ (projected)	Phase 4 (projected)
Cycle 1: current Nov 2024–Mar 2025; projected Apr–Jul 2025 (IPC, 2025)					
Badin	1,535,045	383,761 (25%)	76,752 (5%)	307,009 (20%)	76,752 (5%)
Thatta	904,312	180,863 (20%)	45,216 (5%)	180,862 (20%)	0 (0%)
Sujawal	760,368	190,092 (25%)	38,018 (5%)	152,073 (20%)	38,018 (5%)
Sindh (analysed)	21,354,669	4,314,570 (20%)	501,092 (2%)	3,840,438 (18%)	197,511 (1%)
Cycle 2: current Dec 2025–Mar 2026; projected Apr–Sep 2026 (IPC, 2026a)					
Badin	1,553,166	388,291 (25%)	77,658 (5%)	310,633 (20%)	77,658 (5%)
Thatta†	904,312	180,863 (20%)	45,216 (5%)	180,862 (20%)	0 (0%)
Sujawal	770,478	154,096 (20%)	38,524 (5%)	154,096 (20%)	38,524 (5%)
Sindh (analysed)	15,338,898	3,024,093 (20%)	418,808 (3%)	2,737,491 (18%)	201,646 (1%)

Sources: IPC (2025); IPC (2026a). † Thatta was not included in the December 2025–September 2026 analysis; its values are the November 2024–July 2025 IPC figures carried forward for comparison and are not new IPC estimates.

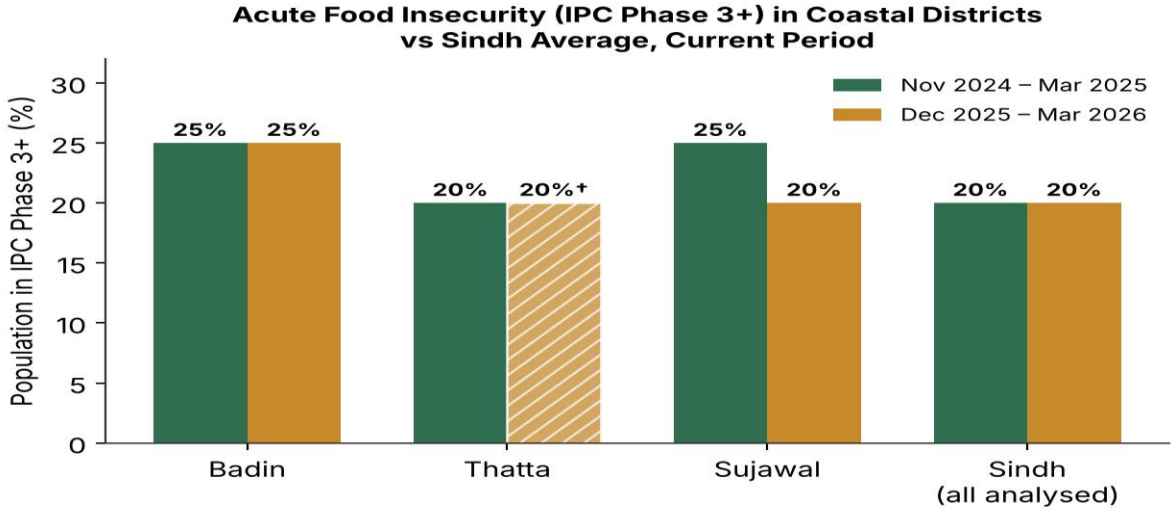


Figure 2. Population in IPC Phase 3+ in the delta districts and the Sindh average, current periods. Sources: IPC (2025); IPC (2026a). † Thatta's value is carried forward from the November 2024–March 2025 analysis (hatched bar).

4.4 Severe food insecurity is concentrated in the delta

Key finding: the delta districts hold about 15 percent of Sindh's analysed population but 28–32 percent of its current Phase 4 population and about 58 percent of its projected Phase 4 population**.** Table 3 pools the coastal districts. Phase 3+ prevalence is 23.6 percent against 19.6 percent in the rest of Sindh in the first current period, and 23.3 against 19.1 percent in the second.

For Phase 4 the CCR is 2.1 and 1.8 in the current periods and 3.9 and 3.8 in the projected periods (Figure 3). The ratio rises in the projected periods because Phase 4 is expected to recede elsewhere in Sindh but to persist at 5 percent of the population in Badin and Sujawal, which is what a structural rather than shock-specific cause would predict.

Period (districts)	Share of Sindh population	Phase 3+ prevalence: coastal vs rest of Sindh	Share of Sindh Phase 4	CCR	CCR at lower rounding bound
Current, Nov 2024–Mar 2025 (Badin, Thatta, Sujawal)	15.0%	23.6% vs 19.6%	31.9%	2.1	1.27
Projected, Apr–Jul 2025 (same)	15.0%	20.0% vs 17.6%	58.1%	3.9	2.73
Current, Dec 2025–Mar 2026 (Badin, Sujawal)	15.2%	23.3% vs 19.1%	27.7%	1.8	1.06
Projected, Apr–Sep 2026 (same)	15.2%	20.0% vs 17.5%	57.6%	3.8	2.67

Table 3. Coastal Concentration Ratio (CCR). Source: computed from IPC (2025) and IPC (2026a). CCR = coastal share of Sindh's Phase 4 population ÷ coastal share of Sindh's population analysed. The last column recomputes CCR with each coastal district's Phase 4 share at 2.5 percent, the lower edge of the 5-point rounding band, and all other districts unchanged.

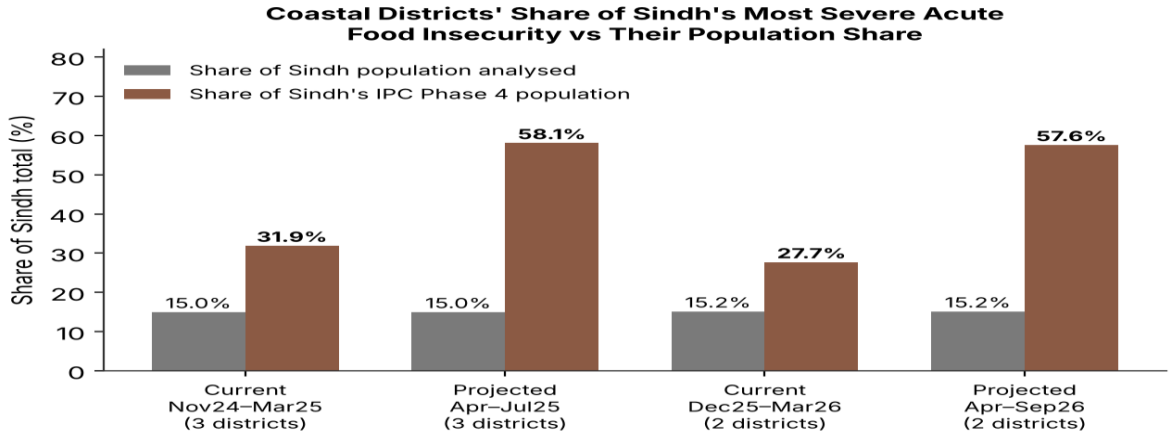


Figure 3. Delta districts' share of Sindh's IPC Phase 4 population versus their share of the population analysed. Source: computed from IPC (2025) and IPC (2026a).

Robustness. Because IPC reports district percentages in 5-point steps, the ratios were stress-tested. If every coastal district's Phase 4 share is set at the lower edge of its rounding band (2.5 percent) with all other districts unchanged, the CCR remains above 1 in all four periods (1.06–1.27 in current periods and 2.67–2.73 in projected periods). It falls below 1 (0.56–0.82) only if that is combined with every other district simultaneously sitting 2.5 percentage points above its reported value, an unlikely joint outcome. Carrying Thatta's earlier values forward into the second cycle gives a three-district CCR of 1.8 (current) and 2.9 (projected), close to the main results, so the finding does not depend on Thatta's exclusion.

4.5 Acute malnutrition shows the same severity

The IPC acute malnutrition analysis classified Badin and Sujawal in Critical (Phase 4) for October 2025–September 2026 (IPC, 2026b). Global acute malnutrition among children aged 6–59 months was 30.7 percent in Badin (145,373 children) and 20.1 percent in Sujawal (41,027

children); together they account for 15.8 percent of the 1.18 million acutely malnourished children across the 12 Sindh districts analysed, against 13.7 percent of those districts' under-five population. Concentration is milder than for food insecurity because 11 of the 12 districts are in Phase 4, so malnutrition is a province-wide emergency; the coastal feature is severity in Badin. Only 8.9 percent of children aged 6–23 months in Sindh receive a minimum acceptable diet, and IPC names poor water, sanitation, and hygiene among the drivers but gives no district-specific drivers (IPC, 2026b). Whether saline water contributes in the delta remains to be tested.

4.6 Evidence gaps are largest where exposure is high

Table 4 integrates the evidence by district. Badin is the best documented and among the most affected on most indicators. Thatta is missing from the latest IPC food-insecurity and malnutrition analyses, and Sujawal, where reported submerged land is largest, has no published flood-loss values. Planning that relies on available indicators would therefore understate risk in the districts with the thinnest data.

Table 4. District vulnerability matrix for coastal Sindh

Indicator	Badin	Thatta	Sujawal
Phase 3+ share, Nov 2024–Mar 2025	25%	20%	25%
Phase 3+ share, Dec 2025–Mar 2026	25%	20%†	20%
Phase 4 share, current (projected), Dec 2025–Sep 2026	5% (5%)	5%† (0%†)	5% (5%)
Acute malnutrition, Oct 2025–Mar 2026	Phase 4; GAM 30.7%	no IPC estimate	Phase 4; GAM 20.1%
2022 flood: share of district area inundated	23.41%	not reported	not reported
2022 flood: expected loss of rice (t); cotton (bales); sugarcane (t)	320,844; 94,432; 1,156,688	49,470; 16,942; 424,746	not reported
Submerged land, revenue records (acres)	not reported	about 170,198 (three talukas)	about 1.32 million (three talukas)
Climate–conflict vulnerability (Fatima et al., 2022)	Highest overall climate–water index and sensitivity	Highest overall climate–agriculture index	Weakest adaptive capacity

Sources: IPC (2025; 2026a; 2026b); Qamer et al. (2023); Khawaja (2025); Fatima et al. (2022). † Carried forward from the November 2024–July 2025 IPC analysis (see Table 2).

5. A Four-Pillar Resilience Agenda

Figure 4 summarizes the compound-stress pathway that the evidence supports. Reduced flows below Kotri, sea-level rise and storm surge, and episodic floods, heat, and drought act through salinity, habitat loss, and asset destruction to depress farm, fish, and livestock incomes, which leads to displacement and reduced food access and appears in the IPC classifications as elevated Phase 3 and Phase 4 populations and acute malnutrition. The channels interact: reduced flows affect both salinity and habitat loss, and floods damage assets directly and also reduce access by displacing households. The pathway is conceptual, assembled from the empirical links documented above rather than estimated as a model. Its implication is that interventions aimed at a single link, such as seed distribution or post-flood relief, will have limited effect because the drivers re-enter at several points.

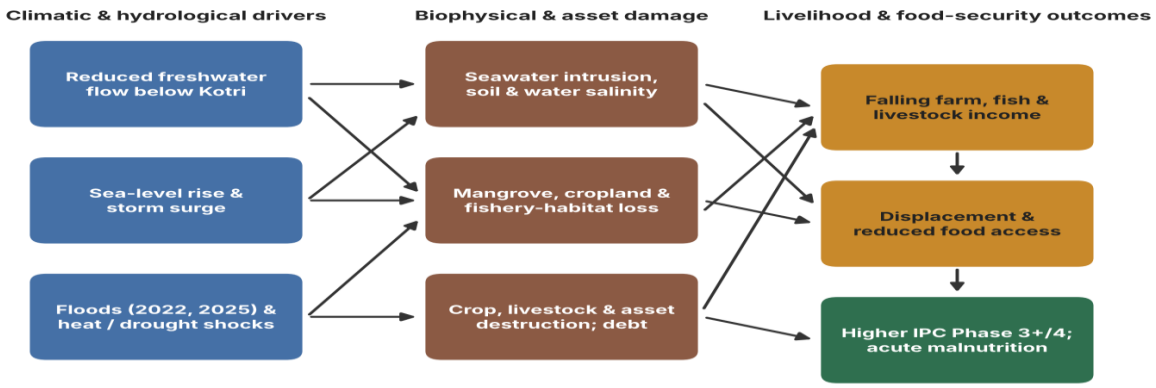


Figure 4. Compound-stress pathway linking hydrological and climatic drivers to food-security outcomes in coastal Sindh. Source: conceptual framework developed by the author from the evidence reviewed.

The findings therefore point to a combined agenda in which hydrological and ecological measures protect availability and stability, while social protection and nutrition services protect access and utilization (Table 5).

Table 5. Resilience agenda for coastal Sindh

Pillar	Priority action	Evidence / rationale
Availability	Restore environmental flows below Kotri toward the 12 BCM stipulated by the 1991 Water Accord	Flow fell to 0.32 BCM in 2002 and arrives mainly as flood pulses (Kalhoro et al., 2016)
Availability	Promote salt-tolerant cropping and agroforestry; expand mangrove regeneration and embankments in the worst-affected talukas	Soils with up to 20% salt patches suit wheat, maize, millet, and sorghum (Ashraf et al., 2022, as cited in Sayeed et al., 2024); Forest Department mangrove target of 350,000 ha (Sayeed et al., 2024)
Access	Diversify incomes beyond farming and fishing through skills and microenterprise support	Agriculture and fishing supply 86% of main income; wage labour only 3% (Jagirani et al., 2021)
Access	Target cash transfers, credit, and insurance using IPC classifications and the CCR, prioritizing Badin and Sujawal	Phase 4 persists at 5% in both districts in projected periods (IPC, 2025; 2026a); lack of finance cited by 69% of farmers across two provinces (Mobeen et al., 2025)
Utilization	Integrate treatment of acute malnutrition, infant feeding, and safe water and sanitation into delta health services	GAM of 30.7% in Badin and 20.1% in Sujawal; only 8.9% of children aged 6–23 months have a minimum acceptable diet (IPC, 2026b)
Stability	Build a delta early-warning system linking salinity monitoring with flood and cyclone evacuation	Seawater-intrusion monitoring began in 2021 in Badin, Thatta, Sujawal, and Karachi (Khan, 2023); 84,610 evacuated in 2023 (Sayeed et al., 2024)

Source: compiled by the author from the sources shown.

Three priorities follow. First, restoring flows is a basin-level governance question beyond the delta districts; local measures buy time but cannot substitute for it. Second, production-side measures

should be combined with access-side measures, because households that have lost land and fishing income will not automatically benefit from higher output. Third, targeting should be dynamic: successive IPC cycles and the CCR should guide resources toward districts where Phase 4 persists, and IPC analyses should include Thatta in every cycle. Sindh revenue records on submerged land should also be published at taluka level with their definitions and reconciled with satellite measurements, and flood-loss assessments should report Sujawal.

6. Conclusion

Coastal Sindh is where Pakistan's food-security problem is most directly shaped by the boundary between river and sea. Flow below Kotri collapsed from 155.36 to 0.32 BCM, cultivable land in Thatta fell by about 58 percent, and reported land loss ranges from 1.2 to 2.2 million acres. The delta districts hold about 15 percent of Sindh's analysed population but 28–32 percent of its current and about 58 percent of its projected Phase 4 population, and Badin's Phase 3+ prevalence stayed at 25 percent across two consecutive IPC cycles. The Coastal Concentration Ratio and district vulnerability matrix introduced here make both the concentration of risk and the gaps in evidence visible. The main limits are the study's reliance on secondary data, IPC's rounding conventions, and Thatta's exclusion from the latest IPC cycle. Household surveys in Thatta and Sujawal, salinity–yield functions, and cost-effectiveness comparisons of mangrove restoration and embankments are the most useful next steps.

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