Л.Н. Гумилев атындағы Еуразия ұлттық университетінің ХАБАРШЫСЫ.
BULLETIN of L.N. Gumilyov Eurasian National University.
ВЕСТНИК Евразийского национального университета имени Л.Н. Гумилева.
ISSN: 2616-7034. eISSN: 2663-130X

IRSTI 34.35.33
Research article

https://doi.org/10.32523/2616-7034-2025-152-3-147-165

Biological and socioeconomic implications of seawater intrusion on coastal agroecosystems

I.A. Bozdar[1], R. Ahmed[1], A.B. Chachar*[1], R.N. Malano[1], H. Magsi[1], A.A. Mahesar[1]

[1]*Department of Agricultural Economics, Faculty of Agricultural Social Sciences, Sindh Agriculture University, Tandojam, Pakistan*

Abstract. Seawater intrusion (SWI) has emerged as a critical environmental and socioeconomic challenge in the coastal belt of Badin District, Pakistan. This study investigates the impacts of SWI on rural livelihoods, food security, and migration through household surveys and socioeconomic profiling. Findings reveal that agriculture remains the dominant livelihood, engaging 55% of respondents, yet declining freshwater availability and salinization have degraded nearly 22% of cultivated land, reducing crop productivity and livestock resources. Average monthly household income (Rs. 17,042) barely exceeds expenditures (Rs. 16,072), leaving families highly vulnerable to food insecurity. Poor infrastructure, limited access to healthcare and safe water, and exploitative credit systems further exacerbate poverty. Natural hazards, including floods, unseasonal rains, and storms, compound the impacts of SWI, while the malfunctioning Left Bank Outfall Drain (LBOD) has intensified land degradation and crop loss. Consequently, migration has become an adaptive strategy, with over 100 households relocating from affected union councils due to declining agricultural opportunities. The study underscores that SWI is not only an ecological issue but also a driver of socioeconomic instability, poverty, and rural–urban migration. Urgent policy interventions such as regulated freshwater releases downstream of Kotri Barrage, rehabilitation of LBOD, embankment reinforcement, and stricter industrial effluent management are essential to mitigate SWI impacts and safeguard food security. These findings highlight the pressing need to integrate climate adaptation, sustainable water management, and community resilience into national strategies for coastal development.

Keywords: seawater intrusion, food security, coastal livelihoods, land degradation, district Badin, Sindh

Introduction

Seawater intrusion (SWI) is a growing environmental challenge in coastal regions worldwide, posing serious risks to human health, agricultural productivity, and sustainable economic

Received: 21.09.2025. Accepted: 30.09.2025. Available online: 30.09.2025.

Corresponding author: abdulbasit.mk678@gmail.com

development [1,2]. The problem is intensified by climate change, unsustainable agricultural practices, and over-extraction of groundwater, which disrupts the freshwater–saltwater balance and degrades soil and water resources [3–6]. As a result, SWI reduces freshwater availability, contaminates aquifers, and undermines food production in many vulnerable regions. Coastal communities in developing countries are particularly exposed due to their heavy dependence on natural resources [7,8]. In Pakistan's Sindh province, Badin district provides a striking case where agriculture, supporting over 70% of the population, faces increasing stress from salinity intrusion and rising temperatures. Productive farmland has been degraded, crop yields have declined, and food insecurity has intensified as household incomes drop [9,10].

Food security, which includes the dimensions of availability, access, utilization, and stability [11–13], is directly threatened in SWI-affected areas. Salinization reduces agricultural output and food availability, while inflation and unemployment constrain household access to food [14–16]. These pressures are compounded by poor education, weak market access, and limited livelihood opportunities, which reinforce chronic poverty and vulnerability.

The Sindh coastal belt, stretching across Badin and Thatta, illustrates these interlinked challenges. Freshwater flow downstream of Kotri Barrage has sharply declined from 400 million tons of nutrient-rich silt annually to nearly 100 million tons, leading to severe salinity intrusion and hyper-saline conditions (40–50 ppt compared to 15–20 ppt a few decades ago) [17]. Badin, one of the most hazard-prone districts, has been repeatedly affected by cyclones, floods, droughts, and heavy rains, leaving communities with degraded land, contaminated water, and weakened livelihoods [18]. The consequences are profound: nearly 1.2 million acres of farmland in Sindh have been rendered unproductive, aquifers have been contaminated, and rural households face migration, indebtedness, and increased exposure to waterborne diseases such as malaria and cholera [19]. Women and children are disproportionately affected, as freshwater scarcity increases the burden of labor, reinforcing poverty and inequality [20,21].

Against this backdrop, the present study investigates the socioeconomic impacts of seawater intrusion on livelihoods, infrastructure, and food security in the coastal belt of Sindh, with particular focus on Badin and Shaheed Fazil Rahoo Talukas. By analyzing household conditions, economic activities, and social vulnerabilities, this research seeks to provide evidence-based insights for designing adaptive strategies and policy interventions aimed at strengthening food security and resilience in Pakistan's coastal communities.

Materials and research methods

Research Design

The study adopted a mixed-methods approach, integrating both quantitative and qualitative techniques to comprehensively analyze the socioeconomic effects of seawater intrusion on food security and rural livelihoods. Primary and secondary sources of information were utilized to strengthen the validity and reliability of the findings.

Study Area and Sampling

The research was conducted in District Badin, Sindh, one of the most severely affected regions by seawater intrusion. Two talukas were purposively selected based on their exposure to salinity and livelihood dependency on agriculture and fisheries. From each taluka, two union

councils (UCs) were selected, and 14 households from each UC were surveyed using a stratified random sampling method, resulting in a total of 56 respondents.

Data Collection

Primary Data

Primary data were collected through structured questionnaires, key informant interviews (KIIs), and focus group discussions (FGDs). The pretested questionnaire (Annexure 1) included modules on household demographics, income and expenditure, agriculture, health, education, migration, assets, and the effects of seawater intrusion on livelihoods and food security. KIIs were conducted with community leaders, government officials, and NGO representatives, while FGDs were organized to capture community perspectives and triangulate findings.

Secondary Data

Secondary data were obtained from published reports, government records, academic literature, and documents from relevant organizations such as the Government of Sindh, International Union for Conservation of Nature (IUCN), Worldwide Fund for Nature (WWF-P), UN agencies, Asian Development Bank (ADB), and NGOs including Pakistan Fisherfolk Forum (PFF) and Rural Support Programmers (RSPs). These sources were used to develop a socioeconomic profile of the area and contextualize the impact of seawater intrusion in relation to past natural disasters and climatic variations.

Socioeconomic Indicators

Socioeconomic characteristics of respondents were examined to assess their influence on household vulnerability and food insecurity. Key indicators included family size, education, household income, access to health facilities, food and non-food expenditures, housing, agriculture and non-agricultural occupations, water supply, and sanitation.

Data Analysis

Quantitative data were entered in Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive and inferential statistics were applied

Results

District Badin

The district derives its name from the headquarters town of Badin. District Badin is spread over a geographical area of 6,726 square kilometers. The district is administratively divided into 5 talukas, 46 union councils, and 511 dehs. Two talukas of Badin district (Badin and Shaheed Fazil Rahoo) are coastal, being geographically located on the eastern periphery of Sir Creek.

Table 1

Taluka-wise geographic area of the district Badin

S. No.	Name of Taluka	Area in (sq km)
1	Badin	1763.200
2	Matli	1056.480

3	Shaheed Fazil Rahoo	1572.340
4	Talhar	804.127
5	Tando Bago	1513.640

Badin Taluka occupies the largest area (1,763 km^2), followed by Shaheed Fazil Rahoo (1,572 km^2). Together, these two coastal Talukas represent nearly 49 % of the district's total area (Table 1). Their economies are highly vulnerable due to the degradation of natural resources such as land, water, and forestry.

Infrastructural Damages

Frequent natural disasters and reduced Indus River flows have facilitated significant seawater intrusion reported up to 30-50 km inland. A 2001 survey by the Sindh Irrigation and Power Department and the Board of Revenue found that in the Badin and Shaheed Fazil Rahoo Talukas, 10 dehs (35,785 acres) were completely eroded and 22 dehs (44,046 acres) were partially affected by seawater [22].

Table 2

Land degradation due to Seawater intrusion in Badin

Taluka	Total Dehs	Total Area (acres)	Dehs Fully Eroded (acres)	Dehs Partially Affected (acres)	Total Area Affected (acres)
Shaheed Fazil Rahoo	102	440,504	1 (6,772)	5 (23,853)	30,625
Badin	140	352,681	4 (28,986)	6 (20,193)	49,179
Total	242	793,185	5 (35,758)	11 (44,046)	79,804

Socio-Economic Characteristics of Respondents

Demographic Profile

Table 3 presents the descriptive socioeconomic characteristics of the respondents. The average age of respondents was 40.78 years (SD = 12.72), with a minimum of 20 years and a maximum of 65 years. The average household size was relatively large, with 10.85 members per family, ranging from 2 to 30 members. On average, households comprised 5.19 male members (range: 1–14) and 5.66 female members (range: 1–16), indicating a slightly higher proportion of females compared to males. The number of working members in each household was limited, averaging only 2.19 members (range: 1–5). Thus, a relatively greater ratio of female members was noted as compared to male members in our research study area.

Table 3

Descriptive socioeconomic characteristics of the respondents

Family size	Average	Minimum	Maximum
Age	40.78	20	65

Total family members	10.85	2	30
Male in Household	5.19	1	14
Female in Household	5.66	1	16
Working member in HH	2.19	1	5

Education

Education is considered as most important indicator for the socio-economic development of any society. It is commonly believed that through the literacy ratio of any community, we understand the social structure of that society. Results in the above figure (Figures 1 and 2) reveal that the education level of respondents was recorded as 10.71% Bachelors (B.A. and B.Sc.), 10.71% were intermediate, 12.5% were matriculation, 23.21% primary, and 42.86% of respondents were illiterate in the study area.

Housing features

In rural areas, housing features reflect the economic dynamics of households with respect to rural development. In this research, it is recorded that (Figure 1a and b) about 77% households were dwelling in wood-made houses in our study area, where 12% people were living in semi-kacha houses, while the rest, 5% in kacha houses, 4% in pacca homes, and 2% people were residing in Jhopra houses.

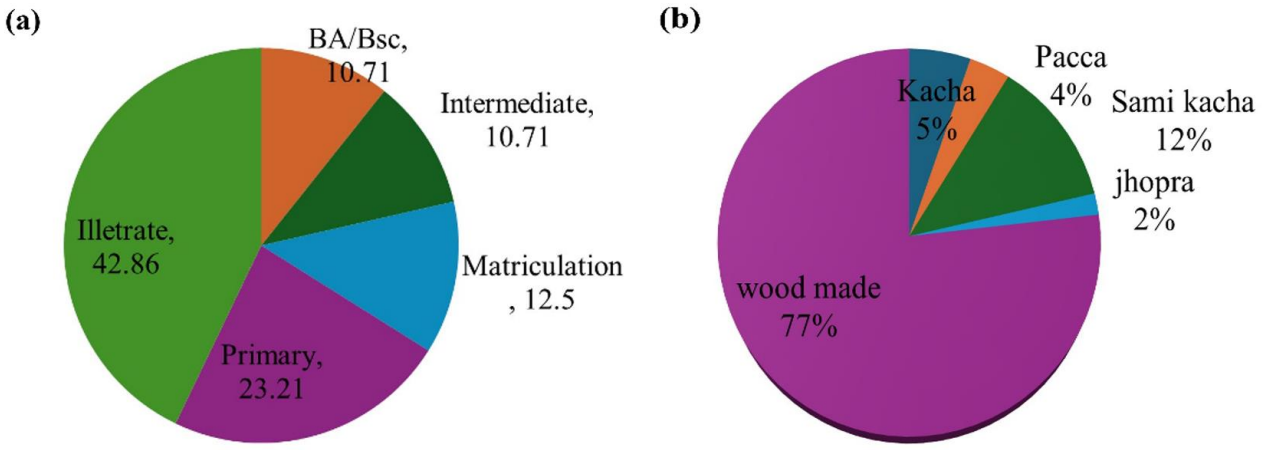

Figure 1. (a) Literacy ratio of respondents in percentage, **(b)** Household classification

Main sources of income

During the research study, it was noted that (Table 4) the coastal area peoples' livelihoods were mainly dependent on agriculture and livestock. In fact, fishing, wage labor, government employment, and small-scale private business were partially sources of their income of study area peoples. The Average/percentage households' sources of income were agriculture 55.36 (55.83%), livestock 18.93 (19%), fishing 3.21 (3%), wage labor 10.71 (11%), government employee 10 (10%), and 1.78 (2%) people used to do their own business.

Table 4

Primary and secondary Sources of income

Sources	Percentage
Agriculture	46
Livestock	16
Fishing	3
Wage Labor	9
Government Employer	24
Business	2

Monthly income of respondents

It was revealed that respondents relied primarily on agriculture and livestock as their major sources of income, while other livelihood options such as fishing, wage labor, government employment, and small-scale business played a relatively minor role (Table 5). Among all income sources, agriculture contributed the highest share, with an average monthly income of Rs. 9,412, ranging widely from Rs. 833 to Rs. 70,000. Livestock followed, contributing an average of Rs. 2,275 per month. In contrast, fishing and wage labor generated relatively lower returns, averaging Rs. 437 and Rs. 1,223 per month, respectively. Income from government employment stood at Rs. 3,428 per month, while business activities contributed the least, with only Rs. 267 per month on average. These results highlight that agriculture remains the economic backbone of the study area. However, the heavy dependence on low-return sectors such as wage labor and fishing, coupled with minimal earnings from private business, reflects limited livelihood diversification and weak entrepreneurial development, thereby exposing coastal households to greater socioeconomic vulnerability.

Table 5

Monthly income of respondents

Sources	Average	Minimum	Maximum
Agriculture	6500	833	70000
Livestock	2275	300	15000
Fishing	437	2500	15000
Wage labor	1223	1000	10000
Government Employee	3428	9000	25000
Business	267	1500	12000

Land holding and its use pattern

Pakistan is primarily an agricultural country, and rural communities largely depend on farming for their livelihoods. In the study area, the majority of households were engaged in land cultivation, making agriculture the dominant economic activity. The findings (Table 6) show that, on average, households cultivated 25.47 acres (69%) out of a total 36.73 acres (100%)

of landholding. However, approximately 7.92 acres (22%) of agricultural land have been lost due to seawater intrusion, while an additional 3.33 acres (9%) remained fallow for various reasons, such as lack of inputs, irrigation issues, or salinity problems. The landholding size varied considerably among respondents, ranging from a minimum of 2 acres to a maximum of 200 acres per household.

Table 6

Land use pattern

Description	Average	Minimum	Maximum	S.D
Total farm size	36.73	2	200	32.11
Cultivated	25.47	2	120	21.86
Fallow land	3.33	1	30	8.74
Seawater effected	7.92	6	80	13.64

Tenancy status

Field observations (Figure 2) revealed that the majority of respondents (76%) owned agricultural land, which served as their primary source of income. In contrast, approximately 20% of households were tenants cultivating land on lease, while a smaller proportion (4%) shared their land with neighbors either on a rental basis or under fixed-term contractual arrangements.

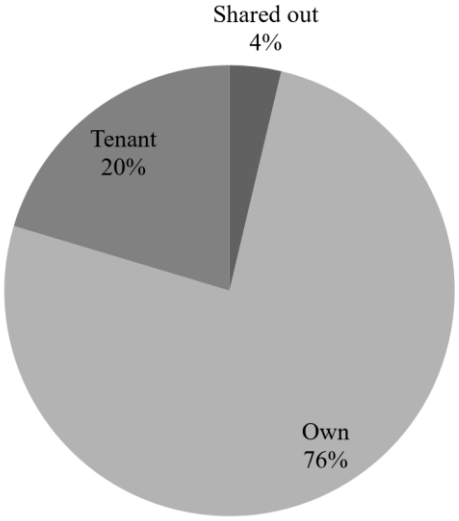

Figure 2. Tenancy status

Power sources

In rural areas of Pakistan, tractors have largely replaced bullocks as the primary source of power for agricultural activities. Traditionally, bullocks played a vital role in conventional farming systems, particularly for tillage and transportation. However, in the study area, the results (Figure 3) show that 96% of households cultivated their land using rented tractors, while only 2% owned tractors or relied on bullocks for land preparation and cultivation purposes.

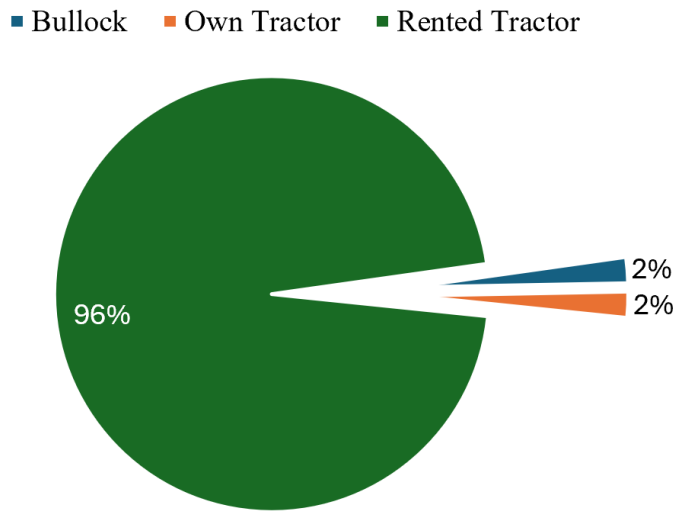

Figure 3. Power sources

Animals kept by households

Livestock plays a crucial role in the national economy, contributing 53.2% to agricultural value added and 11.4% to the national GDP during 2009–10 (GOP, 2013; SCCDP, 2012). Findings from the field survey (Table 7) indicate that, in the study area, households owned on average 2.32 sheep/goats and a similar number of buffaloes. The average number of cows was 1.82 per household, while the presence of bullocks and donkeys was negligible (0.01 each on average). The number of livestock per household varied widely, ranging from a minimum of 1 to a maximum of 20 animals.

Table 7

Animals per household

Sources	Average	Minimum	Maximum	S.D
Sheep/Goat	2.32	1	15	7.92
Buffalos	2.37	1	15	8.32
Cow	1.82	1	20	7.55
Bullock	0.01	1	2	7.55
Donkey	0.01	1	1	7.55

Budget and expenditure

The analysis of household budgets provides insights into the income utilization patterns and socio-economic priorities of rural families in the study area. Results show that food was the dominant expenditure head, accounting for the majority of household spending. On average, 67% of total income was allocated to food items, leaving a relatively smaller share for education, health, utilities, and other needs. Apart from food, significant expenditures were also made on clothing, land preparation, and agricultural inputs such as fertilizers, insecticides, and seeds. Less frequent but important expenditures included the purchase of agricultural implements,

livestock, and house construction. Details of household major expenditures are presented in Table 8.

Table 8

Household major Expenditures in general items

Particulars	Frequency	Ranking
Food	56	1
Clothing	56	1
Land Preparation	51	2
Fertilizer/Insecticide/Seed	50	3
Agriculture Implements	40	4
Animal Purchasing	1	5
House Construction	1	5

A more detailed breakdown of monthly expenditure indicates that the average household spent Rs. 7,830.42 on food, Rs. 912.50 on education, and Rs. 767.85 on mobile communication. Expenditure on health care averaged Rs. 558.92, while ceremonies and social functions accounted for Rs. 730.35 per month. Expenditure on animal feeding (Rs. 428.57), utilities (Rs. 303.57), travel (Rs. 502.85), and washing (Rs. 424.10) were also recorded. Non-essential expenses, including junk food (Rs. 502.85) and smoking-related items, were observed in several households. The details are summarized in Table 9.

Table 9

Household Food and Non-Food Expenditures per Month in Rupees

Particulars	Average	Minimum	Maximum	S.D
Food	7830.4	3000	20000	4071.91
Education	912.5	200	6000	1405.1
Utility	303.57	200	2000	434.64
Health	558.92	200	2000	402.31
Junky	502.85	300	3000	699.09
Ceremonies	730.35	500	2000	731.01
feeding	428.57	500	10000	1723.52
Drinking Water	0.11	500	500	9292
Mobile	767.85	200	5000	913.19
Travelling	502.85	720	3000	950.91
washing	424.1	100	1500	236.53

Household Assets

The distribution of major household assets among the respondents. Electrical assets form the largest share, accounting for 41 percent of total possessions, reflecting the importance of

appliances such as fans, televisions, and other electronic equipment in daily life. Motorcycles follow with 30 percent, indicating their role as a primary and affordable means of transportation. Weapons make up 13 percent, suggesting that many households keep arms for protection or cultural reasons. Jewelry represents 7 percent, serving both as an adornment and a form of savings. Freezers account for 6 percent, highlighting limited cold-storage capacity, while motor cars and tractors are least common, at only 2 percent and 1 percent respectively, showing minimal ownership of high-value transport and agricultural machinery. Overall, the data reveal a strong preference for practical assets that support mobility and household functionality, with comparatively low investment in larger or more capital-intensive equipment (Figure 4).

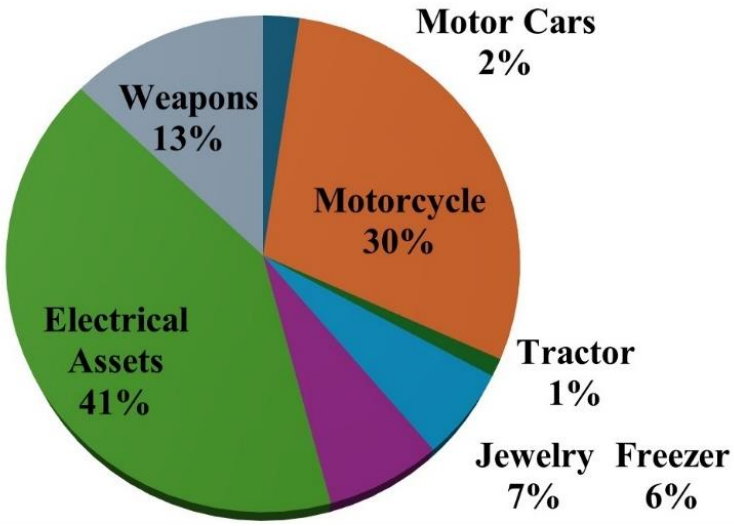

Figure 4. Household & agricultural assets possessed by respondents
Basic amenities available to the households

Households were also asked to share their opinion about whether they are availing basic facilities of life provided by the government. In response, most respondents reported that shops and roads were available and ranked them first (Table 10). Moreover, the School ranked as 2nd, Public transport as 3rd, Electricity as 4th, and Health center facilities on 5th ranking.

Table 10

Available basic facilities in the study area

Facilities	Percentage	Frequency out of 56	Ranking
Shop	73.21	41	1
Road	73.21	41	1
School	69.64	39	2
Public transport	66.07	37	3
Electricity	62.5	35	4
Health center	12.5	7	5

Loaning and credit facilities availed by the respondents

One proverb is popular in our society for the farming community is “Born in debt, lives in debt, and dies in debt.” This is a clear and pour picture of our country's farmer community. In this regard, the respondents were asked to provide data on the credit sources, where in response of the question, it is accounted that about 64% of respondents take loans from shopkeepers, 23% household from land lard, 9% from relatives, and 4% household depend on their friends (Figure 5). They were further asked that why percent of interest (commission) those lenders are demanding when you take loans from them, thus the response was 10% to 35% per year.

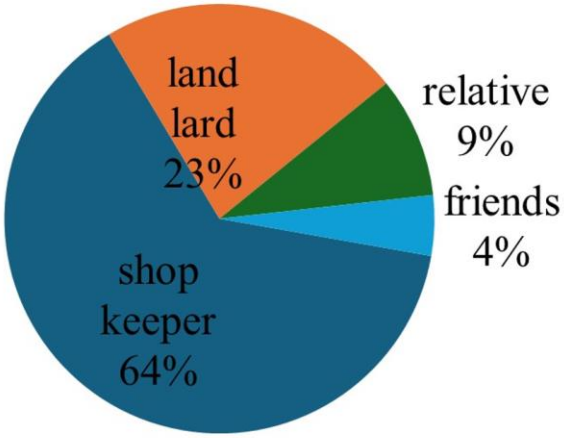

Figure 5. Credit facilities acquired by the respondents

Sea water intrusion impacts and food security challenges

This section is comprised over climate change impacts (in particular seawater intrusion) on rural poverty, migration of the local population, and food security challenges. Therefore, this study was designed to investigate that whether seawater intrusion in the coastal belts of Badin District is causing food insecurity and rural unrest in the study area.

Opinions on Climate Change

Respondents were asked specific questions regarding resource degradation and its perceived impacts on their livelihoods. The findings (Table 11) show that seawater intrusion and unseasonal rains were identified as the most destructive factors, reported by more than 50 respondents and ranked first. Storms were ranked second, followed by rural migration (third), high temperature (fourth), and heavy rainfall (fifth).

Table 11

Recent changes in the climatic felt by the respondents

Categories	Frequency	Ranking
Seawater intrusion increased	54	1
Unseasonal rain	54	1

Storm	45	2
Rural migration	40	3
High temperature	38	4
High Rain	19	5

Major issues and challenges faced by the respondents in the study area

Food is a fundamental human need, yet food insecurity has become one of the most pressing challenges in Pakistan, particularly in disaster-prone regions. The district of Badin has faced six major natural disasters in recent years, which have severely affected the livelihoods of its population. In this study, respondents were asked to identify the main issues contributing to food insecurity in the region. Their responses were summarized in Table 12. Results in Table 12 expose that natural disasters remained the main causes of food supply and lower agricultural and livestock productivity, followed by seawater intrusion, which has transformed agricultural lands into barren and water-logged lands. Badin, being in lower repine, there is unavailability of fresh water, which is ranked as 3rd and is pointed out by 45 respondents. Besides that, unemployment is also highlighted and ranked as 4th, which has lowered the income of the local population and caused starvation among many families, which is of course the result of a low level of education among them. Some of the households also signaled that in rainy seasons, the Left Bank Out-fall Drain (LBOD) has flowed inversely (from tell to head) and caused floods to local communities of Badin, which has not only washed their resources but also forced the local population to migrate from the region. A few of the households have also highlighted that food supply is in efficient in the region because of poor infrastructure and high prices of the food items.

Table 12

Main issues faced by the respondents in Badin and Shaheed Fazil Rahoo Talukas

Categories	Frequency	Ranking
Natural disaster	56	1
Seawater intrusion	51	2
Fresh water	45	3
Unemployment	37	4
Education	37	4
LBOD	27	5
High prices of food items	19	7
Infrastructure	19	7

Discussion

The findings of this research clearly indicate that seawater intrusion (SWI) is a major driver of rural poverty, food insecurity, and migration in the coastal belt of Badin District. The illiteracy rate in the study area was recorded at approximately 43 percent, which is lower than the national literacy level of around 50 percent [23]. With more than half of the respondents (55%)

engaged in agriculture and 19 percent in livestock rearing, it is evident that agriculture remains the backbone of the local economy. However, the average monthly household income was only Rs. 17,042, reflecting limited economic opportunities. Landholding patterns further reinforce inequality; although the average household owned 36 acres of land, with holdings ranging between 2 and 200 acres, this distribution is highly skewed. As highlighted by Hashmi [24], nearly 80 percent of agricultural land in Pakistan is controlled by just 5 percent of landlords, leaving smallholders and tenants highly vulnerable. In the study area, 76 percent of respondents reported owning land, while 20 percent were tenants.

The analysis also revealed the weak infrastructure and limited access to social services in coastal communities. Most households lived in wooden houses (77%) with an average household size of ten members. While basic facilities such as roads, schools, public transport, electricity, and shops were available in some villages, access to healthcare centers, drainage, and water supply systems remained inadequate [22]. To sustain livelihoods, 96 percent of respondents relied on rented tractors for cultivation. Livestock assets were minimal, averaging two goats/buffaloes and one cow per household. A critical challenge observed was the degradation of natural resources due to seawater intrusion. Approximately 22 percent of cultivated land had become degraded and barren because of rising salinity and waterlogging. This has directly reduced crop productivity, undermined the food supply, and pushed households deeper into poverty. Since agriculture is the dominant livelihood, the decline in cultivable land translates into lower incomes and higher levels of unemployment. Consequently, rural households are increasingly dependent on credit, primarily obtained from shopkeepers (64%) and landlords, often at exploitative terms.

The impacts of seawater intrusion are compounded by recurrent natural disasters such as floods, storms, and heavy rains. Respondents identified SWI, unseasonal rains, and storms as their primary sources of unrest, noting that these hazards not only destroy crops but also damage infrastructure and homes. Natural disasters were ranked as the leading cause of food insecurity, followed by seawater intrusion and lack of freshwater availability. The Left Bank Outfall Drain (LBOD) was highlighted as another critical challenge. Initially designed to lower the water table and salinity in upper Sindh, the project failed due to flawed design and frequent natural disasters. Instead of draining into the sea, brackish water accumulated in agricultural fields and water bodies of Badin, leading to widespread land degradation and crop losses. In 2003, the failure of LBOD caused the destruction of millions of acres of cultivated land. Even today, during floods, the drain continues to overflow, causing extensive damage in the district. Nearly 50 percent of respondents considered LBOD to be one of the most pressing problems in the region.

The socioeconomic implications of these environmental and infrastructural challenges are severe. Households reported an average monthly expenditure of Rs. 16,072, mostly on food (67%). Limited income opportunities, coupled with high expenditures, leave families with little scope for savings. In fact, food insecurity is escalating in Badin's coastal belt due to the unavailability of freshwater, degraded land resources, and rising food prices. Similar to other food-insecure regions such as Tharparkar, households in Badin are increasingly unable to meet their nutritional needs [25]. Migration is becoming a coping strategy; the study documented that 117 households had already migrated from just four union councils of Badin and Shaheed Fazil Rahoo talukas due to declining agricultural opportunities and lack of basic amenities. This trend poses alarming implications for rural stability, as migration disrupts social networks, increases urban poverty, and exerts pressure on urban infrastructure.

The study also underscores the larger context of climate change. Pakistan's agrarian economy is highly sensitive to rainfall variability, temperature fluctuations, and monsoon patterns. Seawater intrusion, unseasonal rainfall, and heatwaves collectively threaten agricultural production, livestock, forestry, and overall food security [26]. Previous studies suggest that simulation models, statistical approaches, land-use change analyses, and agro-climatic indicators can be used to assess and predict these impacts [27]. In this context, the challenges faced by Badin reflect broader national vulnerabilities to climate change and environmental degradation. Based on community feedback, several recommendations emerged for the sustainable development of the coastal belt of Badin. These include ensuring the release of sufficient freshwater downstream of Kotri Barrage, effective management and redesign of the LBOD system, reinforcement of embankments with stone pitching to prevent seawater intrusion, and stricter regulation of industrial effluents such as wastewater from sugar mills. Respondents emphasized that without urgent interventions, the combined effects of seawater intrusion, natural disasters, and poor resource management would continue to exacerbate poverty, migration, and food insecurity in the region.

Conclusion

This study demonstrates that seawater intrusion has critically undermined the socioeconomic fabric and food security of coastal communities in Badin. Agriculture remains the primary livelihood, with more than half of households engaged in farming and one-fifth in livestock rearing; however, 22% of cultivable land has been degraded by seawater intrusion, forcing many households to abandon farming or migrate. Livestock ownership remains modest (about two goats/sheep, two buffaloes, and one to two cows per household), yet feed scarcity due to salinity further limits productivity.

Households reported low literacy (43%), high dependence on rented machinery (96%), and limited incomes averaging Rs. 17,042 per month, barely sufficient to meet expenditures. Housing conditions are poor, with the majority (77%) living in wood-made houses, and the average household size is large (10 members). Migration of 117 households from four union councils illustrates the increasing unviability of farming-based livelihoods. Overall, seawater intrusion, coupled with poor water management and inadequate infrastructure, is driving poverty, livelihood insecurity, and food shortages in Badin. Without immediate interventions such as the release of freshwater downstream of Kotri, improved management of the Left Bank Outfall Drain, and protective embankments, food security and rural livelihoods in the coastal belt will remain under severe threat.

Author Contributions

I.A.B.: Conceived the study, contributed to the research design, and led the manuscript drafting. **R.A.:** Assisted in data analysis, provided critical revisions to the manuscript, and contributed to the interpretation of results. **A.B.C.:** Coordinated fieldwork, including participant surveys and interviews, and contributed to the analysis of socioeconomic impacts. **R.N.M.:** Contributed to data collection and analysis, focusing on environmental and land degradation aspects. **H.M.:** Assisted in literature review, data interpretation, and the discussion of findings on migration and food security. **A.A.M.:** Contributed to fieldwork logistics, survey coordination, and manuscript revision.

Funding
There is no funding.

Acknowledgments
We would like to express our sincere gratitude to all the respondents in the Badin District for their valuable time and participation in this study. We especially thank the Department of Agricultural Economics for their financial and logistical support. We also extend our appreciation to the local authorities, community leaders, and field assistants whose cooperation made data collection possible.

Conflicts of Interest
The authors declare that they have no competing interests

Compliance with ethical standards
The authors declare that there are no conflicts of interest regarding the publication of this paper. All research involving human participants was conducted in accordance with ethical guidelines and was approved by the relevant local authorities. Informed consent was obtained from all participants, and their anonymity was maintained throughout the study. Data collection was carried out with full consideration of the participants' rights and welfare.

References

1. Yang H, Sun H, Liu T, et al. Characterization of seawater intrusion based on machine learning and implications for offshore management under shared socioeconomic paths. J Hydrol. 2023;623:129862. doi.org/10.1016/j.jhydrol.2023.129862

2. Butt MN, Shah SK, Yahya FA. Caregivers at the frontline of addressing the climate crisis. Gender Dev. 2020;28(3):479–498. doi.org/10.1080/13552074.2020.1833482

3. Sharif Uzzaman M, Islam MR. Impacts of salinity intrusion on agriculture in the coastal region of Bangladesh. J Coast Conserv. 2024;28(6):79. doi.org/10.1007/s11852-024-01073-y

4. Talukder B, Schubert J, Tofighi M., et al. Complex adaptive systems-based framework for modeling the health impacts of climate. J Clim Chang Health. 2024;15:100292. doi:10.1016/j.joclim.2023.100292

5. Ding Z, Koriem MA, Ibrahim SM, et al. Seawater intrusion impacts on groundwater and soil quality in the northern part of the Nile Delta, Egypt. Environ Earth Sci. 2020;79(13):313. doi.org/10.1007/s12665-020-09069-1

6. Ding L, Li B, Zhang S. Development in researches on seawater intrusion of coastal areas. Mar Sci Bull (Haiyang Tongbao). 2004;23(2):82–87.

7. Brodie LP, Caballero SV, Ojea E, et al. A new framework on climate-induced food-security risk for small-scale fishing communities in Tanzania. Food Secur. 2024;16(5):1125–1145. doi.org/10.1007/s12571-024-01472-x

8. Makanjuola SA, Medupin C. Food and water security in developing economies: impact of pandemic and possible interventions. N Afr J Food Nutr Res. 2020;4(10):32–38. doi.org/10.51745/najfnr.4.10.S32-S38

9. Chi W, Yang Y, Zhang K, Wang P, Du Y, Li X, et al. Seawater intrusion induced cadmium activation via altering its distribution and transformation in paddy soil. Chemosphere. 2022;307:135805. doi.org/10.1016/j.chemosphere.2022.135805

10. Osewe M, Aijun L, Jiqin H. Sustainable intensification and food security: a panel data assessment of the smallholder maize farmers in Uganda. Glob Food Secur. 2023;39:100724. doi.org/10.1016/j.gfs.2023.100724

11.Altintzoglou T, Aschemann-Witzel J. Trade-offs in food systems: how does upcycling edible resources fit in the big picture? Trends Food Sci Technol. 2024;143:104246. doi.org/10.1016/j.tifs.2023.104246

12. Demelash SA, Alemu EA. Measuring food system sustainability in Ethiopia: towards a multi-dimensional perspective. Ecol Indic. 2024;161:111991. doi.org/10.1016/j.ecolind.2024.111991

13. Melesse MB, van den Berg M, Béné C, de Brauw A, Brouwer ID. Metrics to analyze and improve diets through food systems in low- and middle-income countries. Food Secur. 2020;12(5):1085–1105. doi.org/10.1007/s12571-020-01091-2

14. Olufemi-Phillips AQ, Igwe AN, Ofodile OC, Louis N. Analyzing economic inflation's impact on food security and accessibility through econometric modeling. Int J Green Econ. 2024;18(3):142–156. doi.org/10.30574/gscarr.2024.21.2.0411

15. Rasheed R, Ishaq MN, Akbar M. A correlation of socio-economic determinants and food security status in Pakistan. Pak J Humanit Soc Sci. 2022;10(1):416–425. doi.org/10.52131/pjhss.2022.1001.0206

16. Bununu YA, Bello A, Ahmed A. Land cover, land use, climate change and food security. Sustain Earth Rev. 2023;6(1):16. doi.org/10.1186/s42055-023-00065-4

17. Magsi H, Atif S. Water management, impacts and conflicts: case of Indus water distribution in Sindh, Pakistan. Int J Rural Stud. 2012;19(2):3–7.

18. Magsi H, Sheikh MJ. Seawater intrusion: land degradation and food insecurity among coastal communities of Sindh, Pakistan. In: Regional Cooperation in South Asia: Socio-economic, Spatial, Ecological and Institutional Aspects. Cham: Springer International Publishing; 2017. p. 209–223. doi.org/10.1007/978-3-319-56747-1_12

19. Ahmed A, Noonari TM, Magsi H, Mahar A. Risk assessment of total and faecal coliform bacteria from drinking water supply of Badin city, Pakistan. J Environ Prof Sri Lanka. 2013;2(1):52-64. doi.org/10.4038/jepsl.v2i1.5750

20. Narmcheshm S, Esmaillzadeh A, Babashahi M, Sharegh Farid E, Dorosty AR. Socioeconomic determinants of food insecurity in Iran: a systematic review. J Asian Afr Stud. 2024;59(6):1908–1960. 10.1177/00219096231161893

21. Simpson NP, Williams PA, Mach KJ, Berrang-Ford L, Biesbroek R, Haasnoot M, et al. Adaptation to compound climate risks: a systematic global stocktake. iScience. 2023;26(2). doi.org/10.1016/j.isci.2023.105926

22. Sindh Coastal Development Program (SCCDP). Baseline survey of coastal areas. Vol. 1. Main Final Report. Karachi: Sindh Coastal Development Authority; 2012.

23. Government of Pakistan (GOP). Pakistan Economic Survey 2013–2014 [Internet]. Islamabad: Economic Advisors Wing, Ministry of Finance; 2014. Available from: https://www.finance.gov.pk/survey/chapters_14/highlights_es_201314.pdf

24. Hashmi MS, Zhang J, Hashmi MS. Land distribution, technological changes and productivity in Pakistan's agriculture: some explanations and policy options. Management. 2011;1(1):51–74.

25. Arif M, Khalid N. Agriculture and food security in Pakistan. Lahore: South Asia Partnership–Pakistan; 2007.

26. IUCN. Mangroves of Pakistan: Status and management. Karachi: International Union for Conservation of Nature–Pakistan; 2005.

27. Khan MA, Khan JA, Ali Z, Ahmad I, Ahmad MN. The challenge of climate change and policy response in Pakistan. Environ Earth Sci. 2016;75(5):412. doi.org/10.1007/s12665-015-5127-7

Теңіз суының жағалаудағы агроэкожүйелерге енуінің биологиялық және әлеуметтік-экономикалық салдары

И.А. Боздар[1], Р. Ахмед[1], А.Б. Чачар*[1], Р.Н. Малано[1], Х. Магси[1], А.А. Махесар[1]
[1]Ауыл шаруашылығы экономикасы кафедрасы, ауылшаруашылық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Тандожам, Пәкістан

Аңдатпа. Теңіз суының енуі (ТСЕ) Пәкістанның Бадин ауданының жағалау аймағында маңызды экологиялық және әлеуметтік-экономикалық мәселеге айналды. Бұл зерттеу үй шаруашылығын сауалнамалар мен әлеуметтік-экономикалық профильдеу арқылы ауылдағы өмір сүруге, азық-түлік қауіпсіздігіне және көші-қонға ТСЕ әсерін зерттейді. Нәтижелер ауыл шаруашылығының негізгі күнкөріс көзі болып қала беретінін көрсетті, респонденттердің 55%-ы айналысады. Алайда, тұщы судың азаюы және топырақтың сортаңдануы өңделетін жерлердің 22%-ға жуығын нашарлатып, егістік өнімділігі мен мал басының азаюына әкелді. Үй шаруашылығының орташа айлық табысы (17 042 рупий) шығыстардан (16 072 рупий) әрең асып түседі, бұл отбасыларды азық-түлік қауіпсіздігіне өте осал етеді. Нашар инфрақұрылым, медициналық көмекке және қауіпсіз суға қол жетімділіктің шектелуі және пайдаланатын несие жүйесі кедейлікті одан әрі ушықтырады. Табиғи апаттар, соның ішінде су тасқыны, мезгілсіз жаңбырлар мен дауылдар ТСЕ әсерін күшейтеді, ал ақаулы сол жағалаудағы дренаж жүйесі (СЖДЖ) жердің тозуын және егіннің жоғалуын күшейтті. Нәтижесінде көші-қон жеңу стратегиясына айналды және 100-ден астам үй шаруашылықтары ауылшаруашылық мүмкіндіктерінің төмендеуіне байланысты зардап шеккен кәсіподақ кеңестерінен қоныс аударуға мәжбүр болды. Зерттеу ТСЕ тек экологиялық проблема ғана емес, сонымен қатар әлеуметтік-экономикалық тұрақсыздықтың, кедейліктің және ауылдан қалаға көші-қонның драйвері екенін көрсетеді. ТСЕ әсерін азайту және азық-түлік қауіпсіздігін қамтамасыз ету үшін шұғыл саясат шаралары қажет, мысалы, Котри бөгетінен төмен қарай реттелетін тұщы суды шығару, СЖДЖ қалпына келтіру, бөгетті нығайту және өнеркәсіптік ағынды суларды қатаң басқару. Бұл тұжырымдар климаттың өзгеруіне бейімделуді, су ресурстарын тұрақты басқаруды және қауымдастықтың тұрақтылығын жағалауды дамытудың ұлттық стратегияларына енгізудің шұғыл қажеттілігін көрсетеді.

Түйін сөздер: теңіз суының енуі, азық-түлік қауіпсіздігі, жағалаудағы өмір сүру құралдары, жердің деградациясы, Бадин ауданы, Синд

Биологические и социально-экономические последствия интрузий морской воды в прибрежные агроэкосистемы

И.А. Боздар[1], Р. Ахмед[1], А.Б. Чачар*[1], Р.Н. Малано[1], Х. Магси[1], А.А. Махесар[1]
[1]Кафедра аграрной экономики, Факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Тандоджам, Пакистан

Аннотация. Интрузия морской воды (ИМВ) стало критической экологической и социально-экономической проблемой в прибрежной зоне округа Бадин, Пакистан. В данном исследовании изучается влияние ИМВ на жизнеобеспечение сельского населения, продовольственную

безопасность и миграцию посредством опросов домохозяйств и социально-экономического профилирования. Результаты показывают, что сельское хозяйство остается основным источником существования, занимаясь 55% респондентов, однако сокращение доступности пресной воды и засоление почв привели к деградации почти 22% обрабатываемых земель, что привело к снижению урожайности сельскохозяйственных культур и сокращению поголовья скота. Среднемесячный доход домохозяйства (17 042 рупии) едва превышает расходы (16 072 рупии), что делает семьи крайне уязвимыми к отсутствию продовольственной безопасности. Неразвитая инфраструктура, ограниченный доступ к здравоохранению и безопасной воде, а также эксплуататорская кредитная система еще больше усугубляют бедность. Стихийные бедствия, включая наводнения, несезонные дожди и штормы, усугубляют последствия ИМВ, в то время как неисправная система левобережного стока (СЛС) усилила деградацию земель и потери урожая. В результате миграция стала адаптивной стратегией, и более 100 домохозяйств были вынуждены переселиться из пострадавших союзных советов из-за сокращения возможностей для ведения сельского хозяйства. В исследовании подчеркивается, что ИМВ является не только экологической проблемой, но и фактором социально-экономической нестабильности, бедности и миграции из сельской местности в города. Для смягчения последствий ИМВ и обеспечения продовольственной безопасности необходимы срочные меры политики, такие как регулируемый сброс пресной воды ниже по течению от плотины Котри, восстановление СЛС, укрепление дамбы и более строгое управление промышленными стоками. Эти результаты подчеркивают насущную необходимость интеграции мер по адаптации к изменению климата, устойчивого управления водными ресурсами и устойчивости сообществ в национальные стратегии развития прибрежных районов.

Ключевые слова: интрузия морской воды, продовольственная безопасность, прибрежные источники существования, деградация земель, округ Бадин, Синд

Сведения об авторах:

Ихсан Али Боздар – кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Риаз Ахмед – кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Абдул Басит Чачар – кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Раб Наваз Малано – кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Хабибулла Магси – профессор, кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Ахсан Али Махесар – кафедра аграрной экономики, факультет аграрных социальных наук, Сельскохозяйственный университет Синда, Дорога Мирпур-Хас, Тандо-Джем, 70050, Тандоджам, Пакистан

Авторлар туралы мәліметтер:

Ихсан Али Боздар – аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандожам, Пәкістан

Риаз Ахмед – аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандожам, Пәкістан

Абдул Басит Чачар – аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандоджам, Пәкістан

Раб Наваз Малано – аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандоджам, Пәкістан

Хабибулла Магси – профессор, аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандожам, Пәкістан

Ахсан Али Махесар – аграрлық экономика кафедрасы, Аграрлық әлеуметтік ғылымдар факультеті, Синд ауылшаруашылық университеті, Мирпур-Хас жолы, Тандо-Джем, 70050, Тандожам, Пәкістан

Authors' information:

Ihsan Ali Bozdar – department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan

Riaz Ahmed – department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan

Abdul Basit Chachar – department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan

Rab Nawaz Malano – department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan

Habibullah Magsi – Professor, department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan

Ahsan Ali Mahesar – department of agricultural economics, faculty of agricultural social sciences, Sindh Agriculture University, Mirpur Khas Road, Tando Jam, 70050, Tandojam, Pakistan