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Social and ecological climate change vulnerability assessment in the Indus delta, Pakistan

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ABSTRACT

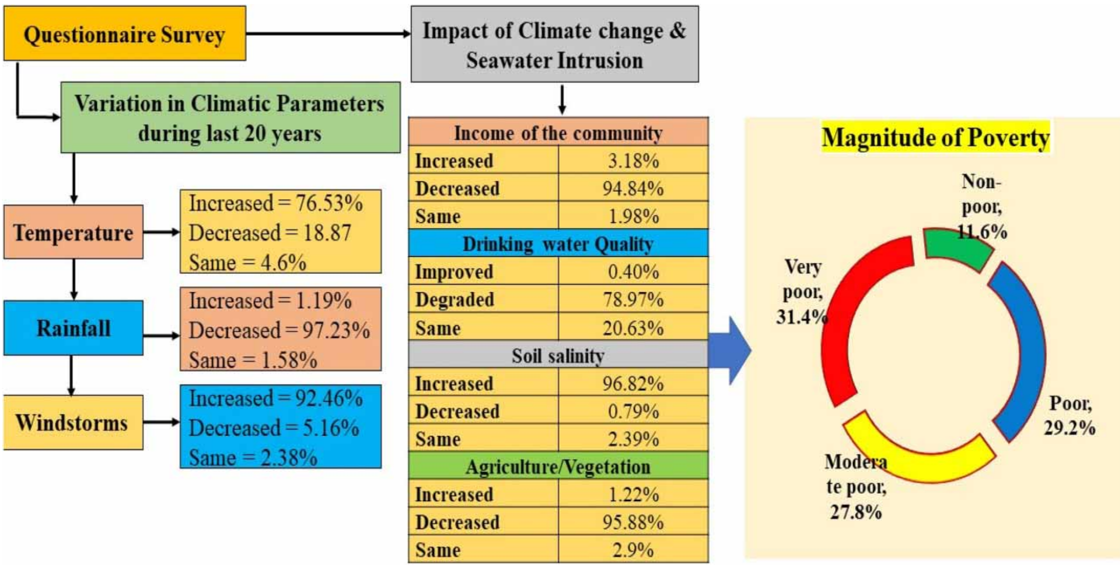
Due to seawater intrusion into the Indus delta, Pakistan under changing climate scenarios, the local communities of the delta are under threat of land and livelihood. The present study was initiated to analyze community perceptions about the social and ecological climate change vulnerability in the Indus delta, Pakistan. About 500 permanent residents of the delta were interviewed using a well-structured questionnaire. The IBM SPSS software was used to analyze the data based on the Pearson chi-square, Goodman, Kruskal's analyses, and Foster Greer Thorbeck (FGT) techniques. Analysis of the data revealed that the people in the delta had poor infrastructure and living standards, and limited social activities. Most of the people were illiterate, and the average family size was 11. On average, 4.7 members lived in a single room, and most of the houses were made of wood. Based on FGT techniques, about 88.4% of the population were living below the poverty line. The statistical analysis identified seawater intrusion and climate change as the most significant parameters affecting soil fertility, water quality, vegetation, mangroves, and livelihood. A large portion of the respondents strongly demanded the ensured freshwater flow to save the ecosystem, water resources, and the livelihood of the delta communities.

Key words: coastal communities, Foster-Greer Thorbeck techniques, Kruskal's analyses, livelihood, pearson chi-square and goodman, seawater intrusion

HIGHLIGHTS

- Statistical assessment for impact of seawater intrusion and climate change.
- Community-based perceptions.
- Application of Pearson chi-square and Goodman, Kruskal's analyses, and Foster Greer Thorbeck techniques.
- To prompt responsible policymakers to devise strategies for mitigation.

GRAPHICAL ABSTRACT



INTRODUCTION

Due to climate change impacts, arid and semi-arid areas of the world are at risk regarding water scarcity and land degradation (IPCC 2008). Pakistan has more than 220 million population, which ranks it the sixth-most populous country in the world. It is one of the most vulnerable countries to the impacts of climate change (Rasul *et al.* 2012), ranking the sixth country on the climate change vulnerability index. The erratic freshwater flows because of temporal and spatial variability in rainfall due to climate change are turning acres of fertile agricultural land into a wasteland and thus threatening the biodiversity of the major ecological zones of Pakistan. The incidents of frequent flooding and droughts in the country are also increasing with larger variability in monsoon rainfall patterns (Rasul *et al.* 2012). The Indus River is a lifeline of the country, and its flows are unpredictable, decreasing at a faster rate. It is expected that due to the changing climate scenario, the River Indus flows will further decrease. Hence, agriculture and food security in the country will suffer the most.

At the end of the current century, the expected rise in sea level is about 180 to 590 millimeters (Ninan & Bedamatta 2012). This rise will ultimately affect the Indus River delta, which is the seventh-largest delta in the world stretching over about 0.6 million hectares (Salik *et al.* 2016). The delta is said to be the most vulnerable to the climate change. It is reported that due to the construction of dams and reservoirs in the Indus River basin and diversion of excessive water for domestic, irrigation, and industrial purposes, fresh water supply to the Indus River delta is significantly decreased (Alamgir *et al.* 2015; Siyal *et al.* 2022). That has converted the fertile agricultural lands of the delta into salt-affected soils and fresh groundwater aquifers and surface water bodies of the area into brackish. The resulting seawater intrusion has also drastically affected the flora, fauna, and mangrove cover, threatened the biodiversity and badly affected the socioeconomic conditions of the community living in the delta (Alamgir *et al.* 2015; Laghari *et al.* 2015; Thomas 2015; Peracha *et al.* 2017).

Furthermore, residents of the Indus delta have numerous difficulties. Most of the places that were once thriving farming, fishing, and commercial networks have now been reduced to little towns (Rasul *et al.* 2012). Floods and waterlogging have also put adverse impacts on the human health and their animals. Diarrhea, dysentery, and respiratory infections are frequent in the area, as are climate-sensitive diseases including malaria and dengue fever (Rahman *et al.* 2017). Climate change affects human-environmental interactions, socio-ecology frameworks, and their activities (Jongman *et al.* 2014), which enable the production of food, fibre, and energy at various levels (Neil Adger *et al.* 2005). Climate stress, and a lack of ability to adapt and modify it are all indicators of the coastal socio-ecological system's vulnerability (Rahman & Miah 2013). Climate change, lack of resources, and a limited adaptation ability in the deltaic community, are worsening the vulnerabilities and posing challenges to long-term food production in the deltaic region of Sindh, Pakistan Rasul *et al.* (2012). As a result, the local communities in the Indus delta are shifting from their ancestral homes to safer locations in search of food and shelter (Mahar 2010; Alamgir *et al.* 2015; Solangi 2019).

A socioeconomic survey collects quantitative data on a region's social, economic, and demographic factors. Seawater intrusion, worsened by climate change is posing a growing threat to the socio-economic conditions of Pakistan's coastal areas (Rahman *et al.* 2017). In light of these facts, the current study was carried out to assess the social and ecological climate change vulnerability in the Indus delta, Sindh, Pakistan.

MATERIALS AND METHODS

Description of the study area

The Indus delta, one of the world's major deltas, is made up of 17 major creeks and so many smaller ones. It is located in the districts of Thatta and Sujawal in Pakistan's Southern Sindh Province (Figure 1). It has a dry tropical climate with an average annual rainfall of about 220 mm (Majeed *et al.* 2010). The temperature ranges between 23 to 29 °C (Majeed *et al.* 2010; Solangi *et al.* 2017; Solangi *et al.* 2018; Solangi *et al.* 2019a, 2019b, 2019c, 2019d, 2019e). The primary cropping seasons are Rabi and Kharif. The main crops farmed in delta fields are rice, sugarcane, wheat, and cotton. In the southeastern and southwestern regions of the delta, where there are fewer human activities, wetlands and marshy lands are common. The area was once famous for its richness, lush farmland, cash crops, and other resources. Now, it is regarded as one of the country's poorest places (Alamgir *et al.* 2015; Solangi 2019; Siyal *et al.* 2022).

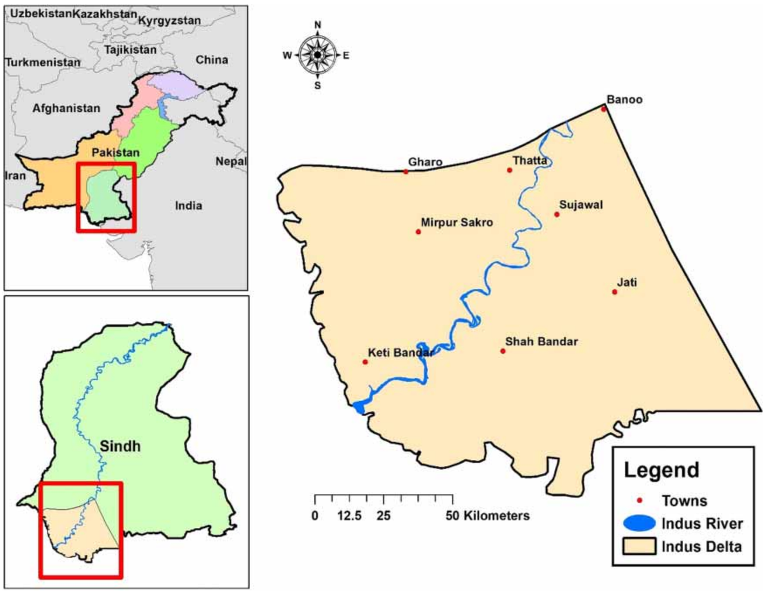


Figure 1 | Location map of the study area (Indus delta).

DATA AND METHODS EMPLOYED

To assess the social and ecological climate change vulnerability in the Indus delta, Sindh, Pakistan, a comprehensive Participatory Appraisal Survey was conducted through a well-structured questionnaire.

The sample size and selection of respondents

The appropriate sample size was determined using a rule developed by Cochran (1977) (Magsi & Sheikh 2017), as explained in Equation (1).

$$n_0 = \frac{x^2 pq}{e^2} \tag{1}$$

where n_0 is the sample size, x^2 is the abscissa of the normal curve that cuts off an area at 95%, x = 1.96, p is the expected proportion of an attribute in the population = 0.5, q = 1−p = 1 − 0.5 = 0.5, and e is the desired degree of precision of 0.05. Now,

$$n_0 = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = 384$$

Using the above calculation, it was determined that the sample size should not be less than 384, hence 500 respondents were randomly selected from the entire deltaic area for the present study.

Data collection and statistical tools employed

The study was conducted in all of the delta's union councils (local administrative divisions). As a result, it accurately represents the delta as a whole. The survey took into account the following factors:

a. Current and previous occupations, current and previous sources of income;
b. Socioeconomic analysis of changes in farm income (past and present), living habits, and any unusual diseases (not before encountered), etc.
c. Any unusual or adverse environmental conditions in comparison to previous circumstances,
d. Any perceived climatic changes by the community,
e. Any perceived understanding by the residents about climate change and seawater intrusion and its effects on their sources of income

The collected data was statistically analyzed using the Pearson chi-square and Goodman and Kruskal's analyses. The IBM SPSS 22 software package was used to analyze the data.

Measurement of poverty in the study area

The poverty levels in the study area were determined using Foster Greer Thorbeck procedures such as the headcount poverty index, the poverty gap, and the severity of the poverty index. These strategies are described in Equations (2)–(4).

$$P_{\propto} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^0 \quad (2)$$

$$P_{\propto} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^1 \quad (3)$$

$$P_{\propto} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^2 \quad (4)$$

The overall sample size is n, the number of poor people is q, the poverty line is z, and the lowest income is y_i. The headcount index calculates the percentage of the population who is poor, but it does not show how poor they are (Imran *et al.* 2013). The poverty-severity index, on the other hand, averages the squares of poverty gaps concerning the poverty line.

RESULTS AND DISCUSSION

After the collection of the required primary field data, it was arranged in tables using descriptive statistics as discussed under.

Socioeconomic characteristics of the respondents

According to the results of the study, each family had an average of 11 people. The average age of randomly interviewed respondents in this study was 43.8 years, with a minimum of 22 and a maximum of 87 years, as no respondent was chosen under the age of 20 years, as in Pakistan, a person of 18 years and above is considered as an adult. Figure 2 shows that respondents aged 30 to 40 years old made up 28% of the total surveyed respondents, followed by respondents aged 40 to 50 years old who made up 27% of the total surveyed respondents. Senior citizens from the Indus delta accounted for 10% of the respondents.

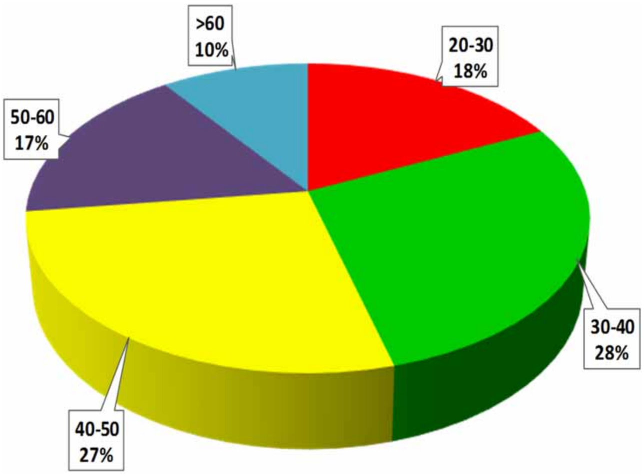


Figure 2 | Age group distribution of the respondents of the study area.

Mulyanto & Magsi (2014) reported that for interpreting the social structure of a society, education is also an important indicator. According to this study, the literacy rate in the study area was around 49.60%, with 8.73% having a graduate degree, the highest qualification in the area. Furthermore, the majority of the people lived in Katcha houses built of wood, whereas only 21.43% of the inhabitants lived in pucca cemented houses, according to the survey. A single room housed an average of 4.7 family members. The findings regarding socioeconomic charactersistics of the present study are comparable to those reported by Magsi & Sheikh (2017) in their investigation of the socio-economic conditions of individuals in Badin District, Sindh, Pakistan.

Income, expenditures, and sources of income

Overall, the study revealed that 39.29% of the respondents were engaged in agriculture, followed by those who were raising animals and fishing. However, about 15% of the people were engaged in government/private jobs; 16.67% engaged in fishing. It was also recorded that 6.35% were landlords, 12.7% were daily wages laborers who were facing hardships because on several days they did not get work. The rest of the population worked in small-scale, self-created businesses. Approximately 17% of respondents had a monthly income of less than Rs. 10,000; 66% had an income of between Rs. 10,000 and Rs. 30,000; 14% had an income of between Rs. 30,000 and Rs. 50,000; and only 3% had an income of more than Rs. 70,000, according to the present study (Figure 3). The majority of respondents complained about long periods of electricity load management (12–20 hours), a lack of health facilities, schools, potable drinking water, and bad road conditions, among other things. Magsi & Sheikh (2017) reported similar results for the coastal community of Badin, Sindh, Pakistan, in terms of

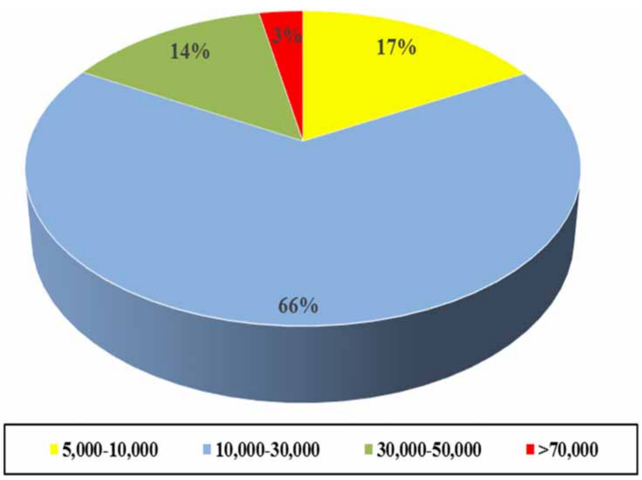


Figure 3 | Monthly income of the respondents.

socioeconomic factors. This survey discovered that 36.11% of the population consumes meals three times per day, whereas 63.89% consumes food just twice per day. This is one of the study's most alarming findings.

However, 55.16% of the population keeps animals, 42.86% keeps animals for milk, and the rest, 57.14%, rely on animals for their livelihood. According to the survey reports, 89.28% of the population cooks with wood, while only 10.72% utilizes gas connections and portable gas cylinders. The majority of them collect wood for themselves, although 3.87% spend Rs. 500–2,000 each month for wood for cooking. Table 1 shows that 44.45% of respondents do not have access to power/electricity. In addition, the majority of respondents said their income is insufficient to maintain their family. As a result, they frequently borrow money from numerous sources on varying terms and conditions to maintain their families.

Table 1 | Monthly income, expenditure, source of energy, roads, vehicle, agricultural lands, and livestock

Description	Statistics
Monthly Income and Expenditures	
Average per month income (Pak. Rupees)	19,137/-
Average per month expenditure (Pak. Rupees)	22,086/-
Sources of Energy	
Electricity	55.55%
Solar	11.91%
No source of energy	32.54%
Roads	
Katcha roads	44.44%
Pucca roads	50.0%
No road facility	5.56%
Vehicle	
Yes	50.0%
No	50.0%
Agricultural Lands	
Yes	48.8%
No	51.2%
Livestock	
Yes	55.16%
No	44.84%
Games	
Cricket	52.4%
Wanjhwati	9.13%
Foot/volleyball	5.55%
Not any game	32.92%

Climate change impacts

This section consists of describing climate change impacts, such as variations in rainfall patterns, temperature, wind storms, etc. as perceived by the community of the delta during the past 20 years.

When asked about climate change indicators, 76.53% of respondents said temperature has risen in the past 20 years (Figure 4). However, 97.23% of respondents said there was a downward trend in rainfall. During the summer, however, 92.46% reported increased wind velocity. Mahar (2010) reported that temperature increased, precipitation decreased, and the socio-economic conditions of the community are badly affected due to climate change and the entry of saline water from the Arabian Sea into the Indus delta. Hadwen *et al.* (2015); MacDonald *et al.* (2017); and Nelson *et al.* (2022) reported that extreme flooding and cyclones can damage infrastructure, threatening quality as well excess of fresh drinking water. According to Alamgir *et al.* (2015), a series of

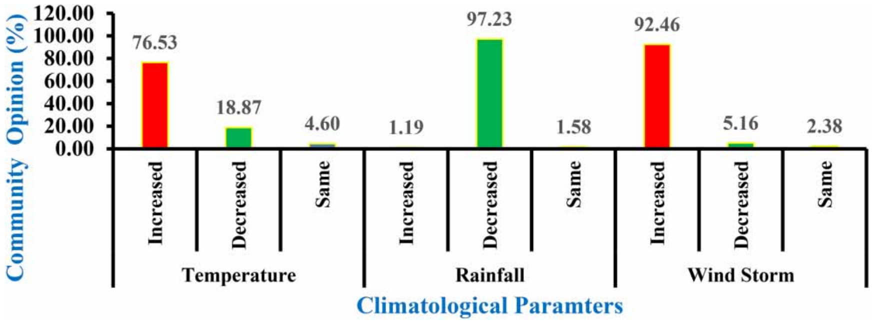


Figure 4 | Change in climatic parameters reported by the people during the past 20 years.

catastrophic climatological occurrences have caused disaster on the physical and biological habitats of Sindh's coast, as well as the community's socioeconomic conditions.

Seawater intrusion impacts

This section describes the effects of seawater intrusion on the Indus delta's water resources, vegetation, crop cover, yield, soil salinity, fishing, and mangrove cover over the past 20 years.

Groundwater is the primary source of drinking water in the research area (Solangi 2019). According to this study, 75.40% of the Delta population uses groundwater extracted through hand pumps and shallow boreholes. While 13.89% of people use surfacewater, 3.17% use water from various water delivery schemes, and 7.54%t use water from tankers. As potable water was once available near their communities at shallow depths, according to the majority of respondents. However, they now have to obtain drinking water 5–10 kilometres away from their villages, which is both time consuming and economically infeasible (Rahman *et al.* 2017). Due to the requirement to collect water and perform all home responsibilities, time management for women in the family becomes tough (Rahman *et al.* 2017). Furthermore, 40.1% of respondents indicated that groundwater has turned brackish due to seawater intrusion into aquifers, and 78.97% said that the taste of groundwater is getting worse with each passing day.

Khanom (2016) reported that due to climate change and seawater intrusion, salinity intrusion in groundwater and natural wetlands has been steadily growing. The survey revealed that 20.4% of the people suffered from gastro-intestinal disease, diarrhea, and chest and stomach problems. 14.8% were affected by skin diseases, 16.4% by hepatitis, 9.2% by cancer and 8.4% by cholera, diabetes, high blood pressure, heart, and kidney problems. Due to the use of contaminated water, insufficient quantity and quality of food, and a lack of healthcare services, the majority of the respondents reported that they are suffering from various diseases. Drinking of contaminated water can cause various diseases, such as: like diarrhea, indigestion, fever and other intestinal diseases (Solangi 2019). Salinity has a direct effect on stroke, left ventricular mass, stomach cancer, and many other disorders (He & MacGregor 2008). Common human ailments such as gastrointestinal distress, vomiting, diarrhoea, skin, and kidney problems, could be linked to low quality drinking water utilised by locals (Memon *et al.* 2011).

According to 96.03% of respondents, the inflow of highly saline water from the Arabian Sea into the delta has a negative influence on water supplies, agricultural fields, and crop yields, and eventually decreases the community's livelihood. The majority of participants said that these losses have become worse over the last 5–30 years. As a result, a number of families (about 15% of those surveyed) have relocated from their ancestral settlements to safer areas nearby cities/towns in search of food and shelter. Mahar (2010) reported that due to seawater intrusion, people are evacuating the traditional populated areas. Additionally, per acreage crop yield of agricultural lands is decreasing continuously, and the socio-economic conditions of the people are badly affected.

When asked about the main causes of seawater intrusion, 47.33% said it was due to a decrease in freshwater flow from the Indus River, while 4.11% said it was due to increasing sea levels. However, 25.51% said there was no flood protection along the Delta's shorelines. Deforestation of mangrove trees, building of the Left Bank Outfall Drain (LBOD), excavation of a tidal link canal, and destruction of Samandi Bandar were named as the main causes of coastal degradation by 18.1% of respondents.

Moreover, 94.84% of respondents (Table 2) reported that seawater has adversely affected their income. While asking about any change in cropping pattern during the past 20 years, 99.9% of the respondents reported no change in the cropping pattern. About 89.29% of the respondents reported there were not any mangrove forests in their area. However, 96.82% of the respondents said salinity in the delta has increased, and their agricultural practices are facing difficulties, due to higher levels of salinity, since increased salinity has an adverse impact on agricultural activities (Rahman *et al.* 2017).

Table 2 | The main issues faced by the people due to seawater intrusion

Description	Statistics
Impact on Income of the Respondents	
Increased	3.18%
Decreased	94.84%
Same	1.98%
Impact on the quality of drinking water	
Improved	0.40%
Degraded	78.97%
Same	20.63%
Impact on Soil	
Soil salinity increased	96.82%
Soil salinity decreased	0.79%
Soil salinity same	2.39%
Impact on Agriculture/Vegetation	
Increased	1.22%
Decreased	95.88%
Same	2.9%
Impact on Mangrove Cover	
Yes	9.92%
No	89.29%
Less as compared to past	0.79%
Impact on Crop Yield	
Increased	6.4%
Decreased	87.22%
Same	6.38%
Education	
Illiteracy	50.39%

Impacts of seawater intrusion and climate change on vegetation, soil, drinking water, and the livelihood of the Indus delta community

The effects of seawater intrusion on several ecological climatic parameters were statistically investigated using Pearson Chi-square and Goodman and Kruskal's methods. Table 3 shows the results of the association between temperature fluctuations and a decrease in fish catch.

According to the data, 92.4% of respondents agreed that the temperature has changed. However, 83.2% of respondents said their fish catch had decreased. While 9.2% indicated no change or a decline in fish catch as a result of temperature changes in the delta. The Pearson chi-square analysis value for the link between change in temperature and decrease in fish catchment in the study region at the significant level of 0.58 was computed as 9.134, indicating that the two variables had a statistically weak relationship. The gamma ($\gamma = 1.91$) value of Goodman and Kruskal, with a significant level of 0.58, also indicates that this link was weak. Imran *et al.* (2013) reported similar findings in the Indus River Belt, demonstrating a link between temperature and fish catchment.

Table 3 | Relationship between change in temperature and decrease in the fish catchment in the study area

Temperature	Decrease in the fish catchment: Yes	Decrease in the fish catchment: No	Total	Percentage (%age)
Yes	416 (83.2%)	46 (9.2%)	462	92.4%
No	28 (5.6%)	10 (2.0%)	38	7.6%
Total	444	56	500	100%
	$\chi^2 = 9.134$ ($p = 0.58$), $\gamma = 1.91$ ($p = 0.58$)			

Table 4 shows the results of the association between increased seawater intrusion and decreased vegetation/agriculture.

Table 4 | Relationship between seawater intrusion and vegetation in the delta

Increase in seawater intrusion	Decrease in vegetation: Yes	Decrease in vegetation: No	Total	Percentage (%age)
Yes	462 (92.4%)	18 (3.6%)	480	96.0%
No	6 (1.2%)	14 (2.8%)	20	4.0%
Total	468	32	500	100%
	$\chi^2 = 14.205$ ($p = 0.03$), $\gamma = 0.238$ ($p = 0.03$)			

According to Table 4, 96% of respondents agreed that seawater intrusion has increased. There had been a decrease in vegetation, according to 92.4% of respondents. However, 3.6% of respondents said there was no change in vegetation as a result of increased seawater intrusion. The Pearson chi-square analysis result for a link between these variables at a significant level of 0.03 was estimated as 14.205, indicating that these two variables have a strong relationship. This relationship was also substantial, as evidenced by the value of gamma ($\gamma = 0.238$). According to Hopkinson *et al.* (2008), the impact of sea-level rise and wind storms on forests has been severe in recent years.

Table 5 shows the results of the link between increased seawater intrusion and increased soil salinity.

According to the table, 94% of respondents indicated an increase in soil salinity. However, 2% of respondents said that increased seawater intrusion in the delta had no effect on soil salinity. The Pearson chi-square analysis value for the link between these variables at a significant threshold of 0.01 was estimated as 112.833, indicating that these two variables have a statistically significant relationship. The gamma value (0.672) also indicates that this relationship was fairly strong.

Table 5 | Relationship between seawater intrusion and soil salinity in the delta

Increase in seawater intrusion	Increase in Soil Salinity: Yes	Increase in Soil Salinity: No	Total	Percentage (%age)
Yes	470 (94.0%)	10 (2.0%)	480	96.0%
No	12 (2.4%)	8 (1.6%)	20	4.0%
Total	482	18	500	100%
	$\chi^2 = 112.833$ ($p = 0.01$), $\gamma = 0.672$ ($p = 0.01$)			

Table 6 shows the results of the association between changes in seawater intrusion and the negative influence on drinking water quality. According to the data, 93.6% of respondents experienced negative consequences. However, 2.4% of respondents said there were no negative effects on drinking water quality as a result of

Table 6 | Relationship between seawater intrusion and drinking water quality

	Adverse impacts on the quality of drinking water			
Increase in seawater intrusion	**Yes**	**No**	**Total**	**Percentage (%age)**
Yes	468 (93.6%)	12 (2.4%)	480	96.0%
No	8 (1.6%)	12 (2.4%)	20	4.0%
Total	476	24	500	100%
	$\chi^2 = 70.604$ ($p = 0.01$), $\gamma = 0.531$ ($p = 0.01$)			

increased seawater intrusion. The Pearson chi-square analysis value for both variables was estimated as 70.604 at a significant level of 0.01, indicating that there is a statistically significant relationship between these two variables, while the value of gamma (0.531) also indicates that this relationship is quite strong.

Table 7 shows the results of the association between increased seawater intrusion and its negative effects on the community's income. According to the table, 94.8% of those surveyed had negative consequences. However, 1.2% of respondents said there was no negative impact on the community's income. The Pearson chi-squared test for a relationship between these two variables was calculated as 171.985 at a significant level of 0.01 indicating a very strong association between these two indicators, while the value of gamma (0.829) was also significant ($p = 0.01$) indicating a very strong association between these two indicators.

Table 7 | Relationship between seawater intrusion and income of the community

	Adverse impact on the income of the respondents			
Increase in seawater intrusion	**Yes**	**No**	**Total**	**Percentage (%age)**
Yes	474 (94.8%)	6 (1.2%)	480	96.0%
No	6 (1.2%)	14 (2.8%)	20	4.0%
Total	480	20	500	100%
	$\chi^2 = 171.985$ ($p = 0.01$), $\gamma = 0.829$ ($p = 0.01$)			

Measurement of the magnitude of poverty in the Indus delta

The degree of poverty was determined using Foster-Greer-Thorbeck techniques, which are the most reliable and extensively used techniques for estimating poverty lines. An international poverty level of 2 dollars (Imran *et al.* 2013; Solangi 2019) was chosen as a baseline, based on the current exchange rate.

Table 8 and Figure 5 based on FGT techniques revealed that 88.4% of the population was poor, accounting for 442 respondents out of a total of 500 people surveyed. Furthermore, the study's devastating findings included the poverty gap ratios, which demonstrated the average disparity between these poor residents and the internationally recognised poverty limit of $2.

Table 8 | Measurement of poverty headcount, poverty gap, and severity of poverty in the Indus delta community

S.No.	Measures of poverty	Foster Greer Thorbeck technique	Poverty Index	Percentage (%age)
1.	Headcount poverty	$\frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^0$	442	88.4%
2.	Poverty gap	$\frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^1$	0.586243	58.6%
3.	Severity of poverty	$\frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^2$	0.454750	45.5%

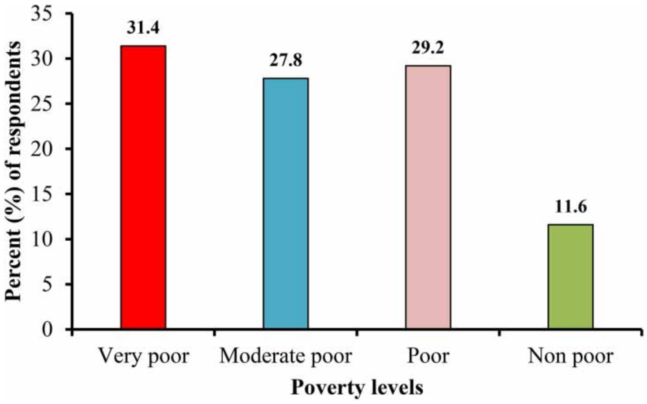


Figure 5 | Distribution of respondents based on their level of poverty.

Respondents were divided into four categories based on the international poverty level of $2: very poor, moderately poor, poor, and non-poor (IFAD 2002; Imran *et al.* 2013). The first class (very poor) was defined as being one-third of the poverty line, the second class (moderate poor) as being between one-third and two-thirds of the poverty line, the third class (poor) as being between two-thirds of the poverty line, and the fourth class as not being poor (Imran *et al.* 2013).

The findings revealed that poverty is quite severe in the coastal belt of Sindh, Pakistan. Based on the village survey (2004–05) as reported by Majeed *et al.* (2010), Thatta and Badin districts of southern Sindh Province of Pakistan were classified as districts below the poverty line. Furthermore, ADB (2005) and Majeed *et al.* (2010) reported that about 79% of the coastal population falls below the poverty line, out of which 54% are in the category of very poor. Similar poverty trends in Pakistan have been reported by Saboor *et al.* (2006). Behind these poverty ratios, the main factors include, at a minimum, the absence of physical infrastructure, less resource possession, lack of market resource integration, poor health, education indicators, and lack of proper management policies for poverty reduction (Joshi 2008; Israr & Khan 2010; Imran *et al.* 2013). It could hamper the growth trend and could create social unrest if attention is not paid to these poor communities (Morrison *et al.* 2007) who reside in the Indus delta.

CONCLUSION AND SUGGESTIONS

The present study revealed that residents of the Indus delta are enduring poor infrastructure, poor living standards, and limited social activities. Most of the people are uneducated. The average family consisted of 11 members, whereas an average of 4.7 people lived in a single room. Many families have migrated from their ancestral areas to search for places that had a better potential to earn a sufficient income. Analysis based on the FGT techniques, about 88.4% community of the delta, were living below the poverty line. The Pearson chi-square and Goodman, Kruskal's analyses identified seawater intrusion as the most significant parameter affecting soil fertility, water quality, flora, fauna, mangroves, and livelihood of the Indus Delta community.Most of the people strongly requested an increased freshwater flow in the Indus River to its delta. In light of the findings of this study, it is concluded that there is a dire need for improving the environmental conditions by increasing freshwater flow below the Kotri Barrage, the last barrage on the Indus River before it flows to the delta. Appropriate water treatment/desalinization plants must be installed, introducing bio-saline agriculture should be considered, the degraded agricultural lands should be reclaimed to improve the infrastructure and protect the environment along the coast of Sindh. The facts reported in this study should certainly prompt responsible policymakers to devise strategies for mitigation of these adverse impacts of seawater intrusion on the socioeconomic conditions of the community living in the Indus delta. This change is necessary to save the ecosystem, agricultural lands, water resources, mangrove forests, fishing revenue, as well as the livelihood of the people living. The study findings will provide accurate data to demonstrate the current disastrous state of the delta area and suggest ways to promote realistic measures to remediate the delta and improve the lives of the residents.

AUTHOR CONTRIBUTIONS

Ghulam Shabir Solangi: concept, design, analysis, writing – review and editing. **Altaf Ali Siyal:** concept, design, analysis, writing – review and editing. **Zain-ul-Abdin Siyal**: concept, design, analysis, writing – review and editing. **Pirah Siyal:** concept, design, analysis, writing – review and editing. **Sallahuddin Panhwar:** review and editing. **Hareef Ahmed Keerio**: review and editing. **Nabi Bux Bhatti**: review and editing.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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