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Adaptation to Environmental Changes: Experiences of Farming Practices in Sagar Island of the Indian Sundarbans

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Abstract

The study examines farmers' perception of climate change, associated natural disasters, and adaptive farming practices in the Sagar Island of the Indian Sundarbans region. The study is based on primary data and information collected from two selected villages of the area, namely, Beguakhali and Gangasagar. In addition, various environmental parameters such as variations in land surface temperature, annual average rainfall, and cyclonic disasters have been examined using Landsat 4/5 TM and 8/9 OLI data for the year 1990 and 2024, rainfall data since 1980, and data on the major cyclonic events affecting the Indian Sundarbans since 1991. The findings indicate a notable increase in surface temperature, a marginal decrease in average annual rainfall, and a rise in both the frequency and intensity of cyclonic disasters. The results are quite similar to what the local farmers perceive. Besides, cyclones, storm surges, and river bank erosion appear as the most devastating extreme events, contributing to salinity intrusion and agricultural land degradation in the area. Nevertheless, despite these environmental challenges, the farmers continue to cultivate during the monsoon and winter seasons. While a paddy-dominated mono-cropping pattern is practiced in monsoon, multiple vegetables and cash crops are cultivated interchangeably during the winter. The study also finds changes in cropping patterns, rainwater harvesting, crop rotation, and crop diversification as important adaptation strategies being practiced by the farmers. The policies and interventions should, therefore, aim at addressing these critical aspects for sustainable growth of agriculture in the area.

Keywords: Agricultural Practice, Land Surface Temperature, Cyclonic Disasters, Adaptation Strategies, Sagar Island

1. Introduction

Climate change has gained momentum globally due to the rapid increase in anthropogenic activities, leaving its own pace that occurs naturally (Khan et al., 2009). Increased concentration of heat-trapping gases in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapour (H_2O), have caused the Earth to warm and changed associated climatic parameters (Thakur et al., 2021), results a variety of extreme weather events, such as droughts, cyclonic storms, floods, heat waves, melting of the polar ice sheet, sea level rise, loss of biodiversity, etc. (Bera et al., 2021). The growing intensity of such extreme events impacts adversely on the country's economy as well as people's livelihoods (Praveen & Sharma, 2020).

Agriculture is the only sector in the world that produces food (Trinh et al., 2018). It serves as an economic base of developing countries and contributes to the growth of secondary and tertiary economic sectors in addition to ensuring food security and means of subsistence (Praveen & Sharma, 2020). However, compared to other economic sectors, agriculture is more vulnerable to climate change because of its dependency on the climate (Kabir et al., 2017). In recent years, climate change has caused a decline in crop production in many major agricultural regions. As a result, food crises and poverty have increased globally (Trinh et al., 2018). Similarly, WHO cautions that climate change threatens nutrition, food security, and water availability, increasing the rate of malnutrition. However, despite a global phenomenon, climate change affects more underdeveloped nations because of their lower coping capacity due to climatic vulnerability.

India has been recognised as one among the nations most at risk from climate change. Significant warming and a weaker monsoon were observed across the Indian landmass, according to studies (Birthal et al., 2014). Furthermore, India has already begun to feel the negative effects of extreme weather events like floods, droughts, and cyclones, and it is predicted that these events will likely intensify and occur more frequently in the years to come due to climate change (Kumar et al., 2021). In India, agriculture continues to be regarded as a vital sector of the economy, accounting for approximately 22% of GDP, 58% of jobs, meeting the country's food and nutritional needs, generating raw materials for industry, and contributing to approximately 14% of exports (Praveen & Sharma, 2020). Furthermore, a significant number of Indian farmers (80%) are smallholders and typically lack financial resources (Birthal et al., 2014). The nation's livelihood and food security would therefore be at jeopardy if climate change had a negative impact on agricultural production (Datta & Behera, 2022). In this regard, evaluating farmers' adaptation potential is essential to creating suitable policy initiatives that can successfully mitigate the adverse effects of climate change.

Assessment of farmers' perception of climate change and their adaptation strategies in any climatically vulnerable zone is important for agricultural sustainability. Such kind of understanding helps farmers to develop climate-smart agriculture in other regions at the pace of global climate change (Kabir et al., 2017). The Indian Sundarbans region is one of the most vulnerable ecoregions in terms of natural disasters such as cyclones, storm surges, embankment breaching, ingress of seawater, coastal flooding, coastal erosion, etc. (Bera et al., 2021). Global climate change is causing the surface temperature to rise at a rate of 0.5°C per decade, which further alters other climatic variables, including air pressure, humidity, rainfall pattern and intensity, seasonal changes, onset and withdrawal of monsoon, etc. Such changes are leading to rise the frequency and intensity of extreme weather events (Dubey et al., 2017). Studies show that between 1980 and 2007, the pre-monsoon season average sea surface temperature (SST) in the Sundarbans region rose from 31 to 32.6 degrees Celsius, and the SST in the northern and southern parts of the Bay of Bengal increased by 0.8 and 1.0 degrees Celsius, respectively, over a 102-year span (Dash et al., 2007; Dubey et al., 2017). Moreover, a decreasing trend of pre-monsoonal rainfall and an increasing trend of post-monsoonal rainfall were found by Mondal et al. (2013). Following the environmental conditions, Dasgupta et al. (2020) have examined several coping strategies followed by the farmers of the Sundarbans region. (Dutta et al., 2020) have identified several adaptation strategies followed by the farming communities in the Indian Sundarbans. Similarly, Dutta et al. (2021) have highlighted several farm-based adaptation strategies. (Kabir et al., 201) have identified several adoption strategies adopted by the farmers in Bangladesh based on their perception of climate change. (Dubey et al., 2017) have shown how the coastal agricultural lands are converted into aquacultural lands by the farmers following climate change. (Sahana et al., 2016; Thakur et al., 2021; Laskar et al., 2021) have shown how the land use patterns are changing in the Sundarbans region over time. Similarly, studies of adaptation strategies taking into account the changes in climatic variables were also conducted in other places, such as the Eastern Bihar (Jha & Gupta, 2021), the Phichit province of Thailand (Arunrat et al., 2017), Southeast Asia (Waibel et al., 2018), the Himalayan foothill regions of West Bengal (Datta & Behera, 2022). Regional variations, however, result in distinct interpretations and approaches to adaptation.

Sagar is an Island of the Indian Sundarbans region. The majority of the residents are small-scale or marginal farmers with low adaptive capacity (Mandal et al., 2020). Paddy is the main crop, and agriculture is the main source of income. The primary supply of water for agriculture is monsoon rain, which occurs due to the southwest monsoon wind from June to September (Mukherjee et al., 2019). During the off-monsoon season, people use this rainwater for irrigation and agricultural production. Climate-induced natural disasters are continuously affecting the Island's environment. So, on the one side, climate-induced devastating extreme events are there. On another side, most climate-sensitive economic activity, like agriculture, is the main source of income. Given these challenges, an important question arises: how do local farmers sustain their livelihoods through agricultural practices? In response to the question, this study reveals a micro-level analysis of people's perceptions about climatic vulnerabilities and their farming behaviour in Sagar Island of the Indian Sundarbans region. The specific objective of the research is to analyze the farmers' perception of environmental changes and their adaptation strategies in farming practices. The subsequent sections are organized as follows: Section 2 provides a brief overview of the study area; Section 3 outlines the materials and methods; Section 4 presents the results and discussion; and Section 5 offers the conclusions.

2. About the Study Area

Sagar Island is the westernmost largest Island of the Indian Sundarbans, which lies between 21°37′20″ to 21°52′28″ north and 88°2′17″ to 88° 10′ 25″ east (Mandal et al., 2020). Figure 1 shows the location map of the study area. The topography is flat and moderately rising, with an average elevation of less than 4 meters, ranging from 2.5 to 3.5 meters above mean sea level (Nandi et al., 2016). According to the latest Indian census, there are 212,037 people living on the island, and it is the largest habitable island in the Indian Sundarbans region. The Island is influenced by hot and humid monsoon climate with three main seasons such as hot summer, rainy monsoon, and cold winter. Average annual rainfall is 1720 mm, which mostly happens in monsoon (Bhattacharjee et al., 2023). Average summer and winter temperatures are 30°C and 18°C, respectively (Mukherjee et al., 2019). The island is surrounded by waterbodies: Hooghly River on the north and west, Muriganga River on the east, and the Bay of Bengal on the south (Mandal et al., 2020). The island is separated into 42 villages that are governed by 9 panchayets and is a part of the Sagar CD block, which is located within the Kakdwip subdivision of the South 24 Parganas district of West Bengal (Mandal et al., 2013). In Sagar Island, agriculture is the primary occupation for the majority of the population, with paddy being the main food crop. Agriculture is primarily practiced by three categories of farmers, such as marginal (less than 1 hectare), small (1 to 2 hectares), semi-medium (2-4 hectares), along with landless cultivators (Agricultural census, 2015-16). Monsoon is the primary season designated for paddy cultivation, while winter serves as the secondary season, during which various vegetables and cash crops are grown with the aid of surface water irrigation (Bhattacharjee et al., 2023).

3. Materials and Methods

3.1 Data Sources

To fulfil the target objectives, both primary and secondary data are used here. Primary data was collected through focused group discussions conducted in April 2024 in the selected two villages of Sagar Island, namely Gangasagar and Beguakhali. Secondary data, such as rainfall data, were collected from freely available websites such as Gangasagar climate averages (https://www.worldweatheronline.com/hwd/) and CFSR global weather data for SWAT 1979-2024 (https://swat.tamu.edu/data/cfsr).

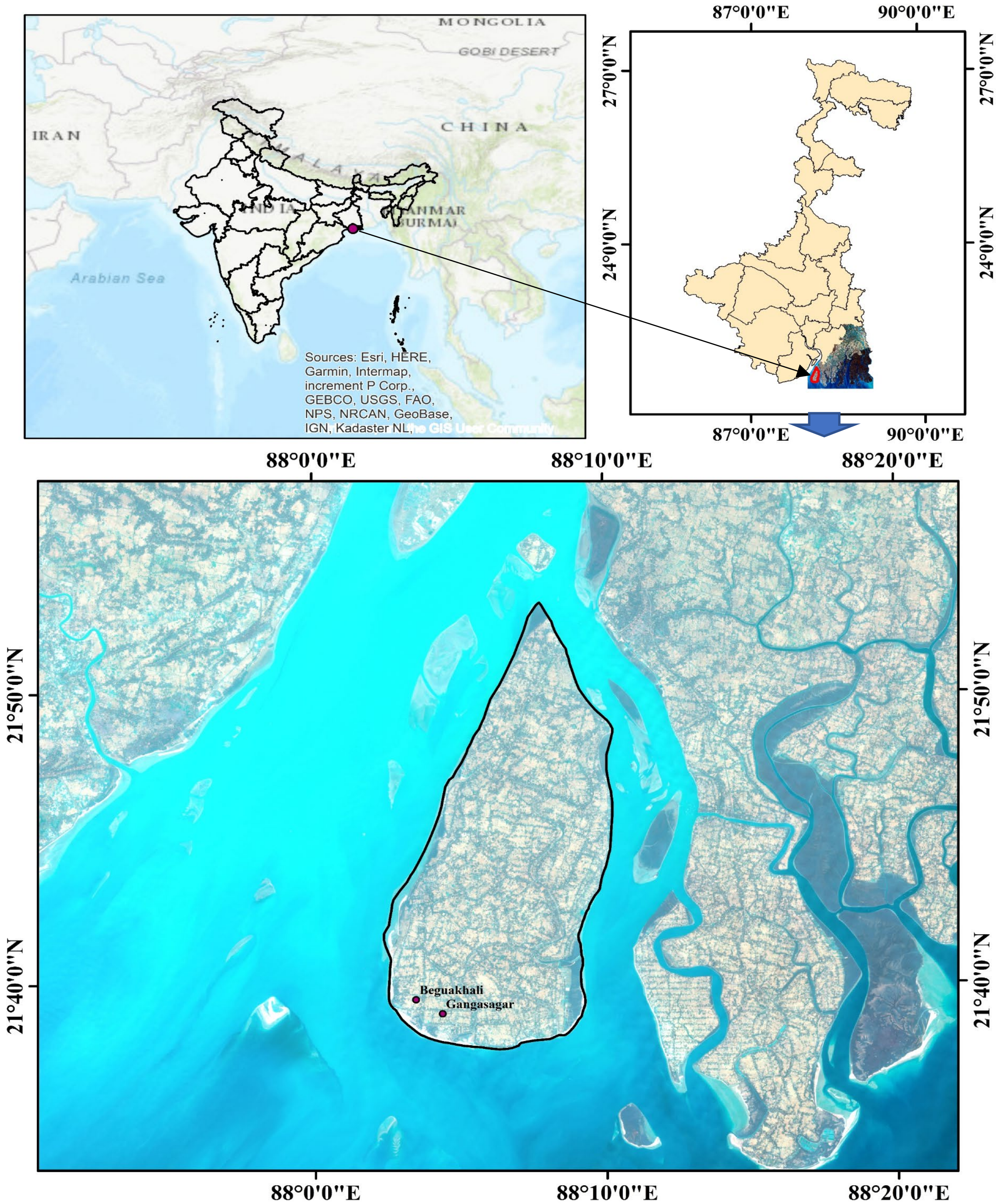

Figure 1: Location map of the study area.

Yearly data related to cyclonic disasters were collected from the website of the Regional Specialized Meteorological Centre for Tropical Cyclones Over North Indian Ocean (https://rsmcnewdelhi.imd.gov.in/report.php?internal_menu=MzM). Satellite images (Landsat 4/5 Thematic Mapper for the year 1990, and Landsat 9 Operational Land Imager) were downloaded from USGS (United States Geological Survey) Earth Explorer (https://earthexplorer.usgs.gov/). Additional secondary information is gathered from literature reviews and different government websites.

Table 1. Description of satellite images.

Image Type	Acquisition Date	Path/Row	Used Band
Landsat 4/5 TM	14/01/1990	138/045	Band 6
Landsat 9 OLI	04/01/2024	138/045	Band 10

Source: USGS Earth Explorer (https://earthexplorer.usgs.gov/).

3.2 Methodologies

Secondary data are used to highlight the changes in environmental parameters, like variations in rainfall, temperature, and cyclonic disasters, while primary data are applied to show the people's perception about the climatic vulnerabilities, including climate change, and observed natural disasters and their adopted farming strategies.

3.2.1 Focus Group Discussion

Information about people's perception of these environmental changes (including climate change) and their adopted farming behaviour was collected through focus group discussions. Two villages, Gangasagar and Beguakhali of Sagar Island, were selected for this purpose. A total of 12 focus groups were prepared for the two villages (six in each village). Every village included three groups for men and three for women (homogeneous groups). The size of the group members for each category was 8; thus, 96 respondents were selected for the discussion in the focus group. The household characteristics and cultivated land areas of the respondents are represented in Table 2.

Figure 2: Focus Group Discussion.

However, a purposive sampling technique was used to select the respondents because the success of focus group discussions depends on members' ability to supply pertinent information (O. Nyumba et al.,2018). Local farmers were selected for the focus group discussion as they could have sufficient knowledge regarding the issues as perceived. Prior to the final discussion, an informal meeting was conducted to select the group members and possible locations in the selected villages. Moderators and note-takers were then assigned for each group.

Table 2. Demographic characteristics and cultivated land areas of the respondents

Types of Farmers	Percentage	Cultivated Land (Hectares)		Leased in Land (Hectare)	
		Monsoon	Winter	Monsoon	Winter
Landless	35.41667	0.20-0.40	0.13-0.27	0.20-0.40	0.13-0.27
Marginal	64.58333	0.54-1.07	0.20-0.33	0.20-0.40	-

Variables	Percentage	Variables	Percentage
1. Age of the respondents (Years)		*5. Size of the Household*	
<30	13.54	3 Persons	18.75
30-40	39.58	4 Persons	37.50
40-50	27.08	5 Persons	25.00
50-60	14.58	6 Persons	14.58
>60	5.21	7 Persons	4.17
Average age is 36.24 years		Average size of household is 5.50	
2. Educational Qualification			
Below 10th	41.67	*6. Annual Income (Rupees*	
10th Qualified	33.33	30,000	10.42
12th Qualified	18.75	30,000-40,000	35.42
Graduate	6.25	40,000-50,000	29.17
Average qualification is below 10th		50,000-60,000	18.75
3. Gender of the respondents		60,000-70,000	6.25
Male	56	Average annual income is Rs. 30,000-40,000	
Female	40		
4. Caste of the respondents		*7. Secondary Occupation*	
SC	63.54	Wage labour	30.21

OBC	36.46	Fishing	17.71
Primary Occupation		Migrated Worker	19.79
Agriculture	63.54	Tailoring	13.54
Fishing	15.63	Betel Cultivation	9.38
Transport-related works	20.83	Tea staller/Grocery	9.38

Source: Focus group discussion conducted by the author.

Discussion followed a pre-designed schedule, and free, open-ended questions, allowing respondents to freely express their views. All the responses were noted down and categorised as per necessity. Descriptive statistics were applied for quantitative analysis, and data were coded, edited, and entered using Microsoft Excel. A conceptual framework of the entire methodology of focus group discussion has been represented in Fig.2.

Focus group discussions are crucial for determining the main issues and their consequences that the majority of participants are facing. These conversations provide useful information about shared problems or opposing points of view, and respondents can agree or disagree on specific themes (Datta & Behera, 2022). Interaction with local farmers has taken place between the hours of 9:00 am and 12:30 pm, and 3:00 pm and 5:00 pm, as this is when farmers often work in the farmland. Further information regarding climate vulnerabilities, agricultural practices, primary crop production issues, and crop cultivation conditions during regular seasons and after disasters has also been obtained through contacts with beneficiary households, village officials, and representatives of local non-governmental organisations.

3.2.2 Extraction of Land Surface Temperature

Land surface temperature (LST) is the radiated temperature of the surface objective/s, captured by the satellite sensor and stored as a DN or digital number in the thermal band of the satellite image (Sobrino et al., 2004). Using this thermal band, with the help of GIS software, LST can be retrieved. In this research, using the thermal band (Table 1) of the respective satellite images, LSTs and associated maps have been extracted for the years 1990 and 2024 to highlight the temperature differences over time. The following steps are used to extract the LSTs.

Step 1: Retrieve the spectral reflectance of Top of Atmosphere (TOA)

$$L\lambda = ML \times Qcal + AL) \quad (1)$$

Where; Lλ = Spectral Radiance (Wt/Mtr2.sr.µm); ML = Radiance Mult_Band (x_i); QCAL = Standard Quantized and calibrated pixel value, AL = Radiance add band (Laskar et al., 2024).

Step 2: Conversion of TOA to B_T

$$BT = (k2/\ln(k1/ L\lambda)+1)) \quad (2)$$

Where; B_T = Brightness Temperature, k1 = Constant-1 of the specific band, k2 = Constant-2 of the respective band, Lλ = calculated spectral radiance value of TOA (Laskar et al., 2024).

Step 3: Calculation of (Normalized Differential Vegetation Index) NDVI

$$NDVI = ((NIR-R)/(NIR+R)) \quad (3)$$

Where; NIR = Near Infrared, R = Red

Step 4: Extracting Proportion of Vegetation *(P_V)*

$$Pv = ((NDVI-NDVI\ min)/(NDVI\ max - NDVI\ min))^2 \quad (4)$$

Where; NDVI min/NDVI max = Minimum and maximum values of NDVI

Step 5: Deriving Emissivity (€) of Land Surface

$$€ = 0.004 \times Pv + 0.986 \quad (5)$$

Where; Pv = Proportion of Vegetation, scaled by the standard value (0.004), and 0.986 = standard emissivity value of vegetation (Choudhury et al., 2019; Laskar et al., 2024).

Step 6: Calculation of Land Surface Temperature (LST)

$$LST = ((BT/1) + \lambda\ (BT/\rho) \times \ln(€)) - 273.15 \quad (6)$$

Where; LST= Land Surface Temperature in (ºC); BT = Brightness Temperature; λ = Wavelength of band 10 (10.895); ρ = (h×c/σ) = (1.4388×10-2mK) = 14388 Mk.

H = Planck's Constant = 6.626×10-34 JK, c = Velocity of light = 2.998×108 m/s, σ = Boltzmann constant = 1.38×10-23JK, € = Emissivity in log-normal (Sobrino et al., 2004; Laskar et al., 2024).

4. Results and Discussion

4.1 Farmers' Perception about Climate Change

On the basis of a pre-designed questionnaire, people of the mentioned villages were asked about their perception of climate change. They shared their experience observing a change in climatic variables (Fig. 3). They said that the summer season has extended; in contrast, the winter season has shortened. Both summer and monsoon seasons are nowadays excessively warm. Pre-monsoonal rainfall has decreased from their childhood to the present. They said that post-monsoonal rainfall nowadays is increasing and it is extending up to the month of November. However, most of them remarked that the average rainfall has decreased according to their perception.

In their words, in summer season, *"Nowadays, to work in the agricultural field has become very tough due to excessive heat in summer"*

During monsoon, *"We feel very hot after the rain, while in our childhood age we felt very cold weather"*

Their remarks for post-monsoonal rainfall *"post-monsoonal rain is nowadays extending up to November, and it becomes a harmful gift of GOD to damage the Boro (winter) field crops"*

Their Experience regarding winter season *"At present very cold winter lasts for 2 to 3 weeks, while in the past (remarking on his childhood life), it extended from November to February last"*

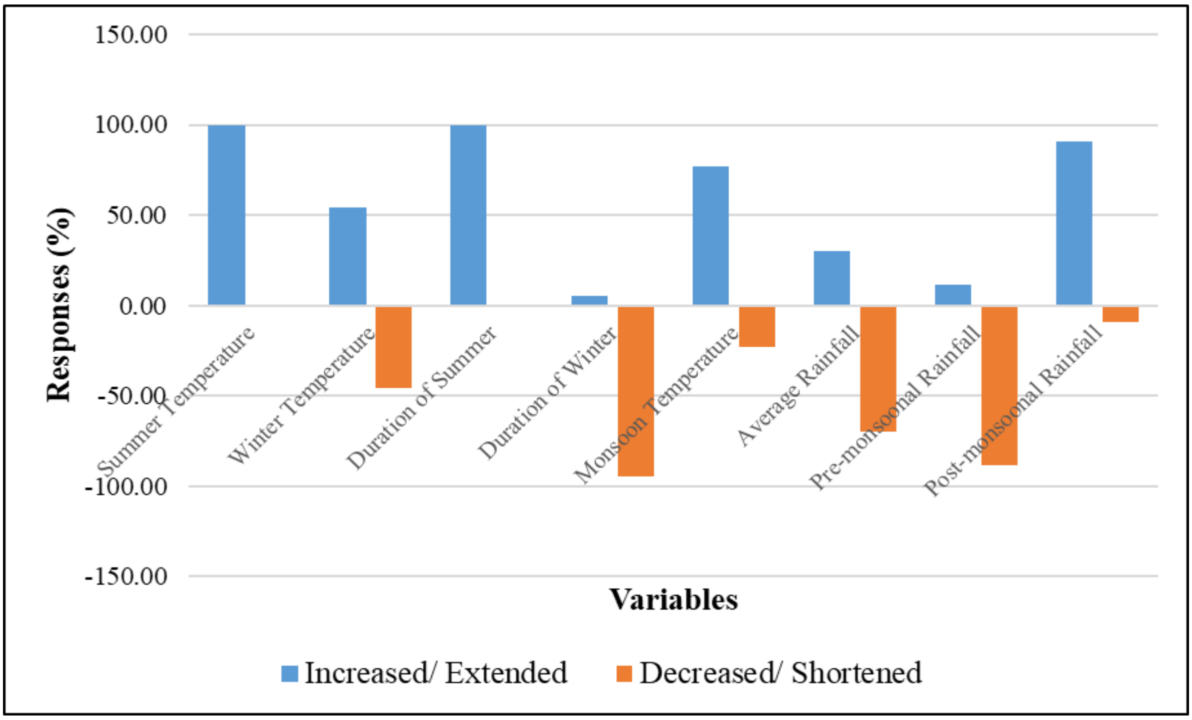

Figure 3. Farmers' responses (positive and negative) about their perception of climate change

Table 3. Observed natural disasters in Sagar Island by the respondents.

Parameters	Disasters
Natural disasters observed by the respondents	Cyclones, Thunderstorms, Storm Surges, Flooding, Waterlogging, Sea Water Ingression, River Bank Erosion
The most severe disasters	Cyclones, Storm Surges, River Bank Erosion, Seawater Ingression
Disasters, responsible for salinity intrusion	Ingression of Seawater, Waterlogging

Source: Focus group discussion conducted by the author

When asked how people perceive natural disasters, they stated that the most dangerous severe events they have seen are storm surges, cyclones, flooding, drought, waterlogging, seawater ingestion, and thunderstorms. Cyclones, related storm surges, and coastal floods are the most severe weather occurrences that negatively impact the region. They also cause soil deterioration, multiple crop failures, and saline intrusion. However, such extreme events do occur, particularly during the post-monsoon (August–October) and pre-monsoon (May–June) periods. Farmers have also stated that, based on their experience, these occurrences have increased in frequency from a few per decade to quarterly or biennial.

4.2 Environment and Its Dynamics in the Study Location

To validate the people's perception regarding climate change and associated natural disasters, variations in rainfall, land surface temperature, and a list of cyclones that have hit the coastal area of the Sundarbans are represented.

4.2.1 Variations in Rainfall

The long-term variations in rainfall in Sagar Island have been shown using yearly average rainfall data from 1980 to 2024. Plotting on excel, flowing graph has been created (Fig.4). A slight decreasing trend is appearing from the picture. And it is decreasing by 4.05 mm annually on an average (according to the graph), along with greater fluctuations. According to a study by Mandal et al. (2013), Sagar Island's monsoon rainfall is trending downward. The findings of Bera et al. (2021) also examine an increase in rainfall after the monsoon, a non-significant decrease in average rainfall, and a significant decrease in pre-monsoon rain.

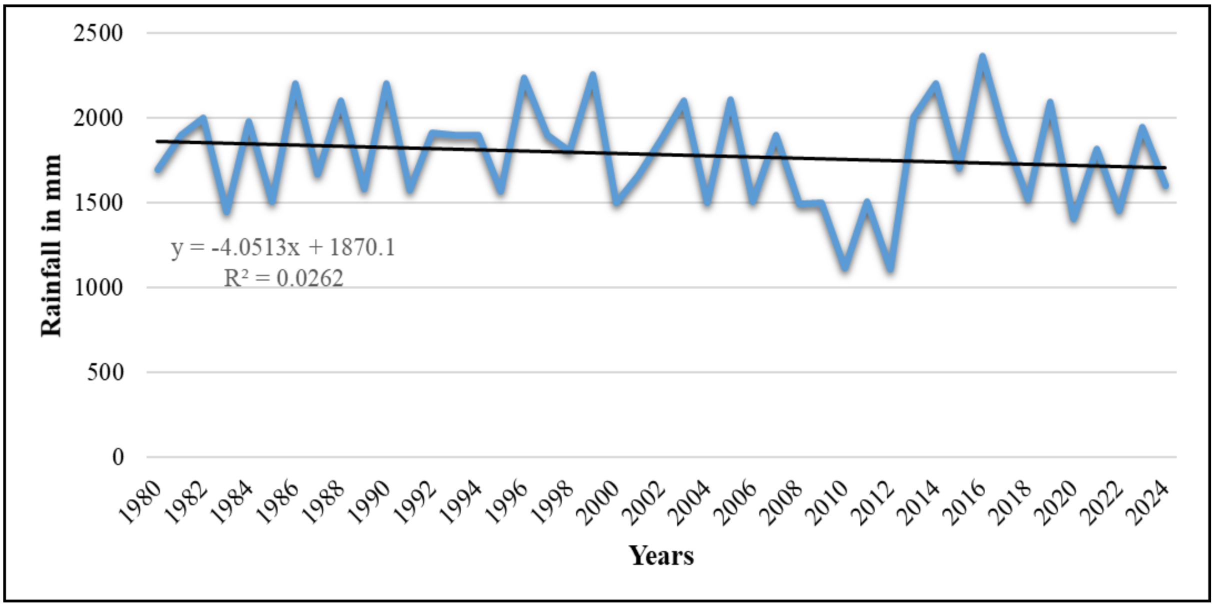

Figure 4. Rainfall variability in the study area location

4.2.2 Variations in Surface Temperature

Using the thermal band of respective satellite images, land surface temperature has been extracted for the years 1990 and 2024 to highlight the temperature differences over the period. Calculated values and respective maps are represented in Table 4 and Figure 5.

Table 4. Calculated surface temperature for the years 1990 and 2024

Variables	LST 1990	LST 2024
Maximum temperature	24.38	27.18
Minimum temperature	15.65	18.42
Average temperature	20.23	22.91

Source: Extracted by author using ArcGIS V.3.4

For understanding the actual variations, same seasonal satellite images (winter) have been collected. Results show that average temperature has increased from 1990 to 2024. The minimum temperature has increased from 15.65 °C to 18.42 °C, and the maximum temperature has increased from 24.38°C to 27.18 °C. Dark red spots on the maps indicate maximum LST zones, while the dark green spots are areas with minimum LST. Similar research works conducted by (Mitra et al.,2009; Sahana et al., 2016; Thakur et al., 2021) suggest a rising trend in surface temperature in the Sundarbans region.

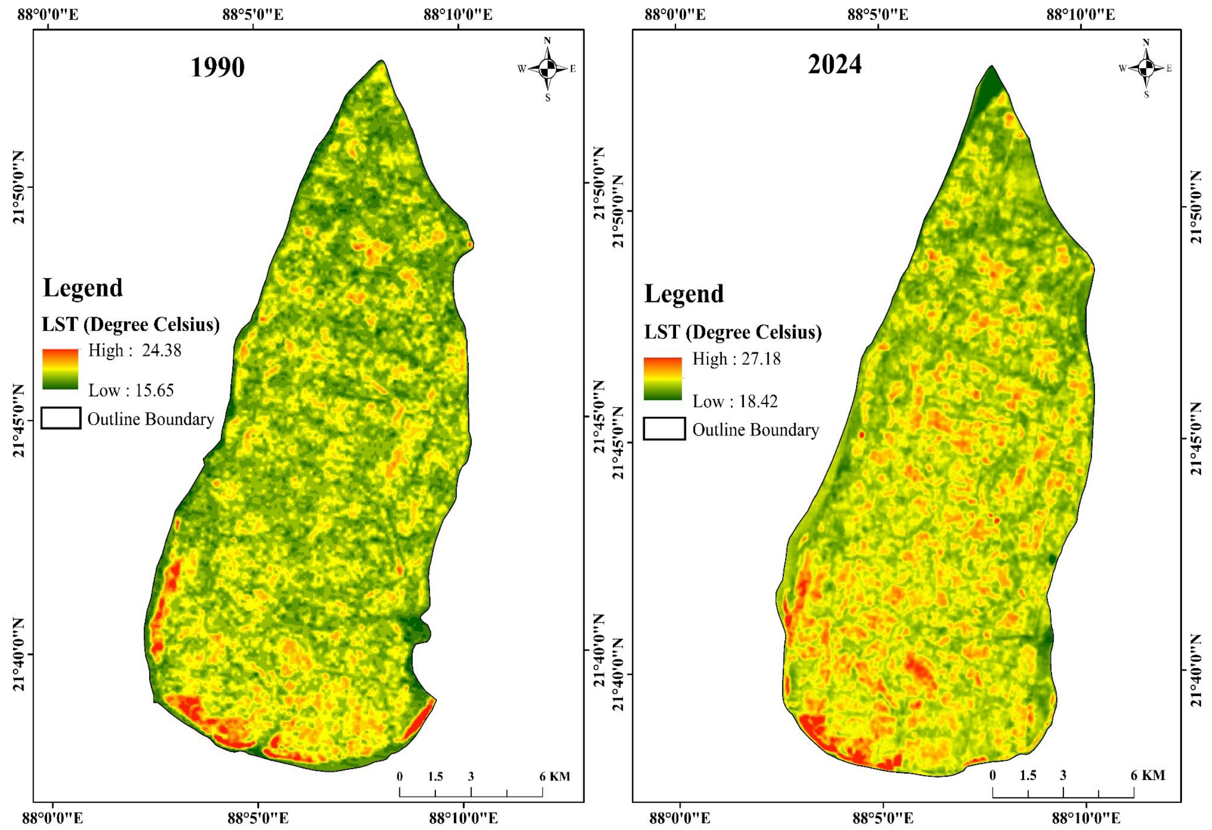

Figure 5. Variations in surface temperature from 1990 to 2024

4.2.3 Cyclonic Disasters from 1991 to 2024

To associate with the farmers' perception about cyclonic disasters, a list of cyclones with their intensity and affected areas has been represented in Table 5. It is noticed that the frequency and intensity of severe to very severe cyclones are increasing nowadays. Findings by Balaguru et al. (2014) showed an increase in cyclone intensity, especially in the post-monsoon period, due to changes in oceanic and atmospheric parameters following global warming. According to Balaji et al. (2018), tropical cyclones have shifted their location eastwards in the Bay of Bengal due to alterations in different criteria of the atmosphere and ocean. Similarly, Singh et al. (2001) found a considerable increase in cyclone frequency, especially before and after the monsoon. Further, the cumulative impacts of rise in sea level and the storms have been severe, along with the intrusion of saltwater (Mahmoodzadeh & Karamouz, 2017). In particular, vulnerability on the eastern coast is higher with respect to saltwater incision because of a low-elevated coastline, thicker alluvium deposition, cyclone-induced flooding and inundation of low-lying areas (Prusty & Farooq, 2020). According to Sarkar et al. (2021), coastal vulnerability in West Bengal is largely due to seawater intrusion caused by the rise in sea level, coastal flooding, surge effects, and falling of the groundwater table, which impact soil fertility negatively and hamper agricultural production.

Table 5. Cyclonic disasters, hitting the coastal areas of Sundarbans since 1991 to 2024.

Name of the Cyclone	Year	Intensity (kmph)	Affected Areas
SC	April, 1991	235	Coastal areas of Bangladesh, West Bengal, Sundarbans
ESCS	April-May, 1994	215	Coastal areas of West Bengal and Bangladesh
SC	May, 1997	230	Coastal areas of Bangladesh, WB
Gopalpur cyclone (ESCS)	Oct 15-19, 1990	170	Sundarbans Region
SC	Oct 25–31, 1999	260	Coastal areas of West Bengal, Sundarbans region
CS	October, 2000	85	Coastal areas of West Bengal, Sundarbans region
SCS	Nov 10–12, 2002	100-102	Sagar Island, Sundarbans region
ESCS (Sidr)	Nov 11 – 16, 2007	215	Coastal WB, Bangladesh, Andaman Nicobar Island.
ESCS (Nargis)	Apl 27-May 3, 2008	165	Coastal areas of Sundarbans, Bangladesh, Myanmar
CS (Rashmi)	October 25–27, 2008	80-85	West Bengal, Bangladesh
CS (Bijli)	April 14–17, 2009	70-75	Bangladesh Coast
SCS (Aila)	May 23–26, 2009	110-112	Coastal states of WB, Bangladesh
DD	June 16–23, 2011	60-65	Heavy rain, Coastal flood in West Bengal
CS (Viyaru)	May 10–17, 2013	80-85	Sundarbans region, Bangladesh
ESCS (Phailin)	October 8–14, 2013	210-215	Coastal areas of Odisha, Andhra Pradesh, Andaman, West Bengal
ESCS (Hudhud)	Oct 7 - Oct 14, 2014	180-185	Coastal areas of Andhra Pradesh, Odisha, West Bengal
CS (Komen)	July 26 -Aug 2, 2015	70-75	WB, Bangladesh, Myanmar
CS (Roanu)	17–22 May, 2016	80-85	WB, Odisha, Bangladesh
SCS (Mora)	May 28-31, 2017	110-115	WB, Bangladesh
VSCS (Titli)	Oct 8-12, 2018	150-155	A.P, Odisha, WB
ESCS (Fani)	Apl 26-May 4, 2019	210-215	Odisha, WB, A.P, Bangladesh
VSCS (Bulbul)	Oct 28-31, 2019	135-137	WB, Odisha, Bangladesh
SC (Amphan)	May 16-21, 2020	235-240	WB, Odisha, Bangladesh
VSCS (Yaas)	May 23-28, 2021	135-140	Odisha, WB
CS (Jawad)	Dec 2-6, 2021	70-75	WB, Bangladesh, Odisha
CS (Sitrang)	Oct 22-25, 2022	80-85	Bangladesh, WB, Odisha
VSCS (Hamoon)	Oct 21-25, 2023	115-120	WB, Bangladesh
CSC (Midhili)	Nov 14-18, 2023	90-95	Sundarbans Region (India & Bangladesh)
SCS (Remal)	May 24-28, 2024	80-85	West Bengal, Bangladesh

Source: (Thakur et al., 2021; Balaguru et al., 2014; Balaji et al., 2018) and (https://rsmcnewdelhi.imd.gov.in/report.php?internal_menu=MzM)

4.3 Adopted Farming Behaviour of the Farmers

4.3.1 Seasonal Variability in Crop Cultivation

Crop cultivation is practiced in Sagar Island in two seasons, namely monsoon (July-September) and winter (November-January) seasons. Monsoon is the prime season, which is fixed for paddy cultivation. However, in Boro (winter) season, crop cultivation persists based on the availability and access to surface water (pond/ government canal).

Figure 6. Sample images of crop cultivation during winter and monsoon seasons

In their voice, *"We cultivate our land mainly in monsoon, while in winter (Boro) seasons, we cultivate our land if we have access to surface water, otherwise we keep our land as uncultivated"*

If a farmer has access to water, he cultivates the land or takes land on lease.

"We take the land from the farmers who have a source of water, and we use their water (pond/tank) in the crop field for cultivation,,

Thus, maximum land areas are cultivated during the monsoon season, while in winter season, it is very few. Similar findings were suggested by Bhattacharjee et al. (2023).

4.3.2 Crop Selection and its Seasonal Variations

Changing Environmental conditions largely control the crop cultivation as well as cropping pattern in Sagar Island. As paddy is the main food crop as well as a water-intensive crop, it is mainly cultivated in monsoon season using rainwater. Therefore, the paddy-dominated monocropping pattern is followed during the monsoon season. In winter (Boro) season, water scarcity interrupts the crop cultivation. Hence, based on availability or accessibility of surface water, farmers cultivate different types of vegetables, cash crops, and paddy (Table 6)

"We produce only paddy during the monsoon in our mainland while different types of vegetables and cash crops are cultivated in the same piece of land in winter (Boro) season" – remarked by respondents.

"Sometimes, we produce different types of monsoonal vegetables in our homestead land to meet the family's needs"

Table 6. Seasonal Variations in Crop Cultivation

Seasons	Nature of Crop	Cultivated Crops
Monsoon	Cereals (Paddy)	Kalma, Dudheswar, Pratiksha, Santoshi, Bongo Bondhu, Mali/ Mali-4, 1075, Nilanjana
	Vegetables	Pumpkin, Malabar Spinach, Bottle Gourd, Snake Gourd, Elephant foot yam, Taro-root, Ridge gourd
	Other Cash crops	Betel leaves
Winter	Cereals (Paddy)	Sonali, Jira Rice, Lal Shankar, Jatau,
	Vegetables	Potato, Sweet potato, Onion, Chili, Okra, Carrot, Sugar beet, Daikon radish, Cabbage, Kohlrabi, Beans, Spinach, Tomato
	Oil seeds	Rape seed or Mustard, Sunflower, Sesame
	Other Cash crops	Termaric, Betel, Ginger

Source: Focused group discussion conducted by the author

4.3.3 Rainwater Harvesting

Since the extraction of groundwater for agricultural practice is prohibited in Sagar Island, rainwater harvesting is a common practice for agricultural sustainability. Farmers build a small pond beside the cropland or in homestead areas, and it is filled by rainwater during monsoon, which is used for fish production as well as for irrigation water.

"We dug ponds beside the crop land for irrigation in winter (Boro) season as well as for fish production"- informed the respondents

 

Figure 7. Sample images showing the rainwater harvested ponds, captured by author during field visit.

During monsoon, rotation of several paddy varieties is applied, while in winter, different types of food crops are grown interchangeably along with cash crops in different years.

"We cultivate different types of paddy varieties during monsoon interchangeably, while in winter (Boro), we produce different food and cash crops in different years interchangeably"- responded by the farmers during the group discussion

4.3.5 Crop Diversification

In Sagar Island, crop diversification is a prevalent strategy that is heavily utilized throughout the winter (Boro) season. According to the respondents, they adopt this method because it lowers the chance of crop failure and increases the opportunity to grow a variety of crops on the same cropland. In addition, it assists us in fulfilling the needs of the family.

In the words of respondents, *"we cultivate different varieties of food and cash crops in the same piece of land in winter (Boro) season to meet the family's needs and to earn money"*

"Diversification of crops reduces the risk of crop failure, if one crop fails due to insect attack or disease"

5. Conclusions

The study evaluates farmers' perception of environmental changes and their adopted farming practices in Sagar Island of Indian Sundarbans region. A mixed-method approach is used, integrating remote sensing and qualitative research. Climate change is reflected by the changes in land surface temperature and average annual rainfall. To highlight the cyclonic disasters, data on major cyclonic events affecting the Sundarbans since 1991 were incorporated. However, to associate with the actual condition, perceptions of local farmers were collected through focused group discussion conducted by the author in the selected villages of the Island. Findings reveal that the farmers have proper knowledge about climate change. They shared that summer and monsoon temperatures have increased, summer season has extended, and winter has shortened from the past to present. Pre-monsoonal rainfall has decreased, while post-monsoonal rain has increased. Surface temperature maps for the years 1990 and 2024 show that it has increased over time. Similarly, rainfall data shows a slight decreasing trend from 1980 to 2024. Following the climatic conditions and associated cyclonic disasters, farmers are sustaining their farming practices by adopting different strategies such as changes in cropping pattern, crop rotation, crop diversification, rainwater harvesting, etc. Though it is a micro-level study, it keeps relevance globally, to spread the knowledge of agricultural sustainability in any climatic vulnerable zone.

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Authors' Contributions

Sakir Laskar: Methodology, Data Collection, Writing the original draft, Visualization, Investigation

Pulak Mishra: Conceptualization, Supervision, Reviewing and editing

Bhagirath Behera: Conceptualization, Supervision, Reviewing and editing

Declarations:

Declaration of interests: The authors declare that they have no conflict of interest.

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