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ORIGINAL PAPER

A preliminary appraisal of the mobility of tribal communities in the Sundarban Biosphere Reserve, India

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Abstract
The Scheduled Tribe (ST) communities inhabiting the Sundarban Biosphere Reserve in the Ganga-Brahmaputra-Meghna Delta are socioeconomically deprived and forced to migrate in the face of intensifying climatic hazards. The lack of caste-disaggregated governmental data, and several lacunae in policymaking and implementation, have made it difficult to assess the socioeconomic conditions, migration patterns, and adaptation needs of these communities. To address this gap, the present study undertakes the analysis of available secondary data and literature alongside village-level hazard mapping and a primary survey of 600 tribal households to understand, for the first time, the mobility of tribal people under multiple climatic hazard conditions vis-à-vis their socioeconomic deprivation. While disparities between the decadal growth rate of the ST population in the region might indicate their permanent displacement and internal migration, the paper draws a few robust observations from the primary survey of the ST households under high and low deprivation categories to understand their seasonal migration behaviour from villages impacted by high, medium, and low levels of climatic hazards. The probability of migration was assessed using binary logistic regression analysis involving hazard incidences, household-level deprivation, agricultural landholding, household size, and access to mangrove ecosystem services. The study seeks to open fresh avenues for future research into suitable pathways for in-situ adaptation, safe migration practices, and progressive policy changes to promote the sustainable development of the tribal communities in climate-impacted regions like the Sundarban Biosphere Reserve.

Keywords Tribal people · Sundarban Biosphere Reserve · Hazard · Migration · Forest dependence · Population movement

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List of acronyms

BLR	Binary logistic regression
CDB	Community Development Block
EMRS	Eklavya Model Residential School
FGD	Focus group discussion
GBM	Ganga-Brahmaputra-Meghna
GoI	Government of India
HDS	Household deprivation score
IPCC	Intergovernmental Panel on Climate Change
LAMPS	Large Area Multi-Purpose Societies
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MPI	Multidimensional poverty index
MSH	(Temporary) Migrant-sending household
NDWI	Normalised difference water index
NSH	Non-migrant-sending household
NTFP	Non-timber forest product
OR	Odds ratio
SBR	Sundarban Biosphere Reserve
ST	Scheduled Tribe
TaSE	Towards a Sustainable Earth
TCRM	Tropical cyclone risk model
UNESCO	United Nations Educational, Scientific and Cultural Organisation

Introduction

Historical background

Nearly 0.2 million tribal people live in the SBR in the GBM Delta, India (Ministry of Home Affairs, GoI, Census 2011a, b), most of whom migrated from neighbouring areas of West Bengal, Assam and the Chhota Nagpur plateau region of the country at the behest of the colonial rulers of Bengal from the late 18th century onwards, to conduct largescale land reclamation, timber extraction, and embankment construction (Richards and Flint 1990; Bera 2013). Historically, the hostile but fertile Sundarbans Delta has seen population influx, outflux, and subsequent reflux several times owing to devastating floods, earthquakes, and attacks by the Portuguese and the Arakans (Sarkar 2012). However, largescale mangrove deforestation did not begin until 1771 after the British acquired full proprietary rights over the region and extended it to include the 24 Parganas districts (of which the SBR is a part) around 1765. The subsequent enactment of the Permanent Settlement Act in 1793 to promote investment in agriculture and alleviate famine and peasant distress by levying a fixed tax on landholders, intensified systemized land reclamation and the killing of the native Royal Bengal Tiger by the migrant forest-dwelling tribes (Richards and Flint 1990; Bera 2013; Stephan Hembrom et al. 2022), some of whom may have been forcefully uprooted from their native lands (Risley 1892).

Mangrove clearance, settlement establishment and revenue collection from agricultural production in the Delta began mainly in its northern parts, and continued even into the early decades of Indian Independence (Richards and Flint 1990). By 1873, these tribal communities were settling in the CDBs of Hingalganj, Hasnabad, Sandeshkhali, and Canning in large numbers, with very few of them being given their own plots of land. Consequently, these CDBs still have a substantial tribal population. While it is known that tribal peoples such the Oraon, the Munda, the Bhumij and the Santhal migrated to the SBR from neighbouring districts in present day West Bengal, Bihar and Jharkhand in India, there is insufficient evidence or recorded data to indicate the return of the original migrants or succeeding generations to their native lands (Stephan Hembrom et al. 2022). These communities continue to live within close proximity with dominant, non-tribal ethnic groups (Banerjee 1998).

The Constitution of India lays down the general principles of positive discrimination for the most disadvantaged socioeconomic groups in the country, designating these and other tribal groups [Arts. 342 and 366(25)] STs with the purpose of uplifting and integrating them into mainstream society. However, none of these ST communities in the SBR have access to any privileges under the Forest Rights Act, 2006 since they were non-aboriginal to the region, not forest-dwelling at the time of the enactment of the Act, and had settled on reclaimed land. When understood in the context of these communities' heavy dependence on the forest ecosystem, the lack of forest rights contributes to their food and livelihood insecurity.

Contemporary context

Scheduled Tribe communities (interchangeably referred to as tribal communities in this paper) in the SBR suffer endemic socioeconomic deprivation, including landlessness, illiteracy, poor health and housing, and inadequate economic prospects. This makes the communities the most socioeconomically vulnerable in the region, even as exposure to a range of environmental and climatic hazards like sea level rise, increasingly frequent and intense cyclones, salinisation, and erosion (Hazra et al. 2002) with retreating mangrove forest cover that leaves the coast progressively exposed to extreme weather events, exacerbates vulnerability in the region (Das et al. 2021; Samanta et al. 2021). Adverse environmental impacts, particularly those associated with climate change, are likely to disproportionately affect rural, poor, marginalised, and ethnic/religious/socioeconomic minorities, further aggravating existing inequalities and vulnerabilities, and driving migration (Adger et al. 2014; IPCC 2014; Islam and Winkel 2017; Mortreaux et al. 2018; Das and Hazra 2020; Das et al. 2021). In the SBR, these factors combine with low adaptive capacity to further disempower and marginalise deprived populations, putting them on the move to secure their lives and livelihoods. Owing to the dearth of disaggregated secondary data on ST communities in the SBR, there is a significant gap in academic understanding of the material conditions of these communities, and researchers interested in studying this population must adopt an aggregative approach or design independent surveys to collect primary data. The present paper seeks to address this research gap by conducting a primary survey to assess the socioeconomic conditions of these ST communities and their likelihood to migrate in response to different climatic and non-climatic stressors and the lack of adequate in-situ adaptive capacity—either temporarily for work (seasonal/cyclical migration) or permanently (displacement-induced involuntary migration). Permanent migrants are people who leave their place of residence permanently to relocate to a receiving area while temporary/seasonal migrants are those who migrate for short durations or seasonally (usually during the lean season) for work or other reasons but eventually return to their place of residence. This is the first attempt to quantify and analyse the socioeconomic conditions of these communities in terms of their ecosystem dependence and mobility and in the face of exposure to climatic and environmental hazards.

Objective of the study

The objectives of this paper are three-fold:

1. Assessing multi-hazard incidence (coastal erosion, cyclone and flooding) of tribal villages in the SBR using the framework of the fifth Assessment Report (AR5) of the IPCC (as demonstrated in Ghosh et al. 2019; Das et al. 2020; Marcinko et al. 2022), which is apt for assessing the 'risk' of climatic disasters to an otherwise vulnerable population, and extending it to a village-level assessment;
2. Examining the tribal communities' dependence on different livelihoods and their mobility under different hazard incidence categories using primary data; and
3. Identifying the drivers of mobility of these tribal communities.

The significance of this study rests on its specific enquiry into the conditions, vulnerability, and adaptive responses of these ST communities, which, as previously stated, has not been done by previous governmental or non-governmental studies. Such an enquiry is critical and highly recommended by the authors to inform targeted policy and adaptation planning for these most vulnerable populations in the Delta.

Study area and demography

The Sundarbans spans nearly 10,000 km^2, from 21°32′ to 22°40′N and 88°05′ to 89°51′E, with 62% of it lying in Bangladesh and only 38% in India. It is the largest contiguous mangrove forest on earth (Sahana et al. 2015; Samanta et al. 2021). The SBR constitutes the south-western part of the populous GBM Delta (Ericson et al. 2006; Woodroffe et al. 2006; Nicholls et al. 2016). It is a UNESCO World Heritage site since 1987 for being a part of the world's largest mangrove forest—the only one with a tiger population, the endangered Royal Bengal Tiger, is a biodiversity and climate hotspot (Ghosh et al. 2018), and was recently designated a Ramsar site in 2019 (Biswas et al. 2023). It comprises nearly 100 geologically young islands, only 54 of which are inhabited (Banerjee 1998). It is densely populated, with nearly 4.5 million people (Census, GoI 2011a, b) inhabiting an area of 5400 km^2 out of the total

9600 km^2 land area that comprises human settlements, farms, and protected mangrove forests of the Divisional Forest area—the Sundarban Tiger Reserve and the Sundarban National Park (Sánchez-Triana et al. 2014). It comprises 19 administrative units (CDBs) under the jurisdiction of two districts in West Bengal—the North 24 Parganas and the South 24 Parganas. These 19 CDBs comprising the SBR is the study area for this paper. Around 0.2 million of the nearly 5 million tribal people of West Bengal presently live in the SBR (Ministry of Home Affairs, GoI 2011a, b).

The region has tropical monsoonal climate and experiences frequent cyclones. High water level during storm surges along with rising sea level causes inundation of its low-lying flood plains. It is also highly sensitive to climate change impacts including coastal erosion, soil salinization and floods. Severe cyclones like Aila (2009), Bulbul (2019), Amphan (2020), and Yaas (2021) as well as massive floods have caused severe damage to the coastal region (Das et al. 2020; Marcinko et al. 2021, 2022).

Three types of embankments of varying heights are common in the SBR: concrete, brick-pitched, and mud. However, embankment breaching and overtopping are frequent, resulting in differential impacts on people inhabiting the same island based on the elevation of their land, their proximity to the creek or sea coast, their resource dependence, and their livelihoods. Villages that are closest to the river embankment or sea shore are most vulnerable to embankment breaching and overtopping, and families with agricultural land close to the embankment are worse affected than others. Destruction of embankment causes saline water inundation and land loss due to erosion.

The local communities are highly attached to the land, air, water, animals, and plants comprising their environment, and these have emerged as a significant part of their cultures and traditions over the years. Indigenous plants, honey from the forest, and fish from rivers, lakes and rivulets have good economic value in surrounding markets (Jamal et al. 2022) and for rural livelihoods (Das et al. 2020). The communities face hardship in maintaining their lives and livelihoods due to frequent natural and anthropogenic disasters with high levels of poverty (Marcinko et al. 2022). Alongside agriculture, the local populace practices several secondary livelihood activities such as aquaculture, honey collection, boat maintenance, and net making (Jamal et al. 2022).

Materials and methods

The present study analysed secondary and primary data from several sources, as detailed below.

Materials

Secondary data

Secondary data on the demography and socioeconomic conditions in the study area were obtained from Indian Census surveys of 2001 and 2011 (Census, Ministry of Home Affairs GoI 2001, 2011a, b), Primary Census Abstract, Socio-Cultural Table, and Housing Data from Census of India (Census, Ministry of Home Affairs, GoI 2011a, b). For developing the multi-hazard index at the village level, several satellite imageries were obtained from online sources. Landsat-TM data (pre and post Aila, 24 April 2009 and 26 May 2009) and TCRM (Arthur et al. 2008) were also analysed. This was accompanied by a review of literature, including data and maps from various international publications written by the authors of this paper and other researchers at the School of Oceanographic Studies, Jadavpur University.

Primary data

Primary data was collected from a survey of 1800 households (tribal and non-tribal) across the 19 CDBs of the SBR in 2020–2021. Out of this survey data, only data pertaining to tribal households (n = 600) was used for the purpose of this study.

Methodology

The study was carried out using both secondary data and primary data. The survey questionnaire included information on the family members of each household, the household livelihood profile along with proportion of income obtained from different livelihoods, housing condition and landholding, standard of living, education, and healthcare, which was used to assess the HDS. Additionally, information on hazard incidences, damage to households due to storm, erosion and flood, access to different insurances and governmental safety nets was collected. The survey design was approved by researchers of the University of Southampton, the Stockholm Resilience Centre, and Jadavpur University who were co-collaborators of the UKIERI-DBT program 'TaSE' with Jadavpur University during 2019–2021. However, the selection of the villages to be surveyed was changed for 5% of the locations due to inaccessibility under Covid-19 restrictions, and alternative locations were selected under similar hazard categories. Several indices like multi-hazard index and HDS were constructed at the village level. Probable drivers of migration were identified from FGDs and expert interviews, and finally the drivers of migration were predicted using BLR analysis.

The only reliable source of secondary data on population as well as satellite imageries in the country is provided by the Indian government, and is used by several national and international agencies. The primary survey was conducted in the presence of researchers of the TaSE project. The survey was constructed in the regional language (Bengali), which is understood by both the surveyed communities and the researchers who accompanied the survey team. Professional surveyors were selected and trained before they were entrusted with the work, and were accompanied in the field by the TaSE researchers and authors.

The limitation of the secondary data used is the resolution up to which the data is made available by the GoI while the limitation of the primary data is that Covid-induced restrictions made some SBR villages inaccessible. The entire survey was carried out during the Covid-19 period (June 2020 to October 2021) which imposed additional constraints on the approachability of the villages for the survey. Such constraints restricted the authors' choice of villages to survey. This may have introduced some bias in data collection but care was taken to ensure adequate sample size, as prescribed by Krejcie and Morgan (1970) to avoid much bias in data and analysis.

Secondary data analysis

A detailed review of relevant literature on the socioeconomic conditions and concerns of tribal populations in West Bengal, and across India, was conducted and the findings analysed and synthesised to enhance our understanding of the realities of indigenous lives and livelihoods. The maps and graphs depicting demographic and socioeconomic variables for spatial analysis were prepared on ArcGIS using data from remote-sensing and literature review. Methodologies for determination of multi-hazard index, such as the BLR model, have been briefly discussed below.

Multi-hazard index at the village level To understand the level of hazard risk in the surveyed villages, a multi-hazard map of the study area was generated on the basis of three hazard layers: inundation (storm surge and floods), cyclone (storm and cyclonic wind) and erosion (coastal erosion and land loss). After the severe cyclone Aila, an inundation layer was developed using pre-cyclone (24.04.2009) and post-cyclone Landsat-TM data (26.05.2009). The storm surge caused extensive flooding of 2–3 m above the high tide level. The "Envi Flash" tool was used to correct for atmospheric interference in the satellite data, which was then clipped by the study area boundary. The water area was extracted from the clipped image using NDWI indices, and a binary raster of the water area was converted into a polygon vector layer. To exclude perennial water bodies, the vector layer was clipped by the previous month's river polygon, resulting in the surge inundation layer. The layer was then subjected to post-editing to improve its accuracy. Cyclonic wind hazard was modelled using the TCRM. The data used were obtained from the Indian Meteorological Department. This model provided output in the form of wind speed of various return periods for the study area. To generate the erosion layer, a time series analysis of Landsat data spanning a decade was conducted. Radiometric and atmospheric corrections were carried out on the Landsat data of 2001 and 2011 using ENVI software. The land-water boundary was determined by differentiating the NDWI index and binarizing the NDWI layer. The resulting binary images were then vectorized to extract the boundaries of the islands. To estimate erosion, the island boundaries from the years 2001 and 2011 were overlapped. This method allowed for the detection and mapping of the changes in the island's shape and size over time. To compute the composite multi-hazard index at the village level in the SBR, all the village-level data was normalized using the dimension index formula. The normalized hazard values were then averaged using the simple arithmetic mean method. This process allowed for the computation of a single index that represents the combined level of hazard for each village.

The threshold values considered for the multi hazard indices analysis are 0–0.25 (low); 0.25–0.50 (moderate) and 0.50–1.0 (high). The multi-hazard (for cyclone, inundation, and coastal erosion) index at the village level was constructed following the methodology described in Das et al. (2020), and detailed further with output from Marcinko et al. (2022).

Conceptual framework of the study From the FGDs and interviews with various stakeholders, a link was found between the environmental impact as well present socioeconomic conditions acting as drivers for migration decisions at the household level in the SBR. Identification of the most important interlinkages between migration drivers and the socioeconomic conditions of households was completed with the help of the conceptual framework proposed in this paper. The drivers indicated by the study's participants were external system drivers, internal dynamics of the area, and, to some extent, policy drivers or actions of government or civil society. Environmental impacts of hazard incidences like coastal erosion, frequent cyclones and flooding were found to influence migration decisions. The social variables that were most commonly indicated as a cause for outmigration were fragmentation of small landholdings, poor educational status, and high household-level deprivation. Thus, a multitude of hazards, the livelihood pattern, and the extent of household deprivation of the surveyed households combine and interact to act as drivers of migration in the SBR. The survey questionnaire was developed to test the following simple conceptual framework (Fig. 1).

Primary survey and analysis

Primary data was collected through a household sample survey by administering a questionnaire schedule. A two-stage stratified sampling technique was applied to the selection of the surveyed villages and households. According to Census 2011 data, the 19 CDBs of the SBR consist of approximately 1032 villages. Jayanagar I CDB was left out of the primary survey owing to its very small tribal population in 2021, the same as in 2011. However, nearly 500 of

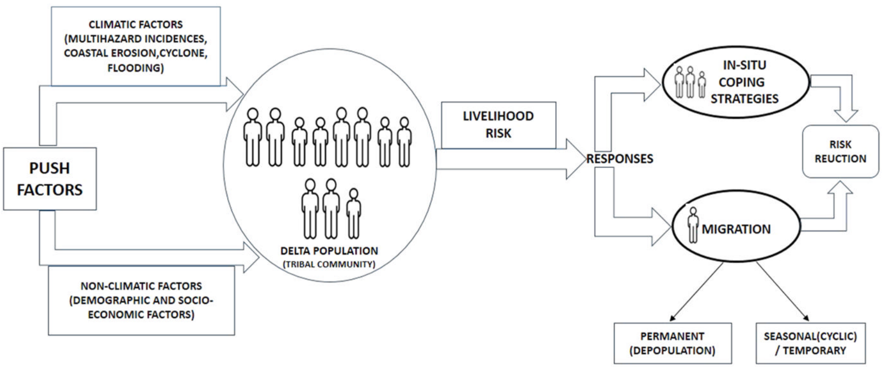

Fig. 1 Conceptual framework for the study (Modified from Maharjan et al. 2020)

these 1032 villages have no tribal population. Census data from 2011 revealed that only 178 villages in the SBR have a tribal population which is at least 10% of the total village population. The present study sought to cover at least 20% of such villages, selecting 36 villages across the 18 CDBs based on their respective rankings in the multi-hazard (cyclone, inundation, erosion) index constructed according to the methodology detailed in section "Multi-hazard index at the village level" and their accessibility in accordance with Covid-19 protocols. Within each village, 50 households were chosen at random. Out of the 1800 households surveyed, 600 were of tribal origin. Hence, the survey data of only these 600 tribal households were used for this analysis. Random selection of households was conducted due to the vast variation of the range of households per village according to Census 2011 data. Additionally, the total number of households sampled (1800) is significantly higher than the required minimum number of units (384) to be surveyed in the study area, and the data of 600 tribal households purposively selected from the sample of 1800. It was assumed that this pilot investigation would succeed in identifying the general pattern of migration in the SBR despite making a small compromise on the statistical significance of the survey result.

To ensure the anonymity of the survey participants, their names and the coordinates of their households were not recorded. All the interviews were conducted with prior informed consent of the respondents. At the beginning of each household survey, each respondent was clearly briefed about the purpose of the interview and the study objective, and informed that they could choose to not answer a certain question or even terminate the interview at any point. As the survey was conducted in several phases between September 2020 and October 2021, all Covid-19 protocols were maintained during the survey. During the interview, very short and specific questions were asked, both closed- and open-ended, regarding respondents' livelihood practices, landholding, education, caste and ethnicity, hazard experiences, health, and housing. While open-ended questions sought to understand the perceived impact of the impact of environmental change on the respondents' livelihoods and socio-economic wellbeing, closed-ended questions sought to gain specific information such as the number of members within the household, different occupation types including circular migration, and the percentage of income from these occupations etc.

Binary logistic regression (BLR) model BLR is a suitable method to analyse the interconnections between potential drivers of migration (independent variables) and migration decisions (dependent variables; indicated as "Yes" or "No") (Hutcheson and Sofroniou 1999; Niedomysl 2011; Akhtar and Jariko 2018; Jha et al. 2018). For the purpose of this analysis, the model was run in IBM SPSS Statistical 22 (Statistical Analysis Software Package) to understand the relationship between the independent variables (multi-hazard category, household size, agricultural land holding, HDS, and ecosystem dependence) and migration. The validity of the model was tested using the goodness of fit (Pituch and Stevens 2016). The quality of the input data was verified before further processing the model. Finally, the variables whose significance value was less than 0.05 were considered for the discussion of the findings of the study. The OR or probability of any event happening to not happening was used to make sense of the interpretation (Tabachnick et al. 2007).

Household deprivation score (HDS) The HDS was computed from primary data using the Alkire-Foster (AF) method (Alkire and Foster 2011). A standard set of indicators under three dimensions and weightages (health, standard of living and education) was used (Table 1). Using the AF method, a deprivation profile for each household was created. Equal weightage was given to each of the three deprivation dimensions, which were then summed up to 1.

Each household finally identified as 'poor' or 'not-so-poor' if the weighted sum of their deprivations was greater than or equal to the poverty cut-off (0.33) (Alkire et al. 2010, 2011; OPHI-UNDP Handbook 2019; Aayog 2021; Marcinko et al. 2022). Poverty scores lower than 0.33 indicated higher well-being of the households while scores higher than 0.33 indicated lower well-being of the households.

Results

This section analyzes both secondary and primary data to understand the relationship between observed migration and non-migration from tribal households in the SBR, depending upon exposure to multiple climatic hazards and other socioeconomic drivers like livelihood pattern, agricultural landholding, household size, forest and ecosystem dependence, and HDS. While the secondary demographic data analysis indicates depopulation (permanent migration) of tribal peoples from the sea-facing hazard-prone areas to areas that are further inland and closer to the northern boundary of the forest within the Delta, the BLR analysis indicates a strong influence of multi-hazard incidence on the probability of temporary or

Table 1 Description of indicators used to construct the village level household deprivation score

Dimensions	Indicators	Weightage	Sources
Health	Access to safe drinking water	1/9 (each indicator)	Bedi et al. (2015), Marcinko et al. (2022), World Health Statistics (2018)
	No proper sanitation		
	Use of unsafe cooking fuel		
Education	School attendance	1/6 (each indicator)	Niti Ayog Multidimensional Poverty Index Baseline Report (2021)
	Years of Schooling		
Standard of Living	Absence of electricity	1/12 (each indicator)	Duflo et al. (2008), Niti Ayog Multidimensional Poverty Index Baseline Report (2021), Marcinko et al. (2022)
	Presence of mud floor		
	Presence or absence of a separate kitchen		
	Asset possession		

seasonal migration of at least one member of ST households, mediated by their various livelihood choices, agricultural landholding, family size, ecosystem dependence, and HDS. This correlation has been further described in the following sections.

Growth and decline of tribal population in the SBR in the 21st century

The rate of population growth of tribal communities within the 19 CBDs of the SBR was assessed with the help of secondary data from the GoI's Census surveys in 1991, 2001, and 2011. Out of the 19 CDBs considered for the study, four CBDs in the southwestern part, including Patharpratima, Kakdwip, Jaynagar I, and Mathurapur I, showed a negative growth rate (< −20.0 to 0%) (Table 2 and Fig. 2). Three other CBDs in the southwestern part, namely Namkhana, Minakhan, and Jaynagar II, show a growth rate which is significantly less than the average natural growth rate of the tribal population in West Bengal during 2001–2011 (20.20%) or even the SBR. The population movement in cases where people living on vested land without personal landholding might be due to social and economic push factors like expansion of aquaculture farms by non-ST communities as well as peri-urban growth of urban facilities like bridges and market, as observed in Jaynagar I and II, and Canning I. But for ST households in Patharpratima, Kakdwip, Mathurapur, and Namkhana, which are sea-facing CDBS, population movement can be attributed mostly to climatic catastrophes like Cyclone Aila (2009) and landloss to the sea. However, such an assertion must be validated in future studies by also tracing migrants' pathways from sending areas to receiving areas.

Table 2 Decadal change (2001–2011) in tribal population in the 19 CDBs of SBR

District	Blocks	Tribal population (2001)	Tribal population (2011)	Growth rate
South 24 Parganas	Mathurapur II	3308	4643	40.36
South 24 Parganas	Canning II	11,654	14,910	27.94
North 24 Parganas	Sandeshkhali II	30,214	37,695	24.76
North 24 Parganas	Hasnabad	6012	7487	24.53
South 24 Parganas	Sagar	691	854	23.59
North 24 Parganas	Hingalgunj	10,419	12,504	20.01
South 24 Parganas	Kultali	4844	5672	17.09
North 24 Parganas	Sandeshkhali I	36,488	42,674	16.95
North 24 Parganas	Haroa	10,962	12,728	16.11
South 24 Parganas	Basanti	17,462	19,963	14.32
South 24 Parganas	Gosaba	20,560	23,343	13.54
South 24 Parganas	Jaynagar II	974	1044	7.19
South 24 Parganas	Canning I	3075	3264	6.15
South 24 Parganas	Namkhana	710	740	4.23
North 24 Parganas	Minakhan	17,547	18,019	2.69
South 24 Parganas	Kakdwip	1941	1836	−5.41
South 24 Parganas	Patharpratima	2834	2640	−6.85
South 24 Parganas	Mathurapur I	589	495	−15.96
South 24 Parganas	Jaynagar I	145	53	−63.45

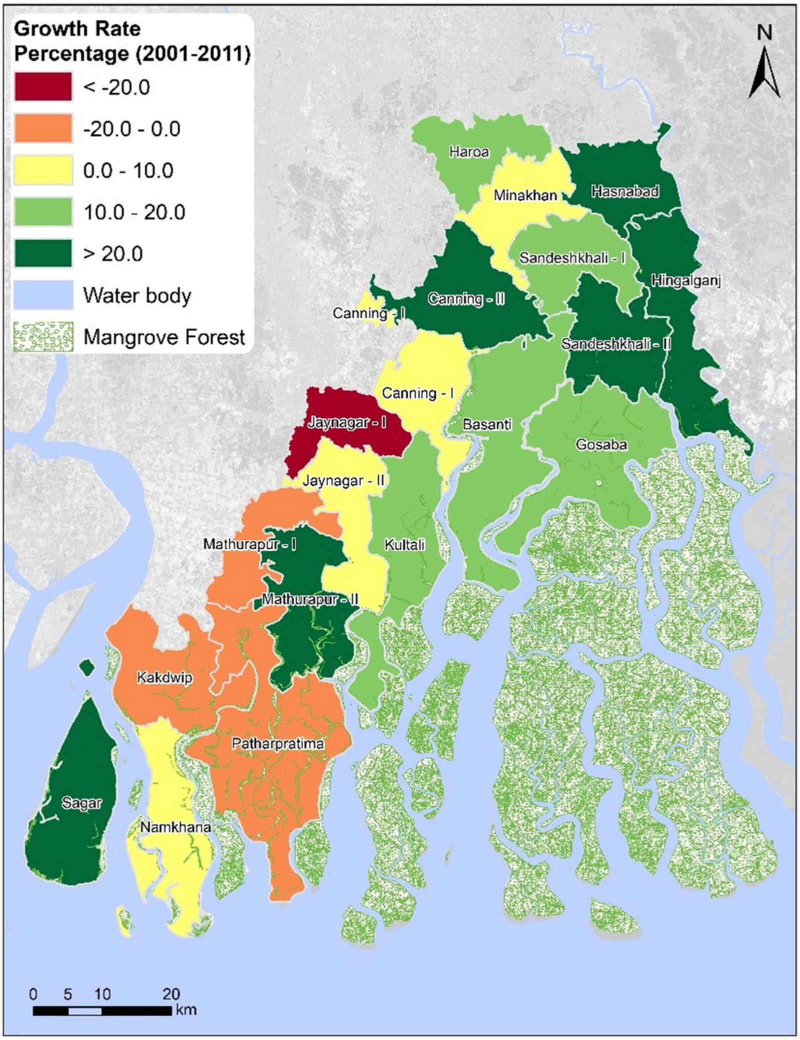

Fig. 2 Decadal growth rate (2001–2011) of the ST population in the SBR

Such depopulation might indicate distress-driven permanent migration of the tribal people from sea-facing or hazard-prone areas to areas they perceive to be safer. In contrast, Mathurapur II, Canning I, Canning II, and Hasnabad, considered 'receiving areas' farther away from the coast, demonstrated a much higher growth rate (20.1–41%) of tribal population, pointing to permanent population movement within the Delta. CDBs with a dominantly tribal population, namely Sandeshkhali I, Sandeshkhali II, and Gosaba, which are closer to the mangrove forest, had a consistent growth rate of 20.20%, which was the same as that for ST communities in West Bengal. As there was hardly any fresh influx of tribal peoples from adjoining districts, states or countries, the disparity in the growth rates might indicate the internal mobility of tribal peoples. Table 2 indicates the decadal change (2001–2011) in ST population in the 19 CDBs of the SBR and their decadal growth rate (Fig. 2).

Climatic hazards and migration

The 36 surveyed villages have varied tribal population, which is reflected in the sampled household data. Table 3 presents the hazard rankings obtained from the village-level hazard index map (Fig. 3) of the surveyed tribal villages as well as the numbers of MSHs and NSHs in each village recorded from the primary survey. An interesting correlation between multi-hazard incidence in the village and the number of MSHs was observed. Out of the 16 villages with high hazard incidence, 11 villages have a higher number of MSHs than NSHs. The value for Pearson's correlation coefficient between the multi-hazard index value of the village and the number of MSHs of the same village was 0.550 (Table 13).

However, exceptions to this simple relationship between hazard and migration were observed in the villages that are situated in more urbanised CDBs like Canning I, Canning II, Jaynagar II, and Sagar, which have good connectivity to urban centres and/or greater proximity to non-farm livelihood opportunities (e.g., religious tourism in Sagar). A very exceptional case is the remote Satyadaspur village in Patharpratima CDB, where the number of MSHs is significantly lower than that of NSHs despite high multi-hazard incidence. This may be due to the high percentage of forest ecosystem dependence of the Lodha-Sabar community (a community identified as "particularly vulnerable tribal group or PVTG" by the Government of India) which inhabits this village. The hunter-gatherer Lodha-Sabars of Satyadaspur are yet to adapt to settled agriculture or even to manual work in the Delta, and prefer to stay within close proximity to the forest. Conversely, there were few-to-no MSHs from the surveyed villages with low hazard ranking. While the data indicated that multiple incidences of climatic hazards may be a driver of migration in the tribal hamlets, there might potentially be other drivers of migration (like loss of ecosystem dependence) from tribal communities, which have been discussed in subsequent sections of this paper.

Drivers of migration/predictor variables for migration

Livelihood

The livelihood pattern of the 600 ST households was analysed to determine their dominant economic activities. Households were assigned a household type depending on dominant (above 50%) economic activity in the last 365 days (National Sample Survey Round 64, 2007–2008). Analysis of the survey data revealed that daily wage work was the primary occupation of 24% of the ST households while, for 32% of the ST households, the dominant occupation was work in the unorganised sector in peri-urban or urban areas through temporary or cyclical migration. This indicated a dominant departure from the prevalent perception that the delta-

Table 3 Surveyed villages with their multi-hazard rank and migration

Sl. No.	Block	Villages	Hazard	Migrant-sending ST households (nos.)	Non-migrant-sending ST households (nos.)
1	Haroa	Nazarnagar	Low	0	1
2	Minakhan	Debitala	Low	1	5
3	Hasnabad	Jamberiabad	Moderate	0	3
4	Hasnabad	Ichapur	Moderate	1	1
5	Canning I	Madhukhali	Moderate	1	4
6	Canning II	Ganti	Low	1	2
7	Basanti	Ful Malancha	Low	4	21
8	Basanti	Parandar	Moderate	5	6
9	Basanti	Harekrishnapur	Moderate	1	2
10	Sandeshkhali I	Baunia Abad	High	2	22
11	Sandeshkhali I	Gazalia	Moderate	2	22
12	Sandeshkhali I	Hatgachi	High	9	4
13	Sandeshkhali II	Jhupkhali	Moderate	6	6
14	Sandeshkhali II	Khulna	High	13	1
15	Sandeshkhali II	Dwarir Jungle	High	10	9
16	Sandeshkhali II	Bhangatushkhali	High	11	9
17	Gosaba	Amtali	High	11	9
18	Gosaba	Pathankhali	High	16	12
19	Gosaba	Baramollakhali	High	6	4
20	Hingalgunj	Lebukhali	High	6	30
21	Hingalgunj	Sandelerbil	Low	3	1
22	Jaynagar II	Gopalnagar	Moderate	1	1
23	Jaynagar II	Chuprijhara	High	0	2
24	Kakdwip	Manmathapur	Moderate	3	8
25	Kultali	Katamari	High	32	12
26	Kultali	Shyamnagar	High	37	9
27	Mathurapur I	Banstola Barogheri	Moderate	5	17
28	Mathurapur II	Gilarchat	Moderate	4	12
29	Mathurapur II	Paschim Jatar Deul	Moderate	4	17
30	Namkhana	Namkhana	Moderate	10	20
31	Namkhana	Baliara	High	16	11
32	Patharpratima	Satyadaspur G-Plot	High	2	9
33	Patharpratima	Laxmi Janardanpur	Moderate	9	11
34	Patharpratima	Purba Dwarikapur	High	19	11
35	Sagar	Chemagari	High	0	7
36	Sagar	Chandipur	Moderate	1	6

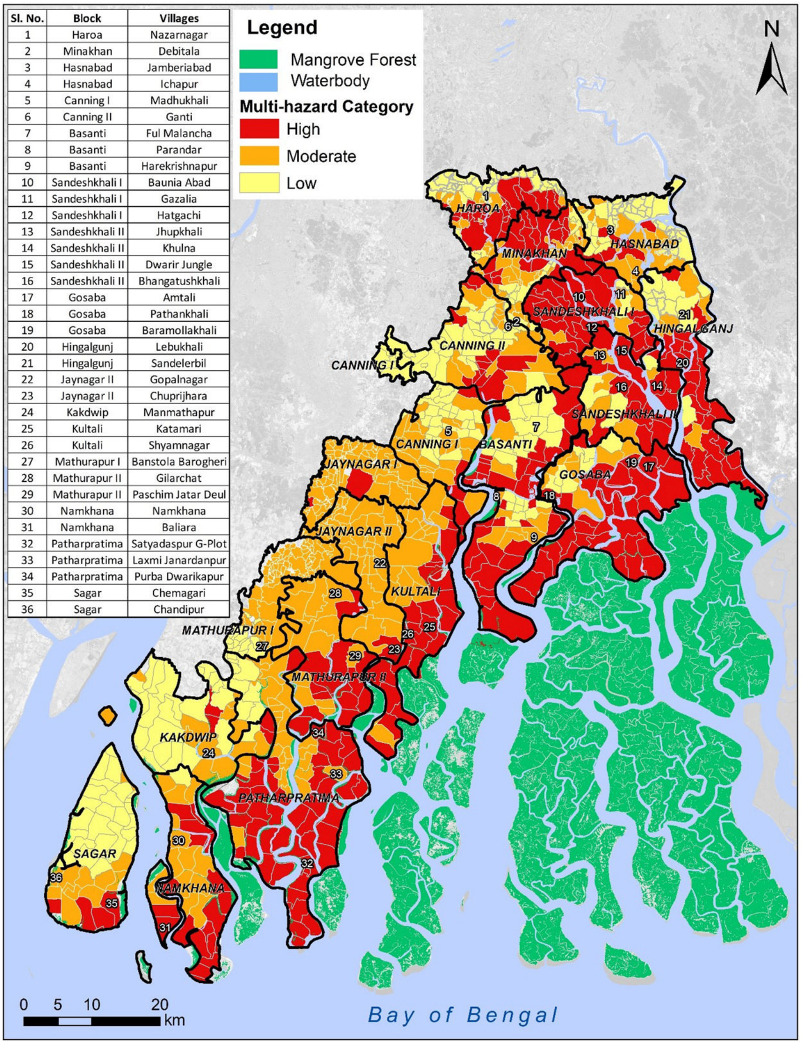

Fig. 3 Multi-hazard map at the village level in the SBR

dwelling communities predominantly depend on agriculture and fishing for their livelihood (Mistri 2013), revealing that 8% of the tribal households were primarily dependent on the forest and mangrove ecosystem services for their livelihood, and 20% on farm activities like cultivation (10%) and agricultural labour (10%). This pointed to a high level of diversification of livelihoods among these communities to improve their economic condition and standard of living. Livelihood diversification refers to attempts by individuals and households to find new ways to raise incomes and reduce environmental risk, which differ sharply by the degree of freedom of choice (to diversify or not) and the reversibility of the outcome (Ellis 1998; Khatun and Roy 2012; Ahmed et al. 2018; Roy and Basu 2020). With or without agriculture-related earning, the surveyed ST households depended on daily wage work, forest and ecosystem collection and other marginal livelihoods.

These results (Table 4) were significantly different from the reported occupation pattern of the tribal communities as being dominantly agriculturists (Dhargupta et al. 2009). Moreover, dependence on forest and ecosystem services did not come up as the primary livelihood strategy for the tribal households as commonly believed. One of the causes for this, as cited by many respondents, was stricter restrictions imposed by the Forest Department on entry into the protected forest area for economic activities like collection of fuelwood, fish, prawn, crab etc. (Mahato and Mondal 2019). However, the scope of MGNREGA and daily wage activities did improve post-Aila i.e., 2011 onwards.

Temporary migration from the SBR can be divided into two predominant types depending on the nature of the drivers, as indicated by interview respondents who migrate: migration induced by fast-onset climatic hazards such as cyclones and storm surges (which cause lasting damage to property and disrupt livelihoods) and migration induced by slow-onset incremental changes to the climate (which cause an incremental increase in livelihood insecurity).

The condition of agricultural landholding by ST families is grim, with the majority owning less than 0.5 hectare. According to Census data (2011a, b), the number of agricultural labourers is highest among the tribal population in the SBR. In subsequent years, with an increase in the frequency and intensity of natural hazards, (cyclones, sea level rise, erosion, soil salinization, and delayed monsoon) agriculture was also highly impacted. To sustain themselves in such adversities, ST households with or without landholding showed a high affinity for out-migration.

Table 4 Primary occupations of the surveyed ST households

Household type (primary occupation contributing ≥ 50% to the household income)	Count of ST household to total respondents (n = 600)	Percentage of ST household to total respondents
Migration	195	32
Daily wage labour	147	24
Harvesting from forest	51	8
Artisanal fishery	10	2
Cultivation	59	10
Agricultural labour	60	10
Small business	28	5
Transport services	22	4
Aquaculture	10	2
Service sector	10	2
Fishing	4	1
Livestock	2	-
Aquaculture (fresh water)	2	-
Total	600	100

Source Primary Survey, 2021

Table 5 Livelihood share from migration (remittance income)

Percentage of total livelihood share from migration	Number of ST households (respondent) (total = 600)	Percentage of ST households (respondent)
1–20	42	15.6
21–40	91	33.7
41–60	65	24.1
61–80	41	15.2
81–100	31	11.5
Total	270	100.0

Migrant-sending households (MSHs)

44.8% of the surveyed ST households, in the absence of a more stable source of income, sent at least one migrant to work outside the SBR (Table 5). Among them, 24% earned 40–60% of their livelihood share from remittance income while 27% earned 61–100%.

The survey participants opined that migration remittances contributed to the wellbeing of the household by meeting the families' health expenses, educational expenses, expenses to modify homesteads by making them flood-proof, and even contributed towards the creation of small savings for future need. Thus, remittances also contributed to the local economy through spending and investment in animal husbandry, backyard fishery and acquisition of household assets like electronic gadgets, motorcycles etc.

Agricultural landholding

Nearly 89% of MSHs and 75.6% of NSHs were found to be landless i.e., they had no substantial agricultural landholding. 9.7% of MSHs and 22.9% of NSHs owned 1–3 bighas (0.10–0.30 hectare) of agricultural land. The BLR analysis indicated that landholding equal to, or greater than, 0.10 hectare was one of the threshold values to determine whether a household sent at least one migrant to work in the past or might do so in the future (Table 6). While most ST households, whether MSH or

Table 6 Agricultural landholding of migrant-sending and non-migrant-sending ST households

Agricultural landholding (hectare)	Percentage of migrant-sending ST household	Percentage of non-migrant-sending ST household
Zero (landless)	45.4	59.6
< 0.133 hectare	15.2	8.1
0.13–0.26 hectare	24.5	21.4
0.28–0.40 hectare	7.1	5.4
0.41–0.53 hectare	3.0	2.1
0.54–0.67 hectare	4.5	1.5
> 0.68 hectare	0.4	1.8
Total	100.0	100.0

NSH, owned less than 0.5 hectare land, consecutive disasters like cyclones Bulbul (2019), Amphan (2020), Yaas (2021), and Asani (2022), and concomitant saline surges, which breached embankments and affected cropland, made even the limited returns from agriculture uncertain. Thus, poor landholding and crop failure may have been push factors of migration from tribal households. The results then indicated that the lower the landholding of a tribal family, the greater is the probability of migration.

Landless NSHs earned a very small share of their income from agricultural labour. Their livelihoods were diversified, including non-farm-based activities like transport, small business, and daily wage work under MGNREGA. Despite their landlessness, they showed a high level of satisfaction with their in-situ coping strategies and might have also had smaller families and more income input from provisioning services of the ecosystem. However, tribal households with moderate landholding and livelihoods that, though highly diversified, were sensitive to environmental shocks, were forced to migrate. These farm and ecosystem-based income opportunities were highly impacted by climate change impacts and led to economic instability. Thus, to ensure household sustenance and wellbeing, those households opted to migrate from the delta, making remittances the major contributor to their household income. ST households owning more than 0.5 hectare of land could survive without migrating as they were able to generate a sustainable income from agricultural production to offset the economic implications of rapid-onset climatic hazards like cyclones and surges. MSHs with agricultural landholding above 1 hectare were rarely found, comprising a mere 3% of the surveyed ST households. The productivity of their land was affected by a multitude of climate change impacts like higher winter temperatures, delayed monsoon, irregular rainfall patterns, frequent cyclones, and sea level rise.

While high livelihood diversification (23%) among NSHs indicated successful in-situ coping, the decision to migrate or not migrate must be perceived as a complex web where social vulnerability is intensified by hazard incidence and mediated by livelihood choices and the percentage of livelihood income from the available livelihood opportunities. The relationship between these factors has been discussed in greater detail in the section on BLR analysis.

Household size

Primary data analysis indicated that the smaller the size of the ST household, the lower is the probability of migration (Table 7). 64.8% of NSHs had 4 or fewer members compared to 52% of MSHs with the same household size. 26% of MSHs had a substantially large household size (6 and above) while only 15% for NSHs had a similar household size. It must be noted that household size includes both able-bodied adults and dependents (children and elderly and disabled members), denoting that larger households do not necessarily have a higher share of members contributing to the household income. Moreover, women members in most households in the SBR perform significant unpaid caregiving and other household duties, which do not reflect on the household income. Migrants from MSHs were found to occupy the age range of 18–50 years. Naturally, a higher number of remittance-

Table 7 Household sizes of migrant-sending and non-migrant sending ST households

Household size	Percentage of migrant-sending ST Household	Percentage of non-migrant-sending ST Household
< 4	19.2	34.8
4	31.8	30.3
5	23.7	19.3
6	10.7	8.4
> 6	14	7.5
Total	100	100

sending members contributed more towards the household income, helping them to cope/adapt to climatic changes and hazards.

Forest access and ecosystem dependence

Mangroves in the SBR provide the local people with numerous direct benefits in the form of ‘provisioning’ services. NTFPs from the mangrove forest ecosystem in the SBR constitutes the mainstay of many of the ST families. NTFPs collected from the mangrove forests include honey, fuelwood, fishes, prawn, crabs, and shrimps. 25% of the surveyed ST households were found to be in some way dependent on these ecosystem services. Among them, households with at least one migrant member demonstrated lower forest dependence for their sustenance compared to households with no migrant member (Table 8). The level of mangrove ecosystem dependence was calculated based on contribution of NTFPs towards annual household income, and subsequently, categorised into three classes (Singh et al. 2010), viz., (i) High Dependence, where NTFPs contributed more than 60% to annual household income; (ii) Moderate Dependence, where NTFPs contributed 40–60% to annual household income; and (iii) Low Dependence, where NTFPs contributed less than 40% to annual household income. It was apparent that 100% of MSHs demonstrated low dependence on the mangrove forest ecosystem

Table 8 Levels of dependence on ecosystem services of migrant-sending and non-migrant-sending ST households

Dependence on ecosystem services	Number of migrant-sending ST households dependent on ecosystem services	Percentage of migrant-sending ST households dependent on ecosystem services	Number of non-migrant-sending ST households dependent on ecosystem services	Percentage of non-migrant-sending ST households dependent on ecosystem services
Low dependency	63	100	41	48
Moderate dependency	0	0	18	21
High dependency	0	0	26	31
Total	63	100	85	100

services vis-vis only 48% of NSHs (Table 8). Nearly 52% of NSHs demonstrated high or moderate dependence on ecosystem services for their sustenance. Higher dependence on ecosystem services for livelihood might have also deterred these households from migrating.

Conversely, tribal communities without sufficient landholding to sustain the whole family, when denied access to the mangrove forest for NTFP collection, were left with no other option but to send migrants for the families' sustenance. Moreover, dominant or secondary dependence on the provisioning services of the mangrove ecosystem also contributed to heightened income insecurity by making the household vulnerable to climatic changes and hazards which affect the availability and accessibility of NTFPs, thus increasing the potential for migration from these households.

A trend can be evidenced from the primary survey, suggesting that the dependence of ST households on ecosystem services decreased with greater involvement in non-ecosystem-based work i.e., daily wage work. Marginal or no agricultural landholding as well as decreasing access to the mangrove forest ecosystem acted as important push factors for cyclical migration from the SBR as households sought to diversify their livelihoods for risk reduction. In the absence of land records, ST communities in the SBR are deprived of their forest rights, which restricts their access to NTFPs. However, even forest dependence is not without serious risks. Landlessness and inadequate returns from daily wage work force many ST households to increasingly rely on dangerous occupations, like illegally collecting crabs, fish and honey from Protected Areas (regulated by the Indian Forest Act, 1927, 1978, 2006), where the indigenous population of tigers, poisonous snakes and crocodiles pose serious threats to their lives. Entry into the forest being strictly regulated by the Forest Department, capture by officials entails heavy fines and even imprisonment. Loss of life in man-animal conflict within the Reserved Forest entails no monetary compensation for the family owing to the illegitimacy of venturing into, and profiting from, reserved areas (MoEFCC, GoI).

Household deprivation score (HDS)

Primary data analysis indicated that a greater number of poor tribal households with high HDS opted for migration. Whereas, very few not-so-poor households with low HDS opted for migration. Nearly 81% of tribal households experiencing a high level of deprivation sent at least one member to work outside the SBR (Table 9). This demonstrated that socioeconomic deprivation was a dominant driver of migration in the face of climatic hazards in the Delta. From all three categories of hazard-

Table 9 Household deprivation status and migration of the surveyed ST households

	Migrant-sending household	Non-migrant-sending household
Not-so-Poor (< 0.33)	47 (19%)	79 (25%)
Poor (> 0.33)	193 (81%)	231 (74%)
Total (n = 550)	240 (100%)	310 (100%)

impacted zones, migration from the poor section was observed to be higher than that from the not-so-poor section (Table 10). A direct relationship between migration and hazard incidence was observed from the data, with 24% MSHs being in the low hazard zone, 33% in the moderate hazard zone, and over 60% in the high hazard zone.

Even among the not-so-poor sections, 80% of which were NSHs in the low hazard zone, the share of NSHs reduced to 40% in the high hazard zone, demonstrating the impact of increasing hazard risk on even the not-so-poor section which could otherwise adapt to climate change under low and moderate hazard risk. While it was difficult to ascertain a particular threshold of hazard and deprivation leading to migration at the present level of data acquisition, the authors venture to suggest that, if the lower limit of alarming rates of migration from a village was considered to be 50%, and the present scenario of migration from the poor sections of the surveyed ST communities crossed this limit when the hazard score exceeded 0.5, then the rates of migration observed in the surveyed villages may be considered alarming.

Binary logistic regression (BLR) model analysis

Results from the BLR analysis were indicative of the dominant factors affecting migration decisions of tribal communities in the SBR. Moderate and high climatic hazard risks were observed to affect the greatest number of households with high HDS and large household size. NSHs, on the other hand, demonstrated higher agricultural landholding and greater dependence on provisioning services of the mangrove ecosystem. The accuracy for the model was nearly 69.2% (Tables 11 and 12). It was also observed that five variables, namely own agricultural landholding, HDS, hazard category of the village, accessibility of the tribal household to mangrove ecosystem services and household size had significant impact ($p < 0.05$) on migration at 95% level of confidence. Poor households (high HDS) were statistically significant to the model, with OR > 1 (1.927) indicating that households with high HDS are more likely to migrate than households with low HDS. Households in the high hazard category showed a greater propensity to migrate than households in the low hazard category (Table 10).

Owning agricultural land has been shown to correspond to a decrease in the tendency to migrate. Mangrove ecosystem dependence (harvesting from the forest)

Table 10 Relationship between hazard, household deprivation and migration of the surveyed ST households

Hazard category	Household deprivation score	Migrant-sending household (%)	Non-migrant-sending household (%)
High Hazard	Not so poor	37.2	62.8
High Hazard	Poor	60.1	39.9
Moderate Hazard	Not so poor	18.0	82
Moderate Hazard	Poor	33.8	66.2
Low Hazard	Not so poor	20.0	80.0
Low Hazard	Poor	24.2	75.8

Table 11 Result of binary logistic regression

Hosmer and lemeshow test

Step	Chi-square	df	Sig.
1	19.935	8	0.011

Model summary

Step	−2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	729.467[a]	0.149	0.2

Omnibus tests of model coefficients

		Chi-square	df	Sig.
Step 1	Step	97.08	9	0
	Block	97.08	9	0
	Model	97.08	9	0

[a]Estimation terminated at iteration number 4 because parameter estimates changed by less than 0.001

Table 12 Drivers/predictors of migration for the ST communities in SBR

		B	Significance	Exp(B) i.e Odds Ratio	95% C.I.for EXP(B)	
					Lower	Upper
Step 1[a]	Agricultural landholding (Zero)		0.001			
	Agricultural land (Own)	−1.016	**0.000***	**0.362**	0.221	0.593
	Agricultural land (Barga)	−0.907	0.109	0.404	0.133	1.226
	Agricultural land (Khas)	−0.446	0.632	0.640	0.103	3.970
	Agricultural land (Lease)	−20.350	0.999	0.000	0.000	
	Forest dependence (Ecosystem dependence)	−0.012	**0.010***	**0.988**	0.979	0.997
	Household size	0.200	**0.001***	**1.222**	1.090	1.370
	Household deprivation (Poor)	0.656	**0.002***	**1.927**	1.268	2.927
	Hazard category (Low)		0.000			
	Hazard category (Moderate)	0.570	0.184	1.767	0.763	4.091
	Hazard category (High)	1.481	**0.000***	**4.395**	1.974	9.785
	Constant	−2.413	0.000	0.090		

Note: The values in “Bold, a, *” are significant at a Confidence Interval of 95%

Table 13 Correlation between hazard index and migration

Multi-hazard index	Pearson correlation	1	0.550
	Sig. (1-tailed)		0.000
	N	36	36
Migrant-sending ST households (nos.)	Pearson correlation	0.550	1
	Sig. (1-tailed)	0.000	
	N	36	36

was a moderate predictor of the probability of a tribal household to migrate. The OR for harvesting from the forest (percentage of livelihood from forest) was 0.988, signifying that the intensity of a household opting for migration decreased with an increase in forest dependence.

Discussion

The present study considers the disparity in the growth rate of the tribal population between 2001 and 2011 at the block level to be a proxy indicator of permanent internal migration of tribal communities in the SBR. This population demonstrated internal movement from the highly hazard-prone CDBs in the southwestern part of the Delta to the CDBs closer to the mangrove forest on the northeastern side. It is expected that this pattern of depopulation and mobility can be further validated in India's next Census survey which is expected to be underway in 2024. Observed interlinkages between hazard incidence and migration reveal that high levels of socioeconomic deprivation and lack of adequate opportunities for in-situ adaptation necessitate reliance on migration as an adaptive response. Such adaptive responses are equally valid for non-tribal populations in the Delta and in the context of hazard-driven migration from vulnerable areas globally. Herein lies the wider relevance of this study as it contributes to such an understanding of the relationship between hazard incidence, socioeconomic vulnerability, and migration potential, and posits that improving in-situ adaptation for the entire vulnerable population through specific measures to facilitate improved physical and mental healthcare, non-farm livelihoods, access to educational assistance in the form of scholarships and efforts to reduce school dropout, assistance to address unsafe migration, cultural and linguistic revival for the wellbeing of tribal societies suffering from language loss and corruption of indigenous knowledge systems (Fowler 2002), and gender-responsive efforts to promote the protection and wellbeing of rural women, alongside prevalent practices to strengthen embankments and promote safe housing, can contribute to the creation of a holistic framework for in-situ adaptation by reducing climate risk and vulnerability and improving climate resilience. Such a framework can also shed light on how concerted efforts for disaster risk reduction and decreased socioeconomic vulnerability of the poor populace, both tribal and otherwise, in other climate-impacted regions can inform adaptation policies at the local, regional, and global levels.

The livelihood pattern of tribal households in the SBR is dominantly non-agrarian, which contrasts with the agrarian livelihood pattern of the non-tribal communities. Landlessness among the tribal population in the area is responsible for their strong reliance on casual manual labour and agricultural labour, which provide meagre compensation. Tribal communities in the SBR are additionally dependent on the mangrove ecosystem for their livelihood (Bandyopadhyay and Guha 2016). In the present analysis, primary survey data indicates that around 31% of the surveyed tribal population is dependent on the ecosystem goods of the mangrove forest in some way. However, a decline in mangrove forest cover and ecosystem goods like timber, fruits, honey, crab, fish, and molluscs in the SBR (Samanta et al. 2021) resulted in the assimilation of dominant socioeconomic practices of non-tribals, like agriculture, fishing, and aquaculture, for instance, by ST communities for their sustenance, leading to a loss of cultural identity. In addition, stringent forest regulation and the risk of man-animal conflict induces them to reduce their dependence on the mangrove forest ecosystem in favour of remittance income from migration. A trend can be evidenced from the primary survey, suggesting that the dependence of ST households on the ecosystem services is lower with greater involvement in non-ecosystem-based labour, viz. daily wage work. Marginal or no agricultural landholding as well as decreasing access to the mangrove forest ecosystem act as important push factors for migration from the SBR as diversification of their livelihood for risk reduction. While a sizeable section of the tribal population in the SBR now sends at least one migrant from each household, NSHs are predominantly dependent on daily wage work in different non-farm activities like work under MGNREGA, in brick kilns, aquaculture farms, industries or masonry within the SBR or in emerging urban centres in the Delta.

The historic shift from a predominantly forest-dependent livelihood of the dominantly Munda-Oraon community to increased reliance on settled agriculture as well as relocation to the Delta led to a gradual loss of tribal identity, customs, and languages. Being in touch with tribal traditions, including the worship of nature, and art, music, performance, and practices that encourage sustainable management of natural resources and environmental risks—such as promoting Joint Forest Management and issuing carbon credits to these communities, is central to effective and holistic in-situ adaptation of tribal communities. It has been observed, for instance, that cultural revival within the Santhali tribal community in hazard-prone areas of West Bengal, and the introduction of Santhali language training up to the postgraduate level, has significantly improved the socioeconomic status and climate resilience of this community. Such facilities are, however, unavailable for the dominantly Mundari tribes of the SBR.

Tribal communities in the SBR live outside Scheduled Areas, which restricts their access to NTFPs. Poverty, landlessness, and inadequate returns from livelihoods force many to sneak into the protected mangrove forest (regulated by the Indian Forest Act, 1927 and 1978), and risk their lives in man-animal conflict. Forest-gathering is recently also being discouraged by the Forest Department, with heavy fines and even imprisonment for violation. Absence of forest rights of ST communities in the SBR also contributes to cyclical migration.

Other major lacunae in policymaking and policy implementation also contribute to lack of improvement in the socioeconomic conditions—which are worsened by increasing hazard frequency and intensity—of tribal communities in the SBR. While healthcare infrastructure and water, sanitation and health (WaSH) facilities in the SBR are weak, certain specialised and culturally-sensitive educational support for STs, such as the EMRS scheme, remains inaccessible to these communities as it is applicable only for administrative blocks with at least 50% and 20,000 tribal inhabitants, which cannot be applied in the SBR where tribal hamlets are sporadically distributed. This contributes to the burgeoning social inequality and social vulnerability of ST communities' vis-à-vis non-ST communities in the SBR. Systematic redesigning of such policies and removing bottlenecks in implementation are key to delivering the best safeguards available with the government to these vulnerable tribal communities in the SBR and in other hazard-prone areas of the country. National and international NGOs play a crucial role in advocating for such measures, and in handholding the communities in non-farm skills training, climateresilient farming practices like natural farming and nutrition gardening with indigenous seeds and water harvesting, and improving access to relevant government provisions and safe migration practices through information hubs.

Recommended policy interventions

Despite the prevalence of various pro-tribal policies at the national and state levels since Indian Independence, the welfare of the tribal population in the country continues to suffer from lacunae in data, policy design and gaps between the mode and tempo of policy implementation and the intended beneficiaries. A good practice such as GoI's Socio Economic and Caste Census (2015), that is now being taken up by various state governments in recent years, is addressing the data gap by generating disaggregated data on the demographic and socioeconomic conditions of marginalised populations, including Scheduled Castes, Scheduled Tribes, and Other Backward Classes. In addition to that, a number of initiatives to ensure food security, such as the West Bengal Government's 'Khadya Sathi' scheme and food grains available at subsidised rates under the 'One Nation One Ration Card' scheme of the Government of India (GoI); improved housing and sanitation, such as the West Bengal Government's 'Nirmal Bangla' scheme, and GoI's 'Swachh Bharat' programme and 'Pradhan Mantri Awas Yojna'; health, such as the state government's 'Swastha Sathi' scheme and GoI's 'Ayushman Bharat'; and education, such as GoI's 'Sarva Siksha Abhiyan' and 'Mid-day Meal Scheme' (to reduce school dropout), are operational in the SBR. But there is an urgent need to improve the access of rural communities to these programmes by NGOs and relevant government functionaries to raise community awareness and handhold them through the complicated application processes.

Illiteracy and low levels of educational attainment, combined with lack of formal employment opportunities and geographical remoteness, contribute to poor socioeconomic wellbeing and development in the region. The absence of schools that teach in tribal languages and observe tribal values and holidays, and caps on the minimum population for the establishment of EMRS makes it difficult for tribal children to want or be able to attend school. Thus, thoughtful and culturally-sensitive policy implementation alongside efforts to handhold tribal households in raising their awareness of Reservation policies, and access to caste certification (ST cards) designed to enhance their benefits from generalised welfare schemes, must support policymaking to strengthen resilience to climate change. The authors acknowledge that it is the latter, i.e., adaptation to climate change, which has received the least legislative attention in India. To that end, it is recommended that the government ensure safe housing against climatic shocks (cyclone and surge impact etc.), protective embankments to resist erosion, sustainable use of mangrove ecosystem services, access to culturally-sensitive and relevant education and healthcare facilities, stronger implementation of the pro-tribal LAMPS scheme, and adequate in-situ adaptation to reduce distress-driven migration and promote a sustainable future for poor communities in vulnerable areas, such as the ST communities in the SBR. While several schemes, such as 'One Nation One Ration Card' (to ensure food security of migrant workers and families), registration of migrants through the state Panchayats, state-level Departments of Rural Development, and GoI's eShram portal and National Tribal Migration Support Portal, are operational, tribal communities in the SBR migrating under distress may benefit significantly from access to these measures through awareness and handholding activities. Additionally, appropriately modifying the Forest Rights Act, 2006, and generating land records to ensure that settler tribal communities which, though non-aboriginal to the area, have inhabited the area for several centuries since colonial times, are bequeathed forest rights which promote legal and sustainable forest use and management.

Conclusion

A first of its kind, this study has established the pattern of permanent and seasonal migration among tribal communities in the Sundarban Biosphere Reserve, India, in response to increasing climatic hazards mediated by severe socioeconomic deprivation. It observed that frequent exposure to multiple climatic hazards, with limited in-situ adaptive capacity, forced 60% of the surveyed multi-dimensionally deprived tribal households in the SBR to send at least one member outside the Delta to meet their livelihood needs. The relationship between hazard incidence (high, medium, or low), intensity of deprivation (poor or not-so-poor) and short-term seasonal migration among tribal households in the SBR has been illustrated (Fig. 4).

While highlighting the need for in-situ adaptation through proper implementation of existing policies on food security, safe housing, and access to education, health and mangrove ecosystem services, the study calls for a fresh perspective towards policy and welfare for safe and informed migration choices for tribal communities considering migration as an adaptive response to climate change. Additionally, schemes to support migrants such as 'One Nation One Ration Card' (to ensure food security of migrant workers and families), and the registration of migrants through the state Panchayats, state-level Departments of Rural Development, and the GoI's eShram portal and National Tribal Migration Support Portal, must be uniformly implemented with handholding support for tribal communities migrating

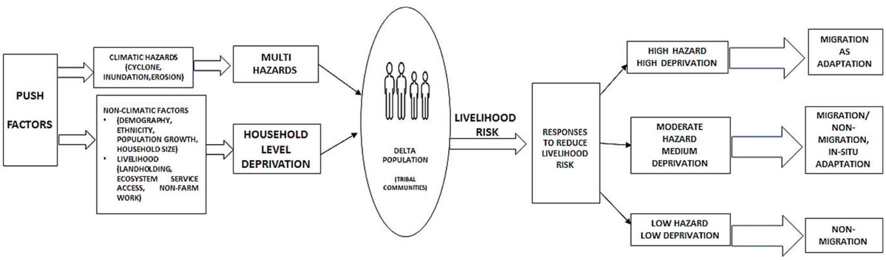

Fig. 4 Validated conceptual model elaborating the relationship between hazard, deprivation and migration

under distress from the SBR and other such hazard-prone areas. The present research has, thus, created a scope for similar research into the possibilities and circumstances of migration to develop holistic frameworks for: (1) Investigating the status of land titles for ST communities; (2) In-situ adaptation in climate hotspots around the world; and (3) Safe migration and support for migrants in transit and receiving areas by tracking migration pathways at the local, regional and global levels in climate-induced migration scenarios.

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Author contributions S.H identified and conceptualised the research problem, reviewed the manuscript, and provided critical feedback. S.P developed the theory, participated in the primary survey, performed the analysis, and contributed to the manuscript. S.D developed the historical background and the contemporary context, wrote the manuscript, and edited and communicated it. These three authors also jointly conceptualised the recommended policy interventions. S.S participated in the survey and prepared the maps and the figures. S.C supervised and guided the preparation of the manuscript.

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Declarations

Ethical approval Not applicable since no human experimentation is done.

Informed consent The authors hereby declare that the informed consent of the participants of the primary survey was duly acquired, and the data collected is fully anonymised and poses no harm to any participant.

Conflict of interest The authors declare that there is no conflict of interest.

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