



# Spatial variation in livelihood security among livestock-based agricultural farming systems in climatically vulnerable Indian Sundarbans

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Received: 13 December 2022 / Accepted: 10 October 2023 / Published online: 23 October 2023

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## Abstract

Farm households in the UNESCO World Heritage site Sundarbans face serious problems, including increased soil salinity, frequent extreme weather events, seawater intrusion and flood damage, all of which cause distress to the livelihoods of the farm families. Policymakers commonly acknowledge livestock as a crucial resource for mitigating economic losses caused by crop failures due to extreme weather events. Despite Sundarbans' vulnerability to extreme weather events, smallholder farmers' livelihoods vary across the region. Identifying spatial livelihood variations aids in targeted strategies to address climate extremes. We chose the highest cow- and buffalo-populated blocks among the 19 blocks in the Sundarbans to assess variations in livelihood dimensions, including nutritional, economic, social and infrastructural security. We used dummy variable regression models to examine the differences in livelihood security dimensions among households living in different locations. The study found that Namkhana had the highest livelihood security score among the blocks studied, while Gosaba had the lowest score because it's in a remote area with limited infrastructure. The study found a significant difference in the overall livelihood security score among the blocks we examined, indicating the need for a location-specific, cluster-based approach for the overall development of the Sundarbans. The study can shape a policy framework for socio-economic development in the Indian Sundarbans through its findings on location-specific livelihood security. For securing smallholder farmers' livelihoods in the vulnerable Sundarbans region, policymakers must give priority to improving infrastructure, viz., roads, marketing facilities and animal healthcare centers.

**Keywords** Livelihood security · Spatial variation · Nutritional security · Economic security · Social security · Infrastructural security · Agricultural enterprise

## Introduction

Agriculture is the main source of livelihood for rural residents of developing countries, but their livelihood is in danger due to climate variability and change (Aggarwal, & Singh, 2010; Mahendra Dev, 2012; Bailey, & Buck, 2016; Keshavarz et al., 2017). Climate-related issues and farmers' livelihood strategies are different in different parts of the

world (Chitongo, 2019). The Sundarbans, located at the southern end of West Bengal (India), fall in one of the most vulnerable zones of abrupt climatic events and the delta has been facing major climatic and other socio-ecological adversities for a long time (Mandal et al., 2019; Mondal et al., 2022a, b). River systems play an important role in the livelihood while also making residents prone to multiple floods with the majority of the population dependent on agriculture (Patel et al., 2021). The fragile ecosystem of Sundarbans has continuously been affected by the degradation processes such as coastal erosion, seawater intrusion and inundation, and salinization (Bhutia et al., 2021). The increased likelihood of climate-related disasters is likely to increase the vulnerability of exposed populations (Krishnamurthy, 2012). Small farmers were more acutely affected by extreme weather events as they found it tough to cope

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with climate extremes (Paltasingh, & Goyari, 2015). Lack of financial assets and poor institutional support are the major constraints on overcoming the negative effects these disasters have on livelihood (Chhotray, & Few, 2012). Agriculture, animal husbandry, fishing, forest product collection and other primary economic activities have long been associated with livelihood in the Indian Sundarbans, with little regard for industrial development (Das & Tripathi, 2013; Mondal, & Paul, 2022). The fertile soil of the Sundarbans yields excellent quality horticulture produce (Andharia, 2020). Livestock helps vulnerable people to cope in variable environment (Ashley et al., 1999). The poor will be able to play a greater role in some livestock production and market chain systems than others and livestock may provide an alternative to crop farming (Jones & Thornton, 2009). Location-specific policies are required to maintain the socio-economic development of humans in the Sundarbans (Halder et al., 2021). Significant spatial variations in soil quality as well as topography have been observed in different locations of Sundarbans which affect the production and productivity status of agricultural and allied enterprises (Mitra et al., 2012; Giri et al., 2022). Despite numerous previous endeavours to uncover location-specific disparities in natural resources, comprehensive investigations into the relationship between livestock husbandry and the livelihood security of individual households are conspicuously absent. With this background, this study identifies the spatial variation of livelihood dimensions, if any, among farm households in Sundarbans. The present study investigated the spatial variability of diverse facets of livelihood security within livestock-based agricultural systems. It aimed to identify potential factors contributing to variations in multiple indicators of livelihood security. Conducting location-specific research on livelihood security and considering pertinent influential factors can yield valuable insights for policies related to livestock-based farming systems. Effective strategic planning, coupled with a deep understanding of the specific requirements of each location, can pave the way for developing a sustainable livelihood model centred on livestock farming. This approach can effectively deal with the frequent adverse weather events in the region.

## Materials and methods

### Locale of the study

Sundarbans is the largest mangrove forest in the world situated at the land ocean boundary of Ganges–Brahmaputra delta. The Indian part of Sundarbans is extended over an area of 9600 sq. km (Dutta et al., 2013) and lies between 21°32' and 22°40'N latitudes and between 88°05' and 89°E

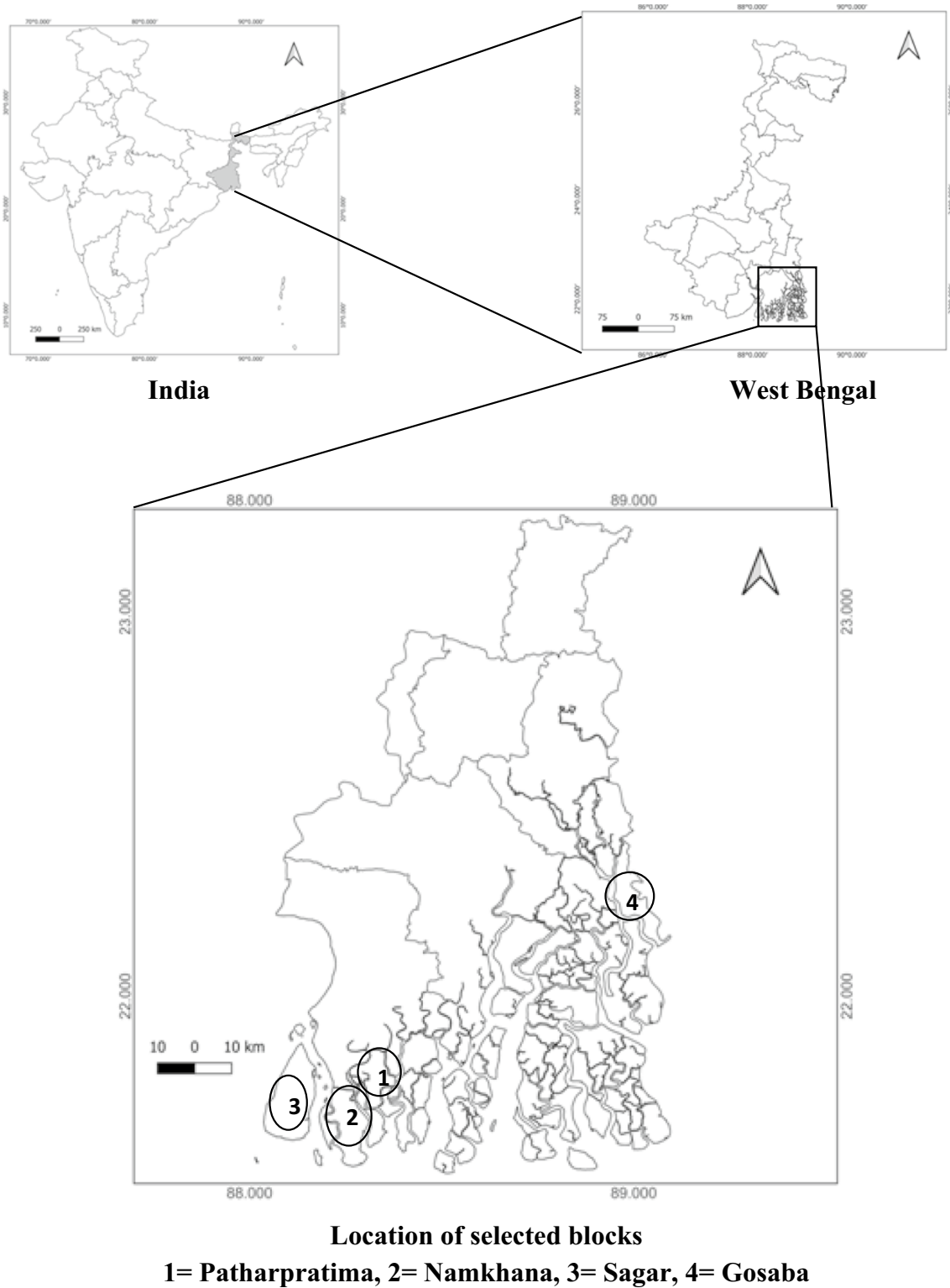
longitudes. It extends up to the Bay of Bengal towards south and stretches up to the Dampier-Hodges line (the line demarcating the limit of Sundarban towards main land mass) in the north (Hazra et al., 2016). The area is predominantly situated in the new alluvial and coastal saline agroclimatic zone of West Bengal, at an altitude of 3–8 m from sea level (Nath et al., 2021). The Sundarbans region of India consists of 19 blocks, six from North 24 Parganas and thirteen from South 24 Parganas district of West Bengal state (Ghosh & Mishri, 2020). On the basis of the highest number of cattle and buffalo population, four blocks namely Patharpratima, Namkhana, Sagar and Gosaba were selected for the study (Fig. 1).

### Data and sampling

From the selected four blocks, 20 villages were selected from each block. From each of these villages, 10 farm households were selected who have engaged in livestock-based farming systems. Thus, data were collected from 80 villages involving 800 farm households. One structured interview schedule was developed for the study, and we collected data by personal interview and focused group discussion method. Focus group discussion and in-depth interviews are excellent methodological approach for gathering viewpoints of local households in measuring livelihood (Kaplowitz, 2001). Collected data were triangulated by experts from local farm science centres, veterinary and agriculture officers, and specialists from local universities. Triangulation helps to validate the information in the conceptualization of certain phenomena, which results in the trustworthiness of findings (Lambert & Loiselle, 2008; Carter et al., 2014).

### Data analysis

We have extensively reviewed the existing literature to identify the dimensions and indicators of livelihood. Pal et al. (2023) analyzed a number of research, papers, frameworks and policies, and these concepts were further synthesized with the help of experts. Following that, they created an integrated framework for identifying dimensions, sub-dimensions, indicators and measurement parameters for index-based tools for assessing livelihood security and resilience. Krishna et al. (2020) collected data on ecological, economic and social indicators to construct the Sustainable Livelihood Security Index (SLSI). Sundar Pani and Mishra (2022) identified 22 suitable indicators for measuring SLSI across three major components: ecological security, social equity and economic efficiency. Das et al. (2020) constructed the Livelihood Vulnerability Index (LVI) by selecting appropriate social and biophysical factors using inductive and deductive approaches. Rahman and Hickey (2020) used a five-step approach to assess Context-Specific Rural Livelihood Vulnerability, which includes (i) identifying the context; (ii) assessing livelihood exposure to climate impacts; (iii) characterizing



**Fig. 1** Location of study area

capital asset usages; (iv) analyzing formal and informal institutional impetus and (v) evaluating the gap between context-specific vulnerability and institutional responses. Asmamaw et al.

(2020) framed the Livelihood Vulnerability Index (LVI) within the Intergovernmental Panel on Climate Change and vulnerability (LVI-IPCC) approach to quantify households' livelihood

vulnerability. The LVI and LVI-IPCC were calculated in each agro-ecology, and one-way analysis of variance was used to assess for differences between agro-ecological zones, but in this approach the societal issues were not given much importance. Tessema and Simane (2019) used the indicator method to measure vulnerability in their study, and indicators related to infrastructure, technology, community and social characteristics were included. Mehzabin and Mondal (2021) developed a livelihood vulnerability index (LVI) that includes six main components: socio-demographic profile, livelihood strategies, health, food, water, natural disasters and climate variability.

After reviewing relevant literature and consultation with experts, the current study used four dimensions to assess livelihood security namely, nutritional security, economic security, social security and infrastructure security. Under each dimension, several indicators were identified based on the extensive literature search and local situation analysis. Total 17 indicators were included in the measurement of the nutritional security component, 21 indicators in the measurement of the economic security dimension, 15 indicators in the measurement of the social security dimension and 11 indicators in the measurement of the infrastructure security dimension. The response (yes = 1 and otherwise = 0) for each indicator available under each dimension was added, and equal weights were assigned to every indicator. We collected exclusively primary data using a meticulously designed, structured interview schedule. Nevertheless, it's worth considering incorporating specific indicators that secondary data sources can quantify. It could potentially customize the study to specific geographical areas or regions. Arrigoni et al. (2022) recommended that averaging with equal weights the indicators successfully produce a composite index that often perform better than, those constructed with more sophisticated statistical methods. Dimension wise security index (DSI) were calculated as a simple means of household's score in the indicator of respective dimension by using the following formula,

$$DSI_k = \frac{\sum_{i=1}^j X_{ik}}{n_k}$$

where  $DSI_k$  is the score achieved in the  $k^{th}$  dimension,  $X_{ik}$  is the response to the  $i$ th indicator under  $k^{th}$  dimension,  $j$  is the total number of indicators under each dimension and  $n_k$  is the number of indicator under  $k^{th}$  dimension. Weights of different dimensions were given as per the method proposed by Iyengar and Sudarshan (1982) and as applied by Devi et al. (2017). For the calculation of weights, initially, variance of indicators under each dimension was found out and square root of variance ( $\sqrt{varX_{ik}}$ ) was calculated. Then, the sum (S) of reciprocals of the square root of the variance for all dimensions was calculated by the following method:

$$S = \frac{1}{\frac{1}{\sqrt{VarDSI_1}} + \frac{1}{\sqrt{VarDSI_2}} + \dots + \frac{1}{\sqrt{VarDSI_k}}}$$

Then, weights of each dimension were calculated as the ratio of the sum of reciprocals of the square root of variance for all dimensions and the square root of the variance of the particular dimension by using the following formula:

$$W_k = \frac{S}{\sqrt{VarianceDSI_k}}$$

Ultimately, the overall livelihood security index was constructed by taking the sum of security scores under each dimension and dividing them by the sum of weights. The formula is as follows:

$$LSI = \frac{\sum_{k=1}^4 DSI_k}{\sum_i w_i}$$

The *F*-test was used to determine the difference in the block-wise livelihood security dimension. After that, measuring the relative difference in weighted dimension scores of different households from the block with the highest score was measured by using estimated coefficients of the dummy variable regression model. In the study, different blocks were considered categorical variables. The following model was used to measure the coefficients of different livelihood dimension scores:

$$Y_i = \beta_1 + \beta_2 B_{2i} + \beta_3 B_{3i} + \beta_4 B_{4i} + \mu_i$$

$Y_i$  (average) weighted security score for particular dimension.

$B_{2i}$  1 if the household is located in block 2; = 0 otherwise (i.e. not located in block 2).

$B_{3i}$  1 if the household is located in block 3; = 0 otherwise (i.e. not located in block 3).

$B_{4i}$  1 if the household is located in block 4; = 0 otherwise (i.e. not located in block 4).

The assumption that the error term satisfied the usual OLS assumptions was made, the mean weighted dimensional security score of the households located in block 2 would be:  $E(Y_i | B_{2i} = 1, B_{3i} = 0, B_{4i} = 0) = \beta_1 + \beta_2$ .

## Results

### Socio-economic condition of farm households

From Table 1, it can be seen that 74.375% of the farm households had less than 0.5 ha of land and only 5.625% of farm households possessed farmland more than 1 ha. Fragmented land holdings hindered the overall agricultural development in

the locality. Only 2% of the farm household in Patharpratima block had a land holding of more than 1 ha, whereas 7.500% and 9.500% of farm households in Sagar and Gosaba blocks had more than 1 ha of land, respectively. Education is a very important socio-economic indicator for the overall development of households. Only 6.000% of the head of the family in the study area have studied beyond the intermediate level whereas 42.000% and 28.000% of heads of family in Gosaba and Sagar block, studied up to primary level, respectively. The farm households in the study area were engaged in seven combinations of livestock-based agricultural enterprises. The combinations were 'LR+FCF', 'LR+FS', 'LR+FCF+HCF', 'LR+FCF+FS', 'LR+HCF+FS', 'LR+FCF+HCF+FS' and 'LR+AL'. Out of these 7 combinations, a majority of the farm households (52.750%) were engaged in 'LR+FCF+HCF+FS' enterprise combination and only 0.250% of the farm households were engaged in 'LR+FS' enterprise combination. The income level of the sampled farm households was very low. It was found that, 63.625% of the

total farm households earned less than 2500 USD per year and more than 60% of the farm households earned less than that amount in all the blocks. Social caste plays a very important role in accessing different social security schemes, as well as indicating the social systems' capability to adopt different agricultural technologies as per the cultural norm of the society. Reservation is governed by constitutional laws, statutory laws and local rules and regulations. Scheduled castes (SC), scheduled tribes (ST) and other backward classes (OBC) are the primary beneficiaries of the reservation policies under the Constitution (Dubey et al., 2017). While caste no longer determines occupation, it continues to play an important role through historically acquired capital, both tangible (viz. land, money and other assets) and intangible—particularly networks (Kumar, 2013). Overall 47.375% of the total respondent household was from the General caste or unreserved category, 40.750% was from the scheduled caste community, 10.375% was from the Other Backward Class community and only 1.500% was from the ST community.

**Table 1** Socio-economic condition of spatially disaggregated farm households

Variables	Category	Name of the block				Total	Chi-square
		Gosaba	Patharpratima	Namkhana	Sagar		
Land	Less than 0.5 ha	117 (58.500)	174 (87.000)	172 (86.000)	132 (66.000)	595 (74.375)	65.200 ( $P < 0.01$ )
	0.5 ha to 1 ha	64 (32.000)	22 (11.000)	21 (10.500)	53 (26.500)	160 (20.000)	
	More than 1 ha	19 (9.500)	4 (2.000)	7 (3.500)	15 (7.500)	45 (5.625)	
Education level	Up to primary level	84 (42.000)	91 (45.500)	52 (26.000)	56 (28.000)	283 (35.375)	31.169 ( $P < 0.01$ )
	Primary to intermediate	103 (51.500)	98 (49.000)	141 (70.500)	127 (63.500)	469 (58.625)	
	Higher than intermediate	13 (6.500)	11 (5.500)	7 (3.500)	17 (8.500)	48 (6.000)	
Enterprise combination	LR+FCF	4 (2.000)	16 (8.000)	55 (27.500)	25 (12.500)	100 (12.500)	465.844 ( $P < 0.01$ )
	LR+FS	1 (0.500)	1 (0.500)	0 (0.000)	0 (0.000)	2 (0.250)	
	LR+FCF+HCF	5 (2.500)	20 (10.000)	61 (30.500)	22 (11.000)	108 (13.500)	
	LR+FCF+FS	1 (0.500)	115 (57.500)	17 (8.500)	21 (10.500)	154 (19.250)	
	LR+HCF+FS	10 (5.000)	0 (0.000)	2 (1.000)	0 (0.000)	12 (1.500)	
	LR+FCF+HCF+FS	179 (89.500)	48 (24.000)	63 (31.500)	132 (66.000)	422 (52.750)	
	LR+AL	0 (0.000)	0 (0.000)	2 (1.000)	0 (0.000)	2 (0.250)	
Income	Less than 2500 USD	123 (61.500)	135 (67.500)	121 (60.500)	130 (65.000)	509 (63.625)	53.262 ( $P < 0.01$ )
	More than 2500 USD but less than 5000 USD	77 (38.500)	55 (27.500)	65 (32.500)	44 (22.000)	241 (30.125)	
	More than 5000 USD but less than 7500 USD	0 (0.000)	8 (4.000)	10 (5.000)	8 (4.000)	26 (3.250)	
	More than 7500 USD	0 (0.000)	2 (1.000)	4 (2.000)	18 (9.000)	24 (3.000)	
Caste	Gen	10 (5.000)	84 (42.000)	143 (71.500)	142 (71.000)	379 (47.375)	356.638 ( $P < 0.01$ )
	OBC	1 (0.500)	41 (20.500)	18 (9.000)	23 (11.500)	83 (10.375)	
	SC	178 (89.000)	74 (37.000)	39 (19.500)	35 (17.500)	326 (40.750)	
	ST	11 (5.500)	1 (0.500)	0 (0.000)	0 (0.000)	12 (1.500)	

LR, livestock rearing; FCF, field crop farming; FS, fisheries; HCF, horticultural crop farming; AL, agricultural labour; Gen, general; OBC, other backward class; SC, scheduled caste; ST, scheduled tribe

## Weighted scores of different livelihood dimensions

Food security is a strong indicator of overall household vulnerability to extreme weather events (Shah et al., 2020). From Table 2, it can be seen that Gosaba block had the lowest mean weighted nutritional security score of  $0.080 \pm 0.012$  and the Sagar block had the highest weighted nutritional security score of  $0.123 \pm 0.025$  among the studied blocks. On the other hand, the highest weighted economic score of  $0.152 \pm 0.021$  was found in the case of Namkhana block and Gosaba block had the lowest economic security score of  $0.133 \pm 0.017$ . The weighted social security score showed a similar trend to the weighted economic security score (Fig. 2); Namkhana block with  $0.152 \pm 0.041$  weighted social security score got the highest score among all the studied blocks and Gosaba block with  $0.114 \pm 0.011$  weighted security score got the lowest score. A similar weighted infrastructural security score was observed in Namkhana block ( $0.258 \pm 0.043$ ) and in the Sagar block ( $0.259 \pm 0.034$ ). Significant variation in livelihood security score among different blocks was observed at the 1 per cent level of significance. The highest overall livelihood security score of  $0.678 \pm 0.119$  was in Namkhana block (Fig. 3) and

the lowest score of  $0.568 \pm 0.048$  was observed in Gosaba block.

## Estimated coefficients of dummy variable regression models

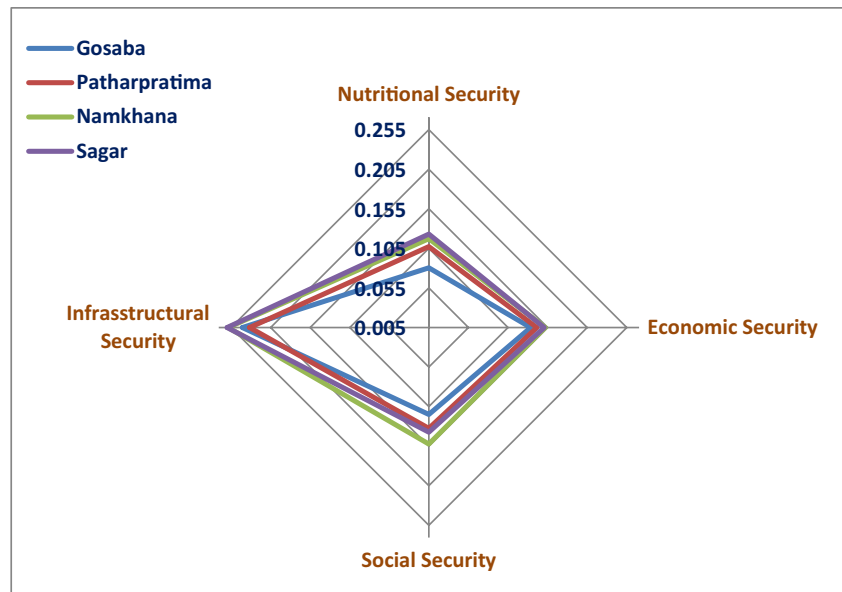
As the Namkhana block had the highest livelihood security, the weighted scores of different dimensions of livelihood security of the farm households residing in the Namkhana block were compared with other blocks of Sundarbans by using a dummy variable regression model. From Table 3, it can be said that the weighted mean score of the Sagar block was significantly higher than Namkhana block at a 1% level of significance. The calculated mean difference in weighted nutritional mean score was highest (0.037, t-cal 16.553) between Namkhana block and Gosaba block. The calculated mean weighted economic security score of Namkhana block was better than all other blocks, though the mean difference was not significant when compared with Sagar block ( $P > .05$ ). The Namkhana block's weighted mean social security score was higher than all other blocks ( $P < 0.01$ ). On the other hand, weighted mean infrastructural score of Namkhana block was better than Patharpratima and Gosaba block

**Table 2** Weighted scores of different livelihood dimensions

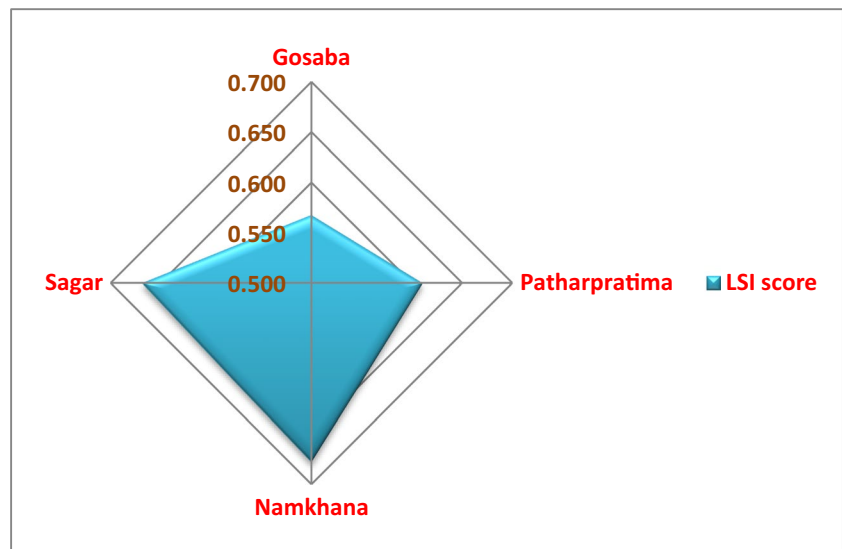
Livelihood security dimensions	Blocks	Mean	Std. error	F-cal
Nutritional security	Patharpratima	0.107	0.018	144.306 ( $P < 0.01$ )
	Namkhana	0.117	0.029	
	Sagar	0.123	0.025	
	Gosaba	0.080	0.012	
	Overall	0.106	0.028	
Economic security	Patharpratima	0.141	0.020	40.592 ( $P < 0.01$ )
	Namkhana	0.152	0.021	
	Sagar	0.150	0.019	
	Gosaba	0.133	0.017	
	Overall	0.144	0.021	
Social security	Patharpratima	0.132	0.024	62.580 ( $P < 0.01$ )
	Namkhana	0.152	0.041	
	Sagar	0.137	0.024	
	Gosaba	0.114	0.011	
	Overall	0.134	0.031	
Infrastructural security	Patharpratima	0.231	0.046	26.447 ( $P < 0.01$ )
	Namkhana	0.258	0.043	
	Sagar	0.259	0.034	
	Gosaba	0.240	0.027	
	Overall	0.247	0.040	
Overall	Patharpratima	0.611	0.088	75.914 ( $P < 0.01$ )
	Namkhana	0.678	0.119	
	Sagar	0.669	0.065	
	Gosaba	0.568	0.048	
	Overall	0.631	0.095	



**Fig. 2** Block-wise scores of different livelihood security dimensions



**Fig. 3** Overall livelihood security score of farm households from different blocks



at the 1% level of significance, though the mean difference of 0.001 (t-cal 0.331) was not significant when compared with Sagar block. Overall livelihood security of Namkhana block and Sagar block was not significantly different; though a mean difference in weighted score of 0.009 (t-cal 1.092) was found.

## Discussion

### Socio-economic condition of the farm households

Education and operational land holding are two of the important variables which influence the overall livelihood

security of the farm households (Lindenberg, 2002; Bhandari & Grant, 2007; Patidar, 2019; Pradhan et al., 2021; Mabe et al., 2021). Fragmentation of landholding is common in Sundarbans which negatively impacts the agricultural field operations by restricting the use of modern farm implements. Livestock provided the farming household an alternate livelihood and with modern veterinary facilities the area can flourish in livestock farming activities (Dhara et al., 2019). Due to the fragmentation of land, farm households were compelled to cultivate field crops or horticultural crop on a small piece of land. Rain-fed paddy farming was the main field crop of Sundarbans (De & Das, 2021), apart from that mustard, some pulse crops, seasonal vegetables and fruits/plantation crops were more popular.

**Table 3** Estimated coefficients of dummy variable regression models

Blocks	Nutritional security			Economic security			Social security			Infrastructural security			Overall livelihood security							
	Coef- ficients	Std. error	t-cal	P-value	Coefficients	Std. error	t-cal	P-value	Coeffi- cients	Std. error	t-cal	P-value	Coeffi- cients	Std. error	t-cal	P-value				
Patharp- ratima	-0.010	0.002	-4.490	0.000	-0.011	0.002	-5.549	0.000	-0.020	0.003	-7.193	0.000	-0.027	0.004	-7.084	0.000	-0.068	0.008	-8.003	0.000
Nam- khana	0.117	0.002	74.345	0.000	0.152	0.001	111.817	0.000	0.152	0.002	78.064	0.000	0.258	0.003	95.314	0.000	0.678	0.006	113.691	0.000
Sagar	0.006	0.002	2.640	0.008	-0.001	0.002	-0.719	0.472	-0.015	0.003	-5.442	0.000	0.001	0.004	0.331	0.740	-0.009	0.008	-1.092	0.275
Gosaba	-0.037	0.002	-16.553	0.000	-0.018	0.002	-9.633	0.000	-0.037	0.003	-13.573	0.000	-0.018	0.004	-4.722	0.000	-0.111	0.008	-13.112	0.000
R-square	0.352				0.133				0.191				0.091				0.222			
F-value	144.306 (P<0.01)				40.592 (P<0.01)				62.580 (P<0.01)				26.447 (P<0.01)				75.914 (P<0.01)			

In case of inland fisheries, farmers were cultivating majorly different types of carp, catfish and tilapia. The status of farm household level income in Sundarbans was not good and a majority of farm households were actually earning less than 7500 USD per year. Maintaining a proper life with this income amount was very daunting for the farm households and this income is an indicator of the underdevelopment of the area (Costanza et al., 2007; Kibria et al., 2022). Livestock and horticultural produce are perishable in nature and the unavailability of cold storage or bulk milk coolers, interrupted power supply forced farmers to sell their produce at a very cheap price. Moreover, due to several extreme weather events like storms, flood, etc. drive farmers to distress sell their farm produce and livestock (Hosain et al., 2022). These factors contributed significantly to farm households' low-income status. Caste is one of the important factors that determine social status and economic activities to secure sustainable livelihood (Nayyar, 1987; Goli et al., 2021; Pattnaik & Lahiri-Dutt, 2020). The general caste and SC communities were the most prevalent in the study area, while the scheduled tribe community was the least prevalent. SCs and STs were the most vulnerable communities in terms of livelihood security dimension, and as a result, the government has formulated several social security schemes for those two communities on the basis of social discrimination. OBCs benefited from some specially designed social security schemes.

### Weighted scores of different dimensions of livelihood security

In almost all the dimensions of livelihood security, Gosaba block had the lowest weighted security scores among the studied blocks. The block is located in one of the remotest parts and there was limited access through the road. Sagar block was also not directly connected to the mainland by road and the residents of the block have to depend on the big vessel to travel, though due to the better navigability, Sagar block had relatively better connectivity. During extreme weather events, many places of Gosaba block remain cut from the mainland and their accessibility to food, medicines and supply of inputs for farm operations is put at risk in that situation. As a result of that, the scores with respect to nutrition, economic and social security were the lowest in Gosaba block than other studied blocks. The farm families from Namkhana and Sagar blocks also got the benefit of better infrastructure due to tourist attractions. Due to the demand and relatively developed infrastructure helped the farm household to get better livelihood security score. The spread of tourism has improved transport and telecommunication, road conditions and ferry services in Sundarbans (Guha & Ghosh, 2007). Cattle farming in those 2 blocks flourished due to the high demand for milk.



Though the Patharpratima block has the highest cattle and buffalo population among the Sundarbans blocks, it has been unable to fully utilize the resources due to poor infrastructure, such as access to veterinary health services and the lack of good quality germplasm, as well as the unprofessional attitude of farm households. Infrastructure development, encompassing elements such as all-weather road networks, a well-structured marketing framework, and accessible livestock healthcare facilities, is instrumental in enhancing diverse aspects of livelihood security during extreme weather events. It is imperative for policymakers to prioritize and invest in robust infrastructure within these sectors, thereby fostering a sustainable livelihood strategy for the remote regions of the Sundarbans.

### Estimated coefficients of dummy variable regression models

Due to the comparatively developed infrastructure and high level of demand for agricultural farm produce, the livelihood status of Namkhana and Sagar blocks of Sundarbans was better than other blocks under the study. Increased salinity due to inundation with flooded saline water, soil health has deteriorated in Sundarbans (Mandal et al., 2018; Paul & Chatterjee, 2019; Mondal et al., 2022a, b). Poor soil health status affected farm productivity; reduced the yield of field crops, aquatic species and livestock, which resulted in poor nutritional security (Mohanty et al., 2017; Rahman et al., 2019; Das, 2022). On the other hand, remoteness and underdeveloped infrastructure resulted in poor livelihood security scores in every dimension for the farm households in Gosaba block. Frequent extreme weather events inflicted heavy damage to small holder farming systems in Indian Sundarbans region (Mukherjee & Siddique, 2022). The lack of organized market structure in the zone seriously affected the economic security of the area. Utilizing economic backwardness as a criterion for formulating social security plans for the Sundarbans, with a specific focus on smallholder livestock farmers, is recommended. Incorporating smallholder farming systems into a robust marketing framework can improve farmers' access to resources and ensure a fair price for their produce. This policy initiative holds promise for ameliorating the present livelihood situation within the Sundarbans region.

### Conclusion

Spatial heterogeneity in infrastructural, nutritional, economic and social security scores has given rise to discernible discrepancies in the overarching spectrum of livelihood security across the Indian Sundarbans. Notably, the Gosaba administrative block emerged with the most subdued scores across

virtually all the livelihood dimensions, contrary to its status of possessing the third-largest populace of cattle and buffalo among the Sundarbans blocks. This substantiates the proposition that asset ownership in isolation does not furnish a salutary assurance of heightened livelihood security. Fragmented land holdings have inhibited agricultural development in the studied area. In such circumstances, livestock farming provides an efficient means to secure a sustainable income. The study revealed that the low income and limited education of farm households may hinder the adoption of advanced agricultural technology. However, implementing animal husbandry technologies like crossbreeding and vaccination programmes offers prospects for long-term livelihood security. During extreme weather events, remote regions become isolated, disrupting access to essential resources like food and medicine. Therefore, prioritizing infrastructure development, including the construction of all-weather roads, becomes imperative to improve diverse dimensions of livelihood in the remote areas of the Sundarbans. Better access to high-quality livestock germplasm can enhance the livelihood of blocks like Patharpratima, where livestock numbers are high.

Policymakers should consider small-scale livestock farmers' needs when designing social security policies. This strategy can enhance regional well-being. Implementing river embankments, applying soil amendments, adopting high-yield crops, providing access to veterinary healthcare facilities, offering credit facilities and establishing reliable marketing infrastructure can significantly improve the livelihoods of farming households. Infrastructure, such as all-weather roads, milk coolers and chilling plants, may be developed so that farmers from remote blocks of the Sundarbans can secure their livelihoods even during extreme weather events. Future research should focus on studying seasonal livelihood security variations in the Sundarbans. The objective would be to identify season-specific interventions at the micro-level. Moreover, it is advisable to assess in-depth the contribution of different types of livestock in securing livelihoods within smallholder farming systems in future research. This approach can offer specific guidelines for rearing livestock species tailored to the location, thus aiding long-term livelihood improvement in the Sundarbans region.

**Author contribution** The data were analyzed by Asif Mohammad, Champak Bhakat, Tapas Kumar Dutta and Anupam Chatterjee. The main manuscript was written by Asif Mohammad and Sheikh Mohammad Feroze. The paper was examined by each author.

**Funding** The data for the study were collected through the financial assistance of the Indian Council of Social Science Research and the Ministry of Education, Government of India-funded project. Data analysis and interpretation were made possible through the NAHEP project of the Indian Council of Agricultural Research, New Delhi.

**Data availability** The datasets generated during the study are not available in public domain to protect the interests of the farmers involved in the study. The data may be shared by the corresponding author on logical request.

## Declarations

**Ethics approval** As this paper is based on the survey study, no ethical approval is taken, although all the reviews used in the paper were properly cited in the references.

**Consent to participate** All the authors were aware regarding participation and publications.

**Consent for publication** All the authors were aware regarding participation and publications.

**Conflict of interest** The authors declare no competing interests.

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