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## Livelihoods dependence on mangrove ecosystems: Empirical evidence from the Sundarbans

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## ABSTRACT

Comprehensive studies that employ larger data sets to explore the degree and conditions under which households depend on mangrove ecosystems account for only a negligible number in Asia's context. We contribute to these lacunae by analysing households' livelihood dependence on the *Sundarbans of Asia*. Specifically, we seek to: (i) appraise the livelihood strategies around the *Sundarbans*, (ii) analyse the conditions and determinants of household dependence on the *Sundarbans*, and (iii) explore perceptions surrounding livelihood dependence. An extensive survey of 1188 directly and indirectly dependent households drawn from 35 villages was conducted using structured interviews to address these topics. Twenty focus group discussions complemented this data. Using logistic regression, we analysed household dependence as a function of socioeconomic attributes. We suggest that socioeconomic factors have a substantial relationship with resource extraction and, therefore, policy prescriptions should focus on coordinating less-extractive diversification activities such as ecotourism to reduce the impact on the Sundarbans.

## 1. Introduction

Despite accounting for a small proportion of global forest cover, mangroves represent a rich, precious ecosystem that contributes a wide range of provisioning, regulating, cultural and supporting services to adjacent communities (Spalding et al., 1997; Palacios and Cantera, 2017). Rural households located near mangrove ecosystems depend on them extensively for their livelihoods and other services. The principal goods and services provided by mangroves include marine resources such as fish, crustaceans, and other seafood; fuelwood, timber, and other forest products such as honey; and protection from coastal events like flooding and storm damage, among others (Spalding et al., 1997;

Orchard et al., 2016).

Accordingly, the functions provided by mangrove ecosystems have been widely studied (DasGupta and Shaw, 2017). Specific attention has been paid to the local characteristics of mangrove dependency across a range of communities, including those of Bangladesh (Chowdhury, 2010; Ahsan et al., 2017), India (Hussain and Badola, 2010), Myanmar (Aye et al., 2019), Vietnam (Orchard et al., 2016) and Senegal (Conchedda et al., 2011); as well as profiling critical mangrove services and activities like fisheries (Seary et al., 2020) and nipa cultivation (Islam et al., 2019). Moreover, the study of mangroves has gained urgency as natural and anthropogenic pressures increasingly threaten these ecosystems and the sustainability of resource-dependent coastal

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livelihoods. Mangrove ecosystems are exposed negatively to the caprices of weather and climate (Lovelock et al., 2015; Duke et al., 2017; Feller et al., 2017) and, especially in developing countries, the increasing conversion into agricultural land, human settlements, and other developmental functions that accelerate forest degradation (Duke et al., 2007; UNEP, 2014). Indeed, the consensus is that mangrove ecosystems' rapid transformation is substantially linked to anthropogenic forces (Ajonina et al., 2008; Feka and Ajonina, 2011; Mukhopadhyay et al., 2018; Van der Stocken et al., 2019). The global estimated mangrove loss during the last quarter of the 20th century is between 35% and 86% (FAO, 2003; Duke et al., 2007). Therefore, mangrove ecosystems and dependency are explored in the literature with an eye to future sustainability and resilience; for example, impacts and responses regarding salinity intrusion (Sadik et al., 2017) or unsustainable shrimp farming practices (Ashton, 2008.) Adaptation and mitigation strategies and the varied effects of management efforts have also been assessed (Rahman, 2016).

The Sundarbans of South Asia are the world's largest contiguous mangrove forest, at over 10,000 km<sup>2</sup>. Designated as a UNESCO World Heritage Site in 1997, they are over 4000 years old and harbour over 700 species of plants and animals, including endangered species (Ali, 1998; Mistri, 2013). Bangladesh accounts for 60% of the Sundarbans landscape (Giri et al., 2015). Within the wider context of mangrove dependence, the Sundarbans in Bangladesh exemplify the challenges of dependency as they contribute substantially to the livelihoods of a vast number of low- and middle-income households (Abdullah et al., 2016a; Mukhopadhyay et al., 2018.) Estimates hold that by 2050, over 13 million people around the Sundarbans in Bangladesh may be forced to migrate due to climate-related crises (Rigaud et al., 2018), and many have already done so (Mistri, 2013.) On the bright side, some efforts to rehabilitate the Sundarbans have been successful (Feller et al., 2017), using both natural regeneration and/or artificial rehabilitation methods that have seen over 15% of the cleared mangrove ecosystems in parts of Asia rehabilitated (Richards and Friess, 2016).

There is increased interest in understanding socio-ecological system dynamics in the context of mangroves, focusing on processes of livelihood dependence, climate change vulnerability and resilience in Asia (Ward et al., 2016; Mukhopadhyay et al., 2018). However, empirical evidence on the degree and conditions under which households depend on mangrove ecosystems account for a negligible number of studies in the Asian context. Studies have found that the key services of the Sundarbans mangrove ecosystems are to protect neighbouring communities against coastal disasters, and to offer natural resources (i.e. woods, fisheries etc.) (Das and Vincent, 2009; Islam and Hossain, 2017; Mukhopadhyay et al., 2018). Such ecosystem services represent a kind of dependency, which is further intensified because of extreme weather events and environmental degradation resulting from climate change (Abdullah et al., 2016a, 2016b, 2016c; Ahsan et al., 2017). While ecosystem functions, threats to stability, and climate mitigation of mangrove ecosystems have been extensively studied, comprehensive studies that employ larger datasets to assess the degree and conditions of dependency itself are comparatively few. For example, Ahsan et al. (2017) claim that dependency on the Sundarbans increased after cyclone Aila in their studied communities, using an empirical survey of 420 households in Koyra Upazila of Khulna district. Similarly, based on 264 households of six villages in Mongla Upazila of Bagerhat district, Abdullah et al. (2016a) show that poorer people were more dependent on Sundarbans resources compared to other income groups. However, they do not provide any critical observations on the socio-spatial differences of dependence on mangrove resources, nor distinguish the pattern of dependency, i.e. direct or indirect use of mangrove resources. Additionally, there is evidence of conflicts between the interests of the local community and the forest department of the government of Bangladesh (Ali et al., 2017; Roy, 2016). Due to various governmental interventions to protect the Sundarbans, local people are losing their livelihood and working opportunities (Ishtiaque and Chhetri, 2016). Thus, the attitudes and perceptions of local communities towards the

conservation of the mangrove forest also influence their resource extraction practices (Roy, 2016).

What is lacking from the aforementioned studies is the distinction between the livelihood and dependency patterns of direct and indirect resource users, and a broader review of the factors influencing their dependency, as well as their perception of the future of Sundarbans ecosystems. While the phenomenon of livelihood dependence on mangroves is complex and variable, exploring these attributes using a large dataset can shed light on the patterns of dependence and their future evolution. Therefore, this paper responds to this gap by using a large dataset to address the following research questions:

- (i) What are the livelihood options of people living around the Sundarbans, and to what extent are livelihoods, directly or indirectly, dependent on Sundarbans resources?
- (ii) How is livelihood dependency segregated across the socio-demographic characteristics of people living around Sundarbans, i.e. what are the determinants of dependence?
- (iii) How do people perceive the future of the Sundarbans ecosystem concerning their livelihood prospects?

This paper proceeds as follows: Section 2 presents state of the art on livelihood dependence, elaborating on the relevance of this study's contribution and introducing the analytical concept employed. Section 3 explains the methodology. Section 4 presents the empirical results. Section 5 discusses the findings in the context of the current state of Sundarbans resources, exploring implications for the future. Section 6 provides the conclusion.

## 2. State of the art

### 2.1. Natural resource dependency and livelihood discourses

People living near mangrove forests use their formal or informal access to its ecosystem services to articulate their livelihoods, depending on resource extraction activities like fishing, timber collection, and honey collection. Despite natural growth, such sustained exploitation of resources, plus other anthropogenic interventions, makes the ecosystem's natural resource base vulnerable to extinction; over the last two decades in the Sundarbans, most ecosystem services have experienced some degree of degradation (Islam et al., 2018). Resource users report awareness of the negative impacts of extraction and other harmful activities like shrimp farming, but poverty, debts and a lack of livelihood options restrict their ability to withhold from exploitative practices (Islam et al., 2018). The increasingly 'everyday' occurrence of many hazards has made communities adept at forms of short-term recovery and adaptation (Ghosh, 2018). Reviewing community-based management initiatives, Datta et al. (Datta et al., 2012) find that alternative uses of mangrove forest resources which have the potential to transform livelihood options are known by communities, but not widely implemented due to social and institutional challenges. Problematic governance and the inadequacy of existing top-down institutional frameworks are noted as barriers to sustainable livelihoods in rural Bangladesh (Misra, 2017; Roy et al., 2012; Rahman et al., 2016.) Nevertheless, as extraction continues amid climate threats, it remains increasingly urgent to understand the imminent consequences for resource dependent livelihoods.

Given these pressing sustainability concerns, inquiries into livelihoods often concentrate on vulnerability and resilience in the face of threats. Comparatively, there are fewer studies that interrogate the underlying socio-demographic causal factors of mangrove dependency on a wide scale. Hossain et al. (2018) use a participatory approach to understand people's perceptions regarding environmental change, drawing impressions on impacts and responses rather than underlying dependency characteristics. A study of fisheries by Islam et al. (2014) likewise spotlights vulnerability; however, despite examining only one

livelihood strategy, it illustrates that factors impacting livelihood conditions are multifarious and vary by context. Significantly, few interrogate the socioeconomic factors inflecting dependency itself, or systematically analyse dependency as a product of such factors.

Conversely, beyond the mangrove context, [Ahammad et al. \(2019\)](#) find that the wealth class of rural households in the Chittagong Hill Tracts impacts use and perception of forest services. Likewise, [Kiruki et al. \(2019\)](#) investigate dependency on charcoal resources in Kenya, using household questionnaires to identify the socio-demographic and economic determinants of participation in charcoal production. Binary logistic regression is employed by [Hussain et al. \(2019\)](#) to analyse similar influences on household forest dependency in Naltar Valley, Pakistan. However, for Sundarbans adjacent livelihoods, such methods have generally not been employed. [Islam and Hossain \(2017\)](#) explain the goods and services, collectively known as ecosystem services, that the Sundarbans deliver to the populations living in the impact zone and to the wider landscape of Bangladesh. However, their study does not explicitly address which cluster of people depend on what category of resources and where, and how their dependence varies. [Abdullah et al. \(2016b\)](#) explore the dependency dynamics of one specific livelihood option, shrimp aquaculture, and [Abdullah et al. \(2016c\)](#) assess the impact of one disaster, Cyclone Aila. Both indeed reveal the relevance of socioeconomic characteristics as factors of dependence, but do not concern the wider landscape of Sundarbans dependence. [Abdullah et al. \(2016a\)](#) explore the relationship more generally between mangrove dependency and income strata - but all three studies draw from a survey of only 264 households in one district. Alongside the small-scale dataset, these studies also do not observe how those socio-economic parameters differ across the level of dependency (direct or indirect), and how it may influence further dependency. Therefore, there is a need for a more comprehensive livelihood portfolio from the Sundarbans area that seeks to analyse the multidimensional determinants of dependence. The analytical concept below outlines how this study conceptualises dependency in order to approach these aims.

2.2. Analytical concept

The analytical concept (see Fig. 1) adopted in this paper draws upon the sustainable livelihoods framework, seeing livelihoods as a function of their direct or indirect dependence on mangrove resources. In this

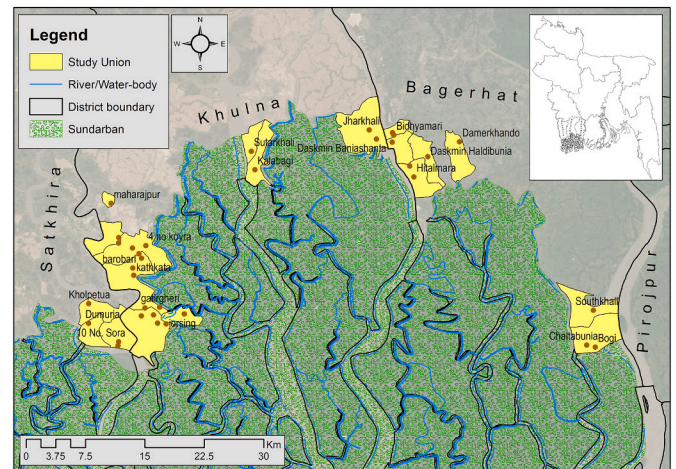


Fig. 2. Study villages near Sundarbans in Bangladesh; Source: Authors' illustration 2020.

context, direct mangrove dependence is defined as the reliance on extraction from the Sundarbans ecosystem, including timber, NTFP (medicinal plants, honey and wax), and fishing. A clear line between direct and indirect dependents is difficult to establish for some households, as they fall in both categories, albeit in different proportions. Indirect dependence is defined as engagement in other livelihood sectors such as civil services and private sector. Although the portfolio of this group presents a seemingly non-mangrove dependent picture, they contribute substantially to degradation of the Sundarbans as buyers and consumers. Thus, there is an inextricable connection between direct and indirect mangrove dependents, whose activities collectively define the status of resource extraction in the Sundarbans.

From an economic standpoint, the changing market for resources harvested from the Sundarbans plays a critical role. Thus, the dependency chain starts from these direct dependents, i.e. resource harvesters and indirect dependents, buyers who utilise Sundarbans resources. Usually, the livelihood of an individual is determined by internal and external resource availability and the surrounding social, economic and political context in their living community. Further, the regional, national or global level forces, (i.e. institutional, economic or

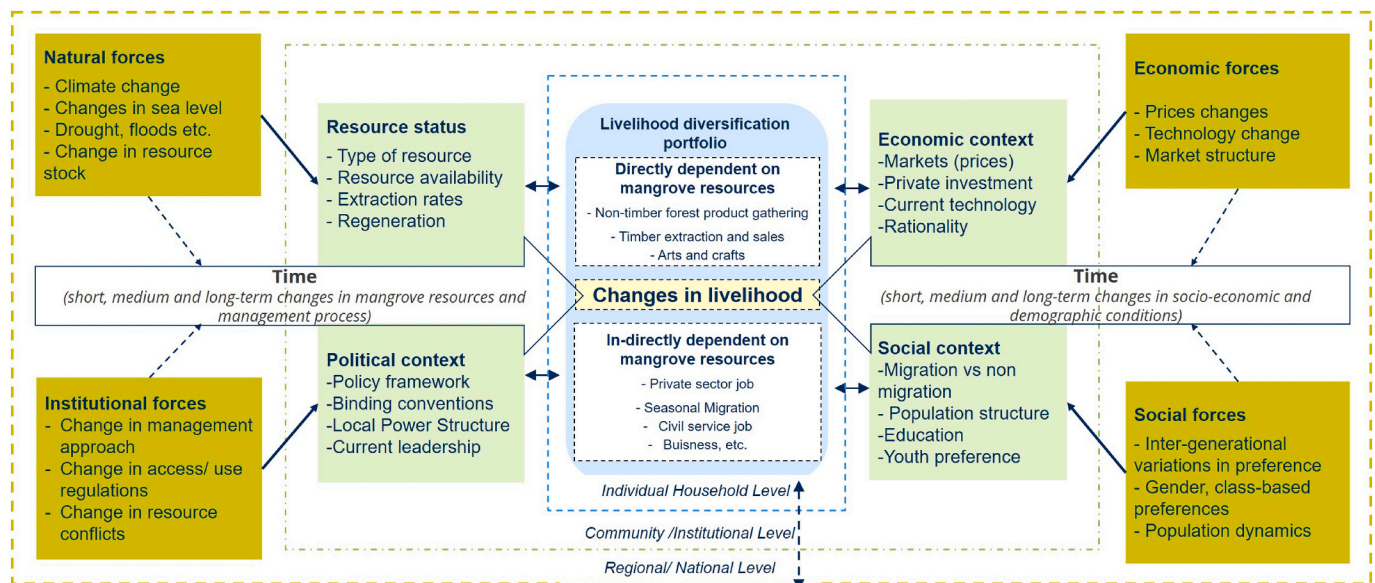


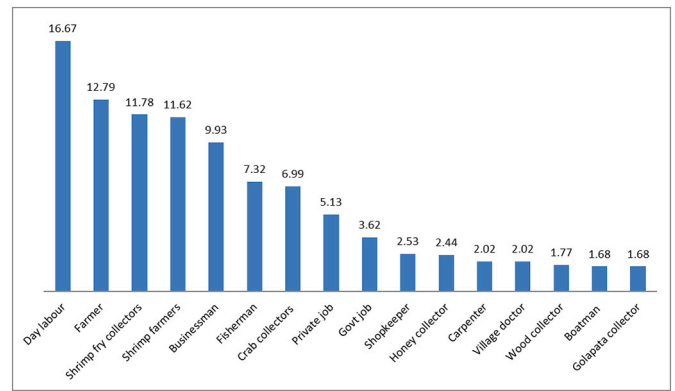
Fig. 1. Analytical framework on livelihood dependence on mangrove resources. Author's illustration. (Adapted from Scoones, 1998; DFID, 2000; Ellis and Allison, 2004; Khatiwada et al., 2017; Kimengsi et al., 2020).



**Table 1**  
Basic information about the study sites.

District	Upazila	Union	# village # sample village	Area (in acres)	Households (in selected unions)	Population (in selected unions)	Household (in sample villages)	Population (in sample village)	Sample size	Sample size (% of HH)
Khulna	Koyra	Koyra	11	1,52,548	7788	33,230	5779	24,434	139	2.41
		Uttar Bedkashi	13	1,02,548	3673	15,225	1595	6682	146	9.15
		Daskin Bedkashi	12	1,10,452	3881	16,755	1463	5985	285	19.48
Bagerhat	Dacope	Sutarkhali	4	1,12,059	7463	30,060	4283	17,318	80	1.87
		Banishanta	16	56,749	3398	14,606	746	3097	48	6.43
		Sharankhola Southkhali	10	9036	6179	24,980	1750	6661	142	8.11
Sakthira 3 districts	Mongla	Sundarban	20	8782	4247	16,834	1165	4144	96	8.24
		Chilla	15	7452	4327	17,607	1613	6627	107	6.63
		Gabura	15	10,195	6762	31,115	2154	9811	145	6.73
		9 unions	35	5,62,369	43,391	1,82,805	20,548	84,759	1188	5.78

Source: Author's illustration, and GoB (2011).



**Fig. 3.** Primary occupation of the households. Source: Field survey 2016.

social, environmental) contribute to setting up the community's livelihood diversification portfolio. Holistically, these influence the changes in livelihood pattern in the community over time (Fig. 1). To summarise, the livelihood portfolio of those living in villages adjacent to the Sundarbans is shaped by resource status, mainly the distribution of natural resources (by access, availability, and equity), framed by the socio-political and socioeconomic conditions of the communities. Furthermore, these influential drivers of livelihood dependence are subject to change over time due to external natural, social, economic, and institutional forces. Thus, the livelihood dependence of these communities is not a straightforward outcome, but rather a combination of many dimensions of social, economic, and environmental attributes that inform the adaptive transformation of the livelihoods. To account for these various dimensions, our analytical concept takes a multi-level approach.

Firstly, as an empirical assessment of the portfolio of livelihood dependency, the concept takes the individual household level as the core of the analysis and considers its characteristics as they relate to dependency. The degree to which the household is directly and/or indirectly dependent on the Sundarbans resources is represented here, including the relevant indicators of dependence, i.e. the occupations/activities that constitute the household's livelihood. Secondly, this first level is conditioned by community and institutional level factors. Here, we discuss the community's socio-economic context, which can precipitate changes in mangrove use over time. These characteristics include the shifting state of local markets, prices and investment, and the local population structure and services. We also include the political context and resource availability, which directly influence mangrove access and use through local leadership, policies and their enforcement, and the type, access and extraction rate of mangrove resources. These factors interact with household level factors to modulate dependency among households. Finally, the third level refers to the regional and global context. This includes the regional/national level policies which shape the community level context, influencing the short-term and long-term planning and management practices both for the mangrove ecosystem and surrounding communities over the time. In addition to institutional factors, forces at this scale include climate change effects, technological changes and market forces, and changes in the socio-cultural fabric and population dynamics. These wider shifts have implications for dependency as they influence the community and household level dynamics.

Employing this concept, we present our results on the dependency portfolio of the households in Section 4 according to the three levels: household, community, and regional.

### 3. Methodology

#### 3.1. Study villages adjacent to the Sundarbans

The Sundarbans cut across India and Bangladesh, with a more

substantial proportion (60%) located in Bangladesh. Geographically, the salty, vast, shrub-covered forest and char-land in south-western Bangladesh, linked by interconnected tidal rivers, is known as the Sundarbans. It is a common-pool resource essential to the livelihoods of adjacent rural communities. The Sundarbans run across three districts - Khulna, Bagerhat and Satkhira. Although there are no settlements directly inside the Sundarbans, a large number of people (mostly fishers, hunters, resource harvesters) spend a substantial period of the year inside the forest, mostly on boats and seasonal or semi-permanent structures such as camps along the riverside or islands. This study was carried out in 35 villages adjacent to the Sundarbans within the Khulna, Bagerhat and Satkhira districts (Fig. 2.)

The study area consists of a total population of 182,805 people found in 43,391 households (Table 1), covering 562,369 acres of land (BBS, 2012.) The residents of these villages are primarily involved in fishing, agriculture, forestry, and livestock for their livelihoods. 35% are engaged in fishing (BBS, 2012), making it the most common directly mangrove-dependent activity. The field survey reveals that day labour is most reported primary occupation in the region, which may include extractive activities, whilst shrimp farming and collection have become popular Fig. 3. A majority of the villagers are uneducated and economically deprived. This is influenced by a lack of political facilitation for institutional and infrastructural development in these peripheral locales. There are a total of 116 villages drawn from the three target districts, located close to the Sundarbans. To ensure representativeness, we selected a sample size that provided a confidence level of 95% that the real value is within  $\pm 14\%$  of the surveyed value. We calculated this sample size to be 35 out of 116 villages. A random computer assisted draw was conducted using Microsoft Excel to select the 35 villages. The selected villages were considered appropriate to reflect the transformations around the Sundarbans, as both direct and indirect dependents could be surveyed therein. Additionally, the villages are similar in terms of their livelihood portfolio, and their socio-cultural fabric. The total number of households in the 35 selected villages was 20,548. From this, 1188 households were surveyed, providing a sampling fraction of 5.78%. Considering the large population of the study, this sample was considered representative enough to provide meaningful results on the livelihood dynamics around the Sundarbans.

### 3.2. Data collection

This paper is a product of mixed-methods research. Data was obtained through quantitative (household surveys) and qualitative (focus group discussions) methods. A structured household questionnaire survey (42 items) was designed to collect data related to the direct and indirect dependency of households on the Sundarbans. Besides the socio-demographic information, the questionnaire captured data relating to:

- (i) the typology of resources extracted from the Sundarbans
- (ii) the degree of dependence (direct or indirect) on this mangrove ecosystem
- (iii) the purpose and extent of resource extraction by different users (e.g. fishermen, honey collectors)
- (iv) the formal and informal institutional potentials and challenges for the directly-dependent households, and
- (v) their perspectives with regards to the future of the Sundarbans

The questionnaire was translated into Bengali and pretested ( $N = 42$ ) on respondents from villages around the Sundarbans, exclusive of the study sites.

Under the supervision of the first author, a team of 6 graduate students from Khulna University, Bangladesh, were recruited to serve as enumerators. They were trained for five days, and also took part in the pre-test and subsequent surveys. The survey began with villages in the Satkhira district, and then proceeded eastwards to the remaining

districts (Fig. 2). Respondents were randomly sampled, targeting male and female villagers who were either primarily resource harvesters (direct dependents) or who were not directly harvesting from the Sundarbans but still dependent on it. Data collection mainly involved two cohort groups: male and female household representatives in the age brackets of 18–40, and above 40. The first phase of data collection ran from February to July 2015, while the second phase ran from March to April 2016. Additional data was collected in March 2020. A total of 1188 respondents were interviewed, each representing one household. A random sampling method was employed in selection of the respondents. For example, if a selected village had a total of 100 households with 20 households as the representative sample, then a respondent was selected from every 5 or 6 households in the village until the representative sample of 20 was met. If someone declined to participate in the survey, the data collector moved to the next household in turn. In each case, the data collector started from a central point in the village, i.e. a marketplace, and travelled along the main access roads of the village, requesting interviews from households at the aforementioned intervals.

Every respondent gave their consent to be interviewed. In total, 269 respondents were direct resource collectors from Sundarbans, hereafter referred as ‘directly dependent’, and 919 respondents were resource users, hereafter referred as ‘indirectly dependent’. At the beginning of the interview, each respondent was asked, ‘Do you regularly collect any form of resources from the Sundarbans?’ in order to explore the nature of dependency. Here ‘direct dependent’ refers to those who regularly collect resources. Alternatively, indirect dependents are the users of extracted resources, who do not themselves collect them as part of their regular livelihood. Within the direct dependents, we further distinguished between complete and incomplete dependents, i.e. those whose occupations relied entirely on the forest resources (e.g. honey collectors) and those who often but not necessarily always extracted from the forest (e.g. fishermen). All cohorts were involved in each data collection phase.

Additionally, a focus group discussion guide ( $N = 10$ ) was developed to explore the life-stories of key resource extractors in the Sundarbans. Out of the 35 villages, 20 were randomly sampled for group discussions, due to time constraints. Emphasis was placed on discussing the challenges and opportunities associated with resource exploitation from the Sundarbans. In all cases, the informed consent of the respondents was sought by the enumerators prior to data collection. Both quantitative and qualitative data were recorded in the questionnaire and using field notes, respectively. Simple statistical operations were employed to analyse the data. Qualitative data was analysed using the Atlas.ti software, as the personal identification of the interviewees are presented anonymously. The quantitative analysis was performed in R Open Source Statistical Software (Version R1386 3.6.1), and the IBM SPSS Statistics 22.

### 3.3. Data analysis

Quantitative data were coded and entered into an Excel sheet to facilitate analysis. A binary logistic regression model was employed to establish the directly dependent cohort among the respondents (Foster et al., 2018). The outcome variable of our model is whether the respondent is directly or indirectly dependent on the Sundarbans. As the dependent variable is dichotomous, the binary logistic regression model is suitable for determining the factors that influence people’s dependency on the Sundarbans. The model is specified as follows:

$$L_i = \ln \left[ \frac{P_i}{1 - P_i} \right] = \delta_0 + \sum_{j=1}^8 \delta_j X_{ji} + \mu_i$$

$$j=1, 2, 3, \dots, m.$$

$$i=1, 2, 3, \dots, n \text{ where,}$$

$P_i$  is the probability of “ $Y_i = 1$ ”.

$Y_i =$  Directly dependent on the Sundarbans (1 = Yes; 0 = No),

$\delta_0$  = Intercept, and.  
 $\ln(p_i/1 - p_i)$ = The log of odd ratio,  $X_{ji}$ =A set of explanatory variables,  $\mu_i$ =error term.

The log of odd ratio is linear in both parameters  $X_{ji}$ . A total of eight variables were incorporated in the model to serve as explanatory variables.

In this model, we include geographical, economic, and demographic variables. We include the physical distance between Sundarbans and respondents' village ( $X_{9i}$ ), as this influences the ability to access the forest for resource harvesting, and we include the working opportunities in their village ( $X_{8i}$ ), as this influences the likelihood of adopting natural resource harvesting as a livelihood strategy. Besides, we add socio-demographic variables like age ( $X_{1i}$ ), gender ( $X_{2i}$ ), religion ( $X_{3i}$ ), family size ( $X_{4i}$ ), educational qualification ( $X_{5i}$ ) and the monthly income of the respondent ( $X_{6i}$ ) into the logistic regression model. Our a priori assumption further holds that older respondents and those with large family sizes are more likely to depend on the Sundarbans directly. For education, we assume that with higher educational qualification, respondents are less likely to depend on the Sundarbans directly. The same applies to respondents with higher monthly incomes. Women are less likely to be direct dependents, i.e. resource harvesters, than men, given social norms and the risks involved in going out to collect resources for extended periods of time (Roy, 2020.) The Variance Inflation Factor (VIF) was conducted to check for multi-collinearity. The mean VIF values were 1.6, indicating that the correlation between the predictors is not strong enough to warrant corrective measures to the original variables. To enhance the robustness of the results, the same set of explanatory variables have been used to run two other regression models - the linear probability and probit regression models. The analysis was performed using R Open Source Statistical Software (Version Ri386 3.6.1), and the IBM SPSS Statistics 22.

#### 4. Results

The results are presented as follows. First, we provide a brief socio-economic profile of the respondents. We then proceed to explain the portfolio of livelihoods as based on the various forms of resource extraction. Then, we consider the dependency portfolio. Finally, we examine the determinants of direct dependence at the individual household, community, and regional/national levels.

##### 4.1. Socio-economic profile of the studied villages

In our sample, we have 27% and 73% directly and indirectly dependent respondents, respectively. A detailed comparison between these two groups is presented in supplementary Table S1. In terms of religion, directly dependent respondents are more likely to be Muslim

(84%) compared to indirect dependents (69%), although a majority of both groups are Muslim. Regarding education, most direct dependents (67%) have *only* primary education, compared to 41% of indirect dependents. Meanwhile, a higher proportion of indirectly dependent people (43%) have completed secondary education as well, against 32% of direct dependents. This suggests that people with lower educational levels are mostly involved in the extraction of natural resources from the Sundarbans. This is further corroborated because about 75% of the directly dependent respondents indicate the lack of job opportunities in their community, against only 17% of the indirectly dependent ones. A minimal fraction (5.9%) of the respondents are university graduates. The negative mean difference (about -0.29 km) in the distances from the village to the Sundarbans suggests directly dependent users have greater proximity to the Sundarbans (about 1.69 km), when compared with indirectly dependent users (about 1.97 km). Most of the respondents earn a monthly income of 50 to 75 US\$, with just 8% earning up to US\$ 100 per month.

##### 4.2. Livelihoods based on Sundarbans resource dependency

The key jobs performed by direct dependents who go out to the forest area for income-generating activities include wood collection, saline water fishing, shrimp fry fishing, crab and nipa palm collection, hunting, and medicinal plant and fruit collection from the Sundarbans. For indirect dependents, the most prevalent jobs are businessman, teacher, and farmer.

For the direct dependents, resource collection can be a long and laborious undertaking that is often highly shaped not only by the hazardous natural environment of the Sundarbans but also by the social and institutional context of access to the forest, such as interactions with moneylenders and forest officials. Users report that they often go into the Sundarbans in a group, not only for security from the wild animals but also pirates, who may otherwise kidnap users for ransom. Furthermore, for most forest products, collection is a seasonal venture rather than an everyday occupation, which can substantially influence lifestyle during such periods. Fishing is the most highly represented resource collection activity taking place in the Sundarbans in the dataset. Usually, the fisherman goes into the Sundarbans for a week or two. A 26-year-old fisherman from Gabura union recounts the process thus:

*When we enter Bada [local name for the Sundarbans], we have to take all of our necessary items, such as drinking water, rice, lentils, vegetables, medicine, and cigarettes for at least for 15 days and even sometimes for a month. Our money-lender bears all the expenses and gives us a boat because we do not have the money to secure it. We cook, eat, and sleep on the boat – the boat becomes our home – we live on the water. We do not take any fish with us, because we can catch fish in the Sundarbans to cook. But we take chicken with us for meat. As we go in a group with different passes, we cut nipa palm or wood or collect honey. We are*

**Table 2**  
 Year round dependency on Sundarbans and extraction of resources (N = 317).

	Wood (%)	Honey (%)	Fish (%)	Fry (%)	Crab (%)	Nipa palm (%)	Fruits (%)	Hunt (%)
January	15.24	0.37	38.66	13.75	53.53	8.18	2.97	4.83
February	13.75	0.37	34.94	13.75	52.79	8.18	1.12	2.97
March	13.75	3.72	34.94	18.96	50.56	10.04	1.12	2.97
April	19.70	21.19	40.89	50.19	46.84	5.20	1.12	2.60
May	18.59	21.19	40.89	52.42	44.61	2.60	1.12	2.60
June	18.22	16.73	39.78	54.28	46.10	2.23	2.97	2.60
July	19.33	5.95	40.89	31.23	47.58	3.35	1.12	2.60
August	18.22	0.00	45.35	25.65	49.44	3.35	2.97	2.97
September	18.22	0.00	44.24	19.70	47.58	0.00	1.12	4.83
October	17.47	0.00	41.26	15.61	47.58	0.00	1.12	2.97
November	14.87	0.00	40.52	13.38	50.93	2.60	1.12	2.60
December	14.87	0.00	40.52	14.50	50.93	4.46	1.12	2.97

Source: Field survey 2016.

**Table 3**  
Dependency of observed livelihood strategies.

Dependency on Sundarbans		Main occupations	Percentage of direct dependents	Collection and uses of Sundarbans resources	
Directly dependent (N = 317)	<i>Directly and completely</i> (N = 131)	Crab collector	26.18	- Fuelwood collection - Timber for construction - Medicinal plants - Honey - Various white fishes (e.g. <i>Mugil cephalus</i> , <i>Lates calcarifer</i> , <i>Labeo boga</i> , <i>Pangasius pangasius</i> , <i>Paira</i> , <i>Dadne</i> , etc.) - Various shrimp (e.g. prawn, harina, fry fish etc.) - Various crabs - Various fruits - Various wild animals	
		Nipa palm collector	6.31		
		Honey collector	9.15		
		Wood collector	6.62		
		Day labour	3.79		
	<i>Directly but not completely</i> (N = 183)	Fisherman	29.02		
		Shrimp fry collectors	18.93		
		Main occupations			Percentage of indirect dependents
		Boatman	2.30		
		Businessman	13.55		
Indirectly dependent (N = 871)	<i>Indirectly and incompletely</i> (N = 871)	Carpenter	2.76		
		Day labour	21.35		
		Farmer	17.45		
		Shrimp farmers	15.27		
		Shrimp fry collectors	9.18		
		Govt. Job	4.94		
		Private job	7.00		
		Village doctor	2.76		
		Shopkeeper	3.44		

Source: Field survey 2016.

allotted to smaller groups during the day, but during the night, all twenty to thirty boats stay together; it is from fear of tigers and pirates in the Sundarbans. A big boat can also not enter inside small channels. We go inside the Sundarbans through small channels at low tide and return at high tide, usually with the harvested products. (Interviewed on 11th April 2016.)

Harvesters of other resources also venture into the Sundarbans by boat for certain periods, working seasonally (Table 2). Around 10% of the directly dependent respondents collect nipa palm between January and March, while only 2–3% collect it in May to August, and likewise in April, November & December. Up to 22% of the respondents collect honey from the Sundarbans from January to July, with the peak collection period between April and May and very little collection between January and February. Like the fishermen, their collection trips may be shaped by the moneylenders and employers who direct their forest resource access. As recounted by one respondent:

*I used to go for wood cutting, but you know, we take some honey-collectors with us, though we work separately from one another. We both work in groups of five to ten people. This group size depends on the size of the boat. You know, our dadondar [moneylender] prefers to contract small groups to maximize benefits. If he sends 5 boats with 5 people, he will reap more benefits compared to sending 25 people in a single boat. They contract harvesters for a whole season and pay them a fixed amount of money for each harvesting trip, and they work us to the bone.*

(Interviewed on 10th April 2016.)

Honey from the Sundarbans is highly demanded all over the country as it is considered to be of high quality. The main purpose of honey collection is for sale in the market, and 24% of harvesters are honey collectors. Honey prices range from US\$ 2 to 4.5 per kilogram. Wood-cutting is another essential livelihood source for directly dependent respondents. They collect both fuelwood (31.2%) and timber (17.8%). Only 14% of the collectors directly sell the wood to the market, at prices ranging between US\$ 1.5 to 5 per 100 kg. This activity is intense in April to July, coinciding with the monsoon season. The wood collection is lowest in January to March, and November to December, when the weather is usually cold and new plants grow more slowly. Compared to wood, palm and honey, medicinal plants constitute a relatively minor

**Table 4**  
Factors that influence dependency on Sundarbans (\*, \*\*, and \* refer to the 0.01, 0.05, and 0.10 significance levels, respectively).

Explanatory variables	Logit model (1)		Probit model (2)	Linear probability model (3)
	Coefficient	Odds ratio		
Age	-0.03*** (0.01)	0.97*** (0.01)	-0.02*** (0.01)	-0.003*** (0.00)
Literacy level				
Primary	2.97*** (0.61)	19.43*** (11.93)	1.65*** (0.30)	0.27*** (0.04)
High school	2.26*** (0.62)	9.56*** (5.90)	1.26*** (0.30)	0.16*** (0.04)
College/University <sup>b</sup>				
Gender	0.28 (0.20)	1.32 (0.27)	0.09 (0.11)	0.03 (0.02)
Religion	1.02*** (0.23)	2.77*** (0.63)	0.64*** (0.13)	0.11*** (0.02)
Family size	0.08* (0.04)	1.08* (0.05)	0.04* (0.03)	0.01** (0.01)
Monthly expenditure	0.00024*** (0.00)	1.00*** (0.00)	0.00014*** (0.00)	0.00003*** (0.00)
Work opportunities	-2.62*** (0.19)	0.07*** (0.01)	-1.53*** (0.10)	-0.44*** (0.02)
Distance from homestead	-0.07 (0.05)	0.93 (0.05)	-0.04 (0.03)	-0.01 (0.01)
Constant	-3.51*** (0.75)	0.03*** (0.02)	-1.95*** (0.39)	0.14*** (0.07)
Observation	1188	1188	1188	1188
Pseudo R2	0.37	0.37	0.37	-
Log likelihood	-432.00	-432.00	-431.35	-
LR chi2(9)	514.28	514.28	515.59	-
R-squared	-	-	-	0.40
Adj R-squared	-	-	-	0.40

resource for collectors; 3% of the respondents collect fruits and herbs in January, June, and August, and only 1.1% gather all year round. Households closest to the Sundarbans also have easy access for hunting. 3% of the population hunt animals, with peak months being February, March, August, October, and December.



### 4.3. Dependency portfolio

Households within or near the Sundarbans depend on its resources to fulfil basic needs, such as food, fuel, materials for construction of houses, boats, furniture and fishing implements, medicinal herbs, and many other items for trade and commerce. Fishermen working in the forest and small traders directly depend on forest resources, earning money from selling or processing them. Most farmers, businesspeople, and service holders in these communities indirectly depend on forest resources because they use them for their households. A detailed percentage distribution of direct and indirect dependency by occupation is presented in Table 3. A more substantial number of people's main occupations in the directly dependent group are crab harvesting (26%), with smaller proportions engaged in nipa palm (6.31%), honey (9.15%) and wood collection (6.62%). Many direct dependents are directly but incompletely dependent on forest resources, most notably fishermen (29%) and shrimp fry collectors (18.93%). Among the indirect dependents, the most represented occupations are day labour (21.35%), farming (17.45%), shrimp farming (15.27%), and business (13.55%). The presence of groups of day labourers, fishermen, and fry collectors who are directly but not wholly dependent on the Sundarbans resources raises issues of complexity when establishing the degree of resource dependence. Unlike farmers and businesspeople, directly but incompletely dependent people often work in the forest, although they do not extract timber or NTFPs. Here, they are counted among the directly dependent cohort as their forest dependence still contributes substantially to their overall livelihood. Respondents state that they buy honey, nipa palm, fruits, wild animals etc., from local businesspeople and direct harvesters, demonstrating the intricate connection between dependent groups.

Overall, about 27% of the respondents are directly dependent on the mangrove forest, many extracting its natural resources all year-round – this provides a safety net for such households (Table 2). The analysis shows that many of these people extract wood, fish, fry and crab, with a limited proportion focusing on collecting fruits and hunting animals. On the other hand, people seasonally collect honey from January to July, although just a small proportion collect it in the first two months. Meanwhile, people collect nipa palm at variable rates from November to August, with collection peaking in March. Thus, those directly dependent on the mangrove resources must demonstrate flexibility in their livelihood options throughout the year as the seasonality of forest products determines what and how much they are able to extract. The determinants of direct dependence are further explored in the next section.

### 4.4. Determinants of direct dependence

#### 4.4.1. Individual household level

The quantitative data collected through the questionnaire survey of households reveals which attributes affect dependency at the household level. By employing a logistic regression analysis in R where direct dependency is considered the dependent variable, the results show that the following attributes influence dependency on the Sundarbans (Table 4.) Among these explanatory variables, the age of the respondent, literacy level, religion, household size, distance from the forest, and monthly expenditure are statistically significant household attributes. A community level factor assessed in the survey, the availability of work opportunities in the community, is also shown to be statistically significant.

All three models, (i.e. the binary logistic model, the probit model, and linear probability model) provide similar results. They suggest that 'age of respondent' and 'the availability of job opportunities' negatively influence dependency on the resources of the Sundarbans. In other words, younger people and those reporting a lack of employment opportunities are more dependent on the forest resources for their livelihood. The logit model's odds ratio demonstrates that respondents with

job opportunities are 93% less dependent on the Sundarbans than their counterparts without them. Further, according to the logit model, a one-year increase in respondents' age reduces the odds ratio of being dependent on the Sundarbans by 3%. The result also shows that the lower the level of education, the higher the dependence on the Sundarbans. Lower education level and age are likely to limit access to diverse livelihood opportunities, pushing people to rely on extraction.

On the other hand, family size and monthly expenditure positively and significantly influenced dependency, although family size is not as influential a determinant according to all models. Regarding family size, the logit model shows that an increase in the number of family members increases the odds ratio of being dependent on the Sundarbans by 8%. A large family is also linked to higher household expenses. Thus, these factors increase the likelihood of scarcity, which pushes families to extract from the Sundarbans in order to meet their household needs. Finally, the odds ratio of being dependent on the Sundarbans for a Muslim respondent is 177% higher than for a Hindu. The models show that 30% of Muslims versus 15% of Hindus are directly dependent on the Sundarbans. As the majority of the overall sample are Muslim (72.81%) while a minority are direct dependents, the sample may favour a representation of Muslim direct dependents. Otherwise, as the mean income of the religious groups does not vary significantly, other variables like distance, gender and level of education may have influence. For example, Hindus are likelier to have secondary level education, and thus access non-extractive occupations; more Hindus reported working in business and government compared to Muslims.

Finally, the negative coefficient reported for distance indicates that people who live close to the Sundarbans are more dependent on the Sundarbans resources when compared to their counterparts who reside farther away. The model shows that a one kilometre increase in distance from the Sundarbans is associated with a decrease of 7% in direct dependency, on average. If considered in this way, the average person living more than 13 km from the Sundarbans does not directly extract resources.

#### 4.4.2. Community institutional level

Besides the prevalence of work opportunities accounted for in the survey, other broader environmental, social, economic and institutional factors interact with the demographic characteristics to influence dependency. For instance, forest product-based incomes are more susceptible to market fluctuations than indirectly dependent ones. These conditions are divulged by the qualitative data from the group discussions, wherein respondents cite several characteristics of the local environment (natural and social) and management as impacting their reliance on the Sundarbans. Firstly, many note depleted fish stocks and forest cover, citing overexploitation, especially illegal overexploitation, as the cause. They take losses due to a reduced yield and may have to venture further afield to collect the resources necessary for their livelihood. While this encourages some to seek alternative income, it also sustains dependency on the forest by reducing the time and money available to pursue other livelihood strategies. It was also reported that dependency increased after two devastating natural disasters, Cyclone Sidr (2007) and Cyclone Aila (2009). When people switch to new occupations, or lose old ones, they are most likely to lean on extractive activities around the Sundarbans.

However, many feel that changes to their livelihoods are predominantly caused by social and institutional factors rather than changing resource status. Forest officers delimit access and use of the Sundarbans. The Bangladesh Forest Department, responsible for the overall management of the Sundarbans, designates certain areas for resource harvesting. Usually, all harvesters require boat licenses to enter the Sundarbans (Chowdhury, 2010; Zohra, 2011). Various rules about harvesting forest resources apply: how honey harvesters should treat the hive, which trees may be cut, and when harvest of certain resources is permitted, etc. (Zohra, 2011). Transit fees also apply when exiting the forest, with additional charges for defaulting. Both legal and illegal



access into the Sundarbans occurs, according to discussants. Resource harvesters link illegal access to the bureaucratic processes and costs involved in securing access permits. These restrictions discourage Sundarbans-based livelihood options, and thus dependence, for some respondents. However, the majority of harvesters, who are poor, seek to circumvent these processes, allowing overexploitation to flourish. One respondent claims it is difficult to police misuse as many officials take bribes. Ultimately, a small proportion (10%) of resource users actually obtain legal permits from the forester. Many users require loans to afford travel into the forest during harvesting seasons. Moneylenders may demand high charges and down payments for these, eating into harvesters' profits.

Furthermore, bandits charge users of the Sundarbans. About 6% of the directly dependent respondents claim that they pay them when entering the forest. Additionally, the illegal acquisition of permits with the aid of powerful actors and security officers is reported. A direct respondent recounts his experience in the following words:

*Sometimes, if we get the chance, we hunt deer, we can sell deer meat, but it is hazardous. But you know – if the forester is with you and your moneylender has a good political connection – all is alright.* (Interviewed 11th April 2016).

Such accounts demonstrate how social networks, social threats and institutional policies impact direct dependents' capacity to extract resources from the Sundarbans. This shapes their livelihoods in terms of the form and frequency of access for resource collection, and thereby their dependence. A cycle of poverty prevails, as those who have more social and economic resources are better equipped to gain access to forest and other income. Resource depletion and institutional costs combine to maintain dependency, as the low income limits people's freedom to explore other livelihoods. As one respondent states, 'I am thinking of alternative [jobs]. But I need money to do it.'

#### 4.4.3. National and regional level forces

The future of the Sundarbans will have implications for all communities that are dependent on its resources. With growing resource extraction, the forest's survival is highly threatened. As this study has shown, various demographic, social, economic, and institutional characteristics influence the Sundarbans' dependence on people living in adjacent communities. However, besides these smaller scale variables, there are broader influences at play that can impact the changing character of livelihood dependence in the long term. These regional, national, and even global influences may include social, cultural, and economic (market) shifts. Price changes, technology, and market structures on the long-term scale shape resource extraction dynamics, and respondents anticipate these. As prices of necessary commodities increase, meeting daily needs becomes a challenge, forcing resource harvesters to intensify extraction. Principally, however, the most pressing issue is climate change. While climate effects do indeed have intense short term impacts on livelihood strategies, importantly, they can mould the parameters of the more 'micro' attributes of natural resource dependence over time. Respondents cite climate-related risks as influences on their livelihood, but show variable awareness of such factors when considering their livelihoods' future viability or their overall dependence on the Sundarbans.

Climate risks include cyclones, floods, and heavy rainfall during the monsoon. Drastic changes are reported by the respondents, such as increasing salinity, diminished rice production, heat stress, fewer freshwater fishes, and a perceived shift from six to three seasons. However, despite these pressures, close to 80% of the respondents report that they do not feel that the Sundarbans ecosystem is under threat of disappearance soon. This outlook may suggest an approach to continued adaptation strategies for the inhabitants, who are used to navigating limited livelihood options and largely do not feel that the challenges will overwhelm them and their local ecosystem. However, it may also imply

lower awareness among some respondents regarding the long term effects of continued extraction. The sustainability of the Sundarbans is not a strong concern for most of its dependents despite existing protection efforts, which suggests that greater educational and diversification efforts may be required to reduce extraction and redirect local communities towards more sustainable livelihoods. Meanwhile, those who think the Sundarbans will disappear share various suggestions for reducing dependency on the ecosystem. Most mention the provision of jobs in the villages as an option to reduce dependency. Aside from this, 'starting small businesses' and 'migrating to the other cities' are cited options. Generally, when considering the future livelihood prospects, resource users suggest improvements in access to freshwater, greater diversity in their livelihoods, improved vegetable production, as well as the possibility of reducing salinity levels as some of the options to help cope with the challenges of dependency on the Sundarbans.

## 5. Discussion and outlook

### 5.1. Discussion on findings

With growing resource dependence on this globally important ecosystem, often as a consequence of climate-related disaster, the Sundarbans have been exposed to substantial transformations over the years (Ahsan et al., 2017). In this paper, we sought to explore the dynamics of livelihood strategies around the Sundarbans to provide a portfolio of livelihoods and dependence, analysing the determinants of dependence on the forest. The study found that socio-demographic factors such as occupation and education level have a more than 30% likelihood of contributing to dependence on Sundarbans, building upon previous studies that highlight the relations between socioeconomic characteristics and dependency (Abdullah et al., 2016a.) Regarding the livelihood portfolio of forest users, it was found that respondents harvest different products at different times, but harvesters have individual preferences for particular products. Although field evidence points to the fact that few persons (23%) directly depend on Sundarbans, patterns of dependence can be complex and variable throughout the year. For example, forest products like honey and timber have seasonal availability, leading harvesters to engage a range of occupations. Weather effects, over-exploitation, and social dangers can likewise motivate harvesters to seek new forest areas or new jobs. Thus, extent of dependence at the household level is liable to shifting. Moreover, institutional factors were also shown to play an essential role in forest use. More than 90% of respondents accessed the Sundarbans without obtaining legal permits, typically citing demanding access rules. This may point to the difficulty of evaluating dependency through official sources. This result coheres with previous studies that explain the complex arrangements linked to mangroves and mangrove resource exploitation (Ajonina et al., 2008; Feka and Ajonina, 2011; Van der Stocken et al., 2019.) Furthermore, a bricolage setting persists, in which resource users variously draw from available rules and enforcement agents to enter the resource system and extract resources. Cases of non-compliance and bricolage governance arrangements have been reported in many resource systems worldwide (de Koning and Cleaver, 2012; Ingram et al., 2015; Gebara, 2019.)

Most respondents depend on the Sundarbans for the following key resources: nipa palm, honey, fuelwood, timber and medicinal plants, resources that have a ready market and are therefore harvested year in, year out, with some rotation of intensity based on the seasons. The prevalence of timber, fuelwood, and nipa collection as a livelihood strategy reflects these resources' economic value (Ahsan, 2014). However, the highly extractive nature of these activities raises questions linked to the sustainability of the Sundarbans. Will the Sundarbans survive the current shocks linked to increasing extraction? Current observations concur with earlier contentions that given the present rate of mangrove extraction, the world may lose such ecosystems within a century (FAO, 2003; Duke et al., 2007). The problem of overexploitation exacerbates environmental forces like sea level changes, drought, and

resource stock changes, which adversely impact the Sundarbans and its dependent communities. For example, in the aftermath of two large meteorological disasters, Cyclone Sidr (2007) and Cyclone Aila (2009), people became dependent on the Sundarbans for timber for construction and cooking. The economic recovery of different income groups following Aila showcased the malleable but evident relationship between socioeconomic factors and dependence, and suggested the flexibility of directly forest-dependent groups in spite of their low income (Abdullah et al., 2016a), an attribute further demonstrated by the variable livelihood patterns and future outlook of dependents in this study. Although migration has been established as a key livelihood strategy of households near the Sundarbans (Mistri, 2013), current dynamics may suggest a trend of non-migration in the face of increasing vulnerability - though it remains doubtful whether this can be sustained given broader geo-climatic transformations. Regardless, respondents conceptualise future environmental threats such as the Sundarbans' disappearance in a manner suggesting an established, pragmatic disposition for adaptation; perhaps, for example, by seasonal/translocal migration which is already practised in Sundarbans communities (Das and Mandal, 2016). Nevertheless, many do feel the challenges of forest dependence are increasingly untenable, desiring less dependent livelihoods, but feel restricted by poverty and debt issues (Islam et al., 2018.)

Overall, the conditions described in the study show that the conservation of the world's largest mangrove forest will be affected by the socio-demographic and economic characteristics of the coastal inhabitants, as these factors determine dependence on the Sundarbans' ecosystem services to a significant extent. As such, the Sundarbans' future well-being may be largely dependent on mitigation approaches related to resource dependence, i.e. changes in access/use regulations and patterns, changes in resource conflicts, and diversification of livelihood strategies. Therefore, this paper argues that the future of the Sundarbans will be shaped by the current policy considerations that expand the portfolio of livelihood options among adjacent communities, and anticipate the global, national and local economic forces that influence dependencies, such as market changes and the availability of locally adapted technology. We suggest that policy prescriptions should focus on (i) coordinating less-extractive diversification activities such as ecotourism to reduce the impact on Sundarbans, (ii) creating an enabling environment for the crafting of local rules to regulate over-dependence on Sundarbans, and (iii) introducing adaptive planning practices to sustain livelihoods and build community resilience to reduce over-dependence on Sundarbans. Such adaptive practices may include mangrove afforestation, investing in renewable NTFPs, and minimising the effects of increasing salinity and lack of freshwater by investing in sustainable, climate-tolerant agriculture and forestry. Finally, in the academic realm, this study makes a succinct plea for further empirical studies to diagnose sustainability issues linked to dependence on the Sundarbans. This is relevant for the globe, considering the significant population growth in Asia, and the importance of reducing natural resource dependency to preserve both sustainable livelihoods and ecosystems.

## 5.2. Conclusion

This study employs a large dataset to find that all villagers near the Sundarbans are dependent on its resources, to differing degrees. Our research has shown that increasing distance from the Sundarbans by one kilometre reduces the direct dependence rate by about 7%. Less educated, younger people are likelier to extract from the Sundarbans due to a lack of job opportunities. Likewise, those with higher monthly household expenses and larger families rely on the Sundarbans to a greater extent. As Muslims in these adjacent villages are more numerous and less educated, they also extract resources at higher rates. At the community level, job opportunities significantly reduce the tendency of extracting from the Sundarbans. Thus, there is no alternative to creating local level employment to reduce dependency. Furthermore, some

respondents express concern that Sundarbans resources may be depleted, believing corruption and illegal acquisition of wealth, and lack of local employment opportunities, will contribute to this. Our research provides examples of local experiences of corruption, illegal entry and wealth amassing.

The following conclusions can be drawn: socio-demographic factors have a role in determining dependence on the Sundarbans, which is correlated with extractive activities that proliferate and remain largely unregulated due to corruption and cumbersome access rules. Although direct dependence is not especially high as a proportion of livelihood strategies near the Sundarbans, it is highly exploitative of the forest resources. Highly extractive activities (e.g. timber, fuel wood and nipa palm collection) can be contrasted against less degrading ones (e.g. honey collection, fishing). A switch in occupation, especially for those moving from less extractive to more extractive options, tends to increase mangrove dependence, indicating the importance of stable livelihood sources. Therefore, in addition to livelihood diversification, policy considerations should encourage a change from more to less degrading extraction activities. This study contributes to the analysis of environmental dependence for rural livelihoods, particularly the role of socio-demographic and institutional factors, making progress on the gap for mangrove literature concerned with analysing dependency.

## Data availability statement

The data will be readily shared upon request.

## Ethical compliance

In this study, the steps/procedures for data collection, treatment and analysis have been provided. Equally, the free prior informed consent of all participants was sought before data collection.

## Declaration of Competing Interest

We declare that none of the authors have competing financial or non-financial interests.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.crsust.2021.100077>.

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