ENVIRONMENTAL VULNERABILITIES INDEX FORMULATION IN FRAGILE ECOSYSTEM OF THE INDIAN SUNDARBANS

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Abstract

Human Development Index (HDI) defined by United Nations Development Programme (UNDP) involves health, education and life standard. HDI as a measurement of development for a community is realistic as it takes into account the condition of common people's livelihood. Here, we study the development of Sundarbans in South and North 24 Parganas districts of West Bengal. Existing data indicates poor infrastructure as well as horrifying poverty, but livelihood, education and health indices for all 19 blocks of Sundarbans do not depict the exact developmental scenario. Climatic shocks reinforce risks and environmental vulnerabilities (EV) leading to long term setback for the human development. EV affects the developmental status and thus modifies HDI. In this work, we propose to take into account the EV. We present through

review of existing data and literature related to human development, HDI, show anomalies in the available data and discuss factors of EV. Finally, we propose a model to formulate Environmental Vulnerability Index (EVI) for Sundarban using model of 4 dimensions with 24 indicators expressed in terms of 120 variables given below. We demonstrate here how to collect EVI using values of variables through house hold survey as well as available secondary data.

1. Introduction

The central issue facing most of the world today are associated with economic development. The discourse on economic development has largely been influenced by the metrics of growth. The reduction of development to calculations of marketed value-added has been criticized in social science literature giving rise to more holistic notions of development that are not insensitive to ecological concerns.

While looking into the issues influenced by the environmental conditions, it is noted that across developing countries, millions of the poorest people are already being compelled to cope with the impacts of climate change. They go unnoticed in financial markets and in the measurement of world gross domestic product (GDP). But increased exposure to drought, to more intense storms, to floods and environmental stress is holding back the efforts of the world's poor to build a better life for themselves and their families. There is an increasing need to evaluate the links between the social and ecological dimensions of human vulnerability to climate change. In Millennium Ecosystem Assessment (2015), it was observed that traditional national accounts do not include measures of resource depletion or the degradation of renewable resources. Consequently, a country may destroy its natural assets like forests, fisheries for development and term it as a 'gain to GDP' despite the irreversible loss of natural capital. Moreover, many ecosystem services are available freely to any user (like the use of the atmosphere to discharge pollutants), and so again their degradation is go unaccounted in standard economic measures.

Addressing this need, the concept of sustainable development was coined by the UN in 1983 which decided to establish the Brundt land Commission. This Commission recognized that human resource development in the form of poverty reduction, gender equity, and wealth redistribution was crucial to formulating strategies for environmental conservation. It also recognized that environmental-limits to economic growth in all societies existed (UN Report of the Brundtland Commission, 1983).

Here, we will discuss the developmental issues and its challenges of Sundarban. It is the world's largest mangrove forest ecosystem, with people having main occupation as agriculture. Other occupations are fishing, forestry including collection of timber and honey. Due to lack of any industry, people's livelihood depends primarily on exploitation of natural resources. Basic infrastructure, including transport and provisions for adequate health care and education are either nonexistent or are at rudimentary state in most of the remote villages. There is extreme environmental vulnerability in terms of regular cyclones, floods and storm surges.

The study of economic development of people of Sundarban must consider the constraints imposed by severe environmental changes which increase the nature of risks faced by them. Environmental vulnerability can retard the progress of human development and negate some of the recent gains. For example, lack of access to improved sources of water and sanitation has an adverse impact on human development due to increase in health risks especially water borne diseases.

Human Development Index is supposed to provide a gross measure of select development indicators accounting for health, education and standard of living of people in a particular region. The United Nations Development Programme (UNDP) published its Annual Report, 2014 entitled "Sustaining Human Progress: Reducing Vulnerability and Building Resilience" (UNDP, 2014). It adopts a holistic approach of development. It considers the factors which contribute to the risks to human development and then discusses the ways in which resilience against a broad group of evolving risks could be strengthened. UNDP annual reports give region/country-wise detailed data of HDI calculation which depends on indices of three dimensions, namely of health, education and living standard.

We find HDI values reported for Sundarban do not represent the actual condition of people living under abject poverty and vulnerability. Particularly, for the administrative blocks prone to climatic shocks, environmental vulnerabilities need to be taken into account in order to assess their state of development.

1.1 Vulnerability and Resilience

We briefly review the vulnerability and resilience issues from the report of UNDP (2014) that will help us to understand the situation of Sundarban.

Traditionally, the concept of vulnerability is used to describe exposure to risk and risk management. Adverse shocks or threats to human development can be attributed to various factors like: a) Economic risks b) Inequality c) Health risks d) Environment and natural disasters e) Food insecurity f) Physical insecurity.

Resilience is considered as the capacity to absorb external shocks without significant deformation. The Intergovernmental Panel on Climate Change extends the definition of resilience as the "ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner" (IPCC, 2012). People are vulnerable to poverty if they are "below or at risk of falling below a certain minimally acceptable threshold of critical choices across several dimensions, such as health, education, material resources, security."(Dutta et al., 2011)

People with higher HDI will generally refer to people with better livelihood and possessing good health and education; so they are more resilient than those who are malnourished, without education and thus in a weaker position to change their activity or location in reaction to adverse shocks. The poor and the near poor sections may not have much savings or many assets to fall back on. In order to face threats to survival, they are forced to reduce food expenses or spend less on health and education of children (Dutta et al., ibid). District Human Development Report, 2009, 24 Pgs. (South) also discussed vulnerability in general based on a) economic and social security issues 2) crime and violence and c) vulnerability to natural disasters. Vulnerability index was constructed based on Rural Household Survey (RHS) data of 8 indicators only. Lack of taking peoples feedback on steps taken by governmental agencies sometimes hinders development as expected by planners. People's quick

reaction on policies being implemented and revision of program by the authority can produce better result. Such feedback system, using social media was discussed by Syaifudin et al. (2017). In the context of special environmental status of Sundarbans, vulnerability imposed by this fragile ecosystem was not taken up in (DHD Report: S24 Pgs, 2009).

The work is organized as follows: In Sec 2, general picture of two 24 Parganas (districts) in which Sundarban is situated and block (smallest administrative units) level data on developmental issues of Sundarban are presented through select data given in Table 1 in Sec. 3, some apprehensions on existing HDI values are presented as they do not correctly express state of human development in Sundarban as given in Sec. 2. Possible reason of failure of HDI to capture real situation in Sundarban is the Environmental Vulnerabilities (EV) specific to Sundarban which are detailed in Sec. 4. We make a brief review of research in this field – both at national and international level in Sec. 5. Based on Sec. 4 and 5, we propose different dimensions, indicators and variables to define EV Index; also give methodology and model to quantify EVI in Sec. 6. Finally, we give remarks in Sec 7 as conclusion.

2. Sundarban: Developmental Issues

Our focus will be on developmental issues of Sundarbans- also spelt as Sunderban or Sundarban in literature. It is located in the remote southernmost part of West Bengal, India and large part is in Bangladesh. Our discussion will be confined to Indian part of Sundarban with nearly 4.5 million people depending traditionally on nature for livelihood. Presently, administrative boundary of the Sundarban is spread over two districts of West Bengal, i.e. North and South 24-Parganas, covering 19 blocks. The blocks are– (13 in South 24-Parganas) Sagar, Namkhana, Kakdwip, Patharpratima, Kultali, Mathurapur-I & II, Jaynagar-I & II, Canning-I & II, Basanti and Gosaba; and (6 in North 24-Parganas) Hingalganj, Hasnabad, Haroa, Sandeskhali – I & II and Minakhan. See map of Sundarban in Fig. 1.

The two 24 Parganas are lagging behind in major indicators of development the state average. For example, in access to Health care, one of the most important factors is average population per Primary Health Centre (PHC). For South 24 Parganas, it is as high as 82,033 per PHC, while for North it is 78,764 while the state average is 50,300 persons per PHC. In access to education, the state of schools is also very poor. In South 24 Parganas, 67% schools do not have

electricity connection, for North 24 Parganas, this is 56%. Almost 90% schools are without any Computer in 2011 (DISE & SEMIS Reports, 2012). Due to extreme poverty, students in these districts enrolled in primary classes are compelled to leave schooling, so number of students at different levels will show this as in Fig. 2.
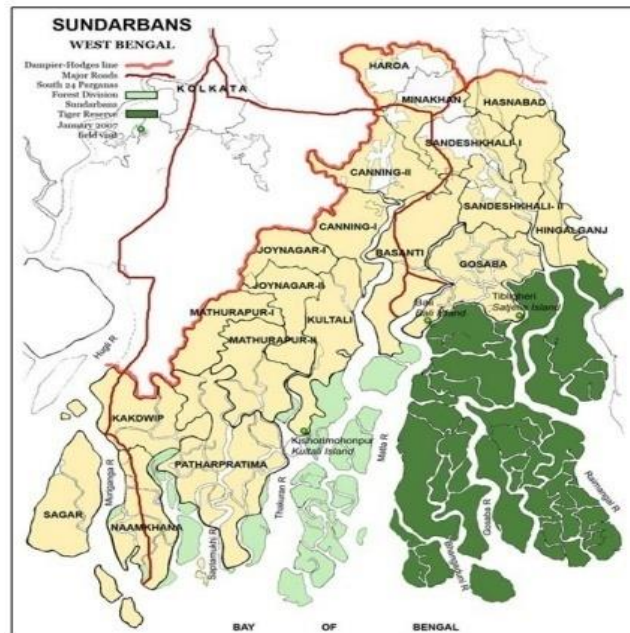

Figure 1: Map *of blocks of Sundarban in two 24 Parganas. Credit* DHD Report: S24 Pgs (2009).
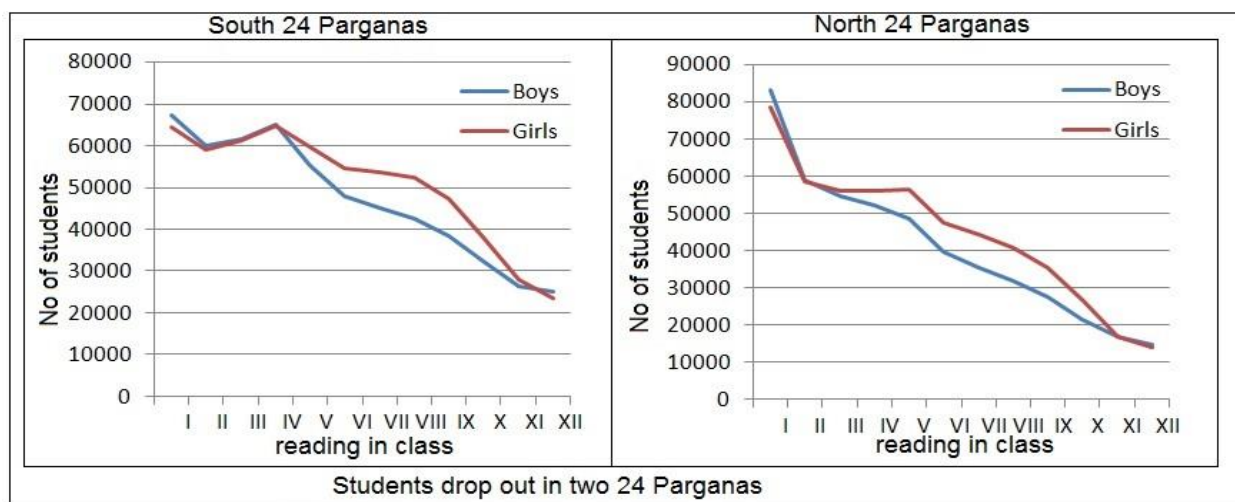

Figure 2: *Problem of dropout of students in Two 24 Parganas*

Now we look into details data of the 19 blocks of Sundarban mentioned earlier which fall in two 24 Parganas. In Sundarban, 36.5% of the population belongs to scheduled castes and scheduled tribes (SC/ST- officially considered as historically most backward part of Indian population) as compared to the State average of 25.61%. More than 40% of the population live below poverty line (BPL)- a socio-economic border line defined by the Government of India DHD Report: S24 Pgs & N24 Pgs, 2009).

We represent below data on different social sectors, infrastructure and economy of people residing in Sundarban in Table 2.1. We also report HDI values in Table 3.1 (collected from governmental or private sources).

Table 1: *Use Showing Educational level, households having basic amenities and possessions in per cent in 2011*

		Literate Male	Literate Female	Full cove-rage drinking water	house permanent *	Light-ning by Electricity	No drain age	Cook by LPG / PNG	TV	Computer + Internet	Mobile
South 24 Parganas	Canning–I	31.47	23.33	19.3	25.7	21.8	94.3	1.3	10.9	4.3	34.4
	Canning–II	30.94	24.34	20.9	17.5	22.4	96.8	0.0	8.1	3.6	30.1
	Mathurapur–I	35.32	27.59	46.2	35.0	31.5	93.9	1.9	15.5	3.4	32.0
	Joynagar–I	35.06	26.92	80.3	45.9	29.2	88.9	4.6	17.1	4.7	32.2
	Joynagar–II	33.20	24.99	29.7	30.0	13.7	95.2	0.7	7.6	7.2	25.4
	Kultali	34.32	24.23	52.4	13.9	6.4	97.6	0.1	7.9	4.7	34.0
	Basanti	32.60	25.15	38.6	10.9	6.6	97.6	0.4	7.5	5.9	32.0
	Gosaba	39.19	30.88	38	6.8	2.7	95.9	0.5	8.9	4.1	30.3
	Mathurapur–II	38.63	29.83	52.5	25.3	27.2	94.5	1.3	16.3	4.6	37.1
	Kakdwip	37.85	30.49	39.5	26.2	33.1	92.6	5.0	20.6	3.3	45.5
	Sagar	41.06	32.74	40.5	16.6	1.1	90.5	0.6	14.0	2.8	44.4
	Namkhana	41.19	34.35	42.9	23.2	22.8	91.9	0.9	12.7	4.4	43.2
	Patharpratim	39.5	32.2	24.6	15.2	7	97.	0.4	10.	3.4	39.9

		0	1			3		7		
	a	0	1			3		7		
North 24 Parganas	Haroa	35.33	28.42	50.0	37.9	84.9	3.2	15.3	4.1	36.7
	Minakhan	33.90	27.32	34.1	26.4	90.6	1.4	8.6	6.0	28.5
	Sandeskhali-I	34.35	27.04	20.6	16.4	92.6	1.3	7.7	8.1	29.6
	Sandeskhali-II	34.92	26.46	8.0	8.3	94.1	0.6	5.0	7.5	22.9
	Hasnabad	34.16	28.23	41.1	31.2	94	1.6	10.8	6.2	29.7
	Hingalganj	38.99	30.74	15.0	10.4	96.5	0.4	8.5	7.7	25.8
	South 24 Pgs			49.4	35	91.3	4.2	21.7	4.7	39.5
	North 24 Pgs			70.5	43.6	85.1	4.8	19.9	6.9	40.4

*Permanent houses refer to those houses whose walls & roofs are made of pucca materials,
Census 2011 data: South 24 pgs, pp 588-610. Census 2011 data: North 24 pgs, pp 684-706.

From above Table, one can understand the extent of economic hardship people of Sundarban are confronted with. The infrastructure for education and health is in very rudimentary state. Extreme poverty has forced people to curtail spending in health and education. Added to it are frequent environmental shocks like periodic cyclones, storm surges, soil salinity and land erosion etc.

3. Some Apprehension on Reported HDI Values

In these circumstances, one can easily understand that the stage of development revealed by given data does not match with mentioned HDI values given in the following Table 3.1.

Table 2: *Value and position) of indices, population density of all Sundarban blocks*
(HDI sorted, positions are as lowest 19 to highest 1)

Sl.	Block Name	District	Livelihood Index	Education Index	Health Index	HDI	HDI position
1.	Sandeskhali-II	N24Pgs	0.43	0.44	0.49	0.45	19
2.	Hingalganj	N24Pgs	0.47	0.51	0.50	0.49	18
3.	Basanti	S24Pgs	0.30	0.78	0.43	0.50	17
4.	Sandeskhali-I	N24Pgs	0.51	0.44	0.57	0.51	16
5.	Canning–II	S24Pgs	0.32	0.76	0.44	0.51	15
6.	Minakhan	N24Pgs	0.51	0.43	0.59	0.51	14
7.	Haroa	N24Pgs	0.52	0.47	0.54	0.51	13

Sl.	Block Name	District	Livelihood Index	Education Index	Health Index	HDI	HDI position
8.	Hasnabad	N24Pgs	0.55	0.47	0.57	0.53	12
9.	Gosaba	S24Pgs	0.38	0.86	0.39	0.54	11
10.	Sagar	S24Pgs	0.34	0.91	0.41	0.55	10
11.	Joynagar–II	S24Pgs	0.39	0.80	0.46	0.55	9
12.	Patharpratima	S24Pgs	0.35	0.90	0.43	0.56	8
13.	Mathurapur–I	S24Pgs	0.40	0.81	0.49	0.57	7
14.	Namkhana	S24Pgs	0.34	0.93	0.46	0.58	6
15.	Kultali	S24Pgs	0.35	0.89	0.53	0.59	5
16.	Mathurapur–II	S24Pgs	0.37	0.85	0.56	0.59	4
17.	Joynagar–I	S24Pgs	0.41	0.83	0.59	0.61	3
18.	Canning–I	S24Pgs	0.41	0.80	0.70	0.64	2
19.	Kakdwip	S24Pgs	0.41	0.88	0.66	0.65	1

Data Source: page 24, DHD Report, 2009. S24Pgs stands for South and N24Pgs stands for South 24 Parganas.

For example, we can check how far Education Index (EI) data given in the Table 2 represent real educational scenario. We find for most blocks, EI is more than 0.8 (out of possible maximum 1). Three blocks have achieved even 0.9 or higher. But interestingly, other educational data don't show such a successful educational scenario. For example, literacy rate is 60% for Kultali block (DHD Report, 2009. S24Pgs) which means that large section of children are not even enrolled in a school. Also many students from poor families are compelled to leave school for some extra income for the family, this is termed as 'drop out' – it is one of the biggest challenges to education in India as well as in Sundarbans. At upper primary level (Class V to VIII) in Sundarban blocks, 'drop out' is as high as 30-40% but it seems that there is no reflection of this reality in the reported EI. In this situation, Education Index for Kultali as 0.9 (out of 1) is certainly unrealistic. This is true for EI of other blocks as well, refer to Fig 2 for this.

Similarly, Health Index data can be checked by looking into micro level parameters. The HDR24Pgs(S) report admits absence of any block level data on life expectancy at birth etc. We checked for an important factor- that is number of people per doctor. This is calculated by dividing population of block by number of doctors deputed there by the government. We find this is far above (up to 5 to 30 times) the Indian average. Patients are to be brought by simple boats which wait for tides. The ratio is extremely high, for Canning II it is 1:65,000 nearly, while

the Indian average is 1: 1,792. For Basanti block, this is 1:1,32,000; the lowest ratio is for Kakdwipas 1:9,569 (District Statistical Handbook, South 24Pgs, 2009).

Anomalies related to the above observation on Educational Index and Health Index of Sundarban blocks are carried to calculation of HDI resulting in inappropriate values. Apart from that, some other factors, specific to Sundarban also affects HDI. This issue will be discussed in the following section.

4. Environmental Vulnerabilities specific to Sundarban

We have seen in previous section that moderate or even high value of HDIs of Sundarban blocks (Table 2) does not represent actual stage of development given by Table 1. This anomaly can be explained by taking into account extreme environmental vulnerabilities specific to Sundarban blocks. Here we like to focus on this issue.

We have stated that District Report for South 24 Parganas (2009) considered general vulnerabilities and constructed block level vulnerability index. But vulnerabilities are present in all districts of West Bengal or India in different forms. Environmental features which are unique to Sundarbans are to be considered while considering vulnerabilities and the extent they modify development. Because of these vulnerabilities, livelihood options as well as standard of living are highly affected and finally, HDI is rather modified. The said District Report records following environmental vulnerabilities (EV):

i) Global warming and the resulting sea level rise. ii) Livelihood strategies destroying biodiversity iii) Threat from embankment erosion iv) Destruction of mangrove v) Conversion of agricultural land vi) Salinity problem and vii) Poverty driven pollution

Apart from the above, people of Sundarban are facing following EV:

Water Quality: Presence of Arsenic above permissible limit is a serious problem as in most cases people depend on tube well waters which gives contaminated water. SOES (2006) in their prolonged study have classified nine districts including north and South 24 Parganas as severely affected (where arsenic concentration is more than 300 µg/L).

Soil salinity and water logging: Inadequate drainage and age old system of irrigation cause water logging and cause soil salinity. These two problems cause huge loss to agriculture output

as well as recursively destroying soil fertility according to Datta et al. (2002) and Agricultural Crop Consulting and Ideas (2015). The researchers actually demonstrated this loss in case of farmers in some North Indian states.

Salinity in the Sundarban Rivers: Increase in salinity is seen from dying of tops of mangrove (*Sundari)* trees, retrogression of forest types, decrease in density and diversity of fish etc. in Sundarbans. Raha et al. (2012) observed associated climate change in Sundarban. Furthermore, during frequent flooding, this saline water enters in paddy field or fresh water aquaculture ponds causing huge loss.

Cyclones and high tidal amplitude: Sundarban is exposed to periodic storms and cyclones, mostly around monsoon months. Tidal amplitude in the Sundarbans is very high. Now, cyclones and resulting high tides damage peoples life and livelihood including cattle, paddy etc. in villages of Namkhana, Patharpratima, Sagar, Kultali and Gosaba blocks which are close to coast. Due to lock of forest cover which somehow protects villages from this danger, and breaking of ill-maintained embankment, Namkhana and Patharpratima blocks are worst affected- as observed by Chaudhuri et al. (2012).

EV and Migration of people: EV also affects livelihood options which compel the people of Sundarban to emigrate to other districts or even other states. Fewer options of higher education as well as livelihood instigate people to move out. Natural disasters such cyclone, storms surges and floods force people to migrate out. *Aila* (super cyclone in 2009) is an extreme example of this which left thousands of people destitute. All these factor also change population density. Cross border infiltration through porous international border of Sundarban, unlawful activity to exploit natural resources accentuates changes in population density. Along with different forms of EV, its direct effect on population needs to be assessed particularly, when population density is selected as an important parameter to measure human development.

5. Review of status of research

5.1 International status

We briefly report some works which are relevant to problems of Sundarban and its people.

- **Environmental Vulnerabilities:** One of the classic examples is the Sahara desert which demonstrates how environmental vulnerabilities as well as human activities can bring once a fertile land into a desert. Many more examples of deforestation and desertification can be found in (National Geographic, 1996).

- **Social Basis of vulnerabilities:** Poverty has been regarded root cause of different forms of vulnerabilities as well as degradation in standard of living by many works, like in SCES, 2006). According to World Health Organization (WHO) Ottawa Charter for Health Promotion 1986) harmonious eco-system, shelter, food, income etc. are considered as precondition of standard of public health.

- **Four pillars of sustainability in Sundarbans:** In 2014, the World Bank Report examined the issue of building resilience for sustainable development of the Sundarbans. This report extensively studied problems of Sundarban and suggested appropriate strategy for responding to the challenges. The report dealt on various developmental issues based on four pillars: Vulnerability reduction, Poverty reduction, Biodiversity conservation and Institutional change.

- **Environment imposed occupational health problem:** Main occupation of people of Sundarban is agriculture, fishing or collecting forest resource. Occupational exposures to fishermen, motorboat men which are common to people of Sundarban were addressed by some studies. Encyclopedia of Occupational Health and Safety by Stellman (2011) of International Labor Organization (ILO) has details of different category of vulnerability of working people, occupational risks and health hazard have been detailed in it. Problems related to fishing (Chapter 66) and Occupational Skin Diseases (Chapter 12) are of particular importance here. Primary or secondary infections of the skin are primarily caused by bacteria, fungi, viruses or parasites that may cause. While bacterial infections can occur in any kind of work setting, certain jobs, such as animal breeders and handlers, farmers, fishermen, have greater exposure potential. Even removal from work cannot eliminate the workplace as the source of the disease. Occupational asthma is frequently found among workers in fishing activities. Hearing loss due to excessive and prolonged noise of motor boats/trawlers during fishing, fatal poisoning due to incidents of fire on board fishing vessels or related to inhalation

of toxic smoke of boat engines are well recognized among workers in the fish-processing industry. Main transport in Sundarban is primitive motorized boats- so people not related to fishing- bound to take long hours of journey from remote islands are affected by these problem. Al Hamdi et al. (2008) noted these effects of health for Basrah (Iraq) citizens. Thu Hong et al. (2017) noted how heavy metals in the wastewater can pollute the water resources because they are durable, have a high toxicity in the environment and body tissues.

- **Stress due to excessive human habitation:** Over centuries, overcrowding caused severe damage to Sundarban's ecosystem which are taking its toll today. This human induced modification was discussed on global scale in many works, for example by Western (1998). It was reported that nearly half of the world's marine fish populations are fully exploited and another 22% are overexploited. Hunter (2000) estimated that during the past three centuries, the amount of Earth's cultivated land has grown by more than 450 percent. A related process, deforestation, is also critically apparent: A net decline in the forest cover of 180 million acres took place during the 15-year interval 1980–1995.

- **Land conversion:** With increase in population, pressure on land also increases. The global phenomena was reviewed by the Scientific Committee on Problems of the Environment (SCOPE) (1971). Shrimp culture is more profitable than cultivation in Sundarban, so paddy fields being converted for shrimp culture in many places. Inappropriate land use has resulted in irreversible degradation of soil and vegetation.

- **Poverty-environment nexus:** Baland (2012) presented an example of deforestation due to exploitation of resources of the Himalaya which further affect people's living standard. Destruction of forest for resources and human settlement is taking place in Himalayan region of Nepal. The decline in Nepal's forest cover is at an annual rate of 2.7%. As a result, time required for poor people collecting fire-wood and fodder have increases substantially- which recursively increased poverty. This 'poverty-environment hypothesis' has subsequently received attention from academics and policy experts.

- **Climate shock induced migration:** Narrating experience people of Bangladesh affected by cyclone Aila, Mallick (2011) said that when the relief program was terminated, male members

of the family started moving towards closer cities in search of livelihood. Most of them started to pull rickshaws or to work as laborer in industries.

5.2 National status

Some important works are reported below which considered specifically problems of Sundarban.

- **Occupational hazards in Sundarban:** Livelihood problems of Sundarban were discussed in the following works. Study by Chattopadhyay (1995) is based on the empirical research to study the man-nature nexus as well as dangers of people living on fishing, timber and honey collection- three major occupations of Sundarban. Hardship of toiling people involved in them has been discussed based on data collected from related police stations of Sundarban. In another work, question of borrowing money for fishing has been addressed. Livelihood vulnerabilities of the *mawallis* (honey collectors) of Sundarban were discussed in study by taking 60 samples of the *mawallis* (Roy, 2014). In the work by Kanjilal et al. (2010) health issues of people in the Sundarbans has been discussed. While estimating health status, it was noted that general morbidity rate is higher than the state average. Children are three times more vulnerable to respiratory ailments which also top the prevalence list. In general, almost all types of communicable diseases are highly prevalent. Environmental problems, such as skin related ailments are also very common. Remarkably high prevalence of mental health problems due to strong presence of various psycho-social stressors was also noted. Das et al. (2016) reviewed problems related to main occupation of shrimp fry farming.

- **Human Animal interaction:** Another attribute of socioeconomic importance is damage caused by animal bites. A study by Chowdhury et al. (2008) attempted analysis of the extent and impact of human-animal conflicts vis-a-vis psychosocial stressors and mental health of affected people. The living conditions of the spouses of animal-attacked victims was studied and it was seen that more than 50% of them have poor health, more than 20% become beggars or maid servants or daily labors.

- **Climate change affects livelihood and enforces migration:** Climate change is triggering a silent yet drastic livelihood change in the agricultural fields and water bodies of Sundarbans. As a result, farmers, who earlier were tending to crops and fishes, are now finding refuge in construction and mining jobs in faraway Mauritius, or in the Indian states of Kerala, Gujarat,

Karnataka and Maharashtra. A household survey (Priyadarshini, 2015) found that at least 30% of the households had at least one member migrating in search of work. Given the availability of other livelihood opportunities, 93% of the 2188 households surveyed did not want to remain dependent on forest resource. It also reported that between 2001 and 2008, the area under agriculture in the Indian Sundarbans had gone down from 2149 sq km to 1691 sq km. Also, as a result of overexploitation of aquatic species in the last 15 years, coastal fishing has seen a decline in catch-per-unit effort – from 150-200 kg per haul to 58-65 kg per haul. As a direct consequence of these, people are forced to emigrate for better livelihood options. Another study (Reuters, 2015) observed that "The Sundarbans is sadly a powerful example of how creeping climatic changes accumulate disaster risks. The expansion of environmental threats to social ones highlights an urgent need for governance processes and systems to target this."

- **Vulnerability as addressed in District Human Development Report:** This report (DHD Report South 24 Pgs, 2009) also discussed vulnerability in general based on a) economic and social security issues b) crime and violence and c) vulnerability to natural disasters. Based on Rural Household Survey (RHS) data, it constructed vulnerability index as a composite of two indices: Economic and Social Vulnerability Index (ECVI) and Bio-Physical Vulnerability Index (BPVI). The RHS provided data on the following 8 indicators only: a) Possessions of land b) possessions of house c) clothing d) food intake e) earning members f) literacy g) indebtedness and h) migration. It may be noted that only EV will be studied here; not as a shock like cyclone etc.

- **Environmental shock induced migration:** The issue of migration due to EV was examined during 2010-2012 by Pakrashi (2014) where primary data were collected from 5 villages. It was found that in Beguakhali (Sagar Block) 25 out of the 41 households interviewed, had at least one member working outside, while for Rangabelia: 30 out of 43, Pakhiralaya: 20 out of 32, Gosaba: 15 out of 28 (all in Gosaba Block) and for Masjidbari: 10 out of 14 (Basanti Block) of the South 24 Parganas. This is one example of high rate of migration. Another survey (Chaudhuri, 2012) was conducted during period: September 2010 – January 2011 with post-*Aila* Sundarbans with sample size of 500. It was found that 75 per cent respondents said

that someone from their family migrated in search of work. Lack of livelihood was pointed as the key reason for migration.

- **Various effects of Aila:** The super cyclone caused severe damage in the Sundarbans. It destroyed huge number of houses along with loss of human and animal lives. In the absence of livelihood options, people migrated to safer places. Debnath (2013) carried out a study to find out the effect of *Aila* in one block (Gosaba) in Sundarban. *Aila* caused high salinity and pH value of soil and thus affected agricultural production. The author assessed the production of paddy before *Aila* during 2008-2009 and post Aila period of 2012-2013. It was found that *Boro* production dropped by 40% while *Aman* paddy reduced by 50% nearly, due to *Aila*.

- **Summary by an Expert on Sundarban:** *Padmashree* TusharKanjilal (2015) is an octogenarian social activist based at Rangabelia, Sundarbans. He is working for comprehensive rural development plans encompassing health, education and employment in the Sundarbans for more than 50 years. He summarized problems of Sundarban as:

  1. In the last two decades, water level in Sundarban and adjacent area is increasing at a rate of 3.14 mm/year. Rise in sea level has submerged islands, namely Redford, Suparibhanga, Kabasgadi and Lohachura.

  2. Out of 102 islands in Sundarban (lying within West Bengal), 56 have been deforested by human settlements. Other islands are suffering from land erosion. Together with increase in population-resources for agriculture, honey/wax collection have been drying up. For a family of 5 members, 14-15 *bighas* of land is required for cultivation to ensure modest subsistence.

  3. Only 15-20% of land has been utilized for double cropping by using high-yield seed, pesticides. These methods are increased production cost, decreased land fertility and even caused different diseases.

  4. Social fabric and culture have been destroyed due to high level of consumerism.

In conclusion, for above mentioned reasons, most of people of Sundarban are leaving Sundarban for better living.

6. Selecting variables to quantify EV

We have seen how EV affects livelihood options. Das Gupta et al. (2015) attempted a five dimensional community resilience assessment framework and a composite resilience index to assess impacts of climate related disasters and considered most of the above mentioned factors. Taking a similar but broadened approach, we have included many more factors, like environment driven migration, also including scope of measuring some physical parameters essential for livelihood like arsenic contamination of water etc. We have framed the assessment of EV Index (EVI) of Sundarban by a proposed model of 4 dimensions with 24 indicators expressed in terms of 120 variables. The proposed model to calculate EVI will consist of the following dimensions and indicators:

A. Dimension: Socio-economic

Indicators: 1.Demography 2.Livelihood 3.Health 4.Social capital 5.Education & Awareness

B. Dimension: Physical

Indicators: 1.Transportation 2.Residential infrastructure 3.Electricity 4.Tele-communication 5.Water Quality 6.Hygiene

C. Dimension: Environmental vulnerability and Safeguard

Indicators: 1.Frequency of natural disaster 2.Climate components 3. Geo-physical components 4. Biogeochemical components 5. Environmental safeguard measure 6. Coordination 7. Emergency response 8.Governance

D. Dimension: Migration

Indicators: 1.Reason of Migration 2.For higher Education 3.For Employment 4.For Marriage 5.Other types

With the help of proposed model, one can calculate EVI for Sundarban which will estimate the environmental vulnerability specific to Sundarban. This was not done before so far our knowledge goes. The value will be in the scale of 0 (minimum) to 10 (maximum). This can modify the existing indicators like HDI with proper mathematical manipulation so that human development can be reliably expressed by them. This will also show the thrust areas needing urgent attention and thus help planners at appropriate level to take correct approach in planning human development of the fragile environment of Sundarban.

6.1 Method and model demonstration

We have mentioned four dimensions. Calculation will be done using following steps:

a. We calculate values of Indices of four dimension described as $I_{(socio-economic)}$, $I_{(Physical)}$, $I_{(Environmental\ vulnerability\ and\ Safeguard)}$, $I_{(Migration)}$

b. EVI= $I_{(socio-economic)}$, $I_{(Physical)}$, $I_{(Environmental\ vulnerability\ and\ Safeguard)}$, $I_{(Migration)}$ to be expressed in 0 to 1 scale to have parity to HDI formalism.

Let us show, for example, the exact procedure to be applied to calculate $I_{(Migration)}$ value.

Table 3: *Demonstration of Calculation of Dimension Values by collecting values of the variables of Indicators describing the Dimension*

Dimension	Indicators	Variables	Max val	Min val	Var no
C. Migration	1. Reason of Migration	a) Shocks	1	0	01
		b) Lack of land/salinity	2	0	02
		c) Job seeking	3	1	03
		d) Before/after *Aila* (2009)	1	0	04
		e) Economical reason	2	0	05
		Total for Indicator C.1 Reason	**9**	**1**	
	2. Education	a) school level	1	0	06
		b) Graduation upward	2	0	07
		c)Technical	2	0	08
		d) Other	3	1	09
		Total for Indicator C.2 Education	**8**	**1**	
	3. Employment	a) Temporary	2	0	10
		b) Skilled	3	0	11
		c) Unskilled	2	0	12
		d) business	1	0	13
		e) Other	3	1	14
		Total for Indicator C.3 Employment	**11**	**1**	
	4. Marriage	a) Entire family	4	1	15
		b) Single migration	2	0	16
		c) Other	3	1	17
		Total for Indicator C.4 Marriage	**8**	**2**	
	5. Other types	a) Seasonal	3	1	18
		b) Under compulsion (political/religious)	2	0	19
		c) Undisclosed	3	1	20
		Total for Indicator C.5 Other Type	**8**	**2**	
		Total for Dimension D. Migration	**45**	**7**	

In the above Table 3, we have shown details of Indicators and variables describing the dimension as detailed in previous section. We shall calculate effect of environment driven migration which is a major issue of population living in Sundarban. The shown maximum and minimum values of variables are different to give relative importance on the variable concerned. Obviously, these values may be fine-tuned according to the real life situation. We have to select a few islands of Sundarban and villages in them for taking a house hold survey based on the questionnaire seeking values above variables.

Say, after survey to a house, we get total value of 25 (out of possible maximum 45 and minimum 7 as shown in the above Table). Converted to scale of 0 to 10, it will be 25*10/(45-7) = 6.58. We shall repeat this calculation for entire selected sample of 200 families and find the average value, say 4.75.

Similarly, other three dimensional indices that is, $I_{(socio-economic)}$, $I_{(Physical)}$, $I_{(Environmental\ vulnerability\ and\ Safeguard)}$ will be found; say they are (in o to 10 scale) 3.53, 4.2, and 7.12.

So we get EVI = 3.53 + 4.2 + 7.12 +4.75 = 19.6 (in total 40) = 0.49 (in 0 to 1 scale). Specialized statistical software will used to collect and manipulate data.

7. Conclusion

We have shown here that HDI used universally to describe level of human development is not properly describing the situation of Sundarban and its people. The main reason for this is the environmental vulnerability (EV) specific to Sundarban. We have identified the factors for EV with a wide literature survey. We have proposed a house hold survey based method to access the impact of various variables of EV index. This unique index of EVI, coupled with HDI may properly express the developmental status of Sundarban and problems challenging it. The planners at appropriate level may find it useful to draw sustainable developmental programs.

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