Pertanika J. Sci. & Technol. 21 (2): 397 - 422 (2013)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Climate Change Resilience Assessment Using Livelihood Assets of Coastal Fishing Community in Nijhum Dwip, Bangladesh

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ABSTRACT

The fishermen of Nijhum Dwip in Noakhali, Bangladesh have lived in an extremely dynamic environment facing tropical cyclones, tidal surges, embankment erosion and salinity intrusion that affect life and livelihood options. This study was conducted to identify human, physical, financial, natural and social assets for analysing fishing community resilience. Landsat TM imagery and asset database of 25 thematic layers were analysed with ENVI and GIS capabilities to identify and prioritise the resilience of coastal fishing community. The resilience assessment focussed on 25 basic criteria, and the weights were determined by a pairwise comparison matrix of Analytical Hierarchy Process according to the effectiveness of the criteria. The study identified natural assets with 48% importance as the most significant in fishermen resilience. The vector of effectiveness indicated that human, financial and social assets showing importance of 18%, 15% and 13% respectively are moderately significant, where the physical asset with only 5% importance is the least significant in fishermen resilience. The results suggest that natural assets with experienced human resource and financial support as well as excellent social relationship are the appropriate option for enhancing coastal fishing community resilience to withstand climate change disaster events.

Keywords: Nijhum Dwip, fishermen resilience, livelihood assets, AHP, climate change

INTRODUCTION

Human-induced climate change is under way (IPCC 2001), and the future climate of Bangladesh, like much of the world, will be warmer. The majority of the world's 200 million fisherfolk (fishermen and other fishing-industry workers and their dependents) live in areas that are highly exposed to human-

Article history:
Received: 27 April 2011
Accepted: 6 March 2012

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ISSN: 0128-7680 © 2013 Universiti Putra Malaysia Press.

induced climate change, and depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation (Allison *et al.*, 2005). Obviously, coastal areas are one of the most vulnerable places due to sea-level rise, increased level of inundation and storm flooding, coastal erosion, seawater intrusion and increased temperature (Torresan *et al.*, 2008). Communities in the coastal areas tend to be dependent on climate sensitive resources, and coastal people do not have the means to adapt fast enough (Ziervogel *et al.*, 2006). Out of an estimated 37 million people living in 21 coastal districts in Bangladesh, about 20 million have been affected by the rising sea. Coastal fisheries in Bangladesh are predominantly low-investment, multi-species and multi-gear fisheries (Chowdhury *et al*., 2011). Population growth and overexploitation increase pressure on coastal fisheries and are recognised causes for their decrease. Climate change effects are likely to put further pressure on resources and livelihoods. Worldwide, fish products provide at least 20% of the protein intake of 1.5 billion people and support the livelihoods of approximately 520 million people (FAO 2009).

This article applied the 'Sustainable Livelihood Approach (SLA)' in an effort to understand fishing community resilience based on level of dependency upon the available assets. SLA provides a way of thinking about livelihoods of poor people in the context of vulnerability (DFID 1999). The application of SLA in the form of climate change adaptation helps researchers and practitioners identify pressing constraints and positive strengths of climate resilient livelihoods in coastal areas with overlaps between micro and macro links. According to the SLA model developed by DFID (1999), the framework compromises three components: livelihood assets (natural, financial, social, human and physical), vulnerability context (vulnerability analysis) and structure and process (institutional analysis) (Fig.1). SLA has seldom been applied to field situations especially in the field of fisheries (Allison & Ellis 2001; Allison & Horemans 2006; Hossain *et al.*, 2007a; Iwasaki *et al.*, 2009).

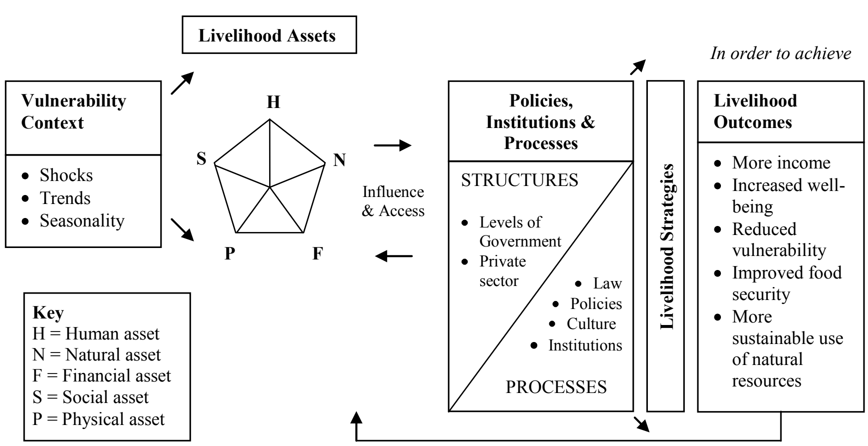

Fig.1: Sustainable livelihoods framework (DFID, 1999)

Resilience intuitively refers to the ability to bend without breaking and to regain the original "pre-bend" shape (Jacob & Showalter 2007). Resilience can be defined in various ways but it is essentially about how systems (bio-physical and socio-economic) are able to respond to change or shocks while maintaining their key characteristics or 'identity'. Socio-economic resilience in terms of fishing communities refers to how they are able to maintain their livelihoods and desired ways of living, without outside assistance, following undesirable shocks. It would include, for instance, their flexibility to make substitutions that would yield more abundant fishery resources or lead to alternative economic activities to help offset declines in harvests from targetted fisheries. Resilience makes strong connections among management and human ecology because it is directed at evaluating responses to disturbances. Responses may include what is commonly referred to as indigenous knowledge, which is the cultural capital of a population in association with the environment. It may include, for example, knowledge of plant and animal, cultivation methods, local medicine and fishing craft and gear. There is a need to understand the resilience criteria and the level of importance of each criterion on coastal fishermen's livelihood. The research used both qualitative and quantitative data including household-head interview, key-informants interviews, participatory field observation and satellite imagery (Hossain *et al.,* 2007b). In addition, Venn diagrams, problem trees and seasonality maps were applied as the PRA exercises for identification of resources and analysing livelihood options. Likewise, semi-structured interviews with key informants (i.e. school teacher, government officer, village leader, NGO worker and mosque *imam*) were carried out to validate and complement the information. This article aims to identify the livelihood assets of fishermen in Nijhum Dwip and analyse the assets into bottom level criteria to measure the relative importance of each criterion in resilience assessment.

STUDY AREA

Profile of study site

Nijhum Dwip (literally "the island of silence") is an accreted island in the central coastal zone of Bangladesh under Hatiya Upazila of Noakhali District, and is situated between latitude 22º1´ and 22º6´N and longitude 90º58´ and 91º3´E (Fig.2). Nijhum Dwip is separated from Hatiya by the Moktaria Channel, which is about 700-1200m wide: the island area is only 10 km^2 in area (Fig.2). Fishermen of the nearby Hatiya Island started to use Nijhum Dwip during the 1940s as temporary homes during fishing season (personal communication with union *parishad* member). In the 1950s fishermen named it *Ichamoti dwip* (meaning mine of prawn; locals referred to island as icha mach, or prawn) due to a high abundance of prawn available in the waters surrounding the island (Amin, 2001). Temporary settlers later renamed it *Baollar char* (meaning accreted sand) *,* due to its high protuberance of sand. A land survey of Nijhum Dwip was conducted during 1959-1960, and after that, some of the fisherfolk came to live permanently on the island. However, Bangladesh's most devastating cyclone of 12 November 1970, which killed about half a million coastal people in Bangladesh, killed all of the 300 households (1200 to 1500 people) settled on this exposed island. In an official visit to the island in 1973, government officials, politicians and social elites gave the island an official name in recognition of its natural beauty, *Nijhum Dwip*. In 2008, the government of Bangladesh declared Nijhum Dwip and the Char Bahauddin as a Union *Parishad* of Hatiya Upazila. The population has since increased to about 4500 households with an estimated 30,000 people living in different cluster villages. The literacy rate on the island is very low, at about 10%. Children below the age of 12 years account for 30% of the total population and married adults represent about 40%. The lack of sanitation facilities on the island causes severe problems because none of the households use sanitary latrines. Drinking water is available from shallow tube wells, which households share at a rate of one well per 50-75 households.

Biodiversity status

The environment surrounding the island is a unique assemblage of marine, brackish and fresh water ecosystem with estuarine characteristics. This combination has endowed Nijhum Dwip with a highly productive ecosystem for fisheries resources. Although limited quantitative data on marine biodiversity of Nijhum Dwip are available, the availability of fishes, shrimps, molluscs and crabs that is common to the rest of Bangladesh is believed to extend to these waters as well. Mangrove plantation started in 1973 with *Sonneratia apetala* (80%) and *Avicennia officinalis* (15%) that covered the northwest part of the island. The ecosystem is biologically diverse with 68 plant and 66 animal species (Rosario, 1997). The island is at the crossroads of two international flyways viz. the East-Asia Australasian flyways and Central Asian flyways and is the southern-most staging ground of around 60 species of migratory birds. The site supports critically endangered species from around the world such as the Indian Skimmer (*Rynchops albicollis*), Spoon-billed Sandpiper (*Eurynorhynchus pygmeus*), Nordmann's Greenshank (*Tringa guttifer*) and Asian Dowitcher (*Limnodromus semipalmatus*) by providing them with their wintering ground (PDO-ICZMP 2004). To further enhance the

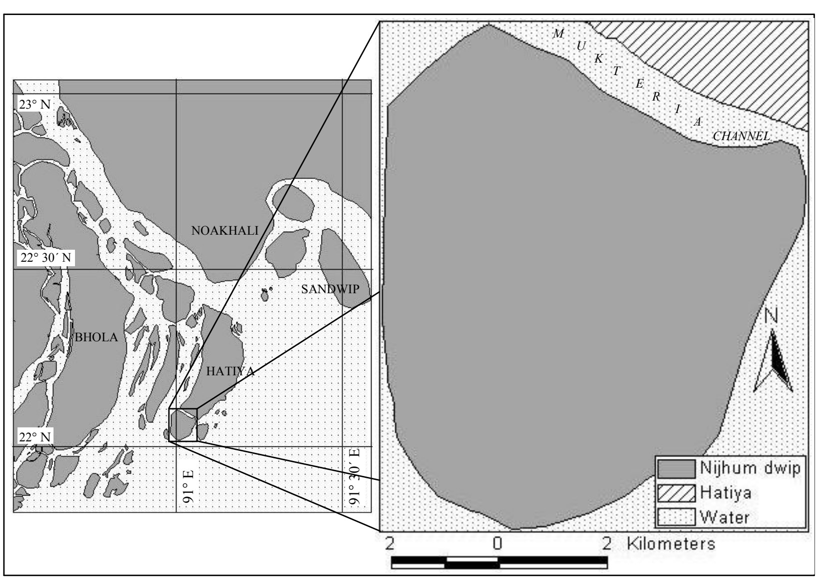

Fig.2: Geographical location of the Nijhum Dwip in the central coastal zone of Bangladesh, based on Landsat TM image of March 2007

biodiversity of the island, three pairs of spotted deer (*Axis axis*) were released in the island in 1980 which increased to 14,400 (Iftekhar and Takama 2008). Subsequent introductions have included several pairs of monkeys (*Macaca mulatta*), snakes (*Python molurus*) and Leopard cat (*Felis bengalensis*). These vibrant biodiversity allowed Nijhum Dwip to be listed as a wetland of international importance under the Bangladesh Wildlife (Preservation) Order 1973, and it was made a National Park of Bangladesh in 2001. Insidious human activity such as hunting, killing or capturing wildlife and damaging or destroying plants or trees has been banned by the government (PDO-ICZMP 2004).

Temperature

Nijhum Dwip is typically tropical with average annual maximum and minimum temperatures of 30°C and 21.6°C respectively (BMD 2009). Changes in temperature, even small changes in water temperature, are expected to exert strong pressure upon fish ecology (WWF 2005). Temperature variations also affect human health, undermining their capacity for operating the fisheries. According to the statistical fixed-point observations in six meteorological stations i.e. Maijdee, Hatiya, Feni, Sandwip, Chittagong and Cox's Bazaar , it seems that the apparent warming trend has not been seen in Nijhum Dwip (Fig.3), as opposed to the world's expectation (IPCC 2007). However, it seems that there is a slight warming trend of mean maximum and minimum temperature especially in the hottest month. In a variation of 20 years (1988-2008), annual maximum temperature increased by 0.08°C, whereas annual minimum temperature decreased by 0.89°C and annual average temperature decreased by 0.32°C. The length of the winter season with a temperature less than 15°C has been recorded as 41 days and 55 days in 1988 and 2008 respectively, where the first day of winter shifted from 8 December to 18 November. Similarly, the length of the summer season with a temperature more than 35°C was recorded as 2 and 5 days in 1988 and 2008 respectively, where the first day of summer shifted from 14 February to 27 February (Table 1).

TABLE 1

Variation of climatic parameters in Hatiya Island of Noakhali District for a period of 20 years (1988-2008) (source: Bangladesh Meteorological Department, Dhaka)

Parameters	1988	2008	Change
Annual max temperature (°C)	29.91	29.99	0.08
Annual min temperature (°C)	22.52	21.63	-0.89
Annual average temperature (°C)	25.97	25.65	-0.32
Length of winter (day <15 °C)	21	55	34
First winter day (<18 °C)	8-Dec	18-Nov	10
Length of summer (day >35 °C)	2	5	3
First summer day (day >30 °C)	14-Feb	27-Feb	13
Annual Rainfall (mm)	3561	3531	-30
Length of rainy season (day >10 mm)	83	75	-8
First rainy day (>10 mm)	13-May	18-May	5

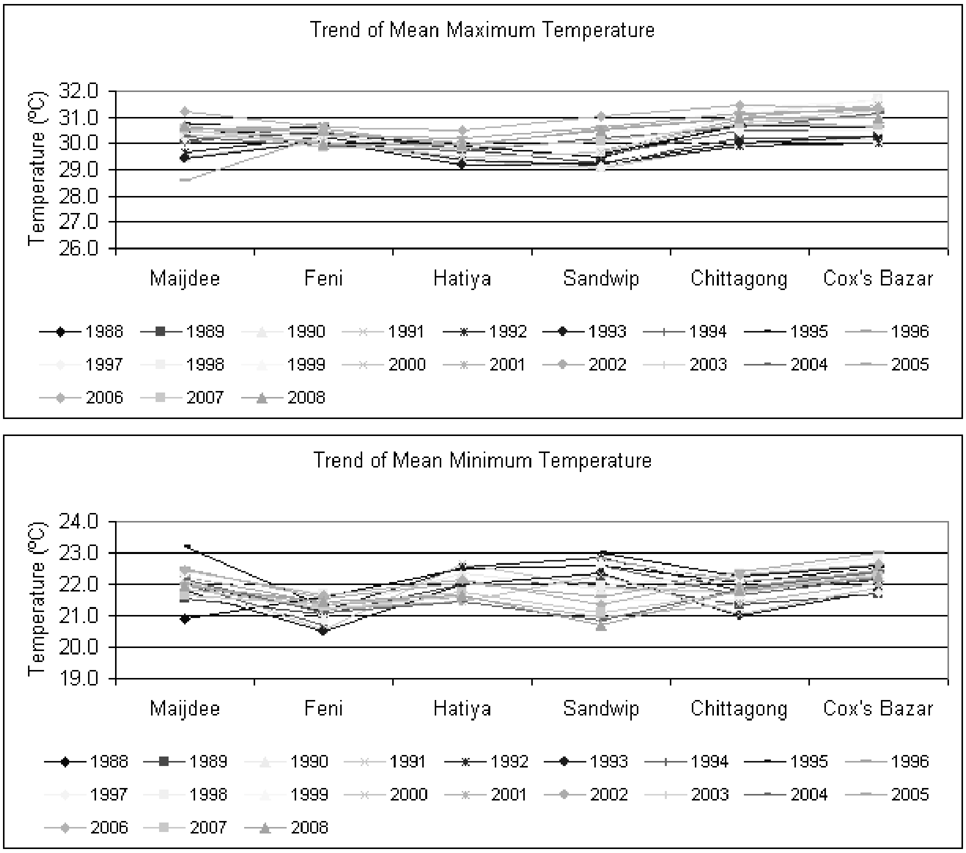

Fig.3: Trend of mean maximum and minimum temperature in Maijdee, Hatiya, Feni, Sandwip, Chittagong and Cox's Bazaar

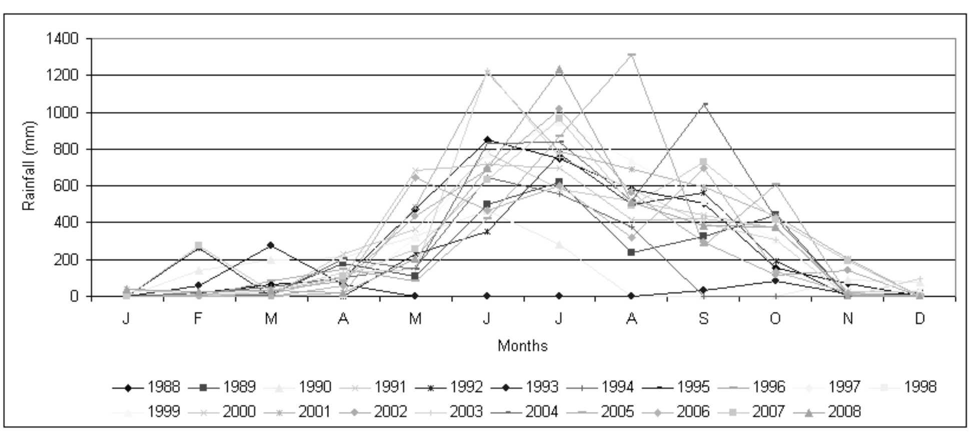

Fig.4: Trend of monthly rainfall in Hatiya Island

Rainfall

The majority of the annual rainfall occurs from May to October (Fig.4). The southwest monsoon brings much rainfall from May to September while the northeast monsoon brings some rain in October and November. About 80-90% of annual rainfall is confined to the monsoon months (April-October). Annual mean total rainfall has decreased from 3561mm in 1988 to 3531mm in 2008. The length of the rainy season with rainfall more than 10mm has been recorded as 83 days and 75 days in 1988 and 2008 respectively, where the first rainy day shifted from 13 May to 18 May (Table 1). Old fishermen have reported noticeable changes in the present climate pattern in comparison to the past. These noticeable changes include increasing variability in the dates of onset and end of the rainy season, changes in wind direction, tidal magnitude, rainfall distribution pattern throughout the season, and an increase in thunderstorm activity. Thunderstorms, as far as the fishermen's observations are concerned, have increased in frequency, and their occurrence has extended throughout the rainy season instead of only at the beginning and toward the end of rainy season.

MATERIALS AND METHODS

Field survey

Extensive field visits and interviewing of fishermen household heads of Nijhum Dwip were used for data collection on human, physical, financial, natural and social assets of the fishing community. To assess fishermen resilience, interviews were conducted with 250 household heads from November 2009 to April 2010. Only the household heads were included in the survey to ensure that participants could make meaningful comparisons between the past and present. Interviews were conducted in the local language. The interviews centred on people's perceptions of climate changes that had occurred in their life time (e.g. erosion, cyclone, tidal surge, rain and temperature) as well as associated phenomena (e.g. seasonal change, abundance and breeding of local fish species, mangrove and grassland cover). While fishermen resilience has been assessed through secondary data and research papers, people's perception is also important to consider behaviour and responsive actions (Grothmann & Patt, 2005). Social, economic and environmental resources were discussed to learn about individuals' perceptions surrounding these resources. In addition to handwritten material, photographs and videos were also used as effective media for conveying results of the interviews. Interviews with key informants such as school teachers, government officers, village leaders, NGO workers and mosque *imam* aimed at (1) identification of the assets and analysis of their relative importance to the fishermen's livelihood, (2) detection of the most vulnerable assets and any known adaptation mechanisms and (3) collection and examination of past and present records on livelihood assets and disasters associated with climate variability. During the visits to the villages participatory observation was used to study the natural environment, housing conditions, social customs and village life. Incentives such as soap, biscuits, chocolate and cooking oil were given to the families for their help and a token of appreciation was given as a reward to the people for having given of their time and for sharing their knowledge and experience. Stakeholder workshops were conducted separately at the village level to present the research findings and to complement the data set collected through participatory interviews. These methods are discussed in detail in Chambers (1992), Mettrick (1993), Mikkelsen (1995), IIRR (1998), Hossain *et al.* (2004) and Trap (2006).

Data and methods

The procedure followed in assessment of fishermen resilience is presented in Fig.5. The model structure for fishermen resilience was developed as a three-level hierarchical structure. Hierarchical structures break down all criteria into smaller groups (or sub-models). To break down a hierarchy into clusters, first it was decided which elements to group together. This was done according to the similarity of the elements with respect to the function they perform

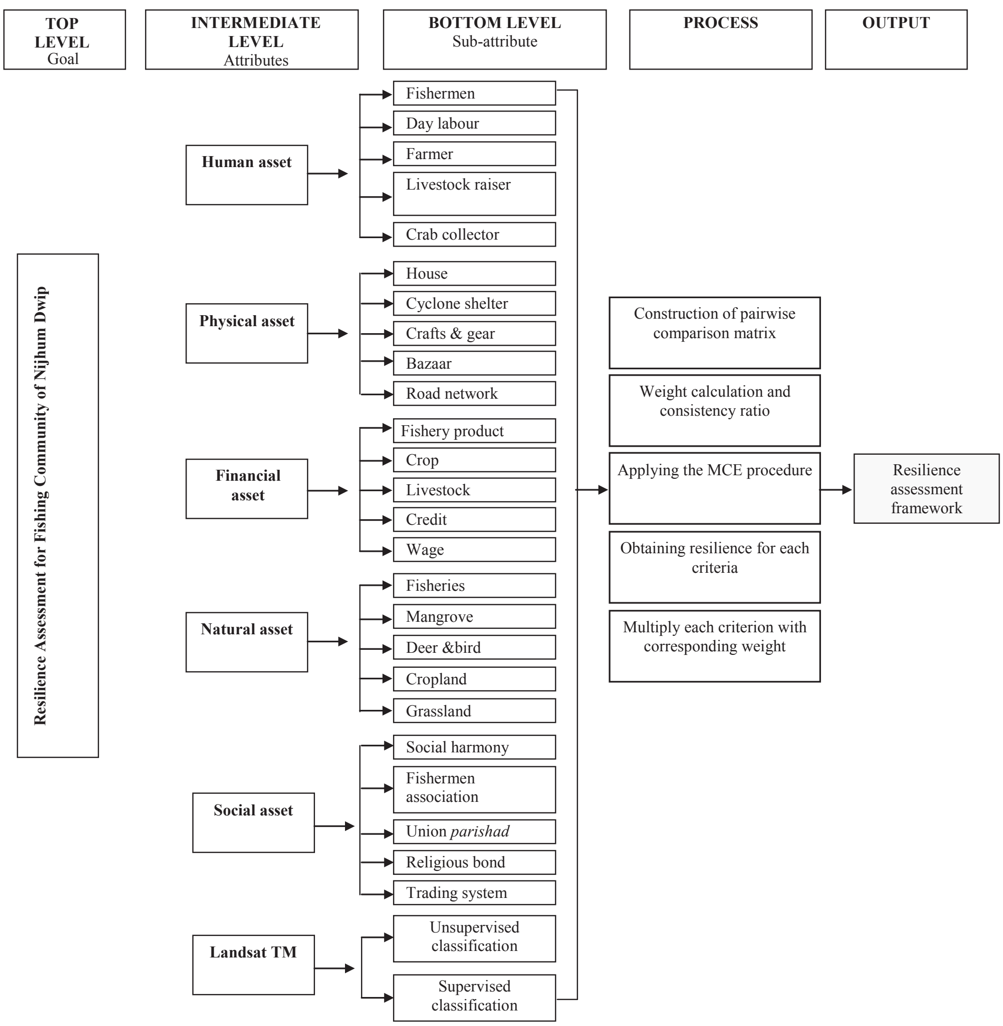

Fig.5: Adapted Analytical Hierarchy Process (AHP) for resilience assessment of fishing community in Nijhum Dwip, Bangladesh

or properties they share (Saaty, 1988). The top or first level in the hierarchy represents the ultimate goal of the multi-criteria decision-making analysis process. The intermediate or second hierarchy level lists the relevant evaluation criteria that were compared pairwise to assess their relative weights. Each of these clusters was considered as a sub-model. The bottom level in the hierarchy contains the evaluation objects. All these criteria (sub-attributes) are identified to influence the goal of the study and may represent primary data or be the result of some secondary data.

The data sources were social survey, field measurement, administrative map, topographic maps of 1:10,000 scale and Landsat TM satellite image for land use pattern and spatial analysis of resources distribution. Land use patterns, road, embankment, cyclone shelter, market location and human settlement were taken from 1:10,000 scale topographic maps and 1:50,000 scale administrative maps, and then updated with Landsat TM satellite image, intensive field survey and participatory interviews. All this information was used to assess the resilience of the island fishing community. The GIS software used in this study was ArcGIS for windows (version 9.3) developed by Environmental Systems Research Institute Inc, USA. Remote-sensing image analysis was done using ENVI (version 4.3) developed by Research Systems Inc, USA. The selected and scored criteria were developed into a series of sub-models which logically grouped certain factors together within a general model. For example, respective sub-attributes were grouped to form sub-models (e.g. in human assets analysis; fishermen, day labour, farmer, livestock raiser and crab collector were grouped to form the sub-model, "human assets"), while other sub-attributes were grouped into sub-models to enable a better understanding (e.g. fisheries, mangrove, deer and bird, cropland and grassland were grouped to form the sub-model, "natural assets").

Satellite image classification

Isodata unsupervised classification (use information from the image itself to identify spectral clusters, which are interpreted as classes,) was performed considering minimum and maximum classes of 5-10, 10-15 and 15-20, where the 5-10 classes turned out to be useful. Supervised classification was carried out on the basis of Region of Interest (ROIs), where the ground truth or so-called training areas (collected during field investigation) were regions of terrain with known properties or characteristics (Research Systems Inc., 2000; Hossain *et al*., 2009b; Hossain & Das, 2010a, 2010b). Maximum likelihood classification strategy was applied and found to be most useful for discriminating the category of interest. After image processing, reference points were chosen for ground verification. All the reference points were surveyed for the ground truthing of Nijhum Dwip and compared with the preliminary map to real position. ArcGIS (The Environmental systems Research Institute Inc., USA) and MS Excel (The Microsoft Corporation, USA) software were used to digitise and analyse all the classified and other necessary maps.

Weight and score

The development of weights is based on pairwise comparison matrix. The comparisons are concerned with the relative importance of two criteria involved in determining resilience for the stated objective. In order to use this procedure, it is necessary for the weights to sum up to 1. Ratings are systematically scored on a 17-point continuous scale from 1/9 (least important) to 9/9 (most important) (Saaty, 1977) as in Table 2. In this research, scores were assigned in rank order according to the number of factors involved in the evaluation for resilience assessment without repetition. The pairwise comparison matrices developed are shown in Table 3. The consistency ratios (CR) of 0.0048 to 0.0139 for the table was well within the ratio of equal to or less than 0.10 recommended by Saaty (1977), signifying a small probability that the weights were developed by chance.

Although factor scores were objectively based upon real data, the assignment of weights during multi-criteria evaluation (MCE) was considered partly subjective because it was dependent upon decisions made by the authors. To help reduce some of this subjectivity, to verify the weights generated and to reach a consensus for weights, two analytical procedures were considered: a) use of questionnaires (Aguilar-Manjarrez, 1996) and b) group discussion for final weight consensus (Eastman *et al.*, 1993; Kapetsky & Nath, 1997, Hossain & Das, 2010a). Because these procedures are complementary, this study combined the two in order to achieve increased objectivity. An important way of learning about local conditions and resources is to ask local communities what they know (Pelto & Pelto, 1978). Direct observation prevents rapid appraisal from being misled by myth and often provides more valid and less costly information than other research methods (Chambers, 1980; Hossain *et al.*, 2007b).

The present study focussed on some basic criteria or sub-attributes. For instance, 25 base layers were developed to assess resilience of the fishing community i.e. human assets (fishermen, day labour, farmer, livestock raiser and crab collector), physical assets (house, cyclone shelter, craft and gear, bazaar and road network), financial assets (fishery yield, crop, livestock, credit and wage), natural assets (fisheries, mangrove, deer and bird, cropland and grassland) and social assets (social harmony, fishermen association, union *parishad*, religious bond and trading system). Weights were given according to the effectiveness of the criteria. The weight for each factor was determined by pairwise comparisons in the context of a decision-making process known as the analytical hierarchy process (Saaty, 1977, 1990), which was also recommended by Pereira and Duckstein (1993), Malczewski (1999), Kovacs *et al.*, (2004), Hossain (2009b) and Hossain *et al.*, (2009). The resilience rating for each level of a factor was determined from the survey results and professional judgment of the authors.

TABLE 2
The relative importance of two criteria (Saaty, 1977)

1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Extremely		Very strongly		Strongly		Moderately		Equally	Moderately		Strongly		Very strongly		Extremely	
LESS IMPORTANT									MORE IMPORTANT							

TABLE 3
A pairwise comparison matrix for assessing the relative importance of different criteria for fishermen resilience at Nijhum Dwip (numbers show the rating of the row factor relative to the column factor).

Human assets

	Fishermen	Day labour	Farmer	Livestock raiser	Crab collector	Weight
Fishermen	1	1/3	1/2	1/5	1/3	0.073
Day labour	3	1	2	1	1/3	0.203
Farmer	2	1/2	1	1/3	1/3	0.113
Livestock raiser	4	1	2	1	3/4	0.249
Crab collector	3	3	3	4/3	1	0.362

Consistency ratio (C.R): 0.0100

Physical assets

	House	Cyclone shelter	Craft & gear	Bazaar	Road network	Weight
House	1	1/6	1/2	1/4	1/2	0.064
Cyclone shelter	6	1	4	2	3	0.437
Craft & gear	2	1/4	1	1/2	5/4	0.129
Bazaar	4	1/2	2	1	2	0.245
Road network	2	1/3	4/5	1/2	1	0.125

Consistency ratio (C.R): 0. 0048

Financial assets

	Fishery yield	Crop	Livestock	Credit	Wage	Weight
Fishery yield	1	1/4	1/5	1/6	1/4	0.047
Crop	4	1	1/2	1/4	3/2	0.154
Livestock	5	2	1	1/2	2	0.252
Credit	6	3	2	1	3	0.409
Wage	4	2/3	1/2	1/3	1	0.138

Consistency ratio (C.R): 0.0126

Natural assets

	Fisheries	Mangrove	Deer	Cropland	Grassland	Weight
Fisheries	1	1/3	1/7	1/2	1/5	0.058
Mangroves	3	1	1	2	3/4	0.230
Deer & bird	7	1	1	3	5/4	0.325
Cropland	2	1/2	1/3	1	1/2	0.117
Grassland	5	4/3	4/5	2	1	0.270

Consistency ratio (C.R): 0.0131

TABLE 3 (continue)

Social assets	Social harmony	Fishermen association	Union *parishad*	Religious bond	Trading system	Weight
Social harmony	1	1/2	1/3	1/3	1/2	0.098
Fishermen association	2	1	2	1	1/2	0.209
Union *parishad*	3	1/2	1	1/3	1/3	0.142
Religious bond	3	1	2	1	1/5	0.156
Trading system	2	2	5/2	4	1	0.395
Consistency ratio (C.R): 0.0139						

Overall	Human	Physical	Financial	Natural	Social	Weight
Human	1	1/3	1	3	1/2	0.136
Physical	3	1	3	9	3	0.464
Financial	1	1/2	1	3	3/4	0.160
Natural	1/3	1/9	1/3	1	1/4	0.048
Social	2	1/3	1	4	1	0.192
Consistency ratio (C.R): 0.0199						

Identification of variables and integration of data

All data integrated into the database needed some manipulation and reclassification to create the thematic layers, as well as to register each layer to a common coordinate system. Given the variety of scales on which all criteria were measured, multi-criteria decision analysis requires that the values contained in the various layers be transformed to comparable units. Eventually, the criteria layers and their weights were integrated to provide an overall assessment of the alternatives. This step is known as multi-criteria evaluation, and was accomplished by appropriate decision rules, which are formal mathematical expressions that combine the weights and scores of each of the layers used. Specifically, findings provide informative examples of how fishermen perceive that a weight of particular assets impacts on their capacity to build and manage resilience in the face of change. The weights of 25 sub-attributes from pairwise comparison matrix had been used to develop the resilience scale to measure their individual effectiveness. The five criteria of each asset were calculated and then all 25 criteria were combined to assess fishermen resilience.

RESULTS

Livelihood assets analysis

Natural asset

Nijhum Dwip consists of fluvial and tidal geomorphological deposits created from weathered materials from the uplands, ultimately carried away by the mighty Ganges-Brahmaputra-

Meghna River systems, and their numerous tributaries and deltaic channels, leading to the formation of a newly-accreted landscape. Analysing the Landsat TM image of January 1997 and March 2007 of the Nijhum Dwip revealed the increasing trend of the island from 4313ha in 1997 to 5231ha in 2007 (Fig.6). The accreted zone increased from 987ha to 1676ha in a duration of 10 years due to the heavy siltration of the Ganges-Brahmaputra-Meghna River systems. The plain land that increased by about 56% from 1078ha to 1686ha (Table 4) in 10 years has been used for ever increasing human settlement, agriculture, cyclone shelter, community market (locally called bazaar or *hat*) and road network. A road-cum-embankment has been constructed along the southeast side of the island, which is the zone exposed to the Bay of Bengal (Fig.7). Most of the human settlements are concentrated in the south and southeast of the island. The satellite-image analysis revealed that most of the tidal canals (locally called *khal*) and creeks are flowing in a southward direction through the mangrove forest and plain land of the island. These include the Char Kamlar Khal, Azam Khali Khal, Jarir Dona Khal and Chowdhury Khal. The mangrove forest decreased from 2248ha in 1997 to 1869ha in 2007 due to removal of forest produce for fuel wood, grazing pressure, agriculture and human settlement. Moreover, the islanders have become dependent on the mangrove forest for housing and boat-making materials. Mangrove plantation and a succession of natural grasses

TABLE 4
Land use change of Nijhum Dwip over 20-year period (1997 to 2007)

	Area in 1997 (ha)	Area in 2007 (ha)	Change (%)
Mangrove forest	2248	1869	(-) 16.86
Plain land	1078	1686	56.40
Accreted zone	987	1676	69.81
Total	4313	5231	21.28

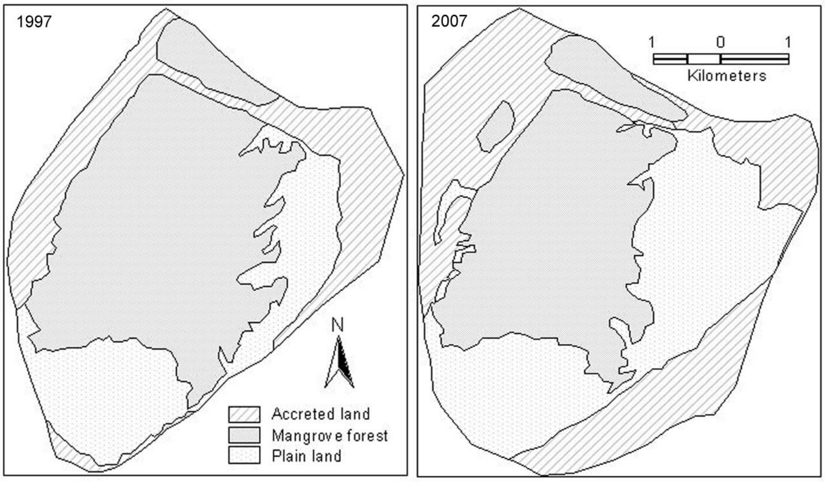

Fig.6: Classified Landsat TM image of January 1997 and March 2007 revealed changing pattern of the Nijhum Dwip with pre-dominant land cover map

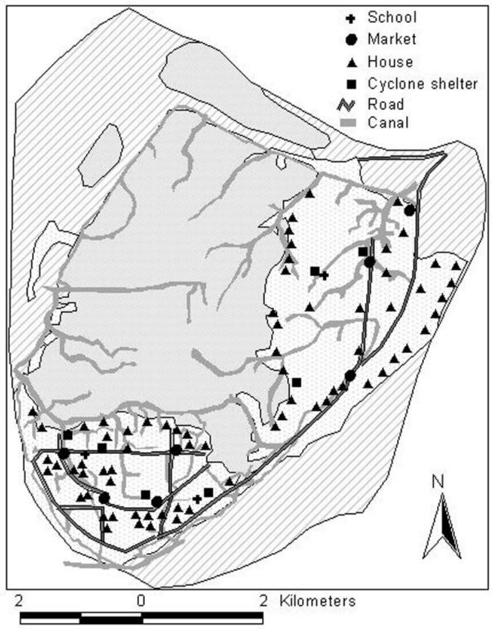

Fig.7: Predominant land cover with spatial location of human settlement, road network, school, cyclone shelter, market and canal of the Nijhum Dwip based on topographic map, Landsat TM satellite image and field survey

are the major uses of the island's accreted land. The dense mangrove ecosystem supports both terrestrial and aquatic biodiversity, where spotted deer, winter bird and fisheries are dominant. The geographical and physical setting of the island provides unique ecological characteristics that support ideal feeding, breeding, nursing and spawning ground for many aquatic organisms, including commercially important fisheries. Climate change affects not only fisheries in the ecosystem but also fishing activities in certain periods. Fishermen are forced not to fish during the monsoon, stormy weather and cyclones. Climate change may favour certain species over others and thereby change the biogeography of fish stocks and their relative abundance. During a field survey, the fishermen mentioned that hilsa shed (*Tenualosa ilisha*, locally called *ilish*) and goby (*Gobioides rubicundus*, locally called *cheowa*) are the two dominant fish catches during May-October and November-April respectively. Other important catches are bombay duck, mullet, ribbonfish, catfish, sharks, shrimp and crab.

Financial asset

The livelihoods of fishing communities largely depend on the fishery yield from the Meghna estuary and the Bay of Bengal. The fishermen use traditional small-scale boats with various fishing gear both as daily labour, and the owners of such businesses and members of fishing boats are limited to family or neighbours. One person may be engaged in two or more different occupations i.e. fishing, fish drying, trading, agriculture and livestock rearing. Some of the occupations are seasonal (Fig.8), so a person can take up different activities in the year on time-sharing basis. Instead of going to school, children from families that lack financial assets

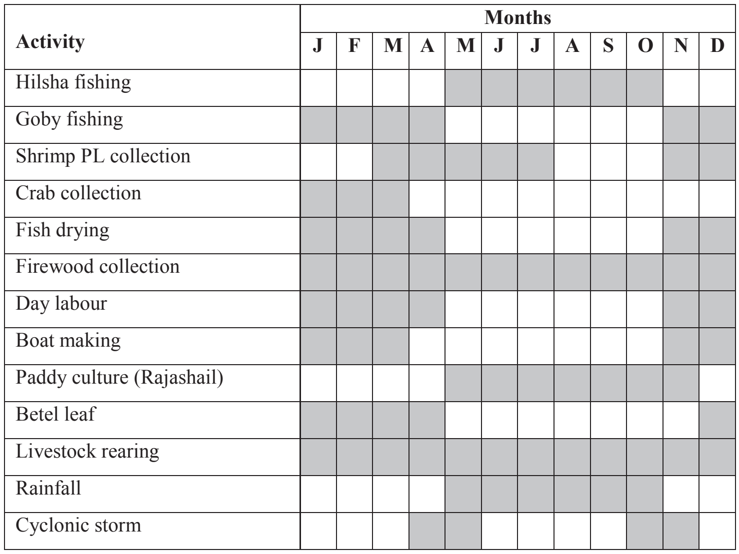

Fig.8: Seasonal activities of fishing community at Nijhum Dwip

are forced to start fishing, and become exposed to climate change risks such as strong sunshine, heavy rain and cold wind. Most households have poor housing that are highly vulnerable to climate hazards. The loss of physical assets compounded with a deteriorating financial asset base can also have significant effects on livelihoods. Expenditure for food and fishing gear was regarded as the highest priority while saving was identified as the lowest. The fishermen are unable to raise formal bank loans due to lack of collateral, which is often lost during extreme weather events, and insurance. Additionally, as observed in many fishing communities, informal sources of credit are often the only ones available to fishermen, but these come typically with high rates of interest and unfavorable terms and conditions.

Human asset

Human assets describe skill in and knowledge of fishing, crabbing, agriculture, livestock raising, trading and other occupants on the island (Fig.9). Human asset considers how other assets can achieve a higher income and food security. Detached from the mainland of the country, about 30,000 people in 4,500 households live in Nijhum Dwip, of which 51% are male and 49% female. The main ethnic groups are Muslim and Hindu representing about 97% and 3% respectively of the total population. It was revealed that higher immigration from the nearby eroded islands caused overexploitation of natural resources as well as increased social crime and sea robbery. The different dimensions of human assets, ranging from safety-at-sea to food security, are affected by climate variability and change. Loss of life and loss of livelihoods can be the two most dramatic impacts of extreme climatic events on human asset, affecting not only surviving household members but also potentially disrupting economic and social activities and systems outside the immediate family.

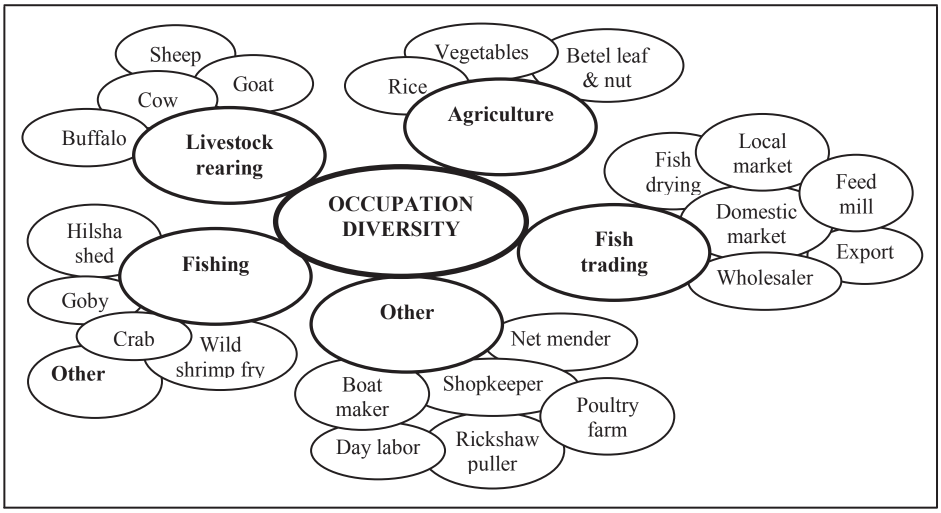

Fig.9: Venn diagram illustrating occupation diversity of fishing community at Nijhum Dwip

Physical asset

Physical assets describe the basic infrastructure and production equipment which enables people to pursue their livelihood. The physical environment surrounding the fishermen's houses in Nijhum Dwip is very poor (Fig.10). Villagers stressed that the catastrophic cyclones and storm surges damaged physical assets, including infrastructures (e.g. embankment-cum-road, bazaar and fish landing centre) and physical goods (e.g. boat, net, house and cyclone shelter). Once such climate hazards occur, physical assets are easily damaged and washed away by the wind and water-driven forces. At the same time, poor housing conditions are affected to a great extent and various diseases are caused by unsanitary environments. Among physical assets, fishermen identified craft and gear as the most seriously vulnerable to extreme events, with about 50% reporting loss of their boat. The loss leads to suspension of fishing activities, resulting in danger to food security and livelihood. Damage to the fishermen's non-productive physical assets such as housing and community infrastructure (cyclone shelter, health center, school, tube well and sewage system) are also important consequences of extreme climatic events.

Social asset

Social assets highlight self-reliance of the community achieved through cultural norms, networks and religious bonds. Membership in associations often enhances the fishermen's bargaining power and reduces income erosion. A strong marketing network among the fishermen increases their ability in selling catch to a wider forum and at a better price. The union *parishad* chairman and members are the local government representatives, and communicate with respective departments for development of road, embankment, school, cyclone shelter, community market and health centre. Social assets are the glue that holds societies together, maintains economic growth and ensures human well-being.

Fig.10: Fisherman's house with seasonal vegetable beside the mangrove forest in Nijhum Dwip

Fishermen resilience assessment

The results of 25 sub-attributes are presented separately in the five capitals or livelihood assets i.e. human assets, physical assets, financial assets, natural assets and social assets to provide a comprehensive analysis. The effectiveness of sub-attributes in each asset is summarised in Fig.11. The sub-attributes of fishery yield, fisheries, house, fishermen and social harmony with 49%, 48%, 40%, 38% and 35% effectiveness respectively indicate the highest role in resilience assessment. The sub-attributes of farmer, cropland, craft and gear, road network, religious bond and union *parishad* with 25%, 23%, 22%, 21%, 21% and 20% effectiveness respectively indicate moderate importance in resilience assessment. The sub-attributes of crab collector, cyclone shelter, credit, deer and bird and trading system with less than 10% effectiveness indicate the least significance in resilience assessment. Considering the overall effectiveness of all attributes, it is quite apparent from the results that natural asset is the most significant (48%), whereas the vector of effectiveness indicates that physical asset is the least significant (5%) in resilience assessment. The respondents mentioned that most of the physical assets are susceptible to cyclonic storms i.e. loss of fishing craft and gear, severe damage to house and road network. Disaster events may also damage natural assets such as uprooting mangroves, covering grassland with a thick layer of sand and salinity intrusion in the cropland and freshwater ecosystem. The 18%, 15% and 13% effectiveness are associated with human, financial and social assets respectively, which all have similar significance in resilience assessment. Human assets with sufficient indigenous knowledge showed professional performance in using other assets to maintain income and livelihood security in Nijhum Dwip.

DISCUSSION

Fisheries managers and fisherfolk have historically had to adapt to the vagaries of weather and climate (Allison *et al*., 2001) while fishery scientists have needed to pay much more attention to the motivation and behaviour of all the human actors in the system, especially resource users (Fulton *et al.,* 2011). The fishing community of Nijhum Dwip is less resilient to the impacts of climate change than other communities in the mainland of the country due to the

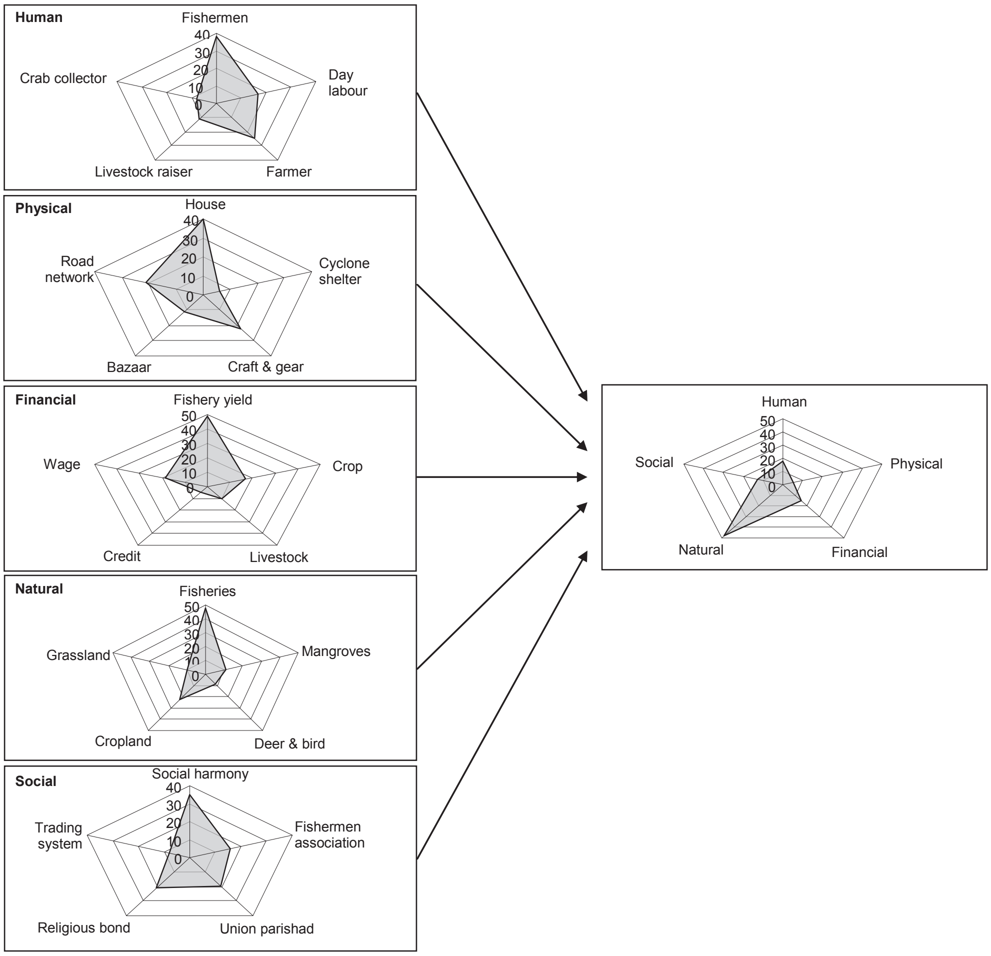

Fig.11: The process of combining 25 sub-attributes of human, physical, financial, natural and social assets for fishing community resilience assessment in Nijhum Dwip

combined risk from multiple interacting weather and climate extremes; high dependence on natural assets, particularly fisheries; limited physical assets; unfavorable financial assets; and their socio-cultural sensitivity. The results of this study indicate that Analytical Hierarchy Process (AHP) is the appropriate tool to illustrate the resilience of coastal fishermen. The AHP has been used primarily as a decision support system, having been applied quite successfully for tackling socio-economic (Golden *et al.*, 1989), environmental and ecological problems (Stagg & Imber, 1990; Mendoza & Prabhu, 2000; Gregory & Wellman, 2001 and Kovacs *et al.*, 2004), ecosystem suitability modelling (Hossain, 2009a, Hossain *et al.*, 2009a, Hossain & Das, 2010a) as well as climate change challenges (Hossain, 2009b; Hossain *et al.*, 2009b). Coastal islands are among the most dynamic natural environments on earth, providing a range of goods and services that are essential to human social and economic well-being. Many people have settled in coastal zones and islands to take advantage of the range of opportunities for food production, transportation, recreation and other human activities provided in these landscapes. This present investigation into the resilience of Nijhum Dwip's fishing community used DFID's sustainable livelihoods model (Iwasaki *et al.*, 2009) that is based on five asset categories including natural, financial, human, social and physical. Five criteria for each asset allowed for resilience assessment. Subsequently, sub-attributes were sought with the perception of local people, which provided a complete picture of their resilience element. The total 25 resilience elements were arranged in ranking of dependency. A similar assessment was observed by Hossain (2009b) and Munny (2009) at Shyamnagar in the southwest coast and Meghna deltaic islands in the central coastal zone of Bangladesh.

The diversity of natural resources found in the Nijhum Dwip, and the open-access nature of many of them means that barriers to entry are low, attracting the poor to the island in search of livelihood opportunities. However, while the island presents many opportunities for the poor, it also exposes them to many forms of shocks that increase their vulnerability. Cyclone, tidal surge, embankment erosion and saline water intrusion are common in Nijhum Dwip, and the livelihoods of islanders have suffered from these. Most of the islanders are fishermen, and they have been specifically identified as one of the poorer groups in Bangladesh. Others are cattle raisers and farmers trying to make a living from soil which is often of poor quality or is degraded and over which they often have little formal control. Some people make a living from harvesting mangrove forests where access rights are often unclear, disputed or insecure. Multispecies fisheries can make the fishermen more resilient to environmental change and future uncertainty than highly specialised fisheries (Worm *et al.*, 2006; Worldfish Centre, 2007; Chowdhury *et al.*, 2008; Johnson & Welch, 2010). Start and Johnson (2004) stressed the importance of assets for coping, especially those that are easily convertible to cash to solve urgent needs. Moser (1998) recognised assets as the primary factor in determining vulnerability and resilience, but viewed assets in the broader perspective of the sustainable livelihoods framework, where assets can be physical, natural, financial, social, institutional or human resources. Moreover, day by day, increasing migration is a drawback to the islander's stability. The islanders prefer more resilience locations for settlement based on their indigenous knowledge that justifies the well known expression "people are the real scientists". The existing settlements can be developed by raising the level with homestead tree plantation for adaptation of climate change extreme events without temporary or permanent relocation -- either to other islands, or to the mainland. Relocation to other islands would not only encounter financial and land rights difficulties, but also significant cultural problems that agree with De Silva and Yamao (2007) and Mercer *et al*. (2010). Islanders do not want to move off their islands, and it is clear that the event of just one community moving would impact the region by affecting the cultural, social and economic resilience of other island communities (Alam & Collins, 2010). The problem tree analysis in Fig.12 revealed various causes why people migrated and effects on people i.e. the vulnerabilities to their life and livelihood in Nijhum Dwip.

Livelihood diversity receives considerable emphasis with regards to resilience and vulnerability (Ellis, 2000). The study specialises on the analysis of resilience, which has typically focussed on entire systems rather than their components or specific locations (Scheffer, 2009; Gibbs, 2009). This permits evaluation of the importance of community characteristics, such as geographic location, in the evaluation of resilience (Perz *et al*., 2011). Responses to climate change impacts will vary across scales (local, regional, national, global) by sector of activity (aquaculture, fisheries, agriculture) or by actors (individuals, communities, private sector, governments) (Badjeck *et al*., 2010). The impacts of climate change will not be distributed equally. There will be relative 'winners' and 'losers'; some communities may suffer significant losses due to physical damages or changes in fish distribution, while other will be less affected, or may even benefit from, for instance, positive changes in the abundance of certain species (Badjeck *et al*., 2010).

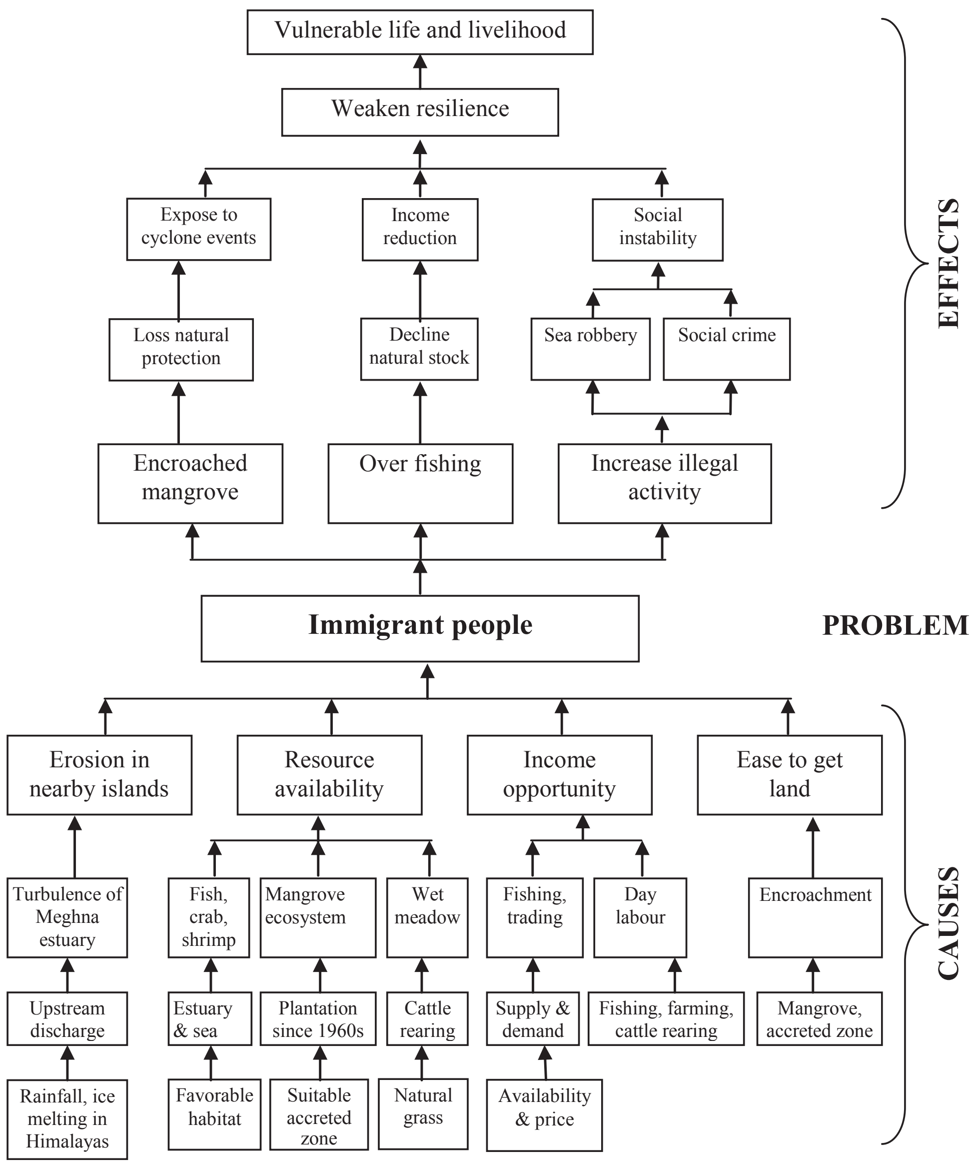

Fig.12: Problem tree analysis showing causes and effects of pressure on Nijhum Dwip as a result of entry of immigrants

This resilience study revealed information regarding indigenous cyclone prediction or understanding of warnings that is significantly related to the age of the household head due to their level of experience: this agrees with Alam and Collins (2010) and Anderson-Berry (2003). On the other hand, owing to the erosion of physical capability, the elderly are less capable of storing up food and saving money, and as a consequence, meals for the day are reduced, family members must be engaged in income-earning activities, assets need to be disposed of and money must be borrowed to overcome the crisis; this agrees with Paul and Routray (2011) and Perry *et al*. (2010). This study also confirms the findings of Agarwal (1990), and Kesavan and Swaminathan (2007) that prevailing social and financial inequities greatly weaken the resilience level of the under-privileged sections of society.

CONCLUSION

This article applied the sustainable livelihood approach (SLA), which enables researchers and policy makers to identify a wide range of livelihood aspects that can provide clues to finding pressing constraints and positive strengths of fishermen resilience. This would further serve fishermen resilience by adding or removing sub-attributes in the long term due to climate change. Thus, practising community-based case studies can provide deep information on fishermen resilience especially through livelihood assets analysis. In this respect, SLA may play a leading role in analysing adaptive capacity to climate change through livelihood asset analysis at the community level. In this article, livelihood assets analysis related to fishermen resilience requires greater examination of the interaction among households on how to allocate their own resources and services to their family members. The consideration can develop a better understanding of climate change adaptation in fishing community context.

Emphasis must be given to conserve the existing mangrove ecosystem and undertake further plantation programs in newly accreted suitable zones to enhance natural barriers against extreme climate events as voiced out by the island dweller, local administrator, NGO worker, social elite as well as conservationist and researcher. Healthy mangroves ensure the fishing community receives diversified benefits in both tangible and non-tangible forms as well as in attracting mangrove-dependent species to boost biodiversity. A fishermen's association and cooperative marketing activities may offer one way to improve their livelihoods and make sure that their children are able to go to school where they will be in a safe environment. In addition, village schools with sufficient facilities for the island's growing population also need to be established. Therefore, the availability of a strategic financial loan scheme for fishing gear and education expense as well as for enhancing disaster awareness and the sense of unity among the islanders is of high importance in efforts to promote climate change adaptations.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh.

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