JOURNAL OF
THE ASIATIC SOCIETY OF BANGLADESH
SCIENCE

ISSN 1016-6947

Vol. 44 | No. 2 | December 2018

THE ASIATIC SOCIETY OF BANGLADESH

Journal of the Asiatic Society of Bangladesh, Science is published twice a year (June and December comprising one volume) in English. Original research papers dealing with all branches of science with special reference to Asiatic studies by the members of the Society are published. Any non-member of the Society may publish a research paper if it is communicated by a member of the Society.

SUBSCRIPTION

Annual per volume:			Single issue:		
Inland	:	Tk. 500.00	Inland	:	Tk. 250.00
Foreign	:	US$ 40.00	Foreign	:	US$ 20.00

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Phone : 9576391, E-mail : asiaticsociety.bd@gmail.com, www.asiaticsociety.org.bd

PUBLISHED BY

The Asiatic Society of Bangladesh

PRINTED BY

SRI Printing Press
8/12 Babupura, Nilkhet, Dhaka-1205

JOURNAL OF
THE ASIATIC SOCIETY OF BANGLADESH
SCIENCE
(J. Asiat. Soc. Bangladesh, Sci.)

Vol. 44 **No. 2** **December 2018**

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THE ASIATIC SOCIETY OF BANGLADESH
Council 2018 & 2019

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Helyar, K.R. and W.M. Porter. 1989. Soil acidification, its measurement and processes involved. *In:* Robson, A.D. (ed.) 'Soil Acidity and Plant Growth', Academic press, pp. 61-101.

Kabir, S.M. 2005. Acid sulfate ecosystem and their sustainable management. Unpublished Ph.D. thesis. Department of Soil, Water and Environment. Univ. of Dhaka, Bangladesh.

Khan, H.R., S.M. Kabir, M.M.A. Bhuiyan, F. Ahmed, S.M.A. Syeed and H.-P. Blume, 2008. Response of Mustard to Basic Slag and Aggregate Size Treatments under Modified-Plain-Ridge-Ditch Techniques Used for the Reclamation and Improvement of Cheringa Acid Sulfate Soil. *Soil and Environ*. **27**(1): 1-10.

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J. Asiat. Soc. Bangladesh, Sci. **44**(2): 101-115, December, 2018

WILDLIFE DIVERSITY AND POPULATION STATUS OF KASHIMPUR UNION, GAZIPUR, BANGLADESH

NAZMUL ISLAM, M. FIROJ JAMAN*, MD. MOKHLESUR RAHMAN AND MD. MAHABUB ALAM

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Abstract

Wildlife diversity (amphibians, reptiles, birds and mammals) of Kashimpur Union in Gazipur Sadar Upazila under Gazipur district was studied from May, 2015 to March, 2016. A total of 110 species of wildlife belonging to 58 families under 19 orders were recorded. Among them, 6 (5.45%) species were amphibians, 14 (12.72%) reptiles, 72 (65.45%) birds and 18 (16.38%) were mammals. Among the amphibians, 5 (83.33%) species were frogs and only one (16.67%) was toad; of reptiles, 7 (50%) species were lizards, 5 (35.71%) snakes and 2 (14.29%) were tortoises. Of the birds, 39 (54.16%) species were passerines and remaining 33 (45.84%) were non-passerines. Resident status shows that 66 (91.62%) species were resident, 5 (7.00%) migrants and 1 (1.38%) species were vagrant. Among the mammals, 8 (44.45%) species were rodents, 4 (22.22%) flying mammals and 6 (33.33%) species were carnivorous mammals. The relative abundance shows that 10 (9.09%) species were very common, 24 (21.81%) common, 31 (28.19%) fairly common and 45 (40.91%) species were few. Considering the conservation status, 5 species were near threatened and 105 were the least concern nationally. According to Shannon-Wiener (H = 3.287) and Simpson's (D = 0.942) diversity indices, diversity of birds was higher than the other wildlife observed. Some potential threats on wildlife diversity were identified such as habitat degradation and fragmentation, expansion of agricultural lands and urbanization. Therefore, conservation and management are necessary in order to protect the diversity of existing wildlife and their population in the study area.

Key words: Wildlife diversity, Population status, Relative abundance

Introduction

Bangladesh has a rich biological heritage of being situated in the subtropical region at the confluence of the Indo-Himalayas and Indo-China sub-regions of the Oriental region (Khan 2008). Unique physiographic characteristics, variations in hydrological and climatic conditions and difference in the soil properties support a diverse set of ecosystems that have enriched the diversity of flora and fauna (Mittermeier *et al.* 1998, Jaman *et al*. 2014). Bangladesh is the home of 138 species of mammals (including 11 regionally extinct species), 566 species of birds (including 19 regionally extinct species),

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167 species of reptiles (including one regionally extinct species) and 49 species of amphibians (IUCN Bangladesh 2015a). Only wild fauna (amphibia to mammalia) of Bangladesh constitute around 3.5% of the total wildlife in the world (Khan 2008, Jaman *et al.* 2015).

Biodiversity became the issue of global anxiety over the past few decades for its rapid reduction worldwide and interestingly, the majority of the world's biodiversity is present in most of the economically non-solvent countries like Bangladesh (Koziell 2001). It is widely supposed that the poorest people of the poor countries depend on their local ecosystems for their livelihoods are responsible for the degradation of biodiversity (CBD 2006 and 2007). Widlife plays ecological and economical role in both invertebrate and vertebrate pest control (Jaman *et al.* 1999), scavenging and pollinating as well as providing food to mankind. The larvae of frogs and toads feed mainly on algae, dead animals in water, diatoms, planktons or other small organisms playing an important role in the ecosystem (Hasan and Feeroz 2014). Unfortunately, the wildlife populations of Bangladesh have been decreasing at an alarming rate mainly due to anthropogenic developmental activities including habitat destruction and fragmentation, water pollution degradation of vegetation, deforestation, conversion of wetlands and forests to agricultural land and conversion of farm-land to urban and industrial uses (Sarker *et al*. 2000, Hossain *et al.* 2004, Khan and Ahsan 2011, Karmakar *et al.* 2011, Rahman *et al.* 2012, IUCN Bangladesh 2015 b,c,d). To address the role of wildlife in an area, rigorous scientific studies are therefore needed to protect them from their critical positions.

However, some studies have been conducted on avian diversity in different parts of Dhaka city (Hussain *et al.* 1974, Das 1975, Sarker *et al*. 2009, Mohsanin and Khan 2009, Akash *et al.* 2013, Chowdhury *et al.* 2014, Islam *et al.* 2014, Jaman *et al.* 2014, Jaman *et al.* 2015, Rajia *et al.* 2015, Banu *et al.* 2016). No specific study has yet been done on wildlife of Kashimpur Union. Therefore, this study may play a significant role to make baseline information on wildlife diversity in the study area.

Materials and Methods

The study was conducted in Kashimpur Union of Gazipur district under Dhaka division, situated on the bank of Turag river in between $23^0$59'04.94" N and $90^0$19'18.46" E. It is bounded by Konabari union on the north-east, Basan union on the east, Gachha union on the south-east, Kaliakair Upazila on the north and Savar Upazila in the south. The total area of the union is about 42.32 km^2 covered mainly by plain land. A number of ponds, swamps, ditches, canals and beels have enriched the aquatic habitat of the union.

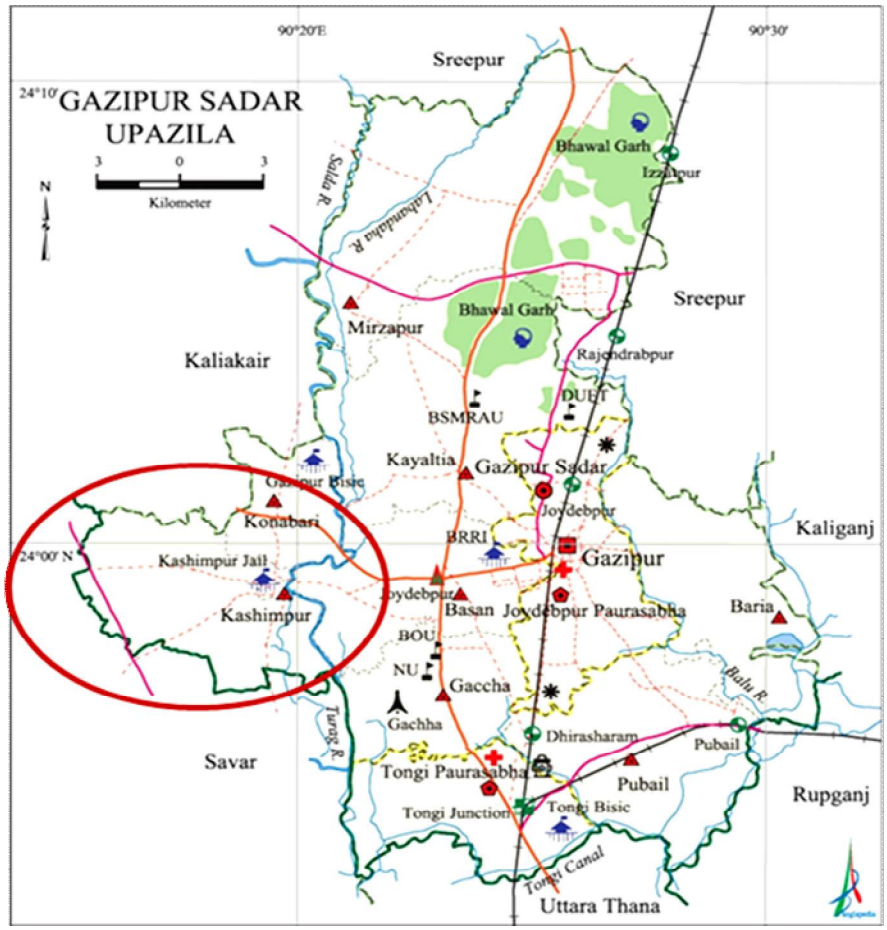

Fig. 1. Gazipur Sadar Upazila map showing Kashimpur Union (Source: Banglapedia 2003).

Observation procedure: Data were collected by direct field observations from May, 2015 to March, 2016. A total of 42 days (3 to 4 days per month) were spent in the field for data collection. Observations were started early in the morning and continued till sunset. We also collected data on herpetofauna, nocturnal birds and mammals after sunset since they are mostly active at night. Random sampling was followed to observe nocturnal birds and mammals. During the study period a pair of binoculars (Bushnell Power View 10 × 42) was used in order to identify bird species from the longer distance. For identification of birds Grimmett *et al.* (1999), Halder (2010) and Khan (2015) were followed. In many cases birds were photographed with a digital semi-SLR camera (Canon SX 50HS) in order to confirm the identification. Hasan *et al.* (2014) and Daniel (2002) were followed

for the identification of herpetofauna. Khan (2008) and Khan (2015) were followed to identify the mammalian fauna. The study period was divided into three seasons, *viz.* summer (March-June), rainy (July - October) and winter (November-February). The relative abundance was estimated following Khan (1982) as very common (VC): 80 - 100%, common (C): 50 - 79%, fairly common (FC): 20 - 49% and a few (F): 10 - 19%. The data were calculated based on total sighting.

The Shannon-Wiener index (1949) and Simpson's index (1949) of diversity and evenness (quantifies how numerically equal the community is) of species in the study area were also calculated using following formulas:

Simpson's index of diversity, $D = l - sum\ (P_i^2)$

Shannon-Wiener Index, $H = -\ sum\ (P_i ln\ [P_i])$ (natural log)

Evenness, $E = H/ln\ (S)$ (natural log), (where, P_i = Number of individuals of a species/ total number of individuals of all species from the same group, and S = Number of species from the same group observed).

Line transect sampling method: The data regarding different species available in the study area were recorded following the transect line sampling method. In every month we followed at least 5 transect lines totalling 60 during the study period. The size of each line was 500 m length and 50 m in both sides. When any species was observed, population was counted along with their habitat type and food habit. Microhabitats had been categorized as tree hole, water body, open forest, branches of tree, woody trees, fruiting tress, shrubs, bushes, jungles, crevices, grass field, crop field, store house and house.

Plot counting: Plot counting method was used for estimating amphibian species. A total of 20 plots were selected during the study period for observation of amphibian species. Each plot size was $10 \times 10\ m^2$. We counted every visible individual inside the plot. There might be chances to escape some individuals from the plot and they were not counted.

Calls and songs: Some avifauna and some amphibians, when hidden in the bushes, jungles and branches of trees, were traced by hearing their songs and calls first and later we identified them by visual encounter.

Interviewing local people: All animals were not visible across the study period and nocturnal animals were not easy to observe. In this regard, some questionnaires were distributed among the inhabitants of the study area to gather more information on those wild animal. Local peoples were asked about the presence of species showing their photographs available in the field pictorial guide.

Results and Discussion

A total of 110 species of wildlife were observed of which 6 (5.45%) were amphibians, 14 (12.72%) reptiles, 72 (65.45%) birds and 18 (16.38%) were mammals. The observed species belong to 58 families under 19 orders (one order of Class Amphibia, 2 of Class Reptilia and 12 of Aves and 4 orders of Class Mammalia) (Tables 1-4).

Faunal composition of observed wildlife: Out of 6 observed amphibian species, only *Duttaphrynus melanostictus* represents the group toad and other 5 species were frogs (Table 1). The most frequently observed species was common toad (*Duttaphrynus melanostictus*) with 2.4 indiv./100 m^2 and the least observed was *Microhyla ornata* (0.1 indiv./100m^2).

There were 14 species of reptiles belonging to three groups, *viz*, lizards, snakes and tortoise. Among them, 7 (50%) species were lizards, 5 (35.71%) snakes and 2 (14.29%) were tortoises. Out of 5 species of snakes, 4 were non-venomous and only one was deadly venomous (*Naja naja*). The highest density (20.67 indiv./km^2) was recorded for House Lizard (*Hemidactylus flaviviridis*) whereas the lowest density (0.33 indiv./km^2) was for Rat Snake (*Ptyas mucosa*).

Of the bird species, 39 (54.16%) were passerines and rest 33 (45.84%) were non-passerine. The highest density (207.00 indiv./km^2) of bird species was the common Myna (*Acredotheres tristis*) and the lowest (0.67 indiv./km^2) was the Dusky Warbler (*Phylloscopus fuscatus*).

A total of 18 species of mammals were observed in the study area. Of them, 8 (44.45%) were rodents, 4 (22.22%) flying mammals and 6 (33.33%) were carnivorous mammals. The most frequently observed species was Irrawaddy Squirrel (*Callosciurus erythraeus*) (30.67 indiv./km^2) and the least observed species were Small Civet (*Viverriculla indica*) and Jungle Cat (*Felis chaus*).

The present study observed 110 species of wildlife that depicts the study area could be better home for wildlife as it supports many flowering plants, fruiting trees, shrubs, large trees, tree crevices, bushes, jungles, crop fields and different types of waterbodies.

Monthly variation of species composition: During the study period, there was surprising fluctuation in the species composition. The maximum number of species were recorded in the month of December (84 species), followed by January (69 spp.) and November (64 spp.). On the other hand, the minimum number of species was documented in August (only 28 spp.); from where there was dramatic increase in the number of species in every month and continued till December. Since the species number has been gradually

Table 1. List of amphibians species observed during the study period.

Order	Family	Species name	English name	Observed individuals	Density (/100m^2)	R/A	Status IUCN BD 2015	Microhabitat
Anura		*Hoplobatrachus tigerinus*	Bull Frog	32	1.6	C	LC	Water body
	Dicroglossidae	*Euphlyctis cyanophlyctis*	Skipper Frog	4	0.2	FC	LC	Pond
		Fejervarya syhadrensis	Small Cricket Frog	4	0.2	FC	LC	Marsh
	Bufonidae	*Duttaphrynus melanostictus*	Common Toad	48	2.4	C	LC	Land
	Rhacophoridae	*Polypedates leucomystax*	Common Tree Frog	5	0.3	FC	LC	Tree
	Microhylidae	*Microhyla ornata*	Ornate Microhylid Frog	2	0.1	F	LC	Forest

(C - Common, FC - Fairly common, F - Few, LC - Least concern, R/A - Relative abundance).

Table 2. Reptilian species observed during the study period.

Order	Family	Species name	English name	Observed individuals	Density (/km^2)	R/A	Status IUCN BD 2015	Microhabitat
Squamata	Gekkonidae	*Hemidactylus flaviviridis*	House Lizard	62	20.67	C	LC	House,tree
		Hemidactylus brooki	Brook's House Gecko	4	1.33	FC	LC	House,tree
		Gekko gecko	Tokey Gecko	5	1.67	F	LC	House,tree
	Varanidae	*Varanus bengalensis*	Bengal Monitor	15	5.00	C	NT	Land
		Varanus flavecense	Yellow Monitor	8	2.67	F	NT	Land
	Scincidae	*Eutropis carinata*	Common Skink	4	1.33	F	LC	Water body
	Agamidae	*Calotes versicolor*	Common Garden Lizard	13	4.33	FC	LC	bush
	Colubridae	*Xenochrophis piscator*	Ceckered Keelback	25	8.33	C	LC	Water body
		Ptyas mucosa	Rat Snake	1	0.33	F	LC	Forest
		Amphiesma stolatum	Stripped Keelback	5	1.67	FC	LC	Bush
	Elapidae	*Naja naja*	Spectacled Kobra	4	1.33	F	NT	Land
	Typhlopidae	*Argyrophis diardii*	Diard's Blindsnake	2	0.67	F	LC	Land
Testudines	Geoemydidae	*Pangshura tecta*	Roofed Turtle	5	1.67	F	LC	Pond
	Trionychidae	*Lissemys punctata*	Spotted-flapshell Turtle	2	0.67	F	LC	Pond

(FC - Fairly common, C - Common, F - Few, NT - Near threatened, LC - Least concer, R/A - Relative abundance).

Table 3. Avifaunal species observed during the study period.

Order	Family	Species name	English name	Observed individuals	Density (/km^2)	R/A	R/M status	Status IUCN BD 2015
Passeriformes	Passeridae	*Passer domesticus*	House Sparrow	203	67.67	VC	CR	LC
	Sturnidae	*Acridotheres tristis*	Common Myna	621	207.00	VC	CR	LC
		Acredotheres fuscus	Jungle Myna	202	67.33	FC	CR	LC
		Sturnus contra	Asian Pied Starling	394	131.33	VC	CR	LC
		Sturnus malabaricus	Chestnut-tailed Starling	33	11.00	FC	CR	LC
	Cisticolidae	*Prinia inornata*	Plain Prinia	9	3.00	F	CR	LC
	Timalidae	*Turdoides striata*	Jungle Babbler	83	27.67	C	CR	LC
		Pellorneum ruficeps	Puff-throated Babbler	4	1.33	F	CR	LC
	Oriolidae	*Oriolus oriolus*	Eurasian Golden Oriole	41	13.67	F	RR	LC
		Oriolus xanthornus	Black-hooded Oriole	93	31.00	FC	CR	LC
	Turdidae	*Zoothera citrina*	Orange-headed Thrush	71	23.67	F	UR	LC
	Corvidae	*Corvus splendens*	House Crow	258	86.00	VC	CR	LC
		Corvus levaillantii	Jungle Crow	84	28.00	C	CR	LC
		Dendrocitta vagabunda	Rufous Treepie	42	14.00	FC	CR	LC
	Dicruridae	*Dicrurus macrocercus*	Black Drongo	339	113.00	C	CR	LC
		Dicrurus aeneus	Bronzed Drongo	22	7.33	F	CR	LC
	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	455	151.67	VC	CR	LC
		Pycnonotus jocosus	Red-whiskered Bulbul	8	2.67	F	CR	LC
	Aegithinidae	*Aegithina tiphia*	Common Iora	4	1.33	C	CR	LC
	Ploceidae	*Ploceus philippinus*	Baya Weaver	35	11.67	FC	CR	LC
	Paridae	*Parus major*	Great Tit	6	2.00	FC	CR	LC
	Estrildidae	*Lonchura punctulata*	Scally-breasted Munia	3	1.00	F	CR	LC
		Lonchura malabarica	Silverbill	6	2.00	F	UR	LC
	Muscicapidae	*Ficedula albicilla*	Taiga Flycatcher	3	1.00	FC	CWM	LC
		Muscicapa dauurica	Asian Brown Flycatcher	3	1.00	F	RPM	LC
		Copsychus saularis	Oriental Magpie Robin	151	50.33	VC	CR	LC
		Copsychus malabaricus	White-rumped Shama	11	3.67	F	CR	LC
		Saxicola insignis	White-throated Bushchat	10	3.33	F	V	LC
		Saxicola caprata	Pied Bushchat	4	1.33	F	UR	LC

(Contd.)

	Campephagidae	*Tephrodornis pondicerianus*	Common Woodshrike	7	2.33	F	CR	LC
	Motacillidae	*Anthus rufulus*	Paddyfield Pipit	13	4.33	F	CR	LC
		Motacilla madaraspatensis	White-browed Wagtail	8	2.67	F	RR	LC
	Turdidae	*Chloropsis aurifrons*	Golden-fronted Leafbird	5	1.67	F	CR	LC
	Sylvidae	*Phylloscopus fuscatus*	Dusky Warbler	2	0.67	F	CWM	LC
		Phylloscopus affinis	Tickelle's Leaf-Warbler	4	1.33	FC	RWM	LC
		Orthotomus sutorius	Common Tailorbird	101	33.67	C	CR	LC
	Dicaeidae	*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	5	1.67	F	CR	LC
	Laniidae	*Lanius schach*	Long-tailed Shrike	11	3.67	C	CR	LC
		Lanius cristatus	Brown Shrike	11	3.67	FC	CWM	LC
Cuculiformes	Cuculidae	*Eudynamys scolopaceus*	Western Koel	22	7.33	FC	CR	LC
		Hierococcyx varius	Common Hawk Cuckoo	7	2.33	F	CR	LC
		Centropus sinensis	Greater Coucal	34	11.33	F	CR	LC
		Centropus bengalensis	Lesser Coucal	6	2.00	F	CR	LC
		Cacomantis merulinus	Plaintive Cuckoo	6	2.00	F	CR	LC
Psittaciformes	Psittacidae	*Psittacula kramari*	Rose-ringed Parakeet	38	12.67	C	CR	LC
Pelecaniformes	Ardidae	*Bubulcus ibis*	Cattle Egret	13	4.33	FC	CR	LC
		Egretta garzetta	Little Egret	8	2.67	F	CR	LC
		Ardea intermedia	Intermediate Egret	11	3.67	F	CR	LC
		Ardea alba	Great White Egret	42	14.00	F	CR	LC
		Ardeola grayii	Pond Heron	111	37.00	C	CR	LC
		Nycticorax nycticorax	Black-crowned Night Heron	33	11.00	F	CR	LC
Piciformes	Picidae	*Dendrocopos macei*	Fulvous-breasted Woodpecker	55	18.33	FC	CR	LC
		Dinopium benghalense	Black-rumped Flameback	41	13.67	C	CR	LC
		Micropternus brachyurus	Rufous Woodpecker	295	98.33	C	CR	LC
		Picus guerini	Grey-headed Woodpecker	5	1.67	F	CR	LC

(Contd.)

		Picus xanthopygaeus	Streak-throated Woodpecker	17	5.67	F	UR	LC
	Megalaimidae	*Psilopogon asiaticus*	Blue-throated Barbet	5	1.67	F	CR	LC
		Psilopogon haemacephalus	Coppersmith Barbet	16	5.33	F	CR	LC
		Psilopogon lineatus	Lineated Barbet	17	5.67	FC	CR	LC
Coraciformes	Halcyonidae	*Halcyon smyrnensis*	White-breasted Kingfisher	25	8.33	C	CR	LC
	Alcedinidae	*Alcedo atthis*	Common Kingfisher	39	13.00	C	CR	LC
	Meropidae	*Merops orientalis*	Asian Green Bee-eater	19	6.33	FC	CR	LC
	Coracidae	*Coracius benghalensis*	Roller	6	2.00	F	CR	LC
Bucerotiformes	Upupidae	*Upupa epops*	Common Hoopoe	7	2.33	F	UR	LC
Columbiformes	Columbidae	*Spilopelia chinensis*	Eastern Spotted Dove	252	84.00	VC	CR	LC
Suliformes	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	7	2.33	F	CR	LC
Strigiformes	Strigidae	*Athene brama*	Spotted Owlet	19	6.33	C	CR	LC
	Tytonidae	*Tyto alba*	Common Barn Owl	8	2.67	F	UR	LC
Caprimulgiformes	Apodidae	*Apus affinis*	House Swift	201	67.00	C	CR	LC
		Cypsiurus balasiensis	Asian Palm-swift	3	1.00	FC	CR	LC
Acciptriformes	Acciptridae	*Milvus migrans*	Black Kite	5	1.67	FC	CR	LC
		Haliastur indus	Brahminy Kite	11	3.67	FC	CR	LC

(VC - Very common, FC - Fairly common, C - Common, F - Few, LC - Least concern, R/A - Relative abundance, R/M - Resident and Migratory status, CR -Common resident, RR - Rare resident, UR - Uncommon resident, CWM - Common winter migrant, RWM - Rare winter migrant, RPM - Rare passage Migrant, V - Vagrant).

Table 4. Mammalian species observed during the study period.

Order	Family	Spescies name	English name	Observed individuals	Density (/km^2)	R/A	Status	Microhabitat
Carnivora	Herpestidae	*Herpestes edwardsii*	Common Mongoose	22	7.33	C	LC	Bush
		Herpestes auropunctatus	Small Mongoose	15	5.00	FC	LC	Bush
		Canis aureus	Golden Jackel	5	-	F	LC	Forest
	Viverridae	*Viverricula indica*	Small Civet	2	0.67	FC	NT	Bush
		Paradoxurus hermaphroditus	Common Palm Civet	3	-	F	LC	Forest
	Felidae	*Felis chaus*	Jungle cat	2	-	F	NT	Jungle
Soricomorpha	Soricidae	*Suncus murinus*	Asian House Shrew	27	9.00	C	LC	Crevices
Rodentia	Muridae	*Rattus rattus*	Common House Rat	47	15.67	VC	LC	Store house
		Rattus norvegicus	Brown rat	7	2.33	FC	LC	Tree
		Bandicota indica	Greater Bandicoot Rat	89	29.67	VC	LC	Store house
		Bandicota bengalensis	Lesser Bandicoot Rat	18	6.00	FC	LC	Store house
		Mus musculus	House Mouse	17	5.67	C	LC	Crop field
	Sciuridae	*Funambulus pennatii*	Five-stripped Palm Squirrel	19	6.33	C	LC	Tree
		Callosciurus pygerythrus	Irrawaddy Squirrel	92	30.67	VC	LC	Tree
Chiroptera	Pteropodidae	*Pteropus giganteus*	Flying Fox	11	-	FC	LC	Tree
	Vespertilionidae	*Pipistrellus coromandra*	Common Pipistrelle	14	-	C	LC	Crevices
		Pipistrellus tenuis	Least Pipistrelle	9	-	FC	LC	Crevices
	Megadermatidae	*Megaderma lyra*	Greater False Vampire	6	-	FC	LC	Cave

(VC - Very common, FC - Fairly common, C - Common, F - Few, NT - Near threatened, LC - Least concern, R/A - Relative abundance).

decreased and sustained up to May. Considering season, the highest number of species were found in winter season (102 spp.) followed by summer (76 spp.) and rainy season (63 spp.) (Fig. 2).

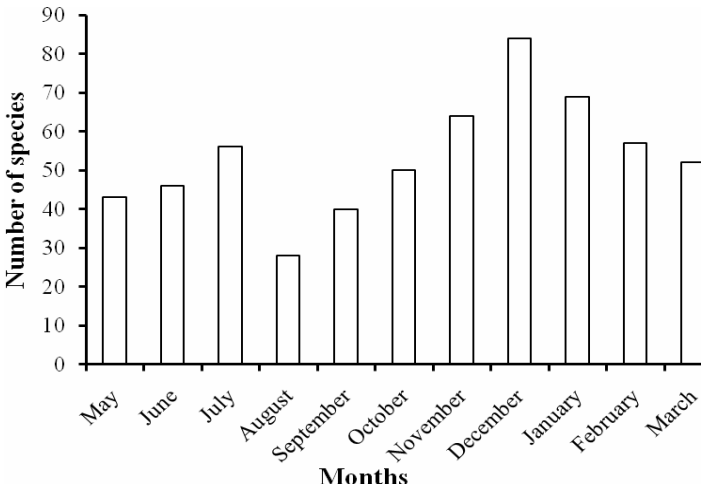

Fig. 2. Monthly variation in the species composition in Kashimpur Union.

The study area was human dominated landscape with enormous number of paddy and other crop fields around. Crop production is generally started in the month of October to December that supports an excessive amount of insects. Thus, insectivorous birds were available in these months. Besides, December is the early month of winter, and some migratory birds visited the area. Hence, number of species was the maximum in winter season. In summer season natural calamities such as storm, cyclone, tornado and hailstorm are often struck in Bangladesh. Probably these natural calamities might affect bird species due to loss of their habitats and paucity of foods in the month of April and May. In rainy season, due to excessive rainfall most of the crop fields and other open areas were inundated with water resulting difficulties to find out the wildlife species in the harsh environment and eventually we found comparatively lower species diversity of wildlife than the other seasons.

Relative abundance and conservation status: The relative abundance of observed wildlife shows that 10 (9.09%) species were very common, 24 (21.81%) common, 31 (28.19%) fairly common and 45 (40.91%) species were few. Among the observed amphibians, 2 (33.33%) species were common, 3 (50%) were fairly common and 1 (16.67%) were few.

Among recorded reptiles, 3 (21.43%) species were common, 3 (21.43%) fairly common and 8 (57.14%) were few. Of the birds, 7 (9.72%) species were very common, 14 (19.44%) common, 17 (23.61%) fairly common and 34 (47.23%) species were few. Among the recorded mammals, 3 (16.66%) species were very common, 5 (27.77%) common, 7 (39%) fairly common and 3 (16.66%) species were few.

According to IUCN Bangladesh (2015a), overall conservation status of recorded wildlife shows that 5 species were near threatened (two mammals and three reptiles) and remaining 105 species were of least concern nationally.

The study area has gradually turned into urban area and this is one of the major causes of habitat loss of wild animals. Sometimes people kill snakes, birds like herons, egrets, jackels, civets and jungle cat unconsciously due to lack of adequate knowledge about the ecosystem services of wildlife.

Resident and migratory status of birds: Regarding the resident and migratory status of birds, 66 (91.62%) species were resident, 5 (7.00%) migrants and 1 (1.38%) species were vagrant. Among the resident birds, 58 species were common resident, 6 uncommon resident and 2 species were rare resident. Of the 5 migratory birds, 3 species were common winter migrants, one was rare winter migrants, and one was rare passage migrants. Siddiqui *et al.* (2008) documented in total 176 migratory birds in Bangladesh. This study found diverse microhabitats, plenty of foods and roosting sites both for resdents and migratory birds that facilitated living for these bird species. The area also provided breeding facilities that might be the reason for greater assemblage of resident birds.

Habitat utilization by wildlife: Wildlife utilizes diverse microhabitats in the study area. Of the wildlife recorded in the diverse microhabitats, 20 (18.18%) were seen in the woody plants followed by 17 (15.45%) in tree branches, 12 (10.9%) in the bushes, 11 (1%) in the fruiting plants, 8 (7.27%) in the open forest, 8 (7.27%) were seen in the different water bodies (marsh, canal, small river and *beel*), etc. (Fig. 3). These results indicate that most of the wild animals occurred in the terrestrial habitat probably because of the large insects population was available there as food items for insectivore wild animals. Besides, there were many large fruiting trees, woody and flowering plants which provide food, shelter and nesting facilities for breeding of wildlife in the study area.

Species diversity indices: The calculated diversity indices indicate that the diversity of birds (Simpson's index of diversity D = 0.942 and Shannon-Wiener Index H = 3.287) was higher than the other groups observed (*viz.* amphibians, reptilians and mammalians). However, mammals and birds were more evenly distributed (mammals = 0.820 and birds

= 0.768) in comparison to amphibians and reptiles (Table 5). Sarker *et al*. (2000) reported that avian diversity was higher in the cultivated and bushy lands because of food availability and adequate shelter. The study area is enriched with homestead forest and garden, cultivated land, fallow land, water bodies and bushy land. This habitat attracted the birds more than the other groups observed in the study area, hence probably diversity of birds was higher than others wild animals.

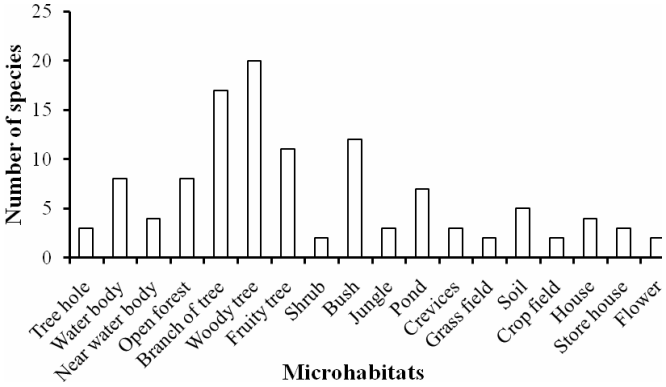

Fig. 3. Number of species found in the different microhabitats.

Table 5. Species diversity indices according to groups.

Parameter	Amphibia	Reptiles	Birds	Mammals
Simpson's index of diversity (D)	0.624	0.789	0.942	0.869
Shannon-Wiener index (H)	1.214	2.008	3.287	2.370
Evenness (E)	0.678	0.761	0.768	0.820

Threats and conservation problems: Frequent use of agro-chemicals in the crop fields, urbanization, conversion of fallow and forest land into agricultural land were the main threats for survival of wildlife in the study area. Additionally, illegal hunting, shooting, clearing of thickets, bushes, jungles and logging of homested forest were also noticed during the study period. Dumping of wastes materials, plastics, polythene and chips packets left by human polluted the environment and eventually leading to the unfavorable habitat for wildlife. Recorded wild animals are being affected by encountering these extrinsic problems and threats in the study area.

Conservation awareness and scientific monitoring of wildlife are limited in Bangladesh results 31 species has gone extinct regionally from the country (IUCN Bangladesh

2015a), and many of them are on the brink of local extinction. Rigorous scientific studies are important to ensure long-term conservation of wildlife and their habitats.

Acknowledgement

The authors would like to acknowledge the Ministry of Science and Technology as the study was partially funded by the National Science and Technology (NST) fellowship program.

References

Akash, M., M.A. Hossain, G.W. Chowdhury, H. Mahmud and M.A. Islam. 2013. Status of avifauna in Curzon Hall premises University of Dhaka, Bangladesh. *Ecoprint* **20**: 1-8.

Banglapedia, Ed: Sirajul Islam, 2003, Asiatic Society of Bangladesh.

Banu, M.F.A, M. Akash, G.W. Chowdhury and M.A. Islam. 2016. Status and seasonal occurance of birds in Dhaka University Campus. *Dhaka Univ. J. Biol. Sci*. **25**(1): 27-37.

CBD. 2006. *Global Biodiversity Outlook 2*. Secretariat of the Convention on Biological Diversity (SCBD), Montreal. 81 pp.

CBD. 2007. *Biodiversity and Climate Change*. Secretariat of the Convention on Biological Diversity, Montreal. 48 pp.

Chowdhury, S., U. Aich and O. Shahadat. 2014. Checklist of avian fauna of Dhaka University Campus, Bangladesh. *Int. J. Fauna. Biol. Stud.* **1** (5): 56-60.

Daniel, J.C. 2002. *The book of Indian reptiles and amphibians*. Bombay Natural History Society. Oxford University Press. 238 pp.

Das, A.K. 1975. A study on birds of Curzon Hall and Ramna Park. M.S. thesis (unpubl.), Dept. of Zoology, University of Dhaka.

Grimmett, R., C. Inskipp and T. Inskipp. 1999. *Pocket guide to the birds of the Indian subcontinent.* Oxford University Press, New Delhi, India. 384 pp.

Halder, R.R. 2010. *A phograpic guide to the bird of Bangladesh.* Baikal Teal Publication, Dhaka, Bangladesh. 257 pp.

Hasan, M.K. and M.M. Feeroz. 2014. Species diversity and habitat preferences of amphibian fauna in six protected areas of Bangladesh. *Bangladesh J. Zool.* **42**(1): 105-116.

Hasan, M.K., M.M.H. Khan and M.M. Feeroz. 2014. *Amphibians and reptiles of Bangladesh - A field guide.* Arannayk Foundation, Dhaka, Bangladesh.191 pp.

Hossain, M.K., M.F. Jaman and S.U. Sarker. 2004. Diversity of herpeto-mammalian fauna and their conservation issues in Hatiya island, Bangladesh. *Tropi. Biod.* **8**(2):71-78.

Hussain, K.Z., A.R. Khan and S.U. Sarker. 1974. Birds of Dhaka. *Bangladesh J. Zool.* **2**(2): 153-170.

Islam, M.S., O. Shahadat, M.M. Kabir, M.A. Rashid, H.A. Razi, M. Kamaruzzaman, S.M.I. Alam, T. Mustafa and M.S. Islam. 2014. Avifauna of the national botanical garden of Bangladesh. *J. Taxon.and Biod. Res*. **6**: 17-20.

IUCN Bangladesh. 2015a. *Red List of Bangladesh: A Brief on Assessment Result. Volume 1:* IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. 24.

IUCN Bangladesh. 2015b. *Red List of Bangladesh Vol. 2: Mammals*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. xvi+232.

IUCN Bangladesh. 2015c. *Red List of Bangladesh Vol. 3: Birds*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. xvi+676.

IUCN Bangladesh. 2015d. *Red List of Bangladesh Volume 4: Reptiles and Amphibians*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. xvi+320.

Jaman, M. F., M.S. Majumder, M.S. Hossain, M.M. Rahman and M. Uddin. 2014. Diversity of Wildlife at Ruhitpur Union, Keraniganj, Dhaka. *J. Asiat. Soc. Bangladesh, Sci.* **40** (2): 295-308.

Jaman, M.F., M. Uddin, M.M. Alam, M.M. Rahman, M.T. Khatun and S.M.I. Alam. 2015. Species diversity and population status of wildlife in Keshabpur, Bangladesh. *J. Biodiv. Con. and Biores. Manage.* **1**(2): 9-21.

Jaman, M.F., S.U. Sarker and N.J. Sarker. 1999. Food habits and feeding behavior of black drongo, *Dicrurus macrocercus albirictus* (Hodgson). *Bangladesh J. Zool*. **26**(2): 57 66.

Karmakar, S., S. Parween and A.M.S. Reza. 2011. Birds of Joypurhat district, Bangladesh. *J. L. Sci.* **6**: 51-57.

Khan, M.A.R. 1982. *Wildlife of Bangladesh (A checklist).* University of Dhaka. Dhaka. 173 pp.

Khan, M.A.R. 2015. *Wildlife of Bangladesh-checklist and guide.* Chayabithi, Purana Paltan, Dhaka 1000. 568 pp.

Khan, M.M.H. 2008. *Protected Areas of Bangladesh - A. Guide to Wildlife*. Nishorgo Support Program, Bangladesh. Forest Department. 304 pp.

Khan, S.I. and M.F. Ahsan. 2011. Birds of the Madhupur National Park, Bangladesh. *Bangladesh J. Zool.* **39**(1): 49-63.

Koziell, I. 2001. *Diversity not Adversity: Sustaining Livelihoods with Biodiversity*. International Institute for Environment and Development (IIED) and Department for International Development (DFID), England. 58 pp.

Mittermeier, R.A., N. Myers, J.B. Thomsen, G.A. Da Fonseca and S. Olivieri. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conserv. Biol.* **12**: 516-520.

Mohsanin, S. and M.M.H. Khan. 2009. Status and seasonal occurance of birds in Jahanginnagar University Campus, Bangladesh. *Bangladesh J. L. Sci.* **21**(1): 29-37.

Rahman, M. S., S. U. Sarker and M. F. Jaman. 2012. Ecological status of the herpeto-mammalian fauna of the Padma River and its adjacent areas, Rajshahi and their conservation issues. *Bangladesh J. Zool.* **40**(1): 135-145.

Rajia, S., M.M. Alam, G.W. Chowdhury, M. Akash and M.A. Islam. 2015. Status and diversity of birds of Ramna Park, Dhaka, Bangladesh. *Bangladesh J. Zool.* **43**(2): 291-301.

Sarkar, N.J., D. Sultana, M.F. Jaman and M.K. Rahman. 2009. Diversity and population of avifauna of two urban sites of Dhaka, Bangladesh. *Ecoprint*. **16**:1-7.

Sarker, S.U., M.F. Jaman, N.J. Sarker and M.K. Hossain. 2000. Status of wildlife of St. Martins Island, Bangladesh. *Dhaka Univ. J. Biol. Sci.* **9**(1): 75-85.

Shannon, C.E. and W. Wiener. 1949. *The mathematical theory*. University of Illinois press, Urbana. 117 pp.

Siddiqui, K.U., M.A Islam, Kabir, S.M.H., M. Ahmad, A.T.A. Ahmed, A.K.A. Rahman, E.U. Haque, Z.U. Ahmed, Z.N.T. Begum, M.A. Hasan, M. Khondker and M.M Rahman (eds.). 2008. *Encyclopedia of flora and fauna of Bangladesh*, Vol. 26. *Birds*. Asiatic Society of Bangladesh, Dhaka. 632 pp.

Simpson, E. H.1949. Measurement of diversity. *Nature* **163**: 688.

(Revised copy received on 1.7.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 117-125, December 2018

YIELD AND BIOCHEMICAL ATTRIBUTES OF BRRI DHAN-44 (*ORYZA SATIVA* L.) AS AFFECTED BY TIBA APPLICATION

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Abstract

A pot experiment was carried out to evaluate the effect of different concentrations (0, 10, 25, 50 and 100 ppm) of TIBA on yield and biochemical attributes of BRRI dhan-44. Results revealed that number of effective tillers and dry weight of panicle per plant, length of panicle, number of grains per panicle, 1000-grain weight, yield per plant and harvest index increased due to all concentrations of TIBA treatments where, treatments mean varied significantly in majority of cases. The stimulatory effect of TIBA treatments on number of effective tillers and dry weight of panicles per plant, length of panicle, number of grains per panicle and 1000-grain weight resulted significant increase in grain yield per plant. The maximum yield per plant (17.83 g) was obtained from 10 ppm TIBA treatment which was 59.76 % higher over the control. Increases in yield per plant due to 25, 50 and 100 ppm TIBA were 50.53, 47.58 and 28.49%, respectively. Findings of this investigation showed that foliar application of TIBA had beneficial effect on pigment content of leaves at tillering and grain filling stages with a few exceptions. Protein content of leaves was also positively influenced by most of the treatment at tillering stage. Out of five treatments, 10 ppm TIBA produced better results.

Key words: BRRI dhan-44, TIBA, Foliar application, Yield, Biochemical attributes

Introduction

Rice (*Oryza sativa* L.) is the chief food of the people of Bangladesh which contributes about 92% of the total food grains produced in the country (Chowdhury and Hassan 2013). The demand for rice is persistently rising in our country with nearly 2.3 million people being added each year to its population (Zohir *et al.* 2002). But, the problem of land scarcity is being compounded by land degradation as there is almost no scope for bringing new land under cultivation. In addition, drought, lack of irrigation facilities, flooding and salinity of soils are the main constraints for better production. Demand of rice can be achieved through the number of agronomic techniques *viz.* selection of high yielding and disease resistant varieties, hybridization, improved cultural practices, proper application of fertilizers, use of growth regulating substances etc. Deficiency of plant growth regulators at any stage of plant growth may create a genetical or environmental barrier in attaining maximum growth and yield. Moreover, these organic substances have been used for many years to boost up crop production.

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Results of several investigations of the world revealed that application of 2,3,5 tri-iodo benzoic acid (TIBA) have potential effects in modifying growth, yield and biochemical component of several economically important plants (Phillips and Chilcote 1981, Ravichandran and Ramaswami 1991, Kler and Dhillon 1993, Rahman and Rahman 1997, Mondal and Dutta 2002, Djanaguiraman *et al.* 2005, Surendra *et al*. 2006, Abdelgadir *et al.* 2009). But, research work regarding the effect of TIBA on cereals crops is limited from elsewhere of the world and also in Bangladesh (Munira 2015, Adam *et al.* 2015). Hence, the present work was under taken to evaluate the effect of TIBA on yield and biochemical component of BRRI dhan-44.

Materials and Methods

A pot experiment was conducted at the botanical garden of the Department of Botany, Jagannath University, Dhaka. Earthen pots of uniform size was filled with 9.0 kg air dried soil. The soil used in this experiment was clay loam in texture. Urea, triple super phosphate, muriate of potash and gypsum were applied at doses recommended by BRRI. Cowdung was also mixed homogeneously during preparation of the pots. The experiment was laid out in a randomized complete block design (RCBD) with five replications. Seeds of BRRI dhan-44 were collected from Bangladesh Agricultural Development Corporation (BADC). It is a high yielding Aman variety, very popular to the farmers of southern part, and also suitable for non-saline tidal zone. Seeds were sterilized with 0.05% calcium hypochlorite solution for two minutes before sowing. Seedlings were transplanted to experimental pots at the age of 40 days after sowing. Three hills were placed in each pot, where each hill contains one seedling. Thinning, weeding and irrigation were done as per necessity. Split applications of urea were done twice at the rates of 2 g per pot at 24 and 54 days after transplanting (DAT). There were five foliar treatments *viz*. 0 (control), 10, 25, 50 and 100 ppm TIBA. Treatments were applied in sunny early morning at 32 DAT. During spraying, precautionary measures were taken to avoid crossing of growth regulator from one treatment to another.

Plants (BRRI dhan-44) were harvested at the age of 120 DAT. During harvesting 10 plants of each treatments were randomly selected to record data on number of effective and non-effective tillers per plant, dry weight of panicles per plant, length of panicle, number of grains per panicle, % of filled and un-filled grains per panicle, 1000-grain weight, yield per plant and harvest index. Yield per plant was calculated according to the formula of ICRISAT (1992). Chlorophyll a and b, carotenoid and protein contents of leaves were determined at three different stages *viz.* tillering, flowering and grain filling stages. The amount of chlorophyll a and b were determined by using specific absorption

co-efficient of Mckinney (1940) and the formulae of Maclachalan and Zalik (1963). The amounts of carotenoid was calculated using the equation of von Wettstein (1957). The method of Lowry *et al.* (1951) was employed for the determination of protein content of leaves. Data were analyzed statistically and treatment means were compared by LSD test at 5% level of significance (Steel *et al.* 1997).

Results and Discussion

Results presented in Table 1 showed that number of effective tiller per plant increased due to all treatments and the maximum increase was recorded from 100 ppm which was 48.38% higher over the control followed by 10 ppm. TIBA treatment. Whereas, in case of non-effective tillers per plant better response was obtained from 50 and 100 ppm TIBA treatments. Reports of Misra and Sahu (1958) revealed that the number of panicles per plant was increased due to 250 and 500 ppm TIBA application. Similar results of increase were also recorded in other plants by several investigators (Chung and Kim 1989, Ravichandran and Ramaswami 1991, Rahman and Rahman 1997, Mondal and Dutta 2002, Djanaguiraman *et al.* 2005).

Present investigation also showed that dry weight of panicles increased following all treatments and the maximum obtained from 10 ppm. Findings of Munira (2015) revealed significant increase in dry weight of cob due to TIBA application in BARI Maize-6. Similar results of increase due to TIBA application were also reported in different plants by other workers (Jahan and Khan 2014, Adam and Jahan 2014).

Results indicated that significantly higher length of panicle was obtained from the plants of 10 and 25 ppm treatments although statistically at par to 50 and 100 ppm. The maximum increase due to 10 ppm was 17.08%. Length of panicle was also found to increase following both 50 and 100 ppm treatments but statistically similar to control. Increases in length of pods due to TIBA application were reported by Munira (2015) in BARI Maize-6 and Adam and Jahan (2014) in BARI Mung-5. However, Misra and Sahu (1958) did not find any significant changes due to TIBA application on rice plant.

Results revealed that number of grains per panicle of BRRI dhan-44 responded positively following all treatments and increased significantly due to 10 and 100 ppm treatments. Misra and Sahu (1958) obtained increased number of grains per panicle from 100 ppm TIBA treated rice plant. Number of karnels per cob increased following TIBA application in BARI Maize-6 (Munira 2015). These results are also in conformity with the findings of other workers (Dholekar *et al.* 2001, Jahan and Khan 2014, Adam and Jahan 2014).

Table 1. Effect of TIBA on yield attributes and yield of BRRI dhan-44 at harvest.

Treatments TIBA (ppm)	No. of effective tillers/ plant	No. of non-effective tillers/ plant	Dry weight of panicle/ plant (g)	Length of panicle (cm)	No. of grains/ panicle	% of filled grains	% of unfilled grains	1000-grain weight (g)	Yield/ plant (g)	Harvest Index (%)
0	13.00	11.43	12.59	21.89 b	109.60 b	42.54 abc	57.46 ab	21.57 b	11.16 c	34.21
10	18.57	12.00	22.59	25.63 a	148.60 a	54.18 abc	45.82 b	25.12 a	17.83 a	63.02
25	16.14	12.86	20.42	26.10 a	137.10 ab	58.23 a	41.77 b	24.90 a	16.80 ab	59.29
50	16.29	10.71	21.34	24.54 ab	141.20 ab	55.01 ab	44.99 b	23.59 ab	16.47 ab	52.18
100	19.29	10.14	16.45	24.97 ab	154.80 a	36.35 c	64.65 a	22.73 ab	14.34 b	40.51
CV (%)	13.65	15.43	11.52	11.38	22.76	12.50	13.34	14.17	16.32	14.05
LSD (0.05)	NS	NS	NS	3.16	36.23	18.08	17.73	2.85	2.74	NS

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

In the present investigation, per cent of filled grains per panicle increased due to all treatments except 100 ppm TIBA treatment. The maximum per cent filled grains per panicle was obtained from 25 ppm treatment although statistically at par to rest of the treatments. Application of TIBA had also beneficial effect on per cent of un-filled grains per panicle with an exception of 100 ppm treatment. By applying different concentration of TIBA, Misra and Sahu (1958) found increased percentage of grain setting where, variation was significant due to 100 ppm treatment.

Results showed that weight of 1000-grain increased due to all rates of TIBA treatments in BRRI dhan-44. The maximum 1000-grain weight was obtained from 10 ppm which was significantly different from control but similar to 25 ppm treatment. Munira (2015) reported that 1000-grain weight increased following all concentration of TIBA treatments in BARI Maize-6 where, significantly highest value was obtained from 25 ppm treated plants. However, findings of Misra and Sahu (1958) did not observe any significant effect of TIBA on 1000-grain weight of rice. Similar results of increases in seed weights following TIBA application were also reported by other investigators (Ravichandran and Ramaswami 1991, Jahan and Khan 2014). Thus, the results obtained during the present study are in accord with the findings of previous workers**.**

Results of the present investigation revealed that yield of BRRI dhan-44 was significantly higher following all concentrations of TIBA treatments. The maximum yield per plant (17.83 g) was obtained from 10 ppm treatment and it was 59.76 % higher over the control followed by 25, 50 and 100 ppm, respectively. Increases in yield per plant due to 25, 50 and 100 ppm were 50.53, 47.58 and 28.49%, respectively. Mishra and Sahu (1958) reported that TIBA induced yield at 100 to 250 ppm in mid- and late-winter varieties of rice by increasing the number of grains per panicle and percentage of seed-setting. Yield of BARI Maize-6 increased following different concentration of TIBA treatment and were significant due to 50 and 75 ppm treatments (Munira 2015). Application of different concentrations of TIBA had also beneficial effect on yield of different plants *viz.* ground nut (Kler and Dhillon 1993), safflower (Dholekar *et al.* 2001), tomato (Razzaque and Rahman 2004), cotton (Djanaguiraman *et al*. 2005), soybean (Jahan and Khan 2014), mungbean (Adam and Jahan 2014). Thus, the findings of the present investigation are in conformity with the findings of many other investigators who have observed that yield of TIBA treated plants may increase depending on the concentrations used and also on the plants.

Results showed that, harvest index increased following all treatments. The highest harvest index was found from 10 ppm followed by 25 ppm treatment. Foliar application

Table 2. Effect of TIBA on pigment content (mg/g) of leaves of BRRI dhan-44 at three different stages.

Treatments	Tillering stage			Flowering stage			Grain filling stage		
TIBA (ppm)	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids	Chl. a	Chl. b	Carotenoids
0	0.122 d	0.119 d	2.398 c	1.158	0.438	7.718	0.440	0.256	5.872
10	1.071 a	0.406 a	7.029 a	0.849	0.103	2.679	0.784	0.190	6.696
25	0.364 cd	0.185 cd	4.631 b	0.450	0.247	5.149	0.556	0.212	7.375
50	0.795 b	0.301 b	5.091 b	0.231	0.188	4.960	0.624	0.431	8.497
100	0.592 bc	0.246 bc	0.935 d	0.362	0.362	5.405	0.792	0.336	7.443
CV (%)	14.58	15.98	9.53	19.08	15.74	10.25	13.57	19.34	23.98
LSD (0.05)	0.262	0.085	1.458	NS	NS	NS	NS	NS	NS

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

of 75 ppm TIBA resulted the maximum harvest index in BARI Maize-6 followed by 25 ppm treatment (Munira 2015) whereas, Adam and Jahan (2014) found highest harvest index with 20 ppm TIBA treatment.

Results obtained during the present investigation showed that the amount of chlorophyll a, b and carotenoids content of BRRI dhan-44 were found to increase at tillering and grain filling stages having few exceptions, whereas, decreased at flowering stage following all treatments (Table 2). Pigment content of leaves significantly increased due to all application of TIBA treatment at tillering stage except carotenoids content due to 100 ppm treatment where, it was decreased significantly. Results also showed that plants treated with10 ppm TIBA produced the highest pigment content of leaves. Both increases and decrease in pigment content of leaves following TIBA treatments was reported by Munira (2015) in maize and Jahan and Khan (2014) in soybean. Findings on pigment content of leaves are in conformity with the results of many other investigators who have observed that pigment content of TIBA treated plants may increase or decrease depending on the concentrations used and also on the variety.

Foliar application of TIBA had affirmative response on protein content of leaves at tillering stage with an exception of 25 ppm treatment. Although, protein content of leaves responded negatively at flowering and grain filling stages with significant variations (Table 3). This results are in agreement with the findings of other authors (Jahan and Khan 2014, Munira 2015).

Table 3. Effect of TIBA on protein content (mg/g) of leaves of BRRI dhan-44 at three different stages.

Treatments	Tillering stage	Flowering stage	Grain filling stage
TIBA (ppm)	Amount of protein (mg/g)		
0	44.28	38.75 a	7.68 a
10	61.45	21.60 c	3.50 b
25	39.30	31.32 b	2.95 b
50	45.80	38.83 a	2.23 b
100	47.75	34.18 ab	2.83 b
CV (%)	14.79	24.06	12.94
LSD (0.05)	NS	6.85	2.02

Mean in a vertical column followed by same letter or without letter do not differ significantly at 5% level.

The overall results of this investigation indicated that various concentration of TIBA had mostly stimulatory effect on various yield contributing parameters and finally increased grain yield significantly. Biochemical components responded differently depending on the concentration of TIBA and stage of growth. Among five concentrations of TIBA, 10 ppm produced better outcome.

References

Abdelgadir, H.A., S.D. Johnson and J. Van Staden. 2009. Promoting branching of a potential biofuel crop *Jatropha curcas* L. by foliar application of plant growth regulators. *Plant Growth Regulation* **58**(3): 287-295.

Adam, A.M.M.G. and N. Jahan. 2014. Growth and yield of BARI Mung-5 (*Vigna radiata* L. Wilczek) following TIBA application. *Dhaka Univ. J. Biol. Sci*. **23**(2): 179-185.

Adam, A.M.M. G., R. Islam, H.H. Begum and M.K. Naher. 2015. Growth analysis of BRRI dhan-44 (*Oryza sativa* L.) following 2, 3, 5-Triiodobenzoic (TIBA) acid application. *J. Asiatic Soc. Bangladesh, Sci.* **41**(1): 67-74.

Chowdhury, M.A.H. and M.S. Hasan. 2013. *Hand Book of Agricultural Technology*. Bangladesh Agric. Res. Council, Farmgate, Dhaka. 230 p.

Chung, I.M. and J.K. Kim. 1989. Effect of plant growth regulator (TIBA, ABA, DGLP) treatment on growth and yield of soybean (*Glycine max* L.) *Korean J. Crop Sci.* **34**(1): 1-6.

Dholekar, P.D., B.N. Patil and R.S. Shivankar. 2001. Effect of foliar spray of different growth regulators on yield and yield attributes of safflower. *Agric. Sci. Digest.* **21**(4): 241-243.

Djanaguiraman, M., J.A. Sheeba, D.D. Devi and U. Bangarusamy. 2005. Response of cotton to atonik and TIBA for growth, enzyme and yield. *J. Biol. Sci.* **5**(32): 158-162.

ICRISAT 1992. *Research Planning and Data Handling*. Diwakar, B. and D. L. Oswalt. International crop research institute for semi-arid tropics. Patancheru, Andhra Pradesh, India. 67 p.

Jahan, N. and S. Khan. 2014. Effect of TIBA on growth, yield and yield component of soybean. *J. Asiat. Soc. Bangladesh, Sci*. **40**(1): 89-96.

Kler, D.S. and G.S. Dhillon. 1993. Effect of cycocel and TIBA spray on the pod yield of groundnut. *Environment and Ecology* **11**(2): 475.

Lowry, O.H., N.J. Rosebrough, A.L. Farr and R.J. Randall. 1951. Protein measurement with folin phenol reagent. *J. Boil. Chem.* **193**: 265-275.

Maclachalan, S. and S. Zalik. 1963. Plastid structure, chlorophyll concentration and free amino acid composition of a chlorophyll mutant of barley. *Can. J. Bot.* **41**: 1053-1062.

Mckinney, G. 1940. Criteria for purity of chlorophyll preparations. *J. Biol. Chem.* **132**: 91-107.

Misra, G. and G. Sahu. 1958. Physiology of growth and reproduction in Rice. II. Effect of plant growth substances on three winter varieties. *Pl. Physiol.* **34**(4): 441-445.

Mondal, M.M.A. and R.K. Dutta. 2002. Effect of TIBA (2,3,5-triiodobenzoic acid) on growth and yield of tomato. *J. Agricul. Res.* **40**(3&4): 273-279.

Munira, S. 2015. Growth, yield and biochemical responses of BARI Maize-6 (*Zea mays* L.) as affected by TIBA application. M.Sc. Thesis, Department of Botany, Jagannath University, Dhaka.

Phillips, J.C. and D.O. Chilcote. 1981. Growth and reproductive development of alfalfa as influenced by 2,3,5-triiodobenzoic acid. *Canadian J. Bot.* **59**: 373-376.

Rahman, M.A. and M.M. Rahman. 1997. Effect of maleic hydrazide and tri-iodo benzoic acid on growth, sex expression and yield of *Lagenaria siceraria* (Mol.) Standl. *J. Asiat. Soc. Bangladesh, Sci.* **23**(2): 172-178.

Ravichandran, V.K. and C. Ramaswami. 1991. Effect of TIBA on yield and yield components of soybean in different seasons. *Haryana J. Agron.* **7**(2): 120-122.

Razzaque, A.H.M. and M.S. Rahman. 2004. Effect of TIBA on chlorophyll, soluble protein content and yield of tomato. *Indian J. Hort.* **61**(2): 140-142.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. *Principles and procedures of statistics*. McGraw Hill Book Co. Inc. New York.

Surendra, P., C.M. Nawalagatti, M.B. Chetti and S.M. Hiremath. 2006. Effect of plant growth regulators and micronutrients on morpho-physiological and biochemical traits and yield in Okra. *Karnataka J. Agric. Sci.* **19**(3): 694-697.

von Wettstein, D. 1957. Chlorophyll-lethal under Submikroskopisoche Formechse der Plastiden. *Expt. Cell Res.* **12**: 427-507.

Zohir, S., Q. Shahabuddin and M. Hossain. 2002. Determination of rice supply and demand in Bangladesh: Recent trends and projection in M. Sombilla, M. Hossain and B. Hardy (eds), Developments in the Asian rice economy, Los Banos, Philippines. Int. Rice Res. Inst. 127-152 pp.

(Revised copy received on 4.7.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 127-136, December 2018

MIGRANT COMMUNITY OF NIJHUM DWIP: COMPARATIVE IMPORTANCE OF LIVELIHOOD CAPITALS TO ADAPT IN THIS ISLAND

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Abstract

The study attempts to explore the factors behind selecting Nijhum Dwip for migration and perceive the relative importance of livelihood capitals (Human, physical, natural, financial and social) for the climate change adaptation of migrant community. Both qualitative and quantitative approaches are followed in this study. Data are collected from primary and secondary sources. The study recognizes, people are moving to Nijhum Dwip rather shifting to main land despite facing numerous disasters like cyclone, river bank erosion, flood, storm surge, sea level rise, salinity intrusion and so on. This is mainly due to low price of land and no alternative place to shift. They consider physical capital as the strongest livelihood capital to adapt in this island followed by human capital, natural capital, financial capital as well as social capital are also suitable option for enhancing the adaptation of migrant community to settle there.

Key words: Migrant community, Adaptation, Livelihood capital, Climate change, Nijhum Dwip

Introduction

Migration is one of the most important survival strategies adopted by people in the face of natural or man-made disasters (IOM 2008, Siddiqui 2014). A number of factors influence people to migrate, often with a combination of forced and voluntary reasons combining to push them away from current situations and to pull them towards new situations. Climate change is one of the main reasons for migration (Stojanov *et al.* 2016). This is likely to contribute displacement and increase both internal and international migration, with current projections estimating that by 2050, 200 million people will become displaced due to environmental factors (Pascoe 2015). Climatic events can affect migration in numerous ways: it might be temporary or permanent, planned or spontaneous, within states or across national borders and can involve individuals, households or communities (Pascoe 2015). Coastal areas are one of the most vulnerable spaces because of sea-level rise, increased level of inundation and

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storm flooding, coastal erosion, seawater intrusion and increased temperature (Torresan *et al*. 2008). However, a great change has been observed in the pattern of migration in Bangladesh especially in the off-shore islands of coastal areas due to the intensification of natural hazards. In the context of Bangladesh, natural disasters play considerable role in forcing people to migrate as a coping strategy (Rayhan and Grote 2007, Siddiqui 2014). Here, the most critical impact of climate change will result in the migration of the people from coastal areas to all over the country (Barman *et al.* 2012). There are major islands in coastal area of Bangladesh like Bhola, Sandwip, Hatia, Kutubdia, Moheshkhali, Saint Martin becoming vulnerable due to climate change (Tanim and Roy 2013). Nevertheless, these people do not migrate to mainland rather they migrate to intra-island among same Upazila or district. Because the new born islands facilitates several pull factors for the poor migrants such as, low land price, high fertility and productivity of agriculture lands, massive amount of unclaimed natural resources like timber or fisheries etc., sometimes incentives from the local government authorities and so forth. It is found from the studies that large number of migrants are shifting to Nijhum Dwip in spite of facing natural calamity like cyclone, river bank erosion, flood, storm surge, sea level rise, salinity intrusion etc. The migrants create many ways for living in this island and they are adapting with climate change induced hazards (flood, river bank erosion, storm surge, cyclone and sea level rise). This vulnerable people may be getting scope for living in this island for having livelihood assets (Physical, natural, human, financial and social).

A study on fishing community used livelihood assets for analyzing their resilience in Nijhum Dwip. The study depicted that natural asset is the most significant for fishermen resilience. The effectiveness of human, financial and social assets are moderately significant, where the physical asset is the least significant in fishermen resilience (Hossain *et al.* 2013). Warrick also added that people of Pacific islands inhabit in coastal areas due to the availability of natural resources for their livelihood and wellbeing (Campbell and Warrick 2014).

A very few studies have been done on migrant community of Nijhum Dwip and livelihood capital has hardly been exercised to perceive the adaptation of migrant community in this island. The study findings can improve our understanding of the issue of internal displacement in the country and might also add value to the existing knowledge products on climate change and disaster. This study can be an important document for policy makers, planners and government officials to take appropriate decision whether to relocate the vulnerable population to new places or retain them in their ancestral home through enhancing their resilience.

The specific objectives of the study are to find out the factors behind selecting Nijhum Dwip for migration and to identify the relatively prominent livelihood capitals to adapt in the island.

The present study was carried out on the migrant community of Nijhum Dwip island under Hatiya Upazila of Noakhali district in Bangladesh. It is Southern most island of Bangladesh that confluences of Meghna estuary of Bengal (South and West), the island is about 2.2 meters high from the sea level (Saha *et al.* 2014). Coastal area is very dynamic in nature. Nijhum Dwip is one of the timeworn islands where erosion and accretion simultaneously happen like other islands situated in the Meghna estuary. According to the satellite imagery the mudflat land is the most unstable and usually its movement is unpredictable. Data found from a study done by Hossain *et al.* (2016) the mangrove forest is decreasing while the homestead forest and cultivable lands are increasing which indicates that population settlement of Nijhum Dwip is growing over the year. Population of Nijhum Dwip increased to 12796 from 7835 in one decade commencing from 2001 (BBS 2011).

Materials and Methods

The study was conducted based on both primary and secondary data. Secondary data were collected from various published and unpublished sources for instance, journal, book, thesis paper and so on while interviews with migrant families using semi-structured questionnaires constitute the major source of empirical data. Information was collected from the household head. The total number of households in Nijhum Dwip are 2464 (BBS 2011). Maximum people live in the southern part of Nijhum Dwip. There is no available statistics how many families migrated to Nijhum Dwip. That is why 50 migrant families were taken from the southern part of Nijhum Dwip by using snowball sampling technique in order to know why they migrated to this island instead of main land and which assets helped them keep staying there. The families, migrated to this island at least before one year were selected for the survey. Livelihood capitals (Physical, natural, human, financial and social) from sustainable livelihood approach (SLA) provided by DFID (1999) has been taken to identify the comparative importance of these capitals in the form of adaptation in this island. The five components for each capital are decided by the author in order to fulfill the objectives. After having the collected data from the field, the surveyed information was examined and processed by using computer software SPSS (Spatial package for social science) while ArcGIS10.3.1 was used to produce the map of migrant's source to Nijhum Dwip and MS Excel was also used for making charts and diagrams. In addition, Adobe Photoshop and Illustrator software were used for preparing

pentagons of livelihood capitals. The relative importance scale (Table 1) was used in order to determine the priority for each criterion of livelihood capitals among migrant's community. The comparative significance of various indicators of capitals was calculated by the given value of the scale. No negative reply was given by the respondents regarding the importance of livelihood capitals. The total value of each criterion multiplied with the scale value and then divided by total number 50 and this result was shown in each pentagon of capitals. Thus from the average value of five capitals, final livelihood pentagon was produced.

Table 1. The relative importance of criteria (Assumed value by author).

Extreme	Very strong	Strong	Moderate	Neutral	Moderate	Strong	Very strong	Extreme
1/5	1/4	1/3	1/2	1	2	3	4	5
	Less importance					More importance		

Results and Discussion

Overall, there are many reasons why people migrate, where contemporary climatic events suggested as a key force towards more migration. The study also recognizes the same, explaining various losses of migrant's family due to natural disasters before their migration to Nijhum Dwip, which disaster mainly forced them to migrate, why they prefer Nijhum Dwip to settle there and from where they arrived in the island for living.

Losses of migrant families due to natural disasters before migration to Nijhum Dwip: People living in coastal and offshore islands of Bangladesh have been facing a problem of losing their homes and sources of livelihoods by natural hazards and are forced to move further into the sea (Siddiqui 2014). The Table 2 shows that before their migration, the migrant families were greatly affected by catastrophic disaster causes loss of homestead, infrastructure, agriculture land, crops, livestock, and employment which actually forced them away to Nijhum Dwip. As per study, cent per cent of the families lost their homestead and agriculture land, 96% families lost their crops, 92% hampered infrastructure and livestock for each and 30% lost their employment due to disaster.

Influential climatic events behind migration to Nijhum Dwip: In 1990, the Intergovernmental Panel on Climate Change (IPCC) noted that the greatest single impact of climate change could be on human migration with millions of people displaced by shoreline erosion, coastal flooding and agricultural disruption (Brown 2008). Extreme climate events like floods, cyclones and tidal surges, as well as gradual impacts of

climate change like salinity or river erosion cause climate induced migration (Anwer 2012). The findings of the study show that most of the families (84%) displaced to Nijhum Dwip due to river bank erosion and 10% families migrated due to cyclone and only 6% families shifted because of flood disaster (Table 3).

Table 2. Losses of migrant families due to natural disasters before migration to Nijhum Dwip.

Losses	N = 50 (%)	Losses	N = 50 (%)
Homestead loss	50 (100)	Crops Loss	48(96)
Infrastructure loss	46 (92)	Livestock Loss	46(92)
Agriculture land loss	50(100)	Employment Loss	15(30)

Source: Field survey, 2017 parenthesis shows the percentage.

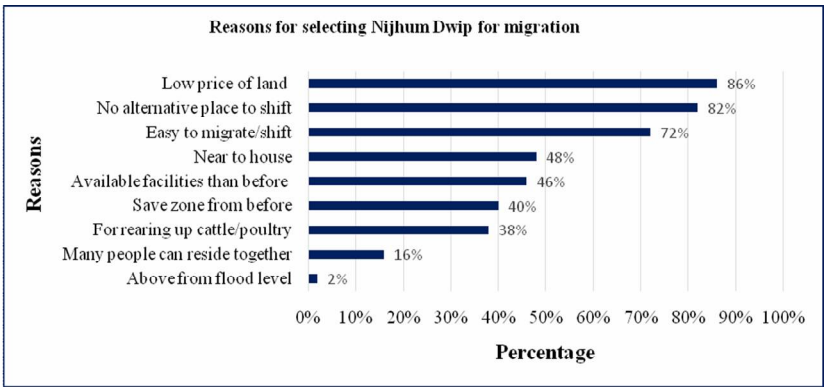
Table 3. Influential climatic events behind migration to Nijhum Dwip.

Name of disaster	Percentage
River bank erosion	84
Flood	10
Cyclone	6
Total	100

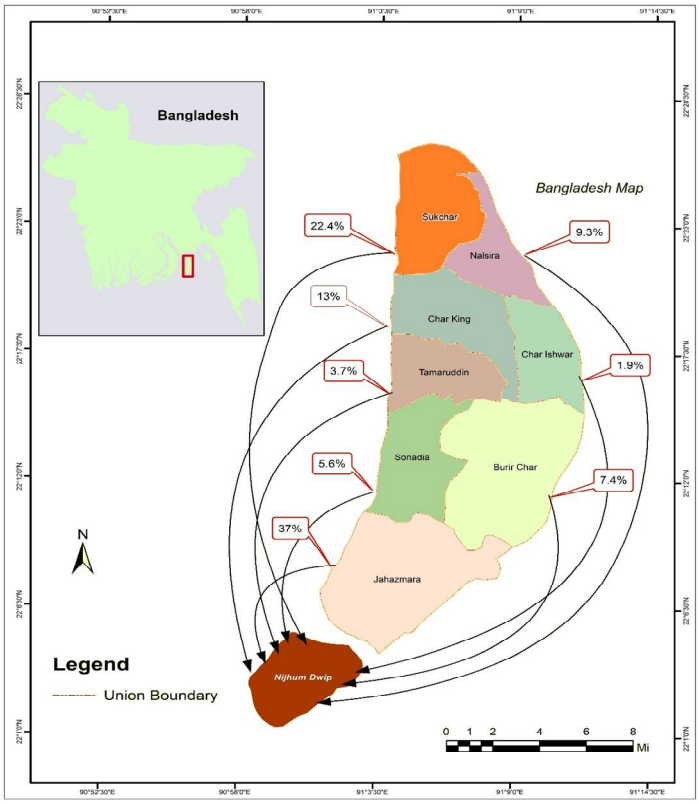
Source: Field survey, 2017.

Reasons for selecting Nijhum Dwip for migration: The study reveals that most of the families (86%) migrated to Nijhum Dwip considering the low price of land, 82% families shifted because they have no alternative place to go, 72% mentioned the area is easy to migrate and the other motives to move this island were followed by near to house (48%), available facilities (46%), save zone from before (40%), rearing up cattle (38%) and very few of them recognized that they can reside together (16%) and only 2% of them said the area is above from flood level (Fig. 1).

Source of migration: The Map 1 demonstrates the origin place of migrant families. It is evident that the migrants were mainly from the neighbouring area of Nijhum Dwip specially from the different unions of Hatiya Upazila, but they came from northern part of Hatiya upazila to Southern most part of the Upazila called Nijhum Dwip which is towards the sea. Most of the respondents (37%) migrated from Jahajmara union, about 22% from Sukh char, 13% from Charking, 9.3% from Nalsira, 7.4% from Burir char, 5.6% from Sonadia union and followed by approximately 4 and 2% migrated from Tomuriddin and Char Ishwar, respectively.



Source: Field survey, 2017
Fig. 1. Reasons for selecting Nijhum Dwip for migration.



Source: Author's Field Survey, 2017
Map 1. Source of migration.

Relative importance of livelihood capitals for adaptation of migrant community of Nijhum Dwip: The livelihood capitals (physical, natural, human, financial and Social) are taken from sustainable livelihood approach (SLA) provided by DFID (1999). The components of each capital comprise, Human capital (education, ecological knowledge, good health, mental strength, disaster management training), financial capital (cash savings, livestock, credit, wage/income, fisheries), natural capital (house steward, garden, wood/fruits, pond, agriculture), physical capital (house structure, sanitary latrine and tube well, electric line, road, cyclone shelter), social capital (social harmony, religious bond, neighbor co-operation, union parisad, co-operative association).

Human capitals: Among the criteria of human capital, it is found that education placed first with score 4.8 within 5 whereas the respondents acknowledged mental strength second with score 4.1 and followed by ecological knowledge, disaster management and good health with score 3.8, 3.7 and 3.1, respectively as the essential human capital for adaptation against climatic events in Nijhum Dwip.

Financial capitals: The Fig. 3 reveals that most important financial capital is cash savings (score 3.3) for coping in this island. The respondents recognized wage/income second with score 3.2 and credit and livestock (3.1) for each, fisheries (3) are also considered as important financial capital for coping with disasters in the area.

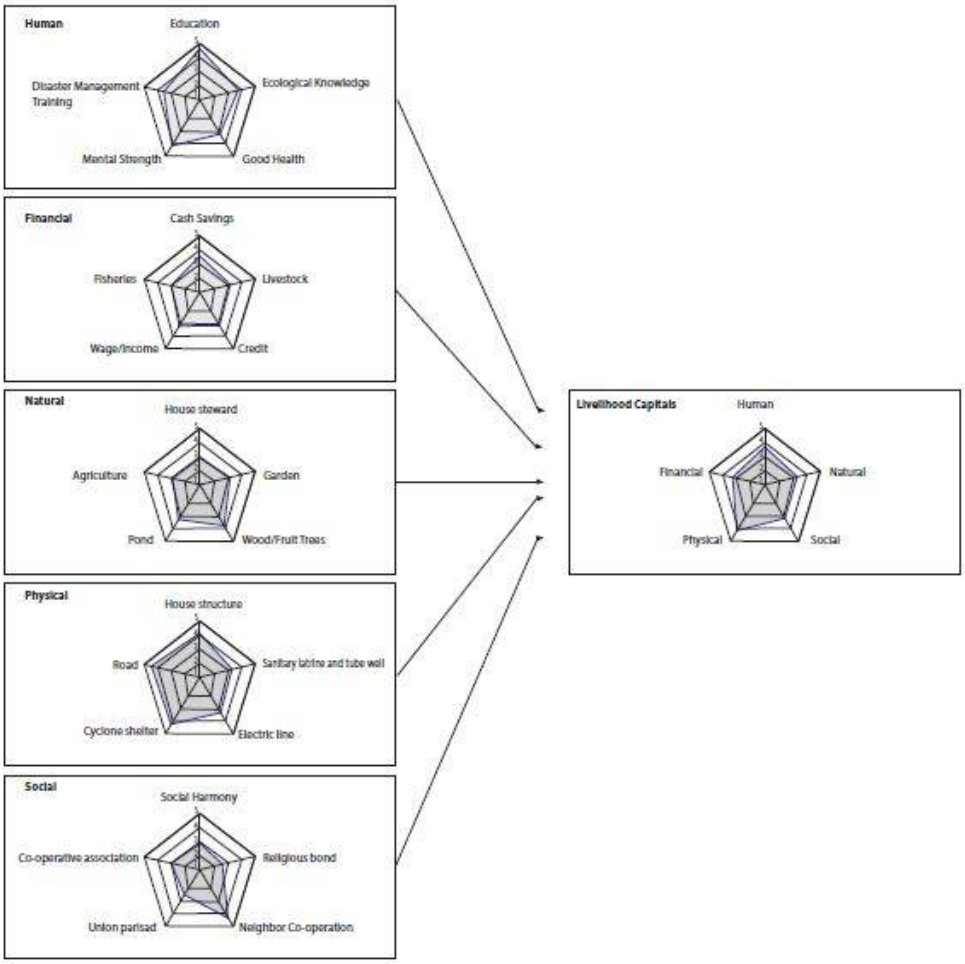
Natural capitals: It is evident from Fig. 3 that wood/fruit tree status first with score 3.9 within 5. To the respondents pond is the second natural capital (3.3) and followed by garden, house steward and agriculture stood next position with score 3.1, 2.9 and 2.8, respectively as the way of adjustment in the island.

Physical capitals: Maximum respondents of the study opined road (with score 4.3) is the most important physical capital. They stated cyclone shelter is second with score 4.2 and house structure (4.1), sanitary latrine (3.3) and tube-well (3.2), as the essential physical capitals to settle in Nijhum Dwip.

Social capitals: Regarding social capitals, most of the respondents mentioned neighbor cooperation is the most significant asset with score 4.3 within 5. They mentioned co-operative operation (with score 3) is second important social capital and followed by social harmony, religious bond, union parisad with score 2.9, 2.4 and 2.3, respectively as the way of alteration for staying in the island.

Livelihood capitals: Among five livelihood capitals, it is found physical capital is the most significant livelihood capital with score 4.1 within 5. The respondents admitted human capital second with 3.8 and followed by natural, financial, social capital scored

3.3, 3.2 and 3.1 respectively were considered as important livelihood capitals for adapting with climatic hazards in Nijhum Dwip.



Source: Field survey, 2017.

Fig. 3. Relative importance of livelihood capitals for climate change adaptation of migrants community of Nijhum Dwip.

Conclusion

The study identified significant findings according to the objectives. As we know coastal areas are one of the most vulnerable places due to natural hazards so people need to migrate in search of alternative livelihoods. In most cases the destinations of such

displaced people are the nearest urban area. However, the people of coastal region are not moving to better place for their economic insolvency rather they shift to new born island towards the sea. Before their migration most of the migrant families lost their homestead, crops, livestock and even job that is why they decided to migrate for different existing. River bank erosion was the prominent disaster to force them away from the place of origin. The respondents acknowledged the low price of land (86%), no alternative place (82%), easy to shift (72%) as the major factors behind choosing Nijhum Dwip for settling there. The migrants were mainly from the neighboring area of Nijhum Dwip such as Jahajmara (37%), Sukhchar (22.4%), Nalchira (9.3%) and so on.

Regarding relative importance of livelihood capitals the respondents admitted physical capital as the most important asset followed by human, natural, financial and social capital are also considered as significant livelihood capitals for adjusting in this island.

The findings of the study can contribute to add value to the existing knowledge on migrant community of Nijhum Dwip and their adaptation strategy. This study might be a significant document for policy makers, planners and government officials to take suitable solution either relocate the vulnerable people or retain them in their origin by enhancing their resilience.

References

Anwer, S. 2012. Climate Refugees in Bangladesh: Understanding the Migration Procss at the Local Level. *Diakonisches Werk der EKD e.V,* Germany.

Barman, S.D., S.C. Majumder, M.Z. Rahman and S. Sarker. 2012. Foundations of migration from the disaster consequences coastal area of Bangladesh. *Developing Country Studies* **2**(4).

BBS. 2011. Population Census of Hatiya Upazila.Bangladesh Bureau of Statistics,Dhaka.

BBS. 2011. Population and Housing census 2011. Bangladesh Bureau of Statistics, Dhaka.

Brown, O. 2008. Migration and Climate Change. *International Organization for Migration.* Geneva. Retrive From June 12, 2017, http://www.iom.int

Campbell J. and O. Warrick. 2014. Climate Change and Migration Issuses in the Pacific. United states: United Nations Economic and Social Commission for Asia and the Pacific.

DFID. 1999. Sustainable Livelihoods Guidance Sheets. *Department for International Development.*

IOM. 2008. World Migration Report 2008: Managing Labour Mobility in the Evolving Global Economy. *IOM ONLINE BOOKSTORE,Geneva.* 562 pp.

IPCC. 2014. Climate change 2014. Impacts, Adaptation and Vulnerability. Summary for Policymakers.Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. pp.1-32.

Hossain, K.T., I.A. Tanim and M. Saluddin. 2016. Change Detection of Forest Cover : A study Nijhum Dwip Natioal, Park,Hatiya, Noakhali. *Journal of Life and Earth Sciences, Jagannath University* **2**(2): 54-90.

Hossain, M.S., S. Thompson, M.R.U. Nabi and M.M. Kibria. 2013. Climate change resilience assessment using livelihood assets of coastal fishing community in Nijhum Dwip, Banglades. *Pertanika Journal of Science & Tecnology* **21**(2): 397-422.

Pascoe, S. 2015. Sailing the Waves on Our Own: Climate Change Migration, Self-Determination and the Carteret Islands. *QUT Law Review* **15**(2): 72-85. Retrived From June 15,2017 doi: 10.5204/qutlr.v15i2.610

Rayhan, I. and U. Grote. 2007. Coping with floods: Does rural-urban migration play any role for survival in rural Bangladesh?. *Journal of Identity and Migration Studies* **1**(2): 82-98.

Saha, P.K., M. Bodiuzzaman, M.N. Uddin, M.N. Hossain and A.S. Shanta. 2014. A Study on the management strategies of protected area in Bangladesh for biodiversity conservation on Nijhum Dwip, Noakhali, Bangladesh. *International Journal of Innovative Research and Development* **3**(7): 140-148.

Siddiqui, M.R. 2014. Patterns and factors of out-migration in the Meghna estuarine islands of Bangladesh. *Malaysian Journal of Society and Space* **10**(1): 11-24.

Stojanov, R., I. Kelman, AKM. Ullah, D. Procház, Duží, D. Procházka and K.K. Blah˚utová. 2016. Local expert perceptions of migration as a climate change adaptation in Bangladesh. *Sustainability* **8**(12): 1223 Retrieved From June 12, 2017 doi:10.3390/su8121223

Tanim, S.H. and D.C. Roy. 2013. Climate Induced Vulnerability and Migration of the People from Islands of Bangladesh: A Case Study on Coastal Erosion of Kutubdia Island. Planned Decentralization : Aspired Development. World Town Planning Day 2013.

Torresan, S., A. Critto., M.D. Valle, N. Harvey and A. Marcomini. 2008. Assessing coastal vulnerablility to climate change: Comparing segmentation at global and regional scales. Sustainability science. *Copernicus Publications on behalf of the European Geosciences Union.* **3**(1): 45-65. Retrived From August 15, 2017, http://www.nat-hazards-earth-syst-sci.net/12/2347/2012/

(Revised copy received on 8.7.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 137-148, December 2018

DELINEATING THE SERVICE AREA OF CYCLONE SHELTER AND VULNERABLE HOUSEHOLDS USING NETWORK ANALYST TOOL: A CASE STUDY ON SOUTHKHALI UNION OF BAGERHAT DISTRICT, BANGLADESH

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Abstract

In Southkhali Union of Bagerhat district in Bangladesh about 47% of the total population is living beyond the service area of cyclone shelters (CS) not only for the carrying capacity of CS but also for the accessibility. Location-allocation tool of Network Analyst tool in ArcGIS determined the service area of each CS in the study area based on its shelter capacity and accessibility. People residing outside the service area of cyclone shelter are highly vulnerable due to low elevation of land and poor housing structure. The location-allocation tool of Network Analyst provided the proper evacuation plan that would identify the shelter location for each household or cluster of population and the evacuation route also. It would also help to find the proper location to build new shelters for unserved community.

Key words: Accessibility, Network analysis, Service area, Vulnerable households, Location-allocation tool

Introduction

Bangladesh is the sixth most disaster prone countries of the world where 97.7% of the total population of 97.1% area are at risk of multiple natural calamities including cyclones (World Bank 2015). Cyclone and storm surge are the most devastating among all the disasters in Bangladesh which devastates lives and properties in coastal areas. Geographic location, the unique natural setting of the country and its tropical monsoon climate make the country more vulnerable to cyclones and storm surges (Paul 2009). Nearest position from equator, warm oceanic temperature, presence of high vertical wind, low pressure areas, easterly wind in the Bay of Bengal are the significant factors that causes to form cyclone. On the other hand, coastal zone is mainly low-lying with 62% of the land having an elevation less than 3 meters and 86% less than 5 meters from the mean sea level (MSL) (CDMP 2009). Since 1960 most of the coastal areas are protected by embankments and polders which protect the coastal communities from tidal surge.

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During the last 100 years, Bangladesh has experienced 53 major cyclones (Ahamed *et al.* 2012). Historically major cyclones hit the coastal areas of the country in 1970, 1991 and 2007. In cyclone SIDR [1](2007), the number of human death was 3,363 and in AILA[2] it was 190 (GoB 2008). It is to be mentioned that Government of Bangladesh (GoB) and NGOs have taken initiatives in coastal areas to reduce the risk of human life and properties. A large number of people who are living outside or near to embankments still are vulnerable to storm surge and cyclone. Frequent attack of cyclone in last 2 or 3 decades and disaster preparedness program of GoB and NGOs raise the awareness level of communities during the disaster period. Though the community people prepared to move, they do not know which cyclone shelter (CS) they should go. As part of disaster preparedness, people should be evacuated to the shelters or safe locations before the cyclone or storm surges stuck. So service area delineation of each CS and determination of the appropriate CS for each house would help to evacuate the people on time.

Accessibility is an attribute of people (and goods) rather than transport modes or service provision, and describes integrated systems from a user viewpoint (Halden *et al.* 2005). There are three primary components that make up accessibility. Accessibility means the easiest or shortest way to move from one place to another. It can be defined as the ease with which activities at one place may be reached from another via a particular travel mode (Liu and Zhu 2003). In the context of health care, accessibility is viewed together with a set of more specific areas of fit between the patient and the health care system-specifically availability, affordability, accommodation and acceptability (Penchansky and Thomas 1981). Measured straight-line distances, driving distances and time method used by Al-Taiar *et al.* (2010) for vaccination facilities development under Yemen and all three measures showed strong association with vaccination of children after adjusting for socio-economic status. Measured distance method used between patient and facility's zip codes in Michigan for patient management Lin *et al.* (2005) where similar differences observed between revealed and potential access in both rural and urban areas. In a word, accessibility can be determined by its route or path of origin to destination and mode of communication which usually better understand with network analysis. Network usually means a set of connected lines. It can represent the river, road, rail line or even telecommunication lines. Network analysis has a strong theoretical basis in the mathematical disciplines of graph theory (Curtin 2013). Network analysis consists of a set of techniques for modeling processes that occur on networks. The network analysis

[1]SIDR a severe tropical cyclone hit Bangladesh on 15 November, 2007.
[2] AILA a severe tropical cyclone hit Bangladesh on 27 May, 2009.

can be able to perform three tasks: locations on networks, routing across networks, and network flow analysis.

Along with the accessibility and communication status, readiness of community to receive a service is very important to determine the boundary of a service area. Parker and Campbell (1998) used calculated network distance for accident and emergency services phenomena and findings suggest that the majority of patients choose medical practices near their home which is geographically closest to their home address. Luo and Wang (2003) developed two-step floating catchment area and gravity based method for primary health care in Chicago. This method was simpler and easier to interpret and used for improving the designation of health professional shortage areas. Couple of studies on people's behavior on moving towards a CS in coastal area of Bangladesh have found that both physical and social barriers may impede their movement. During cyclone, most of the people who were within a range of 1 mile (1.6 km) took safer shelter and all of them have reached there on foot (Paul and Routray 2011). Paul and Routray (2013) found in their study that major causes of refuge in cyclone shelters were poor road communication and also the low capacity of cyclone shelters. Both of the study suggested that during the construction of new CS, maximum coverage should be considered to maximize the coverage of future CS. Eklund and Martensson (2012) used GIS application to analyze accessibility of health services where GIS and network analysis were used to generate different estimations of accessibility based on the existing road network and transport barriers. The study analyzed the service area in three scenarios - worst case, present situation and best case. In the study, worst case considered when all checkpoints, road gates and barriers closed; present situation considered as all checkpoints and some road gates open but barriers closed; best case considered when all checkpoints, road gates and barriers were removed.

Vulnerable households indicate the people living in houses that are exposed to cyclone or storm surge. In other it can be said that the houses which would be damaged in worse level due to weak design and closeness to river or sea. In coastal Bangladesh most of the houses are poorly constructed as the people are living with hardship. To understand the effectiveness of cyclone shelters Quader and Mahbub (2012) conducted a study. The study attempted to determine the appropriate location of cyclone shelter along with evacuation plan for existing CS in coastal area and finally formulate a policy guideline for managing cyclone shelters and locating future shelters. According to the study most of the population is out of shelter coverage.

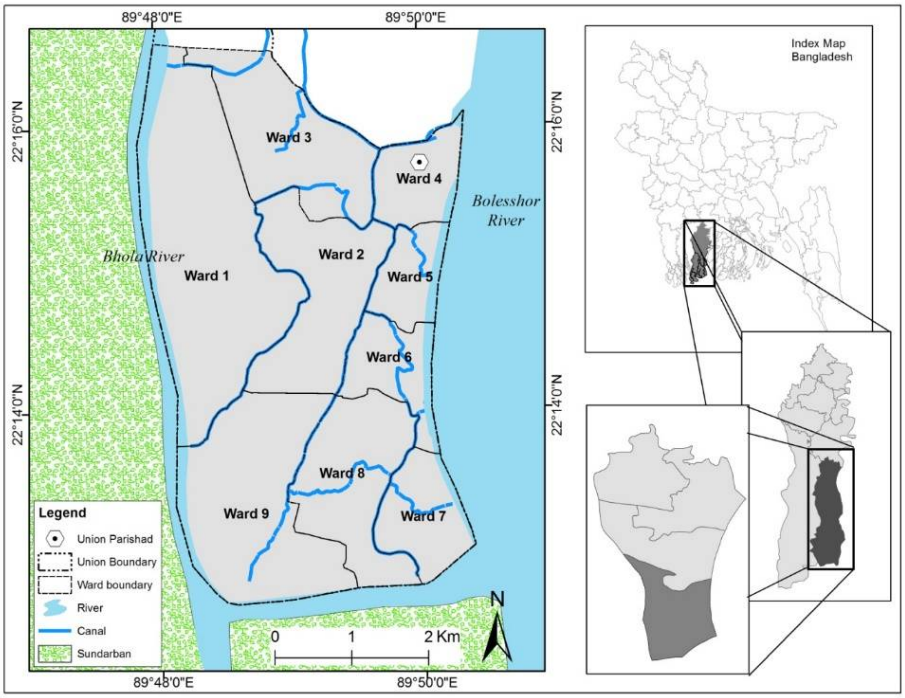
Reviewing cyclone shelter related articles and documents it can be said that very few attempts were made to determine the service area of cyclone shelter. Though CDMP determined the catchment area or service area considering population distribution uniformly in the ground and also not considering physical barriers i.e. canal, pond or crop land etc. This particular paper tries to delineate the boundary of each CS according to carrying capacity of each CS, household level population and detail road network data were analyzed. GIS techniques have the capability to determine the service area of cyclone shelter. The study demonstrated how network analysis of GIS resolves the service area of a CS in capacity constraints and physical barriers. GIS Networks are widely used for usually two kinds of modeling (transportation network and utility network). Network analyst can simply determine the quickest way to reach from one point to another. Location-allocation analysis, a tool in the ArcGIS Network Analyst extension, determines an optimal location for one or more facilities that will service demand from the surrounding population. The major objectives of this study were to:

- delineate the service area of each CS based on its accessibility and capacity,
- find out the nearest accessible CS from each settlement and
- identify the vulnerable households which are beyond the service area of CS.

Profiling study area

Southkhali Union is located in Sarankhola Upazila of Bagerhat District. The union is surrounded on the north by the Royenda Union, on the south by the Sundarbans, on the east by the Baleswar River and on the west by Bhola River and also the Sundarbans. The area is located between 89°48'01"E and 89°50'30"E longitude and 22°17'01"N and 22°13'30"N latitude. The total area of the union is 36.88 sq. km. There are many canals flowing over the villages. According to the Census 2011, the total population of the Union was 24,980 (BBS2011). The economy of Southkhali Union is predominantly agricultural. Its economy is also dependent on the Sundarbans, rivers and Bay of Bengal. The literacy rate in this Union is 54.75%. About 24% people live under the poverty line (BBS 2011). While only 7.26 % households are connected with electricity. The elevation of the Union varies from 1 - 3 m above the mean sea level (MSL). This Union experienced hazard in different times. Cyclone and flood are common hazards in the study area. People of this Union are affected severely by cyclone SIDR and AILA. There are 27 CSs in 23 locations. The total capacity of cyclone shelter is 11,050. Among the 27 CSs, LGED (Local Government Engineering Department) have made 13 CSs. A leading NGO Karitas has made five cyclone shelters and Ashroy Foundation constructed three cyclone shelters. Other cyclone shelters were constructed by World Bank, BRAC, Islamic

Relief, Prodipon, Shusilon and Bangladesh Army. Among the cyclone shelters, 22 shelters have management committees. Community and NGO are the members of the committee. In the study area, total length of road network is 89.36 kilometers. Most of the roads are *katcha*. The percentages of pucca, herringbone and *katcha* road are, respectively 9.3, 24.22 and 66.44%. Southkhali Union is one of the most vulnerable Union because of its low elevation, exposure to the mighty Boleswar River and poor communication with the Upazila headquarter. Sarankhola was worse victim of cyclone SIDR as the highest number of people killed in this Union among the Unions. Considering these issues, Southkhali Union was selected as our study area.



Source: LGED & Field Survey, 2014.

Fig. 1. Southkhali Union (Study area).

Methodology

In case of CS route only road network would be considered as because during a cyclone all other communication are not useable. Network analysis could measure the accessibility of a particular service or a point from another point. Locational barrier like

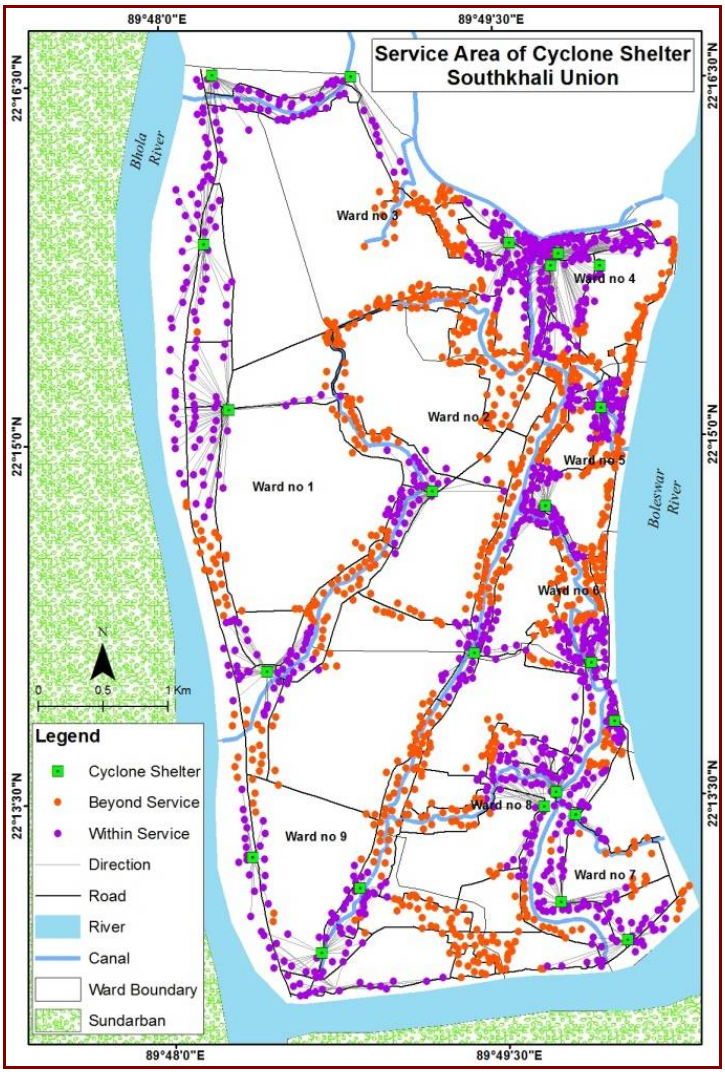
river is considered as a contributing factor towards dithering in response to cyclone warnings in the study.

Source: Field Survey, 2014.

Fig. 2. Settlement pattern of the study area.

Data collection: Data have been collected from both primary and secondary sources. Different tools and techniques were applied to collect data (primary data) from field survey. Location of cyclone shelter, household and other important structures were collected from GPS survey. Detail road network along with the physical condition (Pucca, herringbone or Katcha) recorded through GPS survey using tracking option. To identify the important features like pond, canal, bridge with its physical conditions

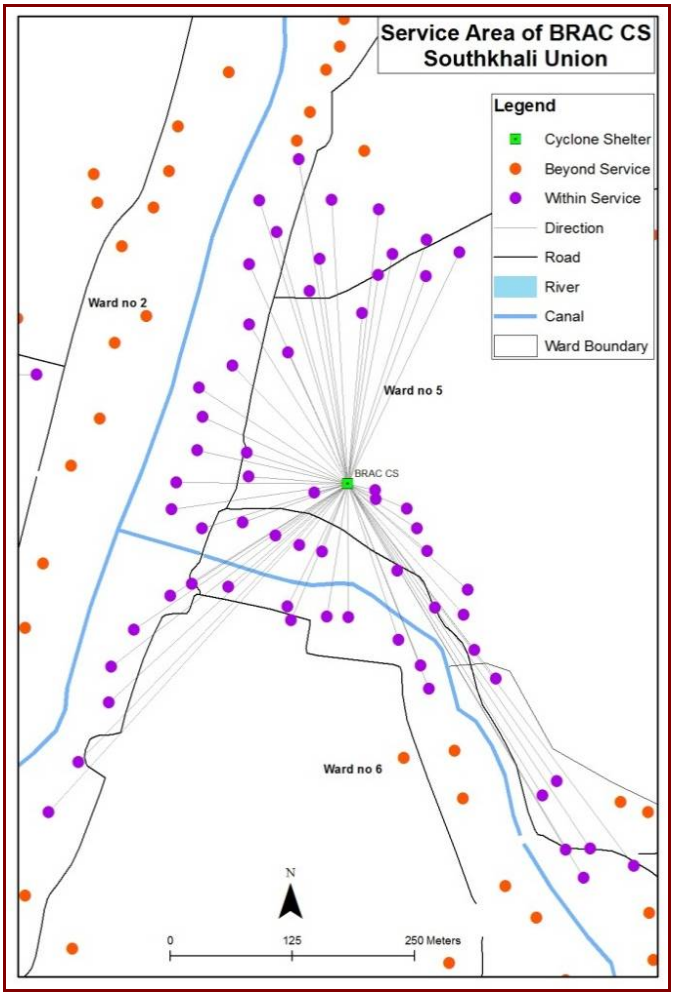
Google earth Image was used. Other qualitative information i.e. capacity of cyclone shelters, condition, water and sanitation facilities of cyclone shelters etc. were collected from secondary sources (i.e. NGOs, Red crescent, related government offices). Administrative boundary of the study area collected from Local Government Engineering Department (LGED). Information about house like owner name, number of family members, housing structure etc. was collected through field survey.



Source: Field Survey, 2014.

Fig. 3. Service area of all cyclone shelters in the study area.

Georeferencing (data preprocessing) and digitizing: To prepare a spatial database (shapefiles and geodatabase) GIS and statistical software were deployed. In the first step value from the GPS are downloaded to PC using DNRGPS software that convert the GPX file to shapefile format. To digitize the physical features of the area satellite image was downloaded in JPEG format from Google earth which was not geographically referenced. Those images were georeferenced using georeferencing tools of ArcGIS10.3.



Source: Field Survey, 2014.

Fig. 4. Service area of BRAC CS.

Information of images was captured through digitization process. The projected value is "WGS 1984 UTM Zone 45N". On the other hand, the information collected in checklist were input into PC using MS excel. Finally the tabular information joined with the shapefile based on location. After completion of data capture, all the shape files were converted to geodatabase. The primary purpose for organizing related feature classes into a common dataset was for building a topology and a network dataset.

Data analysis: The data analysis was integrated with network analysis and statistical analysis for delineating service area through various datasets. Location-allocation tool of network analyst was used to resolve the service area. Location-allocation helps to choose which facilities from a set of facilities to operate based on their potential interaction with demand points. To identify the vulnerable population in case of extreme cyclone event only CS were considered as safe location.

Results and Discussion

The settlement pattern of the study area is linear. Linear settlement patterns are generally associated with linear feature, either natural or constructed. Roads and rivers have influenced on settlement pattern. Fig. 2 shows that in the study area, Settlements are growing along the roads or the river/canal to avail better communication and availability of water. Most of the fishermen are living in just beside the eastern embankment, and along the western embankment, most of the people collect resources from Sundarbans.

In the study area, population concentration is increased from southern to northern direction. The highest density of population is found in Ward nos. 4 and 6.

Service area: When signal no. 6 is given, people must take safe shelter. In this worse scenario, any kind of transport cannot be used without walking. Several studies reveal that in extreme situation usually people are notable to or willing to walk more than 30 minutes. In this study, more than 80% inhabitants opined that more than 30 minutes is not possible for them to walk during cyclone. It is calculated that in 30 minutes they are able to cover 1 km. So the travel time is considered as 2 km per hour in an average. Capacity of CS is also an important factor in this analysis. Because all the people in 1 kilometer distance may not take shelter in cyclone shelter due to low capacity. After analyzing the data, it was found that 52.73% of total people can be evacuated during an emergency in cyclone shelter.

Vulnerable households: In the study area, most of the houses are Katcha. But the number of tinshed and Jhupri is also high. About 59.12 per cent of total settlement is Katcha. The

percentage of Jhupri, tinshed, semi-Pucca and Pucca are 2.84, 28.67, 4.27 and 5.08, respectively. In this study, vulnerable households are those which are beyond the service area where nearly 10,000 people resided. Housing structure is an important factor to analyze vulnerability. Figs. 3 and 4 showed the location of vulnerable households. The study finds that overwhelming majority (93%) of vulnerable households are living in Katcha, tin shed or Jhupri houses. From the previous experience of cyclone, the southern population of the union are the most vulnerable. The study found that insufficient and poor communication system make the situation worse. A cluster of people in western part are living outside the embankment are living dangerously. From the experience of SIDR most vulnerable households are located just beside the embankment of Boleswar River. Analysis showed that a large portion of vulnerable households are located inside the embankment area.

Conclusion and recommendation: In this study, the assessment of CS's service area was based on allocation of population in different shelters for evacuation and people's accessibility based on communication network. Using GIS and RS techniques, the distribution of households, location of CSs and communication networks were recorded. Unique ID was developed for each household and also for the CS. The location-allocation tool of ArcGIS determined the service area of CSs. Designated household with unique ID was assigned for particular CS. According to the study, about 47% of the total population is living beyond the service area of cyclone shelters (CS) not only for the carrying capacity of CS but also for the accessibility. So it can be said that nearly half of the total population is vulnerable to cyclone and storm surge. From field survey it is found that most of the people do not know which particular shelter would be more accessible or suitable for them. On the other hand, volunteers do not have appropriate emergency evacuation plan.

Using GIS for evacuation plan and establishment of new cyclone shelter would reduce the risk of coastal communities. Location-allocation tool of ArcGIS would provide the appropriate location for new shelters. Proper evacuation plan is essential during an emergency which needs a detailed database of population, household location, infrastructures including road network and other important utilities. During Household Census GPS location of each household can be recorded which will be linked with population afterward. The system has been organized in such a way that, any changes, addition, removal or increasing of shelter capacity could be done very easily at Upazila level by Upazila statistics office. Local Government Engineering Department (LGED) collects infrastructural information at regular basis. The Disaster Management Information Centre (DMIC) under the Ministry of Disaster Management (MoDM) can

compile both databases in GIS format. From the database it is possible to determine the service area of CSs is essential for evacuation planning and shelter management practices. According to the service area generated by location allocation tool of ArcGIS, DMIC would prepare the evacuation plan for emergencies and circulate the plan at Upazila level. Upazila office will implement the plan at local level. Thus the GIS would be the best practiced tool for saving life from cyclone and storm surge.

References

ADAB (Association of Development Agencies in Bangladesh) 1992. *The 1991 Apocalypse role of NGOs in emergency cyclone relief*. ADAB, Dhaka.

Ahamed S., M. M. Rahman and M. A. Faisal. 2012. Cyclone impacts in the coastal areas of Bangladesh: A case study of Kalapara Upazila, *Journal of Bangladesh Institute of Planners* **5**:185-197.

Al-Taiar, A., A. Clark, J. C. Longenecker, and C. J. Whitty. 2010. Physical accessibility and utilization of health services in Yemen. *International Journal of Health Geographics* **9**(1): 38.

BBS 2011. Population and Housing Census 2011. Dhaka:BBS.

CDMP 2009. *Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness -2009*.

Comber, A., C. Brunsdon, J. Hardy, and R. Radburn. 2009. Using a GIS-Based network analysis and optimisation routines to evaluate service provision: A case study of the UK post office. *Applied Spatial Analysis and Policy*, **2**(1): 47-64.

Curtin, M. 2013. Network analysis in geographic information science: Review, assessment and projections.*Cartography and Geographic Information Science* **34**(2).http://www. tandfonline. com/doi/abs/10.1559/152304007781002163.

Department of Disaster Management 2013. *Emergency Preparedness Plan for Cyclone*. MoDMR, GOB.

Eklund, L. and U. Martensson, 2012. Using geographical information systems to analyse accessibility to health services in the West Bank. *Occupied Palestinian Territory* **18**(8)796-802**.**. https://www.ncbi.nlm.nih.gov/pubmed/23057367

GOB 2008. *Cyclone SIDR in Bangladesh: Damage, Loss, and Needs Assessment for Disaster Recovery and Reconstruction*.

Habib, A. 2009. Early Warning System for Severe Thunder Storms in Bangladesh. *International Forum on Tornado Disaster Risk Reduction for Bangladesh*. Dhaka, Bangladesh.

Halden, D., P. Jones and S. Wixey. 2005. Measuring Accessibility as Experienced by Different Socially Disadvantaged Groups, DHC Consultancy. *Edinburgh and Transport Studies Group, University of Westminster*. UK.

LGED (Local Government Engineering Department) 2014. Digital Map. http://www.lged.gov.bd/ ViewMap.aspx.

Lin, S. J., S.Y. Crawford, and J.W. Salmon. 2005. Potential access and revealed access to pain management medications. *Social Science & Medicine* **60**(8): 1881-1891.

Liu, S and X. Zhu. 2003. An integrated GIS approach to accessibility analysis. *Transactions in GIS.* **8**: 45-62.

Luo, W. and Wang, F. 2003. Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design* **30**(6): 865-884.

MoDMR 2009. *Catchment Area and Evacuation Route Mapping, Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness*.

MoFDM 2008. *Super Cyclone SIDR 2007: Impacts and Strategies for Interventions*. Ministry of Food and Disaster Management. GOB.

Nappi, M. M. L.and J. C Souza. 2015. Disaster management: hierarchical structuring criteria for selection and location of temporary shelters. *Natural Hazards* **75**(3): 2421-2436.

Parker, E. B. and J.L. Campbell. 1998. Measuring access to primary medical care: some examples of the use of geographical information systems. *Health & Place* **4**(2): 183-193.

Paul, B.K. 2009. Why relatively fewer people died? The case of Bangladesh's Cyclone SIDR. *Natural Hazards* **50**(2): 289-304.

Paul, S. K. and J. K. Routray. 2011. Household response to cyclone and induced surge in coastal Bangladesh: Coping strategies and explanatory variables. *Natural Hazards*, **57**(2): 477-499.

Paul, S. K. and J.K. Routray. 2013. *An Analysis of the Causes of Non-Responses to Cyclone Warnings and the Use of Indigenous Knowledge for Cyclone Forecasting in Bangladesh*. *In:* W. Leal Filho 2013. (ed.), Climate Change and Disaster Risk Management, Climate Change Management, Springer-Verlag, Berlin, Heidelberg.

Penchansky, R. and J.W. Thomas. 1981. The concept of access: Definition and relationship to consumer satisfaction. *Journal of Medical Care* **19**(2): 127-40.

https://www.ncbi.nlm.nih.gov/pubmed/7206846

Quader, M. A. and AQM, Mahbub. 2012. Location analysis of cyclone shelters in the coastal belt of Bangladesh. *Journal of Science* **1**(1).

Saha, C. K. 2015. Dynamics of disaster-induced risk in southwestern coastal Bangladesh: an analysis on tropical cyclone AILA 2009. *Natural Hazards* **75**(1): 727-754.

Walker, R. E., J. Block and I. Kawachi. 2014. The spatial accessibility of fast food restaurants and convenience stores in relation to neighborhood schools. *Applied Spatial Analysis and Policy* **7**(2): 169-182.

World Bank. 2015. *Bangladesh Country Snapshot, The World Bank Group.*

Zhen, Chao. 2013. *Geo-spatial modeling for competition-based accessibility to job location for the urban poor: Case study in Ahmedabad*. MS Thesis, Faculty of Geo-Information Science and Earth Observation, University of Twente. Netherlands.

(Revised copy received on 20.9.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 149-158, December 2018

AN ANNOTATED AVIFAUNAL CHECKLIST OF THE SAINT MARTIN'S ISLAND OF BANGLADESH

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Abstract

Despite being an Ecologically Critical Area (ECA) and a key attraction place for its uniqueness and unique bird fauna to the bird watchers and researchers, a method-based, scientific checklist on the avifauna of the Saint Martin's Island is still lacking. This study was attempted to fill in this gap and produced an annotated bird checklist for the St. Martin's island. A total of 112 species of birds belonging to 36 families under 15 orders was listed. Of these, 37 (33%) species were passerine and 75 (67%) species were non-passerine. Eleven (9.82%) species were found to be very common, 12 (10.72%) species common, nine (8.04%) species uncommon and 80 (71.43%) species rare.

Key words: Avifauna, Transect line, Shoreline, Saint Martin's Island, Checklist

Introduction

Birds are one of the key indicators that play an important role in the food web of an ecosystem (Zöckler 2005). In an ecosystem, birds represents almost all the functional groups that can help to keep all processes going and have the potentials to send important messages on the state of the environment (Zöckler 2005). As found in every ecosystem, birds are highly susceptible to any changes in the habitat they live in, and hence, are good biological indicators and are used in bioassays (Ahsan and Khanom 2005). Regular assessment of the avifaunal status of an ecosystem, therefore, can help to interpret the biological health of that ecosystem.

Bangladesh is a small country of 147,570 square km (Khan 2008). It has a rich biological heritage due to its geographical location between the two major biotic sub regions of the Oriental Region: The Indo-Himalayas and Indo-China (Khan 2008). A total of 138 mammalian species, 566 birds, 167 reptiles and 49 amphibians are reported to occur in Bangladesh (IUCN Bangladesh 2015). In addition, Bangladesh lies at the junction of the Central Asian and East Asian-Australasian flyways (routes that shorebirds use during their migration from the breeding to non-breeding grounds), offering key wintering and staging grounds to numerous migratory waders many of which are of international conservation concern (Chowdhury 2011).

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The Saint Martin's Island is a unique habitat in Bangladesh because it is the only place where coral colonies are found. It has been recognized as an Ecologically Critical Area (ECA) by the Government of Bangladesh in 1999 (DoE 2015) and an important stepping stone along the migration route of many globally concerned migratory birds (BOBLME 2015). Rare bird like Pacific Reef Egret (*Egretta sacra*) and Rosy Starling (*Pastor roseus*)is also found here (Chowdhury 2016, The Daily Star 2010) and an attractive destination for bird watchers. Besides, all five species of marine turtle (including three globally threatened species) known to occur in Bangladesh have been reported from this area (Rashid and Islam 2005). St. Martin's Island is not only significant for its biodiversity value, but also important for Bangladesh in defining its exclusive economic zone and delineating its sea boundary in accordance with the United Nations Convention on the Law of the Sea (Thompson and Islam 2010). However, unregulated tourism, local population explosion and their unsustainable extraction of natural resources have become a great threat to the stability of this ecosystem (Thompson and Islam 2010).

Despite being an Ecologically Critical Area (ECA) and a key attraction place for its uniqueness and unique bird fauna to the bird watchers and researchers, a method-based, scientific checklist on the avifauna of the St. Martin's Island is still lacking. A checklist provides the background on the bird diversity of a place, the uniqueness of that place and to determine the importance of that place based on the presence of endemic, ecologically important or threatened bird species. Moreover, a checklist of any site also provides an accurate reference list and inventory for conservation workers, students, educators, ecologists and naturalists to facilitate documentation and recording of observations (Bryan *et al*. 2006). Therefore, this study attempted to produce an annotated bird checklist for the St. Martin's Island.

Materials and Methods

The Saint Martin's Island is the only coral-associated island of Bangladesh and located between latitude 20.567° and 20.650°N, and longitude 92.327° and 92.327°E (Fig. 1). The total area of this island is only 8 km² (3.1 sq. mile) but it possesses as a wide variety of ecosystems providing habitats for a diverse bird species. The key habitats of this island are shallow water marine habitats, including rocky and sandy inter-tidal habitats, offshore lagoons, rocky sub-tidal habitats, coral aggregations, sea grass beds and soft coral habitats. Several lagoons and wetlands associated with mangrove and floodplain areas also occur on the island (Tomascik 1997).

Field as well as literature surveys were conducted to collect data for this study. Seven field trips were conducted in April, 2016 and between October, 2016 and March, 17. However, due to frequent tropical storm and rough sea condition, study site could not be visited from May to September, 2016. A transect (5.03 L × 0.1 W) line survey along the mid-section of the island from north to south and a shoreline survey was conducted for observing and recording the bird species (Fig. 1). The transect line surveys were conducted in the early morning (starting from the sunrise) and afternoon (starting from

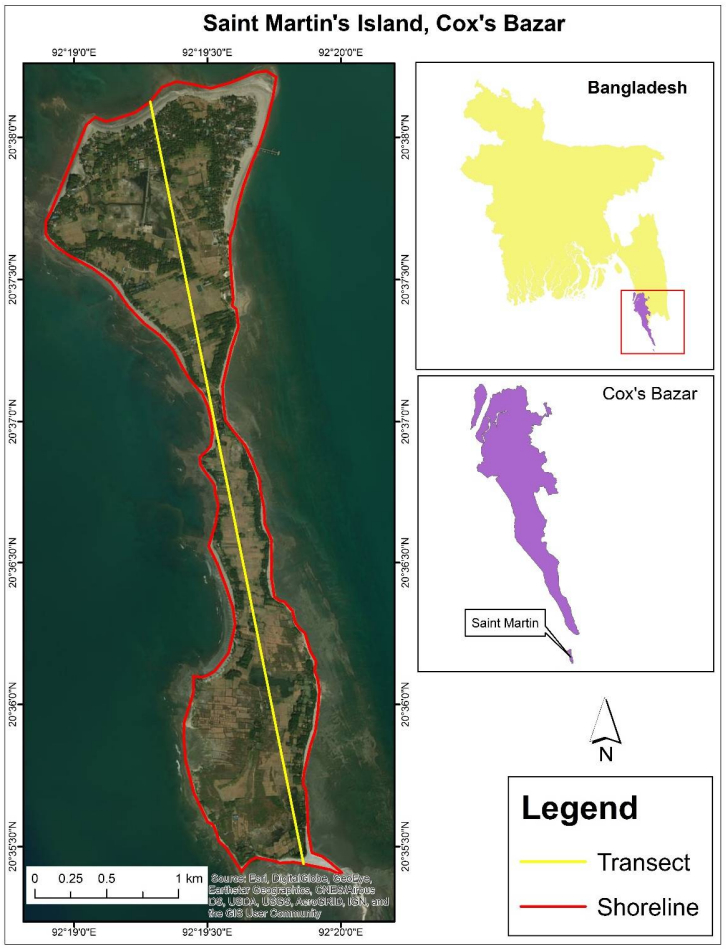

Fig. 1. Study site (St. Martin's Island of Bangladesh). The yellow line showing the transect line followed during the study from north to south of the island and the red line showing the shoreline survey area of the island.

two and a half hours before the sunset). Shoreline survey was started two hours before the high tide and ended two hours after the high tide when they were distributed along the high water line as well as on the adjacent rocks. Relative abundance of bird species was measured into four categories**:** Very common (75 - 100% encounter of the bird species during the total study period**),** common (50 - 75%**),** uncommon (25 - 50%) and rare (1 - 25%). Binocular (Ashika 10 × 42) and Telescope (Swarovski HD 20 - 60 × 65 mm) used to watch the birds in the field. Grimmett *et al.* (1999) and Chowdhury (2011) were used on the field to identify birds and photographs were taken whenever an identification problem arose in the field and subsequently consulted with expert birders. Besides, a thorough literature survey was conducted about previous bird records in the St. Martin's Island through available literature and reports (Islam 2001, Thompson and Islam 2010, BOBLME 2015).

Results and Discussion

A total of 112 species of birds belonging to 36 families under 15 orders were recorded from the St. Martin's Island (Table 1). Of these species, 37 (33%) species were passerine and 75 (67%) were non-passerine (Fig. 2); 11 (9.82%) species were very common; 12 (10.72%) were common; nine (8.04%) were uncommon and 80 (71.43%) were rare (Fig. 3). Four species, namely Bar-tailed godwit (*Limosa lapponica*), Black-tailed godwit (*Limosa limosa*), Eurasian curlew (*Numenius arquata*) and Black-headed ibis (*Threskiornis melanocephalus*) are near threatened and one species Black-bellied tern (*Sterna acuticauda*) is endangered (IUCN Red List of Threatened Species 2017) whether Black-bellied tern (*Sterna acuticauda*) is critically endangered and Black-headed ibis (*Threskiornis melanocephalus*) is vulnerable (IUCN Bangladesh 2015).

Passerine species: The passerine group consisted of 37 species belonging to 16 families of birds. Maximum six species was found under the family Motacillidae, and the families like Passeridae, Pycnonotidae, Alaudidae, Campephagidae and Ploceidae included one species each. However, more than 300 species of birds in Bangladesh are passerines (IUCN Bangladesh 2015).

Non-passerine species: Of the 112 bird species of this checklist, 75 species were non-passerine. The order Charadriiformes dominated (34 species) among the non-passerines. The order Bucerotiformes, Caprimulgiformes, Suliformes and Pelecaniformes included one species each. Of all families of the recorded bird species, Scolopacidae contains large number of bird species (16 species). In Bangladesh, the orders Charadriiformes and Accipitriformes have higher numbers of species among the non-passerine birds (IUCN

Table 1. Avifaunal checklist of the St. Martin's Island of Bangladesh.

Sl. No.	Order	Family	English name	Scientific name	Global (National) IUCN status
1	Anseriformes	Anatidae	Northern shoveler*	*Spatula clypeata*	LC (LC)
2	Anseriformes	Anatidae	Eurasian wigeon*	*Marecapenelope*	LC (LC)
3	Anseriformes	Anatidae	Ruddy shelduck*	*Tadornaferruginea*	LC (LC)
4	Anseriformes	Anatidae	Common shelduck*	*Tadornatadorna*	LC (LC)
5	Anseriformes	Ardeidae	Indian pond heron	*Ardeolagrayii*	LC (LC)
6	Anseriformes	Ardeidae	Grey heron*	*Ardeacinerea*	LC (LC)
7	Anseriformes	Ardeidae	Little egret	*Egrettagarzetta*	LC (LC)
8	Anseriformes	Ardeidae	Intermediate egret	*Ardea intermedia*	LC (LC)
9	Anseriformes	Ardeidae	Cattle egret*	*Bubulcus ibis*	LC (LC)
10	Anseriformes	Ardeidae	Striated heron*	*Butoridesstiatus*	LC (LC)
11	Anseriformes	Ardeidae	Great egret*	*Ardea alba*	LC (LC)
12	Anseriformes	Ardeidae	Pacific reef egret*	*Egretta sacra*	LC
13	Anseriformes	Ardeidae	Black-crowned night Heron*	*Nycticoraxnycticorax*	LC (LC)
14	Passeriformes	Passeridae	House sparrow	*Passer domesticus*	LC (LC)
15	Passeriformes	Corvidae	House crow	*Corvussplendens*	LC (LC)
16	Passeriformes	Corvidae	Large-billed crow	*Corvusmacrorhynchos*	LC (LC)
17	Passeriformes	Dicruridae	Black drongo	*Dicrurusmacrocercus*	LC (LC)
18	Passeriformes	Dicruridae	Ashy drongo*	*Dicrurusleucophaeus*	LC (LC)
19	Passeriformes	Sturnidae	Common myna	*Acridotherestristis*	LC (LC)
20	Passeriformes	Sturnidae	Asian pied starling	*Gracupica contra*	LC (LC)
21	Passeriformes	Sturnidae	Asian glossy starling*	*Aplonispanayensis*	LC (LC)
22	Passeriformes	Sturnidae	Rosy starling*	*Pastor roseus*	LC (LC)
23	Passeriformes	Pycnonotidae	Red-vented bulbul	*Pycnonotuscafer*	LC (LC)
24	Passeriformes	Alaudidae	Oriental skylark*	*Alaudagulgula*	LC (LC)
25	Passeriformes	Campephagidae	Black-winged Cuckooshrike*	*Lalage melaschistos*	LC (LC)
26	Passeriformes	Lanidae	Brown shrike	*Laniuscristatus*	LC (LC)
27	Passeriformes	Lanidae	Grey-backed shrike*	*Laniustephronotus*	LC (LC)
28	Passeriformes	Lanidae	Long-tailed shrike	*Laniusschach*	LC (LC)
29	Passeriformes	Ploceidae	Baya weaver	*Ploceusphilippinus*	LC (LC)
30	Passeriformes	Motacillidae	White wagtail	*Motacilla alba*	LC (LC)
33	Passeriformes	Motacillidae	Western yellow Wagtail*	*Motacilla flava*	LC (LC)

(Contd.)

34	Passeriformes	Motacillidae	Paddyfield pipit	*Anthusrufulus*	LC (LC)
35	Passeriformes	Motacillidae	Olive-backed pipit*	*Anthushodgsoni*	LC (LC)
36	Passeriformes	Muscicapidae	Oriental magpie robin	*Copsychussaularis*	LC (LC)
37	Passeriformes	Muscicapidae	Blue rock thrush	*Monticola solitarius*	LC (LC)
38	Passeriformes	Muscicapidae	Taiga flycatcher	*Ficedulaalbicilla*	LC (LC)
39	Passeriformes	Estrillidae	Scaly-breasted munia	*Lonchurapunctulata*	LC (LC)
40	Passeriformes	Estrillidae	Black-headed munia	*Lonchuramalacca*	LC (LC)
41	Passeriformes	Nectarinidae	Purple-rumped sunbird	*Leptocomazeylonica*	LC (LC)
42	Passeriformes	Nectarinidae	Purple sunbird	*Cinnyrisasiaticus*	LC (LC)
43	Passeriformes	Sylviidae	Common chiffchaff	*Phylloscopuscollybita*	LC (LC)
44	Passeriformes	Sylviidae	Common tailorbird	*Orthotomussutorius*	LC (LC)
45	Passeriformes	Sylviidae	Thick-billed warbler	*Acrocephalusaedon*	LC (LC)
46	Passeriformes	Hirundinidae	Barn swallow	*Hirundorustica*	LC (LC)
47	Passeriformes	Hirundinidae	Red-rumped swallow*	*Hirundodaurica*	LC (LC)
48	Passeriformes	Oriolidae	Black-naped oriole*	*Orioluschinensis*	LC (LC)
49	Passeriformes	Oriolidae	Black-hooded oriole*	*Oriolusxanthornus*	LC (LC)
50	Columbiformes	Columbidae	Eurasian golden oriole	*Oriolusoriolus*	LC (LC)
51	Columbiformes	Columbidae	Rock pigeon	*Columba livia*	LC (LC)
52	Columbiformes	Columbidae	Spotted dove	*Streptopeliasuratensis*	LC (LC)
53	Columbiformes	Columbidae	Eurasian collared dove	*Streptopeliadecaocto*	LC (LC)
54	Piciformes	Picidae	Eurasian wryneck	*Jynxtorquilla*	LC (LC)
55	Piciformes	Picidae	Lesser golden-backed Woodpecker*	*Dinopiumbenghalense*	LC (LC)
56	Piciformes	Picidae	Fulvous breasted Woodpecker	*Dendrocoposmacei*	LC (LC)
57	Coraciformes	Alcedinidae	Common kingfisher	*Alcedoatthis*	LC (LC)
58	Coraciformes	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	LC (LC)
59	Coraciformes	Alcedinidae	Black-capped Kingfisher*	*Halcyon pileata*	LC (LC)
60	Coraciformes	Alcedinidae	Collared kingfisher*	*Todiramphuschloris*	LC (LC)
61	Coraciformes	Meropidae	Green bee-eater*	*Meropsorientalis*	LC (LC)
62	Coraciformes	Meropidae	Chestnut-headed bee-Eater*	*Merops leschenaultia*	LC (LC)
63	Cuculiformes	Cuculidae	Plaintive cuckoo*	*Cacomantismerulinus*	LC (LC)
64	Cuculiformes	Cuculidae	Asian koel	*Eudynamysscolopaceus*	LC (LC)
65	Cuculiformes	Cuculidae	Greater coucal	*Centropussinensis*	LC (LC)
66	Strigiformes	Tytonidae	Spotted owlet*	*Athene drama*	LC (LC)

(Contd.)

67	Strigiformes	Tytonidae	Common barn owl*	*Tyto alba*	LC (LC)
68	Bucerotiformes	Upupidae	Common hoopoe	*Upupaepops*	LC (LC)
69	Caprimulgiformes	Hemiprocnidae	Asian palm swift	*Cypsiurusbalasiensis*	LC (LC)
70	Gruiformes	Rallidae	Ruddy breasted crake	*Zaporniafusca*	LC (LC)
71	Gruiformes	Rallidae	Common moorehen*	*Gallinulachloropus*	LC (LC)
72	Charadriiformes	Scolopacidae	Common snipe	*Gallinagogallinago*	LC (LC)
73	Charadriiformes	Scolopacidae	Common sandpiper	*Actitishypoleucos*	LC (LC)
74	Charadriiformes	Scolopacidae	Eurasian curlew	*Numeniusarquata*	NT (NT)
75	Charadriiformes	Scolopacidae	Whimbrel	*Numeniusphaeopus*	LC (LC)
76	Charadriiformes	Scolopacidae	Ruddy turnstone	*Arenariainterpres*	LC (LC)
77	Charadriiformes	Scolopacidae	Ruff	*Calidrispugnax*	LC (LC)
78	Charadriiformes	Scolopacidae	Sanderling*	*Calidris alba*	LC (LC)
79	Charadriiformes	Scolopacidae	Pintail snipe*	*Gallinagostenura*	LC (LC)
80	Charadriiformes	Scolopacidae	Broad-billed sandpiper*	*Limicolafalcinellus*	LC (LC)
81	Charadriiformes	Scolopacidae	Bar-tailed godwit*	*Limosalapponica*	NT (NT)
82	Charadriiformes	Scolopacidae	Black-tailed godwit*	*Limosalimosa*	NT (NT)
83	Charadriiformes	Scolopacidae	Spotted redshank*	*Tringaerythropus*	LC (LC)
84	Charadriiformes	Scolopacidae	Wood sandpiper*	*Tringaglareola*	LC (LC)
85	Charadriiformes	Scolopacidae	Common greenshank*	*Tringanebularia*	LC (LC)
86	Charadriiformes	Scolopacidae	Common redshank*	*Tringa tetanus*	LC (LC)
87	Charadriiformes	Scolopacidae	Terek sandpiper*	*Xenuscinereus*	LC (LC)
88	Charadriiformes	Charadriidae	Lesser sand plover	*Charadriusmongolus*	LC (LC)
89	Charadriiformes	Charadriidae	Greater Sand plover	*Charadrius leschenaultia*	LC (LC)
90	Charadriiformes	Charadriidae	Pacific golden plover	*Pluvialisfulva*	LC (LC)
91	Charadriiformes	Charadriidae	Little ringed plover	*Charadriusdubius*	LC (LC)
92	Charadriiformes	Charadriidae	Grey-headed lapwing	*Vanelluscinereus*	LC (LC)
93	Charadriiformes	Charadriidae	Kentish plover	*Charadrius alexandrinus*	LC (LC)
94	Charadriiformes	Charadriidae	Grey plover*	*Pluvialissquatarola*	LC (LC)
95	Charadriiformes	Charadriidae	Red-wattled lapwing*	*Vanellus indicus*	LC (LC)
96	Charadriiformes	Laridae	Little tern	*Sterna albifrons*	LC (LC)
97	Charadriiformes	Laridae	Black-headed gull	*Larusridibundus*	LC (LC)
98	Charadriiformes	Laridae	Brown-headed gull	*Larusbrunnicephalus*	LC (LC)
99	Charadriiformes	Laridae	Whiskered tern*	*Chlidoniashybridus*	LC (LC)
100	Charadriiformes	Laridae	Gull-billed tern*	*Gelochelidonnilotica*	LC (LC)
101	Charadriiformes	Laridae	Pallas's gull*	*Larusichthyaetus*	LC (LC)
102	Charadriiformes	Laridae	Black-bellied tern*	*Sterna acuticauda*	EN (CR)

(Contd.)

103	Charadriiformes	Laridae	Lesser crested tern*	*Sterna bergii*	LC (LC)
104	Charadriiformes	Laridae	Caspian tern*	*Sterna caspia*	LC (LC)
105	Charadriiformes	Glareolidae	Oriental pratincole*	*Glareolamaldivarum*	LC (LC)
106	Suliformes	Phalacrocoracidae	Little cormorant	*Microcarboniger*	LC (LC)
107	Pelecaniformes	Threskiornithidae	Black-headed ibis	*Threskiornis melanocephalus*	NT (VU)
108	Accipitriformes	Accipitridae	Shikra*	*Accipiter badius*	LC (LC)
109	Accipitriformes	Accipitridae	Brahminy kite*	*Haliastur Indus*	LC (LC)
110	Accipitriformes	Pandionidae	Osprey*	*Pandion haliaetus*	LC (LC)
111	Falconiformes	Falconidae	Peregrine falcon	*Falco peregrines*	LC (LC)
112	Falconiformes	Falconidae	Common kestrel*	*Falco tinnunculus*	LC (LC)

(LC = Least concern, NT = Near threatened, VU = Vulnerable, CR = Critically endangered and EN = Endangered). * Historic records

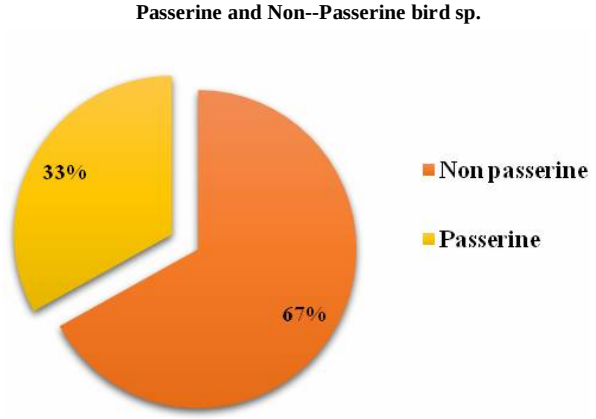

Fig. 2. Two major groups of the recorded bird species; non-passerine birds dominated in this landscape showing its ecological uniqueness.

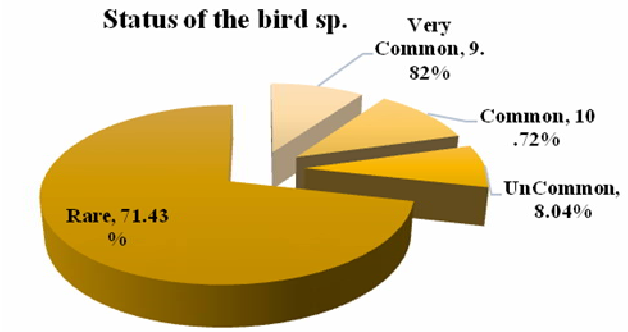

Fig. 3. Status of bird species at the St. Martin's Island; most bird species are rare and hence emphasizing the need of protection of this ecosystem.

Bangladesh 2015). Ahsan and Hannan (2002) recorded 141 bird species at the Karnaphuli river delta and adjacent areas of Chittagong, Bangladesh. Comparing to Karnaphuli river delta and adjacent areas of Chittagong, The St. Martin's Island is a very small Island, but 112 bird species are recorded. A total of 28 wader species was recorded at the Sonadia Island (49.16 km^2), Cox's Bazar, south east coast of Bangladesh (Chowdhury *et al.* 2011). In contrast, 24 species of waders were found in the St. Martin's Island of Bangladesh. However, the scale of congregation differs in a large scale. Sonadia Island recorded a congregation of 12,710 individuals of shorebirds (Chowdhury *et al.* 2011) compared to the St. Martin's Island where a congregation of 820 individuals had been recorded.

We hope that this checklist will act as a baseline source for further study on avifaunal species and their conservation at this site in the face of growing human activities and interventions. Also it will help in future monitoring the environmental health of this island.

Acknowledgements

The study was supported by the Jagannath University Research Grant (2015-2016) and Research Fellowship from the National Science and Technology of Bangladesh (2016). The authors are thankful to Ataur Rahman and his family for providing support on field. They are deeply grateful to Md. Salauddin, Department of Geography & Environment Science, Jagannath University, Dhaka, Bangladesh for creating the map of the study site using ArcGIS software.

References

Ahsan, M.F. and K. Khanom. 2005. Birds of the Chittagong University Campus, Chittagong. *The Chittagong Univ. J. Sci.* **29**(1): 77-88.

Ahsan, M.F. and M.A. Hannan. 2002. Birds of the Karnaphuli river delta and adjacent areas in Chittagong, Bangladesh. *Zoos' Print Journal* **17**(9): 875-882.

BOBLME, 2015. Saint Martin's biological survey report, Bangladesh. BOBLME-2015-*Ecology*-48.

Bryan, K., T. Gallucci, G. Lasley, M. Lockwood, and D.H. Riskind. 2006. A checklist of Texas birds. PWD BK P4000-000M (4/06). ISBN: 1-885696-09-4

Chowdhury, S.U. 2011. *A Pictorial Field Guide to the Shorebirds of Bangladesh*. Dhaka, Bangladesh. 59 pp.

Chowdhury, S.U. 2016. The Daily Star (Bangladesh). Website: file:///F:/Literature%20surveys/FEATURE_%20Nature%20Quest%20-%20Blue%20beauty%20of%20Saint%20Martin's% 20 _%20Asia%20News%20Network.html. [Accessed on 31 January 2018.]

Chowdhury, S.U., M. Foysal, D.K. Das, S. Mohsanin, M.A.A. Diyan, and A.B.M.S. Alam. 2011. Seasonal occurrence and site use by shorebirds at Sonadia Island, Cox's Bazar, Bangladesh. *Wader Study Group Bull.* **118**(2): 77-81.

DoE, 2015. The Fifth National Report of Bangladesh to the Convention on Biological Diversity. Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka. 125 pp.

Grimmett, R., C. Inskipp, and T. Inskipp. 1999. *Pocket Guide to the Birds of the INDIAN Subcontinent*. Oxford University Press, YMCA Library Building, Jai Singh Road, New Delhi 110001. 384 pp.

Hossain, M.A., M.S.E. Mahfuj, S.M.A. Rashid, M.I. Miah, and M.N. Ahsan. 2013. Present status of conservation and management of sea turtle in Cox's Bazar district, Bangladesh. *Mesopot. J.* Mar. Sci. **28**(1): 45-60.

Islam, M.S. 2001. *Sea Level Changes in Bangladesh: The Last Ten Thousand Years.* Asiatic Soc. Bangladesh. Dhaka. 185 pp.

IUCN Bangladesh 2015. *Red List of Bangladesh Volume 3: Birds*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh. pp. i-xvi, 1-676.

Khan, M.M.H. 2008. *Protected Areas of Bangladesh*- A Guide to Wildlife Nishorgo Program, Bangladesh Forest Department, Dhaka, Bangladesh. 304 pp.

Rashid, S.M.A. and Z.M. Islam, 2005. Research and Conservation of Marine Turtles in Bangladesh. In: *Marine Turtles of Indian subcontinent* (ed. Kartik Shankar, B. C. Choudhury). pp. 200-216, Universities press. California.

The Daily Star (Bangladesh). 2010. Website: http://www.thedailystar.net/news-detail-122463. [Accessed on 31 January 2018.]

The IUCN Red List of Threatened Species. 2017. Version 2017-3.Website: http://www.iucnredlist.org/. [Accessed on 31 January 2018.]

Thompson, P.M. and M.A. Islam, (Eds.). 2010. Environmental Profile of St. Martin's Island, CWBMP, United Nations Development Programme, Dhaka. 151 pp.

Tomascik, T. 1997. Management Plan for Coral Resources of NarikelJinjira (St. Martin's Island). Final Report. National Conservation Strategy Implementation Project-1, Dhaka, Bangladesh. 126 pp.

Zöckler, C. 2005. Migratory bird species as indicators for the State of the environment. Huntingdon Road Cambridge, UK. *Biodiversity* **6**(3): 219.

(Revised copy received on 23.9.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 159-171, December 2018

CHARACTERIZATION OF POND WATER CHEMISTRY AND ITS POTABILITY STATUS AT SOUTH-WEST COASTAL REGION OF BANGLADESH

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Abstract

Dacope Upazilla under Khulna district is one of the most affected safe water scarcity regions like any other part of southwest coastal region of Bangladesh. The demands for drinking and cooking water in the area are mostly met from rainwater harvesting and pond water. Pond water from different stations of Dacope Upazilla was analyzed for assessing the water chemistry, source rock evaluation and its potability status. Thirty one samples were collected by purposive sampling and analyzed following standard methods. The analysis reveals that the cations and anions of the ground water showed the order of abundance as Na^{+}> Mg^{++}>Ca^{++}>K^{+} and Cl^{-}>SO_4^{--}>HCO_3^{-}, respectively. Source rock deduction suggests that the water is mostly carbonate weathering of sea water or brine intrusion. Piper diagram suggests that the water is in saline condition. Ionic ratios also justify the aforesaid relations. The chemical constituent of water is (Na^{+}+K^{+}) and (Cl^{-} +HCO_3^{-}) type influenced by sea water, however, ponds are in transition zone influenced by tide. With reference to Bangladesh and WHO standards the research states that most pond water do not satisfy the potable quality, therefore management options need to be formulated for further exploitation.

Key words: Pond water, Chemistry, Coastal region, Potability

Introduction

The southwest coastal region of Bangladesh is characterized by a highly productive mangrove ecosystem; intricate web of life, unique type of biodiversity and world's largest sediment load estimated to be annually about 1.5 to 2.4 billion tons per year.

The area is gently slopping towards the regional slope to the south from the north. Morphological features as slope, elevation, drainage pattern, flooding condition in the area by the fluvial and tidal rivers, vegetation, settlement density and subsurface sediments encountered in the auger holes are jointly considered to classify the area into various geomorphic units. Tidal flats originated from marsh or boggy environment, flood basin, undifferentiated depression, point bars of the present and past fluvial cycle, sand bar, ox-bow lake, abandoned channel have occupied most of the mapped area and are

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forming the low lying coastal region (Rashid 1991, Umitsu 1993). On the other hand, natural levee and flood plain deposits formed the elevated region mostly in the northern and some of the middle parts of the area. Elevation of the area ranges from 0.5 to 5.79 m above mean sea level. Highest elevation of the area is 5.79 m above mean sea level.

The southwest coastal region of Bangladesh suffers from an acute crisis of safe water. About 170,000 people of Dacope Upazilla under Khulna district in Bangladesh are suffering from lack of safe water (BBS 1996). The sources of drinking and cooking water are mostly met from rain water harvesting and ponds. There is limited number of tube wells and ponds. Most of the shallow tube wells are contaminated with saline water intrusion. Though the people depend on pond water round the year, the certainty of safe water is assured only during the 5 - 7 months of the monsoon. According to government sources 46% of the people of Dacope Upazilla have access to safe water, although 27-30% of the people have access to it (Saha *et al.* 2006).

The south west region of Bangladesh is vulnerable to frequent natural disasters and calamities due to its geo-hydro-physical settings. The area is ecologically sensitive and amongst the most productive ones in the country. Moreover, a massive destruction of the physical nature of the area has been done by the unplanned mammoth scale shrimp aquaculture and other associated activities which contaminated the safe water system with salinity. Pond water chemical characterization can find out the status of the problem that can carry proper solution of this problem.

Materials and Methods

Dacope Upazila is situated in Khulna district at the southwest coastal region of Bangladesh having total area of 991.85 square km, out of which 799.01 sq.km comprises forest area. The area located to the south of Khulna city between $22^0 24'$ N and $22^0 40'$ N latitude and between $89^0 24'$ and $89^0 35'$ E longitudes.

Water samples from 31 ponds were collected from 9 Union and Chalna municipality area following the standard sampling procedure. The nine Unions were decoded as Dacope (D), Sutarkhali (S), Kamarkhola (K), Tildanga (T), Bajua (Bz), Kailashgonj (K), Laudobe (L), Pankhali (P), Banishanta (B) and Chalna Municipality (Ch).

The physico-chemical properties of water sample of the study area were conducted in the laboratory of the Department of Geology, University of Dhaka. The analysis of water temperature, pH, salinity, electrical conductivity (EC) and total dissolved solid (TDS) was done in the field by the field kit test equipments. The values of other parameters of water sample such as sodium, potassium, calcium, silicate, sulfate, ortho phosphate were

estimated by flame Photometer and Spectrophotometer, using standard methods (APHA 1992).

Results and Discussion

Status of surface water chemistry in Dacope Upazilla: The study deals with major components such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, SO_4^{2-}, PO_4^{3-} and NO_3^- of surface water. As the shallow and deep aquifers in the area are contaminated with saline water intrusion most of the people are habituated with consuming pond water. In some places pond water is treated through pond sand filter (PSF) which hardly can separate floating materials.

In the study area, most of the water pH ranged from 6.40 (Bz2) to 7.75 (D1) (Table 1), which show a very gentle pH range that satisfies the pH value of Bangladesh and WHO standard; pond water pH is suitable for domestic and irrigation purpose.

EC varied from 1.50 (P1) to 14.25 (Kl3) mS/cm in pond water. About 80% sample of the pond water is within 5 mS/cm. It is also evident that TDS is not strongly correlated with EC, where the correlation value is 0.015. EC is negatively correlated with Na^+ (–0.173), K^+ (–0.118), Cl^-(–0.147), Mg^{2+} (–0.119) and poorly correlated with salinity (0.044) (Table 2).

TDS varied from 5510 ppm (P2) to 204 ppm (B1) in pond water, where Bangladesh and WHO standard is 1000 ppm. Here 21.9% of the samples of pond water contained TDS above the standard. This may be due to the presence of Ca^{++}, Mg^{++} and HCO_3^- or SiO_2 which may be due to intrusion of fertilizer/salt water from surrounding fishing ghers. In general, water with a total solid content of less than 500 mg/l is most desirable for such purposes. Water with higher solid contents often has a laxative and sometimes the reverse effect upon people.

In Dacope Upazilla surface water salinity varied from 0.05 (K2, Ch3) to 4 ppt (Bz2). Sample Bz2 shows salinity of 4000 ppm for its storage teqnique in earthen pot (*Mutki*).

The average concentration of sodium varies from 50 (D1) to 934 (S2) ppm in pond water and most of the pond water within 200 ppm. The highest value of sodium found at a pond of Sutarkhali union (S2) and lowest in ponds situated in Dacope Union (D1). The influencing factors of sodium may be due to the natural agencies such as storms, high tide and intrusion of seawater in coastal aquifer. In general sodium is a dominant cation in most mineralized groundwater. In humid environments, sodium flushed from the soil and unsaturated zones, whereas in more arid environments, the concentration of sodium in

Table 1. Pond water chemistry (in ppm) of 31 sources of Dacope Upazila.

Code	pH	EC	TDS	Salinity	HCO_3^-	SO_4^{-2}	PO_4^{-3}	Cl^-	NO_3^-	Na^+	K^+	Ca^{++}	Mg^{++}
P1	7.10	1.50	892	0.06	170	104	2.1	420	2.15	150	16.0	28	45
P2	7.38	11.02	5510	1.50	150	320	2.0	1250	2.20	900	9.2	76	110
P3	6.90	8.99	4.48	3.00	80	332	2.0	1100	2.35	880	10.2	68	150
T1	7.40	2.79	1530	1.00	120	312	2.1	700	4.00	450	8.2	32	16
T2	7.15	3.70	1870	1.00	130	188	3.0	950	3.15	450	12.8	42	23
T3	7.12	1.54	886	2.00	600	15	6.0	410	1.65	215	8.4	36	30
K1	7.30	3.40	1820	2.00	155	150	2.3	87	6.50	485	11.8	36	36
K2	7.10	1.61	974	0.05	120	104	3.0	650	2.60	225	11.0	38	34
K3	7.23	9.50	476	1.00	70	60	2.1	300	5.60	110	9.2	30	11
B1	7.15	4.05	204	1.00	25	16	2.0	70	4.10	125	14.0	70	09
B2	6.60	2.58	1420	1.00	120	115	2.15	610	3.35	210	11.8	45	28
B3	7.65	1.55	824	2.00	25	170	2.4	412	5.50	225	7.8	32	18
L1	7.26	1.54	820	1.00	80	140	2.2	522	3.76	225	17.0	42	94
L2	7.00	1367us	682	1.5	30	18	2.0	250	4.32	55	9.0	54	16
L3	7.20	1.79	1060	1.50	130	150	4.1	600	3.13	200	9.2	120	40
Bz1	7.70	1.82	1066	0.08	190	342	1.95	495	2.50	105	3.5	52	17
Bz2	6.40	11.95	599	4.00	160	104	1.96	125	3.14	105	10.2	38	48
Bz3	7.10	1.53	880	1.05	170	334	1.94	410	2.53	100	22	42	43
Kl1	7.75	12.19	612	0.08	120	160	1.98	450	4.0	105	12.5	30	16
Kl2	7.20	5.44	271	1.00	80	17	2.0	90	3.14	100	11.8	22	06
Kl3	6.75	14.25	711	1.00	25	205	2.5	300	6.0	150	26.0	34	11
D1	7.75	9.01	4 50	0.06	25	225	2.0	140	3.24	50	12.8	28	19
D2	7.55	2.03	1176	1.00	100	152	1.88	424	3.10	255	16.0	54	38
D3	7.66	1.70	1004	1.00	125	300	2.1	412	2.15	152	20.0	60	27
Ch1	7.18	2.64	1445	0.08	90	50	2.3	750	2.85	300	11.6	52	40
Ch2	7.30	7.72	3820	3.00	135	54	3.0	1140	5.75	625	36	62	138
Ch3	7.20	1.54	810	0.05	180	52	3.2	250	1.95	152	38	22	20
S1	7.28	2.03	1166	2.00	190	335	3.1	512	2.00	450	30	48	88
S2	7.20	9.67	4630	3.00	130	316	2.3	1200	3.18	934	70	44	186
S3	7.42	1.51	925	1.00	100	138	2.4	300	2.85	155	54	58	04
S4	7.10	7.70	3890	2.00	220	338	2.3	1102	2.45	428	32	64	81

groundwater may be due to saltwater intrusion and humid environments (Sivasankaran and Ramesh 2005).

Potassium varied from 3.5 (Bz1) to 70 (S2) ppm in pond water in the study area. Most of them are within 10 and 30 ppm. Sixty four per cent of those samples contain potassium concentration above the standard value (12 ppm). The highest value found in a pond in Sutarkhali union (S2). Potassium exhibits positive correlation with SO_4^{2-}(0.174), Mg^{++} (0.451), Na^+ (0.325), PO^{3-}_4 (0.021) and Cl^- (0.264). Potassium exhibits positive correlation with Ca^{++}, Mg^{++}, HCO_3^- and Cl^- (Table 2). Because of its lower geochemical mobility in freshwater, potassium is seldom found in greater or almost equal concentration of sodium (Na^+). In spite of the greater resistance of K-feldspars and K-silicates to the weathering, K^+ ions are released by weathering. However, after prolonged migration they tend to become fixed again through sorption on clay minerals and formation of secondary minerals (Matthess 1982).

In Dacope Upazilla calcium varied from 22 ppm (Ch3) to 120 (L3) ppm in pond water. Almost all the samples (86%) in the study area showed high concentration (>10 mg/l) of calcium, that means those concentrations fall out of range of natural freshwater. This high concentration may be due to primarily the presence of CO_2 which causes $CaCO_3$ to dissolve. Magnesium varied from 4 ppm (S3) to 186 (S2) ppm. Bangladesh standard of magnesium is 30 - 35 ppm, where 22% of the sample contains magnesium above the standard. This may be due to high solubility of Mg; the metals tend to remain in solution and are less readily precipitate than calcium.

The concentration of chloride in the area varied from 70 to 1250 ppm in pond water where Bangladesh standard is 150 - 600 ppm. Twenty nine per cent samples of pond water exceeded the potability standard and near about 16.13% samples of pond water exceeded the tolerable concentration of chloride in the coastal region (1000 mg/l). The higher value of chloride in pond water indicates the admixture of mineralized water or pollution (Narayana and Suresh 1989).

Commonly the natural water contains bicarbonate less than 500 mg/l (Todd 1980). Carbonate and bicarbonate represent alkalinity of water. The concentration of bicarbonate at different location ranges from 25 to 600 ppm in pond water. It is evident that bicarbonate has a correlation with K^+ (0.67) and pH (0.49). Bicarbonate is the primary anion in the water, which is mainly derived from carbon dioxide released by the organic decomposition in the soil (Todd 1979). Most of the bicarbonate must have been derived from the soil CO_2 (Sivasankaran and Ramesh 2005).

Table 2. Correlation matrix of 15 parameters of the sample of Dacope Upazilla.

	pH	EC	TDS	Salinity	HCO_3	SO_4	PO_4	Cl	NO_3	Na	K	Ca	Mg
pH	1												
EC	–0.140	1											
TDS	0.000	0.015	1										
Salinity	–0.416	0.044	–0.419	1									
HCO_3	–0.083	–0.187	0.094	0.166	1								
SO_4	0.244	–0.247	–0.195	0.137	–0.013	1							
PO_4	–0.084	–0.121	0.204	0.128	0.746	–0.243	1						
Cl	–0.023	–0.147	–0.346	0.300	0.117	0.466	0.044	1					
NO_3	–0.008	0.152	–0.265	0.172	–0.442	–0.273	–0.193	–0.202	1				
Na	–0.045	–0.173	–0.565	0.524	0.076	0.460	–0.003	0.817	–0.057	1			
K	–0.004	–0.118	–0.143	0.234	0.001	0.174	0.021	0.264	–0.081	0.325	1		
Ca	–0.018	0.063	0.012	0.247	–0.040	0.187	0.148	0.390	–0.158	0.289	0.002	1	
Mg	–0.137	–0.119	–0.380	0.603	0.086	0.396	–0.015	0.751	–0.138	0.838	0.451	0.297	1
N = 31													

The concentration of phosphate ranged from 1.84 to 6 ppm in pond water in the area, where Bangladesh standard is 6 ppm. It is found that most of the samples showed very low concentration of phosphate compared to the standard.

Sulphate is one of the major anions occurring in natural waters. Considerable sulphate is added to the hydrologic cycle from precipitation (Sivasankaran and Ramesh 2005). This comes from dried sea spray as cyclic salt, continental dust, oxidation of H_2S that enters the atmosphere from coastal marshes and air pollution (Matthess 1982). In the study area considerable sulphates may have been added due to the decomposition of organic matter in soil. Natural water contains generally less than 300 ppm sulphate (Todd 1980).The concentration of sulfates varied from 16 to 342 ppm in pond water. Sulfate has also correlation with the K^+ (0.174), Na^+ (0.460), Ca^{2+} (0.187), Mg^{2+} (0.396), and Cl^- (0.466). Considerable sulfate is added to the hydrologic cycle from precipitation (Sivasankaran and Ramesh 2005). In the study area sulfate concentration is within the standard value of Bangladesh (400 ppm/l). The concentrations of nitrate-nitrogen ranged from 1.65 to 6.50 ppm in pond water in the study area.

Correlation matrices: According to Hounslow (1995) the relationship between two variables is called correlation, and it measures the degree to which two variables vary together (or vary inversely). It is measured by an index called correlation coefficient (r), where the value of r vary from –1 to +1. Correlation between ions suggests the likely source of surface water.

From the above correlation matrix it is found that, there is a strong correlation between magnesium and chloride, sodium and chloride, where the correlation value is 0.751 and 0.817, respectively. In this study, chloride, sodium and magnesium have significant correlation with salinity, the value is 0.300, 0.524 and 0.603, respectively. It is also found that the ions have no significant effect on EC and TDS. Negative correlation is found between those ions and parameters.

The result suggests that Na has strong positive correlation with Cl, that Na and Cl is co-origin in nature. Mg shows moderate correlation with SO_4, so there is possibility of seawater intrusion. K shows poor correlation with HCO_3, so carbonate weathering is rare.

Source rock deduction according to parameter ratio: The ions commonly determined in a water station includes Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^- (Table 3). Other parameter includes TDS and hardness. It is essential for water quality analysis to determine the source of major elements that are found in water and the ways by which they may be removed from solution. The initial composition of groundwater originates from rainfall which may be considered to be diluted seawater.

During its return path of ocean, the water composition is altered by rock weathering, evaporation (Gibbs 1970) and aeration. During rock weathering Ca^{2+}, Mg^{2+}, SO_4^{2-}, HCO_3^- are added to the water. The amount of each is dependent on the rock mineralogy.

Table 3. Source rock deduction summary of the water samples (Hounslow 1995).

Parameter	Attention value (mmol/l)	Analysis value (mmol/l)	Conclusion
$\frac{Na^+ + K^+ - Cl^-}{Na^+ + K^+ - Cl^- + Ca^{2+}}$	>0.2 and <0.8 <0.2 and >0.8	0.557	Plagioclase weathering possible Plagioclase weathering unlikely
$\frac{Na^+}{Na^+ + Cl^-}$	>0.5 =0 <0.5 TDS >500 <0.5 TDS <500 <0.5 TDS <50	0.475	Sodium sources other than halite-albite ion exchange Halite solution Reverse softening, sea water Analysis error Rainwater
$\frac{Ca^{2+}}{Ca^{2+} + SO_4^{2-}}$	=0.5 <0.5 pH<5.5 <0.5 neutral >0.5	0.397	Gypsum dissolution Pyrite oxidation Calcium removal- ion exchange or calcite precipitation Calcium sources other than gypsum-carbonates or silicates.
$\frac{Cl^-}{sumanions}$	>0.8 TDS >500 >0.8 TDS<100 <0.8	0.676	Sea water or brine or evaporates Rainwater Rock weathering
$\frac{HCO_3^-}{sumanions}$	>0.8 <0.8 sulphate high <0.8 sulphate low	0.103	Silicate or carbonate weathering Gypsum dissolution Seawater or brine.
TDS	> 500 <500	> 500 <500	Carbonate weathering or brine or seawater Silicate weathering

The ratio $\frac{Na^+ + K^+ - Cl^-}{Na^+ + K^+ - Cl^- + Ca^{2+}}$ shows if the result is > 0.2 and < 0.8, there plagioclase weathering is possible. The samples show the possibility of plagioclase weathering.

The ratio $\frac{Ca^{2+}}{Ca^{2+}+SO_4^{2-}}$ shows if the result is < 0.5 then the source of calcium is removal of ion exchange or calcite precipitation.

All stations from the study area show the source of calcium is removal of ion exchange or calcite precipitation.

The ratio $\frac{Na^{+}}{Na^{+}+Cl^{-}}$ shows if the result is <0.5 then the sodium source is other than halite solution or reverse softening, sea water.

The stations from the study area show that the sodium source is other than halite solution or reverse softening, sea water.

From the ratio if $\frac{Cl^{-}}{Sumanions}$ is <0.8 then the stations are from rock weathering. Here shows the stations are from rock weathering.

From the ratio $\frac{HCO_3^{-}}{Sumanions}$ if the result is <0.8 and sulfate is low, then the source is seawater or brine but if the sulfate is high, the source is gypsum dissolution. Most of the stations from the study area are from seawater and a few from gypsum dissolution.

Sources of water according to piper (after Piper 1953): Piper diagram is a combination of anions and cations triangle that lies on a common baseline. Per cent meq/l are plotted on piper diagrams, approximate ratios may be calculated by measuring the placement of the sample on the diagram. Four basic conclusions can be derived from the Piper multiple analyses plotted on Piper diagram (Hounslow 1995). These are: (1) Water type, (2) precipitation or solution, (3) mixing and (4) ion exchange.

Water that plots at the top of the diamond is high in (pond water) both Ca^{2+} + Mg^{2+} ; Cl^{-} and Na^{+} +K^{+}, which results in an area of salt water mixing as shown in figure 1. The pond sand filtered water also has the same nature. Plotting the collected 31 samples from different sources of Dacope Upazilla and from the nature of Piper diagram, it is clear that the area is in abundance with Na, Cl and Mg. The presence of Na and Cl suggest the salinity of the area and the presence and abundancy of Mg suggest the sea water intrusion from surrounding shrimp culture ghers or other locations and its marine source.

Ionic hierarchy: A higher hierarchy of ions can be established based on the relative importance of marine sea salt sources and continental sources.

$Cl^{-} = Na^{+} > Mg^{++} > K^{+} > Ca^{++} > SO_4^{--} > NO_3^{-} = NH_4^{+}$

mostly marine mostly continental

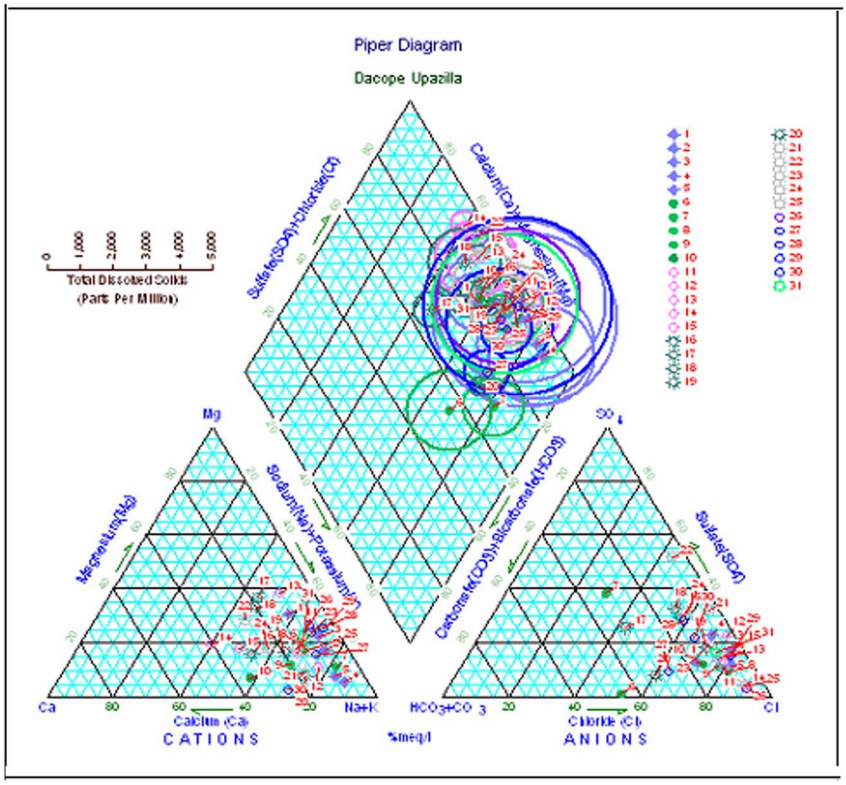

Fig. 1. Piper diagram of the study area.

Surface water containing significant amount of chloride also tend to have high amount of Na ions indicating the possibility of contacts with water of marine origin. The major cations of the average surface water in Dacope upazilla are in the order of $Na^{+} > Mg^{++} > Ca^{++} > K^{+}$ and major anions are in the order of $Cl^{-} > SO_4^{2-} > HCO_3^{-}$ (Table 4). The samples of pond water shows highest chloride concentration and higher concentration of bicarbonate sulfate than bicarbonate. The analytical data reveal that sodium and chloride are the dominant ions in the study area.

In general, sodium is the dominant cation in most surface water. It is also evident that if Na>>K then K is more readily removed from solution by plants and clay mineral than sodium. Both elements are equally common in most rocks originating as constituents from the weathering of feldspars (albite and K feldspar) and micas. In addition sodium commonly occurs from ion exchange (Hounslow 1995). Because of its lower

geochemical mobility in freshwater, potassium is seldom found in greater or almost equal concentration of sodium (Na^+).

Table 4. Summary output of ANOVA analysis of the samples results.

Groups	Count	Sum (meq/l)	Average (meq/l)
HCO_3^-	31	66.2613	2.137461
SO_4^{2-}	31	110.7752	3.573394
PO_4^{3-}	31	2.373	0.076548
Cl^-	31	463.48	14.95097
NO_3^-	31	1.669	0.053839
Na^+	31	394.58	12.72839
K^+	31	14.607	0.471194
Ca^{2+}	31	72.753	2.346871
Mg^{2+}	31	118.599	3.825774

Table 5. Drinking water standards (DoE 1997).

Water quality parameter	Unit	Bangladesh standard	WHO standard (1993)	Study result from Dacope Upazilla
Temperature	ºC	20 - 30	-	27.6 - 35.3
pH	-	6.5 - 8.5	7 - 8.5	6.40 - 7.75
EC	µs/cm	-	-	1.50 - 14.25
TDS	ppm	1000	1000	204 - 5510
Sodium (Na^+)	ppm	200	200	50 - 934
Potassium (K^+)	ppm	12	-	3.5 - 70
Calcium (Ca^{2+})	ppm	75	75 - 200*	22 - 120
Magnesium (Mg^{2+})	ppm	30 - 35	50 - 150*	4 - 186
Chloride (Cl^-)	ppm	150 - 600*	200 - 600	70 - 1250
Bicarbonate (HCO_3^-)	ppm	200	-	25 - 600
Phosphate (PO_4^{3-})	ppm	6	-	1.84 - 6
Sulfate (SO_4^{2-})	ppm	400	250	16 - 342
Nitrate (NO_3^-)	ppm	10	-	1.65 - 6.50

* For coastal areas of Bangladesh, in case of non-availability of alternative sources value is 1000.

Potability status of pond water: Drinking water quality refers water supplies which is free from any potential health hazard to the consumers. The different impurities in water which cause undesirable effects may be classified into physical, chemical, bacteriological and radiological parameters.

The standards prescribed for potable water supplies by different authorities usually give two types of norms e.g. permissible and tolerable range. Bangladesh has also set a national standard for different physical, chemical and biological parameters level for drinking water. WHO (1992, 1993) has set international standard for drinking.

To assess the suitability of potable surface water for drinking, WHO and Bangladesh have standards for different parameters (Table 5).

According to the drinking water standards of WHO and Bangladesh, it is summarized that the results from the laboratory analysis sometimes have been exceeded and sometimes remained below the standard. In case of some parameters, the result is quite satisfactory for the standards. But it can be easily said that the water used for drinking purpose, is no more suitable for the local inhabitants.

The protected ponds in Dacope Upazilla, annually replenished by rainwater are the main source of potable water in the area. However, various uses and unhygienic practices pollute these ponds. In some areas, due to high salinity problem, around 36% of households have been found to harvest rain water in the rainy season for drinking purposes. But the quality of this water is deteriorated due to improper management of preservation. Collection, storage and usage pattern of rainwater are not in an organized manner and development through adoption of appropriate technologies.

References

APHA 1992. Standard Method for the Examination of water and waste water (14th ed.). American Public Health Association, New York.

BBS, 1996. "Population Census, Community Series, Khulna District", Statistics Division, Ministry of Planning, Dhaka, Bangladesh.

Gibbs, R.J. 1970. Mechanisms Controlling World Water Chemistry, *Science* **170**: 1088-1090.

Hounslow, A.W. 1995. *Water Quality Data: Analysis and Interpretation*, Lewis Publ, Oklahoma, 397 p.

Matthess, G. 1982.*The properties of groundwater*, John Wiley and Sons, New York. 350 p.

Narayana, A. and G. Suresh.1989. Chemical quality of groundwater of Mangalore City, Karnataka. *J. Env. Health.* **31**(3): 228-236.

Piper, A.M. 1953. A graphic procedure in the geochemical interpretation of water analysis., *USGS Ground Water Note,* No. **12** : 63.

Rashid H. 1991. *Geography of Bangladesh* (2nd Edition). University Press Limited, Dhaka, Bangladesh. 579 pp.

Saha, S.K., S. Naznin and F. Ahmed. 2006. A Household based safe water intervention programme for a slum area in Bangladesh. *Asian Journal of Water, Environment and Pollution* **3**(1): 21-25.

Sivasankaran. M. A. and R. Ramesh. 2005. Geochemical characterization of groundwater in the Pondicherry region India. *In:* Ramesh, R., S. Ramachandran. (Eds). *Freshwater Management*. Capital Publishing Company. New Delhi: 92-107 p.

Todd, D.K. 1980. *Groundwater Hydrology*, University of California, Berkeley, John Wiley and Sons, 2nd Edition. 312 p.

Umitsu M. 1993. Late Quaternary environment and landforms in the Ganges delta. *Sed. Geol*. **83**: 177-186.

World Health Organization, 1992. The International Drinking Water Supply and Sanitation Decade. Geneva, Switzerland.

World Health Organization, 1993. Guidelines for Drinking Water Quality, Second Edition, *Volume 1, Recommendation*, Geneva.

(Revised copy received on 20.10.2018)

J. Asiati. Soc. Bangladesh, Sci. **44**(4): 173-183, December 2018

IMPACTS OF RICE HULL AND PISTIA ON THE VEGETATIVE GROWTH OF RICE AND PHYSICO-CHEMICAL PROPERTIES OF SALINE SOIL UNDER VARIABLE MOISTURES

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Abstract

A pot experiment was conducted using BRRI Hybrid Dhan-6 variety of rice at the premises of the Department of Soil, Water and Environment, University of Dhaka, Bangladesh to evaluate the capabilities of rice hull (RH: 0, 2, 4 t ha^{-1}) and pistia (PT: 0, 400, 800 kg ha^{-1}) for the improvement of growth performances of rice grown under field moist (FM: 70% moisture) and 2 - 5 cm standing water (SW) conditions in saline soil. Among the vegetative growth, the plant heights, number of productive tillers, fresh shoot and shoot dry matter weights were found to be increased significantly ($p \leq 0.05$) with the increased rates of rice hull and pistia treatments, and the increments were more striking by their combinations in most of the cases under both FM and SW conditions. The tallest plant heights (112 cm in FM and 120 cm in SW) and the maximum number of productive tillers (13 in FM and 16 in SW) were recorded at maturity stage of rice in the T_8 (RH_4PT_8) treatment where rice hull and pistia were applied at the highest (RH: 4 t ha^{-1}, PT: 800 kg ha^{-1}) dosages. Based on superiority in both the plant heights and number of tillers, the amendments can be arranged in the sequence of $T_8 > T_7 > T_6 > T_5 > T_2 > T_3 > T_4 > T_0 > T_1$. The analysis of variance on these data indicated that in the standing water condition, fresh shoot and shoot dry matter weights of rice plants were found to be increased significantly ($p \leq 0.05$) by the application of the higher rates of the treatments and their combinations. Thus, the application of indigenous organic amendments such as, rice hull and pistia showed significant contribution for the growth performances of rice under variable moistures but further researches are needed under variable soil and climatic conditions to ensure food security under saline soil.

Key words: Moistures, Plant height, Pistia, Rice hull, Shoot yield, Tiller production

Introduction

Bangladesh has 710 km long coastline running parallel to the Bay of Bengal. The economy of Bangladesh largely depends on agriculture and rice is the staple food of the country. More than 30% of the cultivable land in Bangladesh is in the coastal area. Out of 2.86 million hectares of coastal and off-shore lands, about 1.056 million ha of arable lands are affected by varying degrees of salinity (SRDI 2010). Farmers mostly cultivate

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low yielding, traditional rice varieties during wet season. Most of the land remains fallow in the dry season (January - May) because of soil salinity, lack of good quality irrigation water and slow draining condition (SRDI 2010). Crop production of the salt affected areas in the coastal regions differs considerably from non-saline areas. Because of salinity, special environmental and hydrological situation exists, that restrict the normal crop production throughout the year. In the recent past, with the changing degree of salinity of some areas due to further intrusion of saline water, normal crop production becomes very risky. Crop yields, cropping intensity, production levels and people's quality of livelihood are much lower than that of other parts of the country (SRDI 2010).

The problem of salt-affected soils has gained ever-increasing importance in science, technology, ecology and society during the last few decades. It has been evidenced that the coastal salinity is increasing in the coastal zone due to sea level rise, reduction of fresh water flow in the southern rivers and also due to entrainment of sea water with recurrent storm surges caused by the increasing frequency of tropical cyclones of higher intensity (Quadir and Iqbal 2008). Salt affected coastal areas in Bangladesh mainly include the problematic saline (>20%) and acid sulfate (>3%) soils, which occupied >23% of the cultivable lands (Khan *et al.* 2016). They also added that these soils displayed high agricultural potentials when they were to be reclaimed by appropriate methods. Because of the highly saline (2% salts) sea or river waters and ground waters, application of salt free water is quite impossible.

The agro-climatic conditions of the country are suitable for growing rice round the year. However, the country's average rice yield is much lower (2.97 t/ha, BBS 2017) than those of China and Japan (6 - 6.5 t/ha, BRRI 2015). The BBS also reported that rice is the staple food for about 160 million people of the country. The population growth rate is 2 million per year, and if the population increases at this rate, the total population will reach 238 million by 2050 (BBS 2017). An increase in total rice production is required to feed this ever-increasing population. Rice has been reported as salt susceptible in both seedling and reproductive stages leading to a reduction of more than 50% in yield when exposed to 6.65 dS m^{-1} ECe (Reddy *et al*. 2017). So rice production is drastically reduced due to salinity and low fertility of coastal soils.

As an organic material, there is a significant quantity of rice hull at farmers' level. It improves water holding capacity of soil. It also increases organic matter content of the soil and subsequently increase crop yield (Begum and Khan 2013). Prakash *et al.* (2002) emphasized that rice hull improved soil silicon status and sustained better rice production. Another organic amendment, *Pistia stratiotes* (water lettuce) is the world's

most productive freshwater aquatic plant and considered an invasive species. On dry matter basis, it contained 49.3% total C, 2.95% N, 0.57% P, 4% K, 103.6 ppm Zn, 19.03 ppm B in leaf and 46.4% total C, 2.45% N, 0.49% P, 1.2% K, 264.8 ppm Zn, 17.08 ppm B in root (Kanwal *et al.* 2011). They also added that it contained 94% moisture. In saline soils, water movement is one of the major problems due to the adverse effects of salinity on soil physical properties which may be improved by the indigenous organic amendments like rice hull and pistia. Hence, the salinity affected coastal areas could be reclaimed by different management strategies, such as improved hydrology, application of agricultural amendments, adaptation and screen out of different salt tolerant crops. These multi-approached works will not only be helpful for understanding the real nature of the problem but also assist proper reclamation, improvement of soil health resulting in food security under variable climates and economic use of saline soils which could be a new resource for the society/country. Against this background, this present research was undertaken to evaluate the effects of rice hull and pistia on the vegetative growth of rice and physico-chemical properties of saline soil under variable moisture levels.

Materials and Methods

A pot experiment was carried out using BRRI Hybrid Dhan-6 variety of rice in the premises of Department of Soil, Water and Environment, University of Dhaka. The saline soil used in the experiment was collected from Musulliabad, Kalapara, Patuakhali during April to July, 2017. Indigenous organic amendments such as Rice Hull (RH) and Pistia (PT) were used for the studied soil. Five kilograms of air dried, ground and 5 mm sieved composite soil was filled in each earthen pots (size: 8 kg). The experiment was designed following completely randomized design with the application of Rice Hull (having 3 doses 0, 2, 4 t/ha) and Pistia (having 3 doses 0, 400, 800 kg/ha) having 3 replications under 2 sets of moisture levels (Field moist: FM and 2 - 5 cm standing water conditions: SW). The treatments were T_0 = (Control) RH_0PT_0, T_1 = RH_0PT_4, T_2 = RH_oPT_8, T_3 = RH_2PT_0, T_4 = RH_2PT_4, T_5 = RH_2PT_8, T_6 = RH_4PT_0, T_7 = RH_4PT_4, T_8 = RH_4PT_8. Basal doses of N, P and K were applied at the rate of 120, 60 and 80 kg/ha from urea, TSP and MoP fertilizers, respectively. The whole TSP, MoP and half of the urea were applied during soil preparation by thorough mixing of the fertilizers with soils. The remaining urea was top dressed in two splits, one at active tillering and another at panicle initiation stage.

Seedling was collected from Bangladesh Rice Research Institute. Thirty-day-old seedlings of BRRI Hybrid Dhan-6 were transplanted at the rate of 3 plants per hill and 3 hills per pot. For the proper establishment of the rice seedlings, all pots were irrigated

with tap water for two weeks after transplantation and then the moisture levels were maintained by the irrigation from the same tap water. In the case of moist condition: 70% water content seemed to be optimum for the survival of rice plant and did not allow standing water. But in the case of saturated condition: more than 100% water, i.e. 2 - 5 cm standing water was maintained during irrigation and kept the field always wet throughout the growing period. Intercultural operations were practiced throughout the experiment when necessary. The physico-chemical characteristics of initial soil were determined by following standard methods (Table 1). The bulk soil samples were air-dried, crushed and passed through 2 mm seive before analysis. After treatment with 1 M CH_3COONH_4 (pH 5.0) and with 30% H_2O_2 to remove free salts and organic matter respectively, particle size distribution of the initial soil was determined by the Hydrometer method (Piper 1966).

Table 1. Physico-chemical characteristics of initial saline soil (1 - 15 cm) on oven dry basis.

Properties	Values	Properties	Values
Textural class (Hydrometer)	Silty clay loam	Exchangeable cations (C mol/kg)	
Soil pH (soil: water = 1 : 2.5)	6.3	Na^+ (Flame Photometer)	4.02
EC (soil : water = 1 : 5, dS/m)	4.17	K^+ (Flame Photometer)	1.90
Organic carbon (g/kg, wet oxidation)	14.3	Ca^{2+} (AAS)	2.90
Total N (Micro Kjeldahl, g/kg)	1.4	Mg^{2+} (AAS)	2.50
C/N ratio	10.20	Water soluble ions (C mol/kg):	
Cation exchange capacity (C mol/kg)	21.23	Cl^-	2.63
Available N (mg/kg, Micro Kjeldahl)	42	$SO4^{-2}$	1.75
Available S (mg/kg, Spectrophotometer)	192	Carbonate	Nil
Available P (mg/kg, Spectrophotometer)	14	Bicarbonate	0.98
Available K (mg/kg, Flame photometer)	24.16	Sodium adsorption ratio	2.45
Base saturation percentage	53.32	Exchangeable sodium percentage	20.92

*AAS = Atomic Absorption Spectrophotometer.

Soil pH was measured at the soil-water ratio of 1 : 2.5 (Jackson 1973). The electrical conductivity was determined at a ratio soil : water = 1 : 5 (Richards 1954). Organic matter content was determined (Nelson and Sommers 1982) by wet combustion with $K_2Cr_2O_7$. Available N (1.3 M KCl extraction, Jackson 1973), available P (0.5 M $NaHCO_3$, pH 8.5 extraction, Olsen *et al*. 1954), available K (Pratt 1965) and available S

($BaCl_2$ turbidity, Sakai 1978) were determined. Cation exchange capacity was determined by saturation with 1 M CH_3COONH_4 (pH 7.0), ethanol washing, NH_4^+ displacement with acidified 10% NaCl, and subsequent analysis by steam (Kjeldhal method) distillation (Chapman 1965). Water soluble SO_4^{-2} and Cl^- (Jackson 1973), HCO_3^- and CO_3^- (USSLS 1954) contents were determined. Exchangeable Na^+, K^+, Ca^{2+} and Mg^{2+} were extracted with 1 M CH_3COONH_4 (pH 7.0) and determined by flame photometry (Na^+, K^+) and atomic absorption spectrometry (Ca^+, Mg^+).

Plant samples were collected after harvesting the crop at maturity. The plants per pot were cut at the 1 cm above ground level and the N contents were analyzed by the H_2SO_4 digestion through the micro-Kjeldhal method (Jackson 1973) and P contents by spectrophotometry (Jackson 1973), K contents by Gallenkamp flame photometry (Black 1965). The analysis of variance (ANOVA) of the data and the test of significance of the different treatments' means were assessed by Tukey's range test at 5% level.

Results and Discussion

The plant height is one of the most indicative parameters and the response of the application of different organic amendments reflected quickly on this parameter. Moreover, it indicates the influence of various nutrients on plant metabolism. Analyses of the results demonstrate that the individual variables, such as, rice hull and pistia exerted significant ($p \leq 0.05$) effects on the growth of rice. Plant heights increased significantly ($p \leq 0.05$) with the increased rates of rice hull and pistia treatments and their combinations under both field moist (FM) and standing water (SW) conditions. The tallest plant heights (112 cm in FM and 120 cm in SW) were recorded at maturity stage of rice in the T_8 (RH_4PT_8) treatment where rice hull and pistia were applied at the highest dosages (Fig. 1). The lowest plant heights (65 cm in FM and 70 cm in SW) were observed at maturity stage of plants in the control treatment ($T_0 = RH_0PT_0$). Though the soil is different but almost similar results were reported by Kamara *et al.* (2015). They used rice straw as organic amendment and reported that rice plants grown on soils treated with rice straw were significantly ($p \leq 0.05$) taller than those grown on soils without treatment. Another study indicated that incorporation of rice straw into the soil combined with application of cattle manure gave the maximum plant height (Parham *et al*. 2002).

The number of productive tillers at maturity stage of rice was influenced by the different rates of rice hull and pistia and their combinations (Fig. 2). There was a positive significant ($p \leq 0.05$) increase in number of productive tillers with higher rates of organic amendments and their combinations under FM and SW conditions. The maximum

number of productive tillers (13 in FM and 16 in SW) was recorded at maturity stage in the T_8 (RH_4PT_8) treatment followed by the T_7 (RH_4PT_4) treatment (Fig. 2). Based on superiority, in case of tiller production, amendments could be arranged in the following sequence of $T_8 > T_7 > T_6 > T_4 > T_2 > T_3 > T_1 > T_0 > T_5$. Tiller production was the lowest in the T_5 (RH_2PT_8) treatment which was unexpected. This might be due to the attack of insects

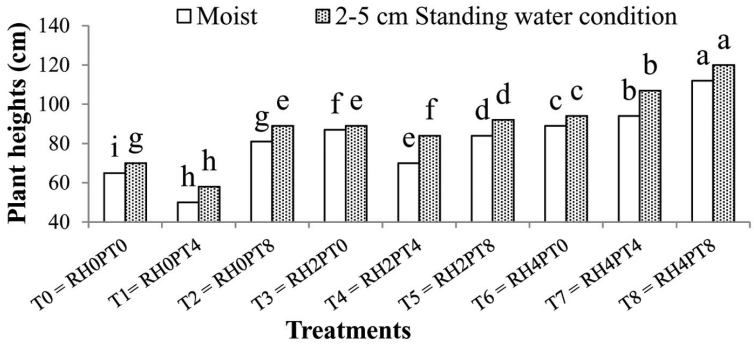

Fig. 1. Effects of rice hull and pistia on plant heights of rice (BRRI Hybrid Dhan-6) grown under field moist (70% moisture) and 2 - 5cm standing water conditions.

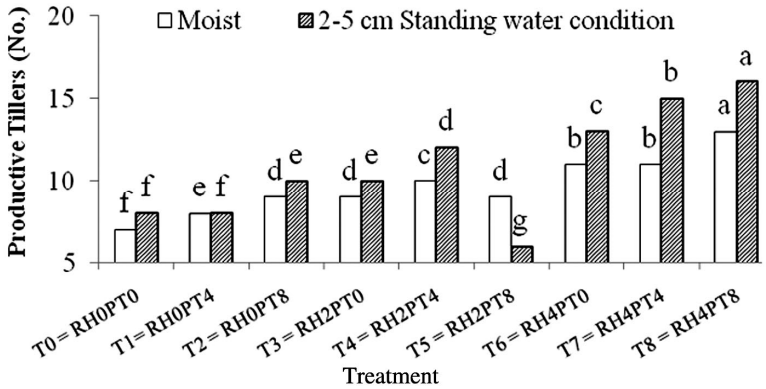

Fig. 2. Effects of rice hull and pistia on the number of productive tillers of rice (BRRI Hybrid Dhan-6) grown under field moist (70% moisture) and 2 - 5 cm standing water conditions.

on rice plants. Almost similar observation was found from another study conducted in other coastal areas of Bangladesh (Kaniz and Khan 2013). They found that application of rice hull increased growth and yield contributing characters of BRRI Dhan 47. Though they have practiced for the higher rates and suggested to practice for the lower rates of

treatments. So they concluded that the application of rice hull is effective in improving the adverse effect of salinity and growth performance of rice plant.

The fresh shoot and shoot dry matter weights of rice plants were found to be influenced by different rates of organic amendments (rice hull and pistia) and their combinations under both the field moist and 2 - 5 cm standing water conditions (Figs 3 and 4). The analysis of variance on these data indicated the fresh shoot and shoot dry matter weights increased significantly ($p \leq 0.05$) by the individual application of rice hull, pistia and their combinations at the higher rates. In moist condition, the maximum fresh shoot (32.4 g) and shoot dry matter weights (18.4 g)

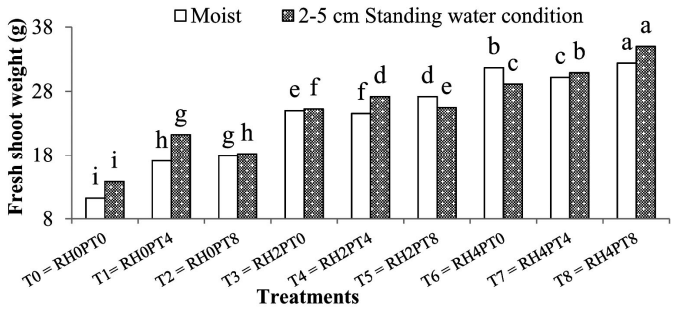

Fig. 3. Effects of rice hull and pistia on the fresh shoot weight (g) of rice (BRRI Hybrid Dhan-6) grown under field moist (70% moisture) and 2 - 5 cm standing water conditions.

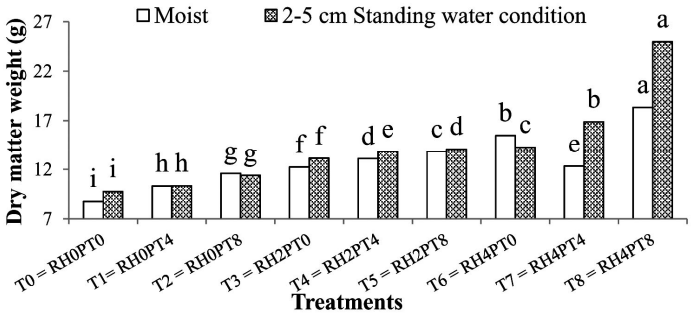

Fig. 4. Effects of rice hull and pistia on the shoot dry matter weight (g) of rice (BRRI Hybrid Dhan-6) under field moist (70% moisture) and 2 - 5 cm standing water conditions.

were recorded at maturity stage in the T_8 (RH_4PT_8) treatment which received the highest rates of the combination of these treatments. The minimum fresh shoot (11.25 g) and shoot dry matter weights (8.75 g) were measured at maturity stage in the control

condition where no treatment was applied. In the standing water condition, fresh shoot and shoot dry matter weights of rice plants were found to be increased significantly ($p \leq 0.05$) by the application of the higher rates of treatments and their combination. In case of standing water condition, almost similar patterns of increase in fresh shoot and dry matter weights were found with the increased rates of amendments.

There were remarkable variations in pH of post harvest soils with the changes in the doses of organic amendments (rice hull and pistia) under both field moist and 2 - 5 cm standing water conditions (Fig. 5). The highest value of soil pH (7.4) was recorded in the treatment T_6 (RH_4PT_0) in the field moist condition. In the standing water condition, the maximum value (7.3) of soil pH was measured in the T_2 (RH_0PT_8) treatment. Though thesevalues did not comply with the best treatment regarding vegetative growth of rice,

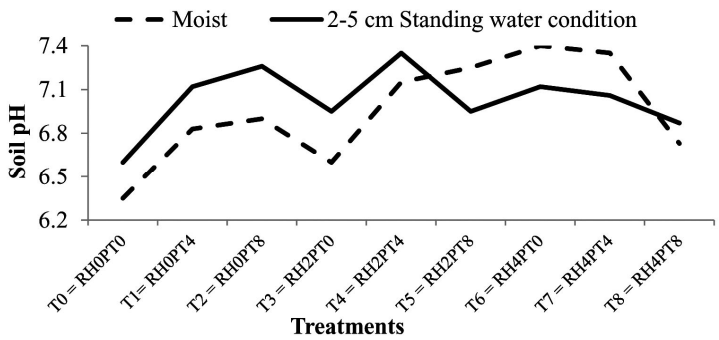

Fig. 5. Effects of rice hull and pistia on the pH of the post harvest soils under field moist (70% moisture) and 2 - 5 cm standing water conditions during cultivations.

which might be attributed to the soil pH values (7.3 - 7.4), which are not in the optimum range of soil pH (5.5 - 6.5) for rice production. The lowest value of soil pH was obtained from the control condition under both FM (pH 6.73) and SW (pH 6.87) conditions. The pH of the soils were found to be increased bythe individual lower doses of these treatments ($T_1 = RH_0PT_4$, $T_2 = RH_oPT_8$) and reached a peak value by the increased doses of these treatments ($T_4 = RH_2PT_4$, $T_6 = RH_4PT_0$) and then declined by the highest dose of treatment ($T_8 = RH_4PT_8$). When the higher rates of organic amendments were applied, decomposition of orgnaic amendments might help in releasing oranic acids, which are responsible for decreasing soil pH. Moreover, pH of soils in SW was a little bit higher in comparison to FM condition, which might be due to submergence as occurred by the 2 - 5 cm standing water condition. Another study conducted by Li *et al.* (2013) and they

reported that initial soil pH 8.27 reached 7.36 due to 5% raw rice straw application which is also aggreed with the present findings.

The EC values of the post harvest soils both in the field moist (FM) and 2 - 5 cm satnding water (SW) conditions were found to be influenced by different rates of indigenous organic amendments (rice hull and pistia, Fig. 6). The maximum EC values (3.60 dS/m in FM and 3.43 dS/m in SW) were recorded for the T_0 (control) treatment. It was observed that the increased levels of treatments from T_0 to T_3, the soil EC values were decreased and in the treatment T_3 to T_5, the EC values were almost stable. But the EC of soils

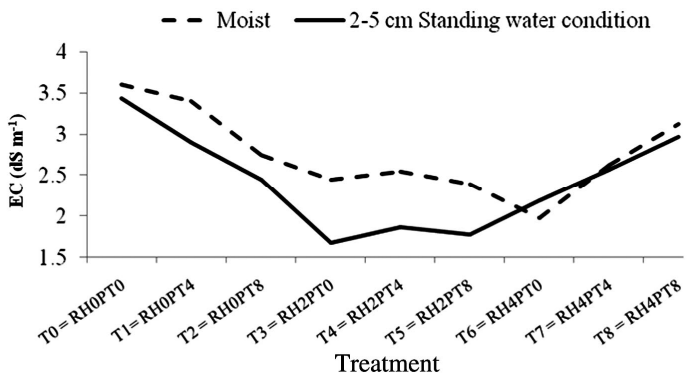

Fig. 6. Effects of rice hull and pistia on the EC values of the post harvest soils under field moist (moisture 70%) and 2 - 5 cm standing water conditions during rice cultivations.

increased gradually from the T_5 to T_6 treatments and reached maximum with the higher rates of amendments and their combinations. Another study conducted by Gonzalez *et al.* (2010) and they achieved a substantially decreased EC of saline-sodic soils with the addition of different organic amendments. The decrease in EC value was the result of organic matter triggered leaching of excessive ions by improving the physical properties of soil. The further increase in EC of soils might be due to presence of salts in organic amendments. The present study is also in accordance with the finding of Gonzalez *et al.* (2010).

Conclusion

The findings of the present study demonstrated that the application of rice hull and pistia to the studied saline soil significantly ($p \leq 0.05$) increased the vegetative growth of rice variety BRRI Hybrid Dhan-6. Further, plant height, tiller production, fresh shoot and dry shoot matter weights were found to have better responses in the 2 - 5 cm standing water

condition than that of the field moist condition. The soil pHs in standing water condition were a little bit higher in comparison to FM condition, which might be due to the impacts of submergence as happened due to the application of standing water. The findings also suggest further research is needed to carry out for the elevated dose of rice hull and pistia to reduce the adverse effect of salinity in a cost-effective way. On the other hand, moisture variation plays a potential role for the production of rice that suggested for proper irrigation is necessary aimed at the higher production and reclamation of saline soil.

Acknowledgements

The study was carried out under the project entitled 'Assessment of Impacts of Climate Change on Soil Health and Food Security, and Adaptation of Climate-smart Agriculture in Most Adversely Affected Areas of Bangladesh' funded (2017-'18) by BCCT, MoEFCC, Government of the People's Republic of Bangladesh. They are also grateful to the Ministry of Science and Technology for providing NST fellowships for all authors, except for the second author.

References

BBS (Bangladesh Bureau of Statistics). 2017. *Yearbook of Agricultural Statistics-2016*. Planning Division, Ministry of planning, Government of the People's Republic of Bangladesh, Dhaka.

Begum, M. and H.R. Khan. 2013. Influence of gypsum, rice-hull and different levels of saline water irrigation on water soluble cations and organic matter content in different saline soils in response to wheat. *International J. Res. Applied Nat. and Social Sci.* **1**: 15-22.

Black, C.A. (ed.). 1965. *Methods of Soil Analysis: Part 2*, Series 9, pp. 894-1372, Am Soc. Agron. Inst. Publ., Madison, WI.

BRRI (Bangladesh Rice Research Institute). 2015. *Modern Rice Cultivation*, 18th Edition.

Chapman, H.D. 1965. Cation exchange capacity, *In: Methods of Soil Analysis, Part 2 (ed.)* C.A. Black. Agrn. Series 9. pp 891-900, Am. Soc. Agron., Publ. Madison, WI, USA.

Gonzalez, M.E., R. Gomez and R. Comese. 2010. Influence of organic amendments on soil quality potential indicators in an urban horticultural Sys-Tem. *Biore-Source Technol.* **101**: 8897-8901.

Jackson, M.L. 1973. *Soil Chemical Analysis*. pp. 46-183. Prentice Hall of India Pvt. Ltd., New Delhi.

Kamara, A., H.S. Kamara and M.S. Kamara. 2015. Effect of rice straw biochar on soil quality and the early growth and biomass yield of two rice varieties. *Agricultural Sciences* **6**: 798-806.

Kaniz, F. and M.H.R. Khan. 2013. Reclamation of saline soil using gypsum, rice hull and saw dust in relation to rice production. *J. Adv. Sci. Res.* **4** (3): 1-5.

Kanwal, S., S. Iram, M. Khan and I. Ahmad. 2011. Aerobic composting of water lettuce for preparation of phosphorus enriched organic manure. *African Journal of Microbiology Research* **5**(14): 1784-1793.

Khan, M.H.R., M.M.A. Bhuiyan, and S.M. Kabir. 2016. Effects of selected treatments and techniques for the reclamation and improvement of Cheringa acid sulfate soil under rice production in the coastal plain of Cox's bazar. *J. Asiat. Soc. Bangladesh, Sci.* **42**(1): 29-40.

Li, F., X. Cao,L. Zhao, F. Yang, J. Wang and S. Wang. 2013. Short term effects of raw rice straw and its derived biochar on greenhouse gas emission in five typical soils in China. *Soil Sci. Plant Nut.***59** (5): 800-811.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. *In: Methods of Soil Analysis. Patr-2.* (2nd Ed.). pp. 539-579. A. L. Page (ed.), American Society of Agronomy Publication, Madison, WI.

Olsen, S.R., C.V. Cale, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA *Circ.* **939**, Washington, USA.

Parham, J.A., S.P Deng, W.R Roun and G.V. Johnson. 2002. Long-term cattle manure application in soil. *Bio. Fertile Soils* **35**: 328-337.

Piper, C.S. 1966. *Soil and Plant Analysis*, pp. 77. Hans Publisher. Bombay.

Prakash, N.B., H. Nagaraj, N. Vasuki, R. Siddaramappa and S. Itoh. 2002. Effect of recycling of plant silicon for sustainable rice farming in south India. *In:* 17th WCSS, August, Thailand, pp. 851(1-7).

Pratt, P.F. 1965. *Methods of Soil Analysis* (Black C.A. Ed.) pp. 1022. Am. Soc. Agron. Madison, Wisconsin, USA.

Quadir, D.A. and M.A. Iqbal. 2008. Investigation on the Variability of the Tropical Cyclones Impacting the Livelihood of the Coastal Inhabitants of Bangladesh, Consultancy Report, International Union for Conservation of Nature (IUCN) - Bangladesh IUCN Contract No. IUCNB-Consult-069 & IUCNB-Consult-070.

Reddy, I.N.B.L.,B. Kim, I. Yoon, K. Kim and T. Kwon. 2017. Salt tolerance in rice: Focus on mechanisms and approaches. *Rice Science* **24**(3): 123-144.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. US Govt. Print. Office, Washington, USA, 1954: *In:* USDA Hand Book No. **60**: 84-156.

Sakai, H. 1978. Some analytical results of sulfur deficient plants, soil, and water, Workshop on sulfur nutrition in rice, December, BRRI, Publication No. **41**: 35-59.

SRDI (Soil Resource Development Institute). 2010. Saline Soils of Bangladesh. Ministry of Agriculture, Dhaka, Bangladesh.

USSLS (United States Salinity Laboratory Staff). 1954. Diagnosis and improvement of saline and alkali soils. *In: USDA Hand Book No.* **60**. pp. 84-156. US Govt. Print. Office, Washington, USA.

(Revised copy received on 23.10.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 185-193, December 2018

LENGTH-WEIGHT RELATIONSHIP AND SEX RATIO OF *AMBLYPHARYNGODON MOLA* IN DEKAR *HAOR* OF SUNAMGANJ, BANGLADESH

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Abstract

The study was carried out to determine length-weight relationship and sex ratio of a freshwater fish *Amblypharyngodon mola* (Hamilton 1822) collected from Dekar *haor* of Sunamganj district during the period of January to August 2017. A total of 2000 fishes were collected for the study and categorized these fishes into three groups namely males, females and combined sexes. Among 2000 mola 777 were male and 1223 were female. Length-weight equations and the correlation coefficients obtained for males, females and combined ones were: males Y = –1.97 + 3.00X, r = 0.883; females Y = –2.30 + 3.41X, r = 0.914 and combined Y = –2.11 + 3.16X, r = 0.904. Female's *A. mola* attained more weight with the increases in length. Value of correlation coefficient 'r' was 0.883 for male and exhibited highly positive correlation between length and weight. On the contrary, 'r' value for female was 0.914 and it had also strongly positive correlation between length and weight relationships. Length-weight relationship of *A. mola* for male, female and combined sexes showed allometric pattern of growth. Condition factor 'K' for male, female and combined sexes was 1.09, 1.05 and 1.06, respectively and indicated better condition of fishes. The highest sex ratio (1 : 2.05) was found in May and the lowest (1 : 1.33) was in February. Dominance of females over males throughout the year was observed with an average ratio of male and female 1 : 1.57. Therefore, results of the study indicate that the existing hydrobiological conditions of the *haor* are conducive for food availability, free movement, feeding and better growth of the fish.

Key words: Correlation coefficient, Condition factor, Sex ratio, *Haor*

Introduction

Amblypharyngodon mola (Hamilton 1822) is one of the most abundant and nutritious fish species found all the year round in Dekar *haor* (depressed low land with seasonal and perennial waterbodies connected with canals and rivers). It is commonly known as 'Indian carplet' or 'pale carplet' and widely distributed in freshwater habitats like ponds, streams, rivers, flood plain wetlands, canal and paddy fields. Though *A. mola* is a small indigenous species (SIS), it has tremendous importance due to its high content of vitamin-A. The studies on its nutritive value revealed that *A. mola* contains >2680 retinol

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activity equivalents per 100 g of raw and edible portions (Roos 2001). It is also rich in Fe, Zn and Ca (Roos *et al.* 2007). This fish is relished by the common man of the region in fresh, smoked, dried as well as pickle form. In different parts of Bangladesh, it is locally known as *mourala*, *mola*, *mowa* or *mowka*. This fish is distributed in India, Bangladesh, Pakistan and Myanmar (Talwar and Jhingran 1991). Earlier the fish was considered as weed fish but in advent of time the fish is now highly demandable, economically valuable and costly fish in the market. Considering nutritious value, taste, income source, availability, family chosen fish and to alleviate poverty recently emphasis is given to culture small indigenous fish in Bangladesh, out of which *mola* is one of them (ARG 1986). Recently, it has also got its entry in ornamental fish trade and has been reported to be available in ornamental fish markets with moderate demand and availability. *Mola* (*A. mola*) is a self-recruiting species and its culture is being encouraged among the farmers in national economy of Bangladesh to overcome the nutritional deficiency (Gupta and Banerjee 2012).

Morphometric relationships between length and weight can be used to assess the well-being of individuals and to determine possible differences between separate unit stocks of the same species (King 2007). In addition, length-length relationships are also important in fisheries management for comparative growth studies (Moutopoulos and Stergiou 2002).

Condition factor is one of the standard practices in fisheries, which is used as an indicator of the variability to attribute growth coefficient. It expresses the condition of a fish such as degree of well-being, relative robustness, plumpness or fatness in numerical terms. The condition of a fish reflects recent physical and biological circumstances and fluctuates by interactions among feeding condition, parasitic infections and physical factors (Le Cren 1951). It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish lives. Condition factor also gives information, when comparing two populations living in certain feeding, density, climate and other conditions, the period of gonadal maturation and when following up the degree of feeding activity of a species to verify as to whether it is making good use of its feeding source (Anene 2005).

According to Pantulu (1961), sex ratio is an indicator of population behavior and fecundity. An understanding of the sex ratio of a fish in different months and seasons is essential for obtaining information on different segregation of the sexes and also their differential growth. To the best of the knowledge, information on length-weight relationship and sex ratio of *A. mola* in *haor* environment are not available in

Bangladesh. Considering these, the study was undertaken with the aim to determine length-weight relationship and sex ratio of male, female and combined of *A. mola* from Dekar *haor* of Sunamganj district, Bangladesh.

Materials and Methods

The study was conducted in Dekar *haor* of Dakshin Sunamganj, which lies between latitude 24°46´N and 24°57´N and longitude 91°20´E and 91°31´E. Sample collection was done during eight months from January to August 2017. Samples were collected twice in a month at 15-day intervals.

A total of 2000 samples were collected randomly. After collection, the samples were transported to the laboratory in a large polyethylene bag with 5% formalin. Then washed and transferred to a filter paper to remove excess water from the body surfaces of fishes.

Standard length of fish was measured from tip of the snout to base of the caudal end using measuring scale (cm) and weight up to 0.1 g using digital weighing balance, respectively. Statistical relationship between length and weight was established by the parabolic equation given by Froese (2006), $W = aL^b$, where, W = Weight of fish (g), L = Length of fish (cm), a = Constant and b = A regression coefficient expressing relationship between length and weight. The relationship ($W = aL^b$) was converted into logarithmic form of equation giving a straight line relationship graphically, Log W = Log a + b Log L. The equation is same to Y = a + bX, where, Log W = dependent variable (Y), Log L = independent variable (X), b = regression coefficient or slope, a = intercept.

Condition factor 'K' was calculated by Fulton's (1904) equation, $K = W \times 100/L^{3,}$ where, K = Condition factor, W = Observed body weight (g), L = Observed length of fish (cm).

Sex determination was done by secondary (external) sexual characteristics of fishes. Normally female fish is larger than male and male is brighter than female. In matured female, abdomen is soft and swollen, pelvic fins are smooth and caudal fin is deeply forked in spawning season and their distended abdomen is easily visible. For determination of sex ratio, a total of 2000 fishes were used and ratio was analyzed by χ^2 test.

$$\chi^2 = \frac{\sum(O - E)^2}{E}$$

where, O = Observed value and E = Expected value.

Data were analyzed using Microsoft Office Excel and SPSS software (Version 20) with $p < 0.05$ considered significantly different.

Results and Discussion

Higher degree of correlation between length and weight was indicated by correlation coefficient 'r'. The observed length and weight relationship of male, female and combined are presented in scatter diagrams (Figs 1 - 3). Values of regression coefficient computed were 3.00, 3.41 and 3.16, respectively for male, female and combined sexes.

Table 1. Length-weight relationship and condition factor of male, female and combined *Amblypharyngodon mola.*

Sex	No. of sample	Value of 'b'	Logarithmic equation	Correlation coefficient 'r'	Condition factor 'k'
Male	777	3.00	Y = –1.97 + 3.00X	0.883	1.090
Female	1223	3.41	Y = –2.30 + 3.41X	0.914	1.052
Combined	2000	3.16	Y = –2.11 + 3.16X	0.904	1.066

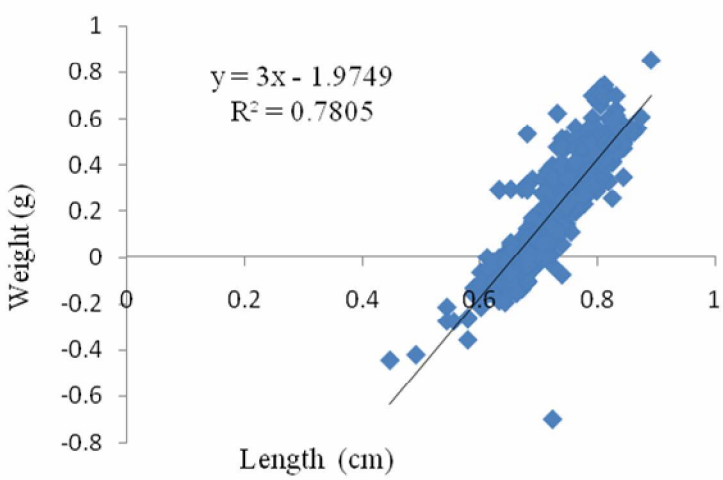

Fig. 1. Length-weight relationship of male *A. mola*.

Correlation coefficient 'r': Values of correlation coefficient 'r' for both male and female were 0.883 and 0.914, respectively and showed strongly positive and significant relationships between length and weight (Table 1 and Figs 1 - 2). Combined population also exhibited strongly positive correlation and showed 'r' value as 0.904, which is closed to 1 (Table 1 and Fig. 3). Findings of the study reveal that the growth performance of both male and female *A. mola* are higher owing to correlation coefficient 'r' exhibits high degree of positive allometric correlation between the length and weight relationship

of *A. mola* (Table 1). Positive allometric growth might be due to higher proficiency in feeding and better environmental condition for survival of the species (Soni and Kathal 1953, Saikia *et al*. 2011). Gohain and Goswami (2013) and Deka and Bura (2015) also reported the effect of availability of food and other associated factors to be responsible for positive allometric growth.

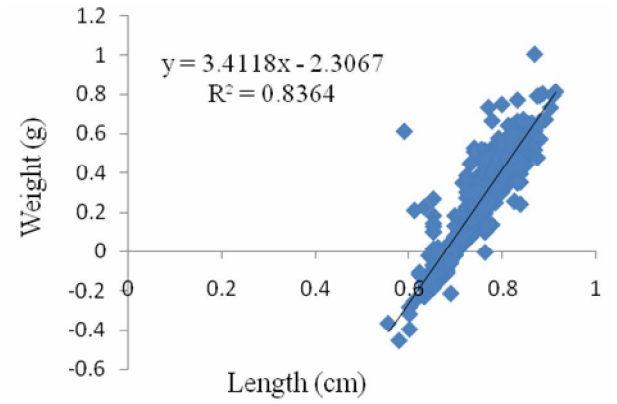

Fig. 2. Length-weight relationship of female *A. mola*.

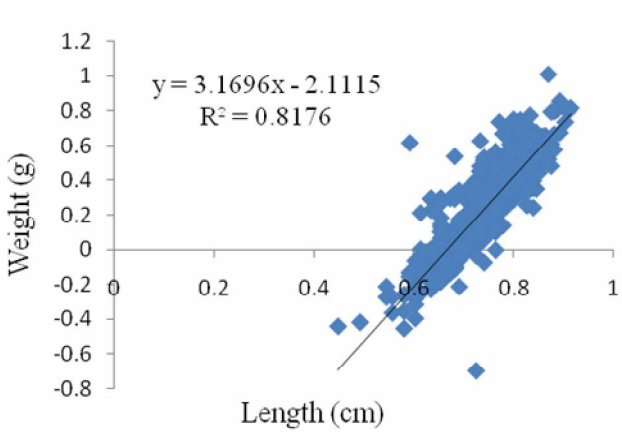

Fig. 3. Length-weight relationship of combined *A. mola*.

Regression coefficient value 'b': Regression coefficient 'b' is an indicator of isometric/allometric pattern of fish growth. In the present study, value of 'b' was 3.00 for male, which indicated isometric pattern of growth in ideal condition and 3.41 for female, which indicated positive allometric pattern of growth (Table 1 and Figs 1 - 2). 'b' value of combined sexes was 3.16, which also indicated positive allometric growth (Table 1 and Fig. 3).

In all cases the values of 'b' are not found in normal ranges between 2.5 and 4.0. Findings of the study also indicate that 'b' value follows the 'Cube law' strictly for male as it remains constant at 3.0 for an ideal fish and deviates from female in a particular environmental condition. Several biological factors like sex, size of fish, physiological condition and gonadal maturity, feeding and fatness have significant influence over length-weight relationship of fishes (Le Cren 1951, Devaraj 1973, Reddy and Rao 1992). Regression value of female and male of the present study is more or less similar to the findings of Mitra *et al.* (2005), Kumar *et al*. (2006), Prasad and Ali (2007) and Baishya *et al*. (2010) who worked on *Puntius sophore, Labeo bata, Rasbora daniconius* and *Amblypharyngodon mola*, respectively in India and Bangladesh. Higher regression value of female fish may be attributed to the general condition of appetite, gonadal contents of fish and also environmental conditions.

Condition factor 'K': Values of condition factor 'K' for male, female and combined sexes were 1.090, 1.052 and 1.066, respectively and it was higher than the value of 1, which indicate good condition of the fishes (Table 1 and Figs 1 - 3). It was observed that males indicated slightly better condition than females, which might be associated with food proficiency, physiological or other better environmental factors of the waterbody.

Fish with higher value of 'K' are heavy for its length, while with low 'K' are lighter (Bagenal and Tesch 1978). 'K' value greater than 1 indicates better condition of fish (Le Cren 1951). These findings are in agreement with the findings of the present study.

Sex ratio: Data on sex ratio of *A. mola* revealed that number of females was more than that of males. Per cent of individual month and total percentage of male and female showed females were dominated in natural population throughout the year (Table 2). Out of 2000 fishes, 777 were males and 1223 females. Monthly sex ratio between males and females ranged from 1 : 1.33 to 1 : 2.05 and average was 1 : 1.57 ($\chi^2 = 68.34$, $p < 0.05$, N = 2000). The highest sex ratio was obtained 1 : 2.05 in May, which are not coincided with the result of Gogoi and Goswami (2014) who reported the highest sex ratio of male and female as 1 : 3.61 in July. These may be occurred due to location, food availability and environmental factors.

Dominance of females over the males in freshwater fish *A. mola* was also reported by Azadi and Mamun (2004) as well as Afroze *et al.* (1991-92). Dominance of females was also seen in other species of fishes like *E. vacha*. Different populations inhabit in different regions and show different sex ratios. Higher sex ratio was found during first breeding season and lower sex ratio in second breeding when water parameters are at their peak as reported by Singh (1994). A rising temperature and moderate water

velocity, vulnerability of females to their predators and other natural hazards, migratory phase in brood population are some of the reasons for changes in sex ratio in fishes (Gogoi and Goswami 2014).

Table 2. Monthly distribution of sex ratio and Chi-square (χ^2) value of *Amblypharyngodon mola.*

Month	Male		Female		Combine		Ratio of male & female	Chi value	p value
	Count	%	Count	%	Count	%			
January	102	42.7	137	57.3	239	100.0	1.00:1.34	50.25	<0.05
February	112	42.9	149	57.1	261	100.0	1.00:1.33	18.665	<0.05
March	106	40.2	158	59.8	264	100.0	1.00:1.49	63.24	<0.05
April	90	38.1	146	61.9	236	100.0	1.00:1.62	52.95	<0.05
May	81	32.8	166	67.2	247	100.0	1.00:2.05	102.23	<0.05
June	95	37.5	158	62.5	253	100.0	1.00:1.66	74.14	<0.05
July	99	40.6	145	59.4	244	100.0	1.00:1.46	44.25	<0.05
August	92	35.9	164	64.1	256	100.0	1.00:1.78	72.25	<0.05
Total	777	38.8	1223	61.2	2000	100.0	1.00:1.57	68.34	<0.05

Findings of the study imply that females of *A. mola* are more healthy and haviour with increases in length than males. Length-weight relationship of *A. mola* in male, female and combined sexes shows positive allometric pattern of growth of the fishes. So it can be concluded that existing hydrobiological conditions of the *haor* is conducive for feeding, free movement and better growth of the fishes. Results of the study also indicate that most of the fishes are females during breeding season, whereas numbers of males are close to female fishes during nonbreeding seasons but not above.

Acknowledgements

Authors are indebted to Krishi Gobeshona Foundation (KGF), BARC, Farmgate, Dhaka for providing financial support to perform the research.

References

Afroze, S., M.A. Hossain and S. Parween. 1991-92. Notes on the size frequency distribution and length-weight relationship of freshwater fish *Amblypharyngodon mola* (Hamilton). *Univ. J. Zool. Rajshahi Univ.* 10 &11: 103-104 pp.

Anene, A. 2005. Condition factor of four Cichlid species of a man-made lake in Imo State, South-eastern Nigeria. *Turk. J. Fish. & Aqua Sci.* **5**: 43-47.

ARG (Aquatic Research Group). 1986. Hydrobiology of the Kaptai reservoir. FAO/UNDP research project contact No. DP/79/015-4/F1. Final Report, 192 pp.

Azadi, M.A. and A. Mamun. 2004. Reproductive biology of the cyprinid *Amblypharyngodon mola* (Hamilton) from the Kaptai reservoir, Bangladesh. *Paki. J. Bio. Sci.* **7**(10): 1727-1729.

Baishya, A., A. Dutta and S. Bordoloi. 2010. Morphometry and length-weight relationship of *Amblypharyngodon mola* (Hamilton-Buchanan, 1822). *Indian J. Fish.* **57**(1): 87-91.

Begenal, T.B. and A.T. Tesch. 1978. Conditions and growth pattern in fresh water habitats. Blackwell Scientific Publications, Oxford. 75-89 pp.

Deka, P. and G.A. Bura. 2015. Length-weight relationship and relative condition factor of *Rita rita* (Hamilton, 1822), *Pangasius pangasius* (Hamilton, 1822) and *Chitala chitala* (Hamilton, 1822) of Brahmaputra river system of Assam, India. *Inter. J. Fish. and Aqua. Stud.* **3**(1): 162-164.

Devaraj, M. 1973. Biology of the large snakehead *Ophiocephalus marulius* (Ham) in Bhavanisagar waters. *Indian J. Fish.* **20**(2): 280-307.

Froese, R. 2006. Cube law, condition factor, and weight-length relationship: History, meta-analysis and recommendations. *J. Appl. Ichthyol.* **22**(4): 241-253.

Fulton, T.W. 1904. The rate of growth of fishes.Twenty-second annual report, part III. Fisheries board of Scotland, Edinburgh. 141-241 pp.

Gogoi, R and U.C. Goswami. 2014. Length-weight relationship and sex ratio of fresh water fish *Amblypharyngodon mola* (Ham.-Buch) from Assam. *Inter. J. Fish. and Aqua. Stud.* **1**(4): 68-71.

Gohain, A.B. and M.M. Goswami. 2013. A study on length-weight relationship and condition factor in different age groups of *Clarias brachus* (Hamilton, 1882) in wetland aqua habitat of Assam. *India. J. Aqua.* 14(1-2): 65-70.

Gupta, S. and S. Banerjee. 2012. Indigenous ornamental fish: A new boon in ornamental fish trade of West Bengal. *Fishing Chim.* **32**(1): 130-134.

King, M. 2007. Fisheries biology, assessment and management. 2nd edn. Blackwell Sci. Publ, Oxford. 43-48 pp.

Kumar, H.K., B.R. Kiran, R. Purushotham, E.T. Puttaiah and S. Manjappa. 2006. Length-weight relationship of cyprinid fish *Rasbora daniconius* (Hamilton-Buchanan) from Sharavathi reservoir, Karnataka. *Zoos' Print J.* **21**(1): 2140-2141.

Le Cren, E.D. 1951. Length-weight relationship and seasonal cycle in gonadal weight and condition in the perch *(Perca fluviatilis*). *J. Anim. Ecol.* **20**: 201-219.

Mitra, K., V.R. Suresh, G.K. Vinci and B. Naskar. 2005. Length-weight relation, reproductive characters and condition of *Puntius sophore* (Hamilton) from a flood plain wetland in West Bengal. *J. Inland Fish. Soc. India.* **37**(1): 16-22.

Moutopoulos, D.K. and K.I. Stergiou. 2002. Length-weight and length-length relationship of fish species from the Aegean sea (Greece). *J. Appl. Ichthyol.* **18**(3): 200-203.

Pantulu, V.R. 1961. Determination of age and growth of *Mystus gulio* by the use of pectoral spines with observations on its biology and fishery in Hoogly estuary. Proceedings of the National Institute of Science of India. **27**(4): 198-225.

Prasad, G. and A.P.H. Ali. 2007. Length-weight relationship of a cyprinid fish *Puntius filamentosus* from Chalakudy River, Kerala. *Zoos. Print. J.* **22**(3): 2637-2638.

Reddy, V.S. and M.B. Rao. 1992. Length-weight relationship and relative condition of *Puntius sophore* (Ham-Buch) from lake Hussain Sagar, Hyderabad, India. *J. Inland Fish. Soc. India.* **24**(1): 22-25.

Roos, N. 2001. Fish consumption and aquaculture in rural Bangladesh: Nutritional contribution and production potential of culturing small indigenous fish species in pond polyculture with commonly cultured Carps. Ph. D. Dissertation, Research Department of Human Nutrition, RVAU, Denmark.

Roos, N, M.A. Wahab, C. Chamnan and H. Thilsted. 2007. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *The J. Nutri.* **137**(4): 1106-1109.

Saikia, A.K., A.S.K. Singh, D.N. Das and S.P. Biswas. 2011. Length-weight relationship and condition factor of spotted snakehead, *Channa punctatus* (Bloch), Bulletin of Life Science **17**: 102-108.

Singh, S. 1994. Some aspects of fishery and biology of *Labeo rohita* (Ham-Buch) from Jaisamand, Rajasthan. M. Sc. (Agri.) Thesis, Rajasthan Agricultural University, Bikaner.

Soni, D.D. and M. Kathal. 1953. Length-weight relationship in *Cirrhina mrigala* (Val.) and *Cyprinus carpio* (Ham.). *Matsya* **5**: 67-72.

Talwar, P.K. and A.G. Jhingran. 1991. Inland fishes of India and adjacent countries. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. **1**(2): 1158.

(Revised copy received on 26.10.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 195-210, December 2018

COMPARATIVE STUDY OF THE CHANGES IN CLIMATIC CONDITION AND SEASONAL DROUGHT IN NORTH-WESTERN PART OF BANGLADESH

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Abstract

The study examines the long-term and seasonal climatic variations in north-western part of Bangladesh (NWPB). Long-term variation of different climatic parameters reveals that significant increases in temperature are associated with decreasing evaporation which could be attributed to wind speed variation and seasonal variation of temperature. Increase of monsoon rainfall during monsoon period and scarcity or absence of rainfall during dry periods increase the region's vulnerability to monsoon flood and seasonal drought, respectively. The area witnesses a single peak of rainfall in July during the first half of the study period (1964-1985), whereas the same experiences bimodal peak of rainfall during July and September in the second half of the study period (1986-2007). This may signify the changes of climatic condition in the studied area. Annual variability of rainfall as well as the unpredictable shifting of rainfall periods might be a possible reason for the seasonal drought. The aridity index indicates that the overall dryness of the area has increased during winter season. The study shows that humidity increases at all stations throughout the year. The study also shows that long-term seasonal variation of both surface and groundwater level is also prominent. Gradual decrease of surface water level was observed in Teesta River which might be due to unilateral withdrawal of surface water in the upper riparian. Detailed investigation on hydrometeorology of the study area is required to see whether there is any trend of climate change in the area.

Key words: Aridity index, Climate change, Hydrometeorology, Seasonal drought, Monsoon flood

Introduction

Geographically Bangladesh extends from 20º34´ N to 26º38´ N and 88º10´ E to 92º41´ E latitude and longitude, respectively. Climatically the country belongs to sub-tropical region where monsoon weather prevails throughout the year. Three distinct seasons can be recognized in Bangladesh from climatic point of view: (i) The dry winter season from November to February, (ii) the pre-monsoon hot summer season from March to May, and (iii) the rainy monsoon season which lasts from June to October (Rashid 1991).

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Bangladesh is one of the most disaster-prone countries in the world. High spatial and temporal climatic variability, extreme weather events, high population density, high incidence of poverty and social inequity, poor institutional capacity, inadequate financial resources, and poor infrastructure have made Bangladesh highly vulnerable to disaster (Ahmed and Kim 2003).

The average temperature of Bangladesh ranges from 17 to 20.6ºC during winter and 26.9 to 31.1ºC during summer. The average annual rainfall of the country varies from 1,329 mm in the northwest to 4,338 mm in the northeast (Shahid *et al.* 2005). The gradient of rainfall from west to east is approximately 9 mm/km. The western part of Bangladesh experiences an average areal rainfall of approximately 2,044 mm, which is much lower than that of other parts of the country. The rainfall is also very much seasonal, almost 77% of rainfall occurs during monsoon. Like high annual variability of rainfall, temperature also fluctuates intensely in the country. In summer, the hottest days experience temperatures of about 45ºC or even more in the region. Again in the winter the temperature even falls at 5ºC in some places. Hence, the region experiences the two extremities that clearly contrast with the climatic condition of rest of the country (Banglapedia 2003).

Drought is a prolonged, continuous period of dry weather along with abnormal insufficient rainfall. It occurs when evaporation and transpiration exceed the amount of precipitation for a reasonable period. Drought causes the earth to dry up and a considerable hydrologic imbalance resulting water shortages, wells to dry, depletion of groundwater and soil moisture, stream flow reduction, crops to wither leading to crop failure and scarcity in fodder for livestock. In the context of global warming, most of the climatic models project a decrease in precipitation in dry season and an increase during monsoon in south Asia (Christensen *et al*. 2007).

The study area is located in the north-western part of Bangladesh and extends from 23º 80' to 26º 38' N latitude and from 88º01' to 89º 70' E longitude (Fig. 1). The climate of the study area i.e., the NWPB is dominated by tropical monsoons. It is characterized by high temperature, moderate rainfall with often excessive humidity and fairly marked seasonal variations. The most striking feature of this climate is the reversal of the wind circulation between winter and rainy season, which is an integral part of the circulation system of the Indian subcontinent (Rashid 1991). Drought has become a recurrent natural phenomenon of NWPB in recent decades.

Prime objectives of the study were to determine the long term and seasonal changing patterns of various hydrometeorological parameters with time. The partial influences of

changing climatic condition and human intervention for the recurrent drought and flood in the study area were also emphasized.

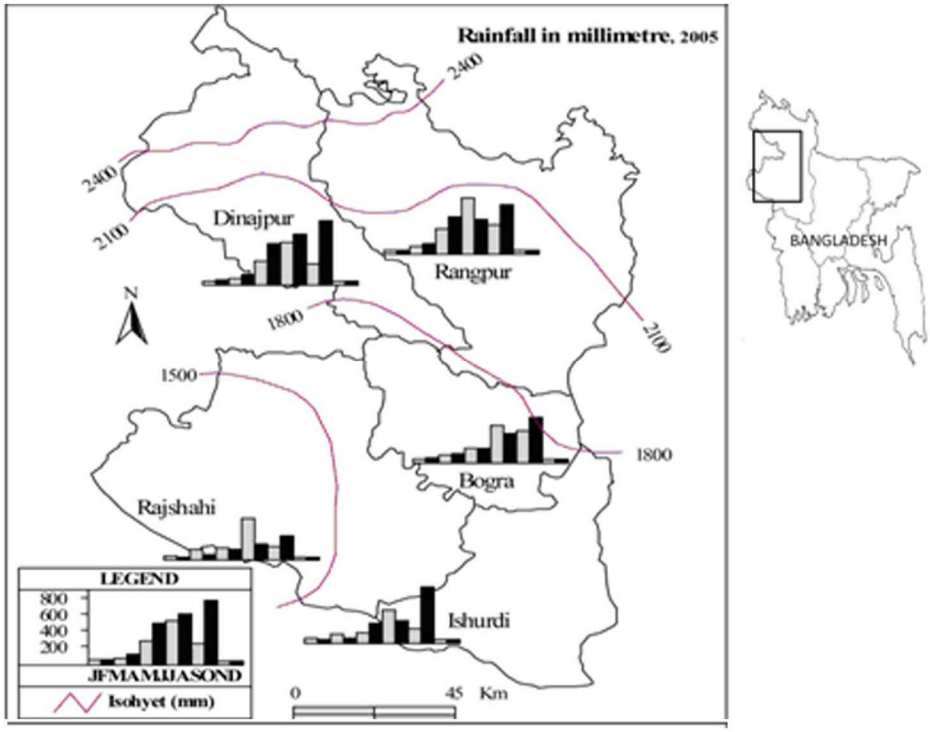

Fig 1. Relative location of the stations and the rainfall distribution map in the study area (Modified after Shamsuzzoha *et al*. 2011).

Materials and Methods

Time series data of available hydrometeorological parameters were collected and simple mean (M) was used for this work. Data of mean wind speed, humidity, temperature, rainfall were divided into two halves (1964 - 1985 and 1986 - 2007) in all stations to determine and compare the long term seasonal variation. The periods ranging from the years 1964 to 1985 and 1986 to 2007 hereinafter are referred to as first half and second half, respectively. Data of temperature and rainfall during winter, monsoon and summer were prepared to determine the long-term seasonal variation with time. Data for evaporation, surface water level (SWL) and groundwater level (GWL) were analyzed at selected time intervals (1968 - 1972, 2003 - 2007), (1995 - 2004) and (1995 - 2004),

respectively. Aridity index (AI) curves were prepared to determine the variation of dryness at two selected intervals. Hydrographs from selected rivers were prepared to determine the long-term variation of SWL. Mean maximum and minimum SWL and GWL were measured at two intervals (1995 - 1999, 2000 - 2004) to understand the change of water level at different locations with time. GWL data were collected from nine observation wells and hydrographs were prepared to determine the GWL fluctuation at different locations. At last all of these parameters were correlated to understand the long term change in climatic condition of the study area. All hydrometeorological data were procured from Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDB).

Results and Discussion

Temperatures: Significant differences in seasonal temperature occur across the NWPB which is influenced by latitude and monsoon activities (Brammer 1996). Mean minimum temperature increases throughout the year at all stations. On the other hand, summer and winter mean maximum temperature decreases except at Ishurdi and Bogra. The highest increase of both mean maximum and minimum temperatures were found during monsoon. Both mean maximum and minimum temperatures at all stations during monsoon period were found higher than the previous years.

Most significant increase was observed at Bogra which rose from 34.67 to 35.52ºC. Highest temperature was found about 35.67ºC at Rajshahi during the period of 1986 - 2007. The lowest monsoon temperature was found at Rangpur which was about 22.17ºC during the second half. The fluctuation between the summer mean maximum and minimum temperature decreased during the year range of 1986 - 2007 compared to that during the period 1964 - 1985. The mean maximum temperature at all the stations decreased during summer except that at Ishurdi. The highest summer temperature increased up to 40.2ºC at Ishurdi and the lowest summer temperature was found at Rangpur which was 16.44ºC during the second interval. No significant fluctuation of mean winter temperature was observed at all stations. Highest winter temperature was found at Bogra which was about 30.49ºC and the lowest was found about 9.36ºC at Ishurdi (Table 1).

Wind: Wind in NWPB generally shows nearly the opposite direction of movement due to the differential heating and cooling of landmass and oceans during summer and winter. During the monsoon, a center of low pressure and monsoon trough develops over the west-central part of India because of intense surface heat. To replenish the low air

pressure zone air containing high water vapor moves from the southern sea i.e. the Bay of Bengal which takes its route along the studied area. On the other hand, the high Himalayan mountain acts as an effective barrier for the airflow during winter period. Air subsiding beneath westerly jet stream (southern) causes subtropical high pressure and gives dry out-blowing over the studied area towards south which is mostly devoid of water vapor (Trewartha 1968). Pre-monsoon summer and autumn are the transition season which is characterized by lighter wind speed and more complicated flow patterns (Islam 2003).

Table 1. Mean maximum (Max) and minimum (Min) temperature at selected stations during monsoon, summer and winter period in the studied area.

Location	Monsoon temperature (ºC)				Summer temperature (ºC)				Winter temperature (ºC)			
	1964-1985		1986-2007		1964-1985		1986-2007		1964-1985		1986-2007	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Bogra	34.67	22.27	35.52	22.77	38.26	16.96	37.14	17.67	30.23	10.15	30.49	10.9
Dinajpur	35.04	22.28	35.26	22.78	37.95	16.95	36.97	17.67	29.26	10.09	29.18	10.93
Ishurdi	35.16	21.75	35.37	22.52	37.3	19.4	40.2	21.2	30.16	8.52	30.19	9.36
Rajshahi	35.45	22.19	35.67	22.53	39.71	16.82	39.5	16.72	30.22	9.95	30.12	9.37
Rangpur	34.9	22.02	35.01	22.17	36.57	15.7	35.76	16.44	28.72	9.75	28.79	10.15

Source: BMD.

Mean wind speed at Ishurdi, Dinajpur and Rajshahi decreased but it was increasing at Bogra and Rangpur during second half (1986 - 2007). During the first period (1964 - 1985), mean maximum wind speed was observed at Ishurdi which ranged from 5.37 to 7.48 knots. However, during the second period (1986 - 2007) the wind speed at Ishurdi was significantly lower than the past. The highest wind speed of about 4.76 knots was observed in April during the second half of the study period at Rangpur (Fig. 2).

Rainfall: Amount of precipitation in north-western Bangladesh shows spatial and seasonal variation. In the studied area the highest mean annual rainfall was recorded about 2338 mm at Rangpur. On the other hand, Dinajpur, Bogra, Ishurdi and Rajshahi experienced 2083, 1844, 1688 and 1465 mm of rainfall, respectively. From this observation it can be assumed that the amount of rainfall is gradually decreasing from the N-E to the S-W part of the studied area which is more or less controlled by the geographical location of the area based on the proximity of the Himalayan.

The variations of mean annual rainfall at successive years are prominent in the studied area. The amount of precipitation in different years varied between 1758 and 2877, 1427 and 2969, 1431 and 2243 mm, 1184 and 2097 and 1161 and 1806 mm at Rangpur,

Dinajpur, Bogra, Ishurdi and Rajshahi, respectively without following any definite increasing or decreasing trend during the period from 1965 to 2007. The upward and downward shifting of the amount of rainfall is given in Table 2 (Shamsuzzoha *et al*. 2011).

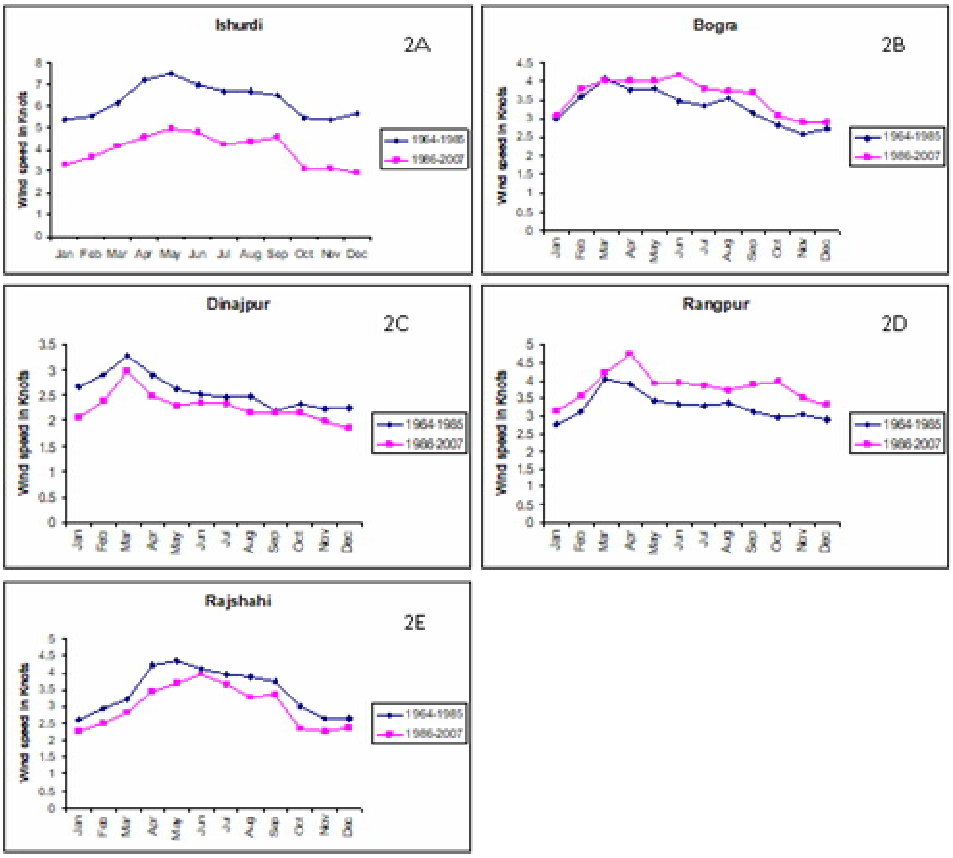

Fig. 2. Changes of mean monthly wind speed in the studied area - 2A: Ishurdi; 2B: Bogra; 2C: Dinajpur; 2D: Rangpur and 2E: Rajshahi.

At all the stations the maximum peak distribution of rainfall were observed at July both in 1964 - 1985 and in 1986 - 2007. Long-term seasonal changes in rainfall show that rainfall increased in most of the stations during the period between 1986 and 2007 compared to the first time interval especially during monsoon. Exception was observed at Ishurdi, which shows the opposite result during the months between April and August (Fig. 3). One important observation was that during the first half the pattern of rainfall exhibits unimodal peak which was found in July at all the stations but during the second

half pattern of rainfall shows bimodal peak distribution. During the second interval, the first peak was found in July and another one in September with comparatively lower values. In Ishurdi the two rainfall peaks were almost equal. These evidences of the changing trend of rainfall pattern might be considered as a precursor for the shifting of rainfall peak seasons.

Table 2. Variation (Var.) of mean annual rainfall (mm) and their percentage.

Year	Bogra (1847)		Dinajpur (2089)		Rajshahi (1461)		Rangpur (2333)		Ishwardi (1681)	
	Var.	%	Var.	%	Var.	%	Var.	%	Var.	%
1970	↓087	4.67	↓668	31.90	↓085	5.76	↓336	14.37	↑130	7.68
1975	↓42	22.49	↓040	1.89	↓305	21.00	↓568	24.27	↓177	10.48
1980	↓22	11.8	↓128	6.17	↑116	7.88	↓211	9.12	↓227	13.39
1985	↓14	7.6	↑006	0.25	↓210	14.49	↑540	23.11	↑097	5.82
1990	↑236	12.71	↓010	0.44	↑342	23.51	↑155	6.65	↑411	24.39
1995	↑403	21.75	↑522	24.90	↓028	1.97	↑477	20.49	↓498	29.69
2000	↓019	0.94	↓566	27.07	↑231	15.69	↓579	24.76	↑128	7.57
2005	↑245	13.24	↑887	42.42	↓057	3.84	↑522	22.30	↑139	8.22

↓ Rainfall decrease, ↑ Rainfall increase. Source: Shamsuzzoha *et al*. 2011.

Comparatively higher rainfall during the monsoon period might aggravate the intensity of monsoon flood in the studied area. On the other hand, relative decrease in rainfall during dry period along with shifting of higher rainfall period and the uneven distribution of total annual rainfall in different years might increase the possibility of seasonal drought in the studied area.

Evaporation: In general, sunshine duration in Bangladesh is decreasing at an alarming rate. The overall annual decrease for the entire Bangladesh is about 0.36 hours a day in every 10 years. In general, evaporation rate during winter was comparatively lower than the rest of the months at all of the stations. Significant lowering of evaporation rate was observed at Dinajpur and Rajshahi but in Rangpur evaporation slightly increased during winter compared to the past (Fig. 4). Higher reduction of mean evaporation rate at Dinajpur and Rajshahi might be correlated with lower wind speed and decrease of mean maximum temperature at those two regions. Both maximum and minimum winter season temperature slightly increased in Rangpur which was not singly sufficient to explain the increasing amount of evaporation rate. Here, the variation of wind speed along with temperature might play a vital role for the variation of evaporation rate in all of these

three areas. The reduction of sunshine duration can also be ascribed as one of the principal reasons for such a decrease in evaporation (IWFM 2009).

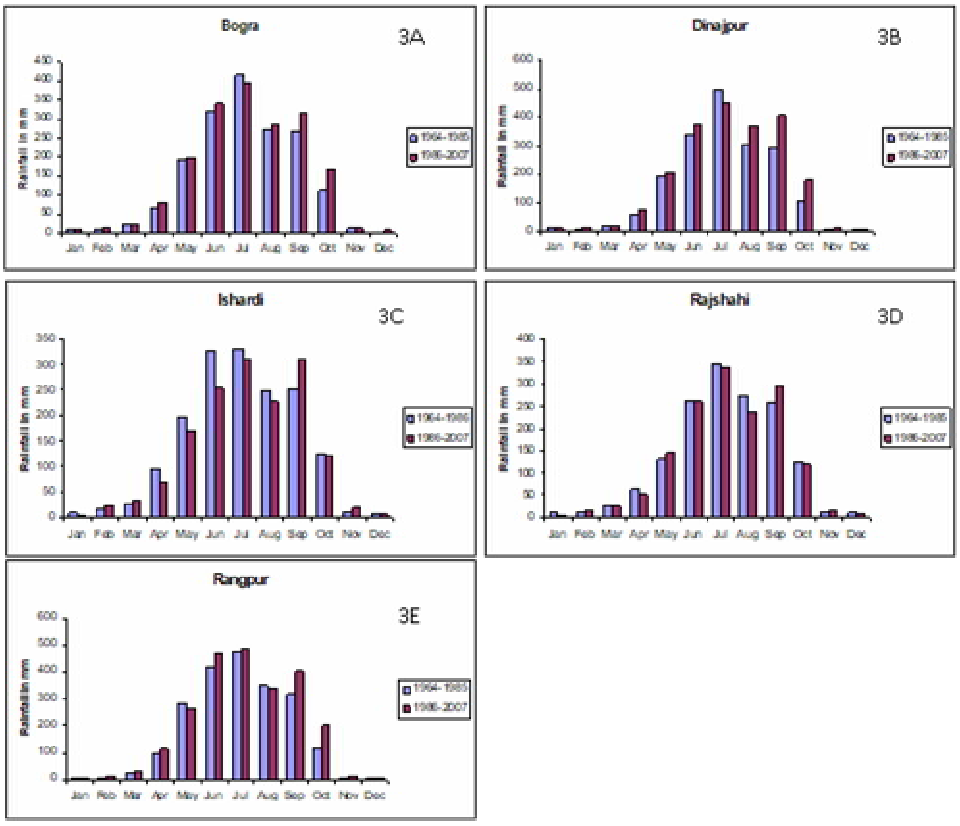

Fig. 3. Changes of mean monthly rainfall in the studied area - 3A: Bogra; 3B: Dinajpur; 3C: Ishurdi; 3D: Rajshahi and 3E: Rangpur.

Values of mean monthly evaporation during 1968 - 1972 varied between 48.65 and 147.17 mm, 34.02 and 121.66 mm, and 58.65 and 168.8 mm at Dinajpur, Rangpur and Rajshahi, respectively. During the period 2003 - 2007, the values ranged between 32 and 109.02 mm, 59.37 and 101.58 mm, and 38.38 and 98.01 mm, respectively.

Aridity index (AI): Aridity Index (AI) can be used to demarcate the dry and wet periods and also to estimate the intensity of dryness and wetness of an area. AI values below 0.5 signify potential evaporation is two times the rainfall (McIntosh 1972) indicating a region of dry climate and vice versa. Values of AI at all of the measured stations were below 0.5 in winter and exceeded this limit during the rest of the months. Wet condition increased

significantly during July in all of the regions but the difference declined during August. In Rangpur, the dryness significantly increased during August compared to the past years and also during the winter.

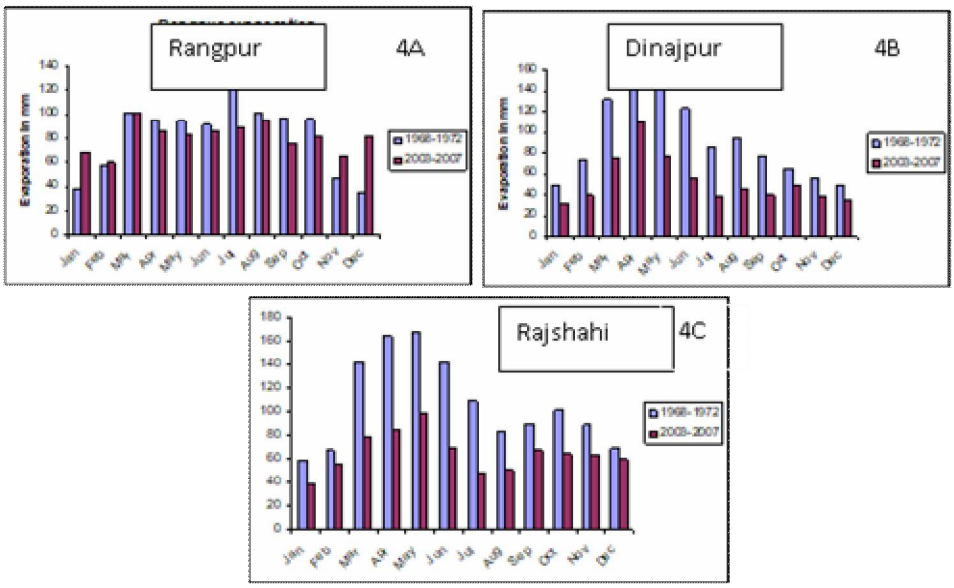

Fig. 4. Changes in mean monthly evaporation in the studied area - 4A: Rangpur; 4B: Dinajpur; 4C: Rajshahi.

In Dinajpur, AI value ranged between 0 and 6.19 during the period of 1968 - 1972 whereas the value ranged between 0.17 and 11.96 during 2003 - 2007. At Rangpur, AI value ranges from 0.01 to 3.93 during the period of 1968 - 1972 and 0.06 to 6.26 during 2003 - 2007. Comparison of AI values in both of the regions showed that the value slightly reduced in winter especially during November to January. The value increased during the rest of the months. Most significant increase in AI value was found during monsoon. At Rajshahi, AI value was found between 0 and 3.44 during the period of 1968 - 1972 whereas the value ranges between 0.04 and 14.51 during 2003 - 2007. The value increased throughout the year except winter. Significant increase in AI value was found during monsoon. Here, the highest AI value of about 14.51 was found at Rajshahi which indicated the higher possibility of flood in that area (Fig. 5).

Comparison of the second half with the first interval showed that the dryness of the area increased during the winter. Significant increase of AI value during monsoon represents the higher possibility of flood during those months.

Humidity: In general, highest values of humidity were observed during monsoon period. During the period of 1964 - 1985 mean annual humidity in the studied area varied between the lowest 872 at Isurdi and the highest 962 at Rangpur. On the other hand, humidity increased up to 969 at Rangpur and 931 at Isurdi and Dinajpur during 1986 - 2007. During the second interval total mean annual humidity increased at all of the stations. The highest increase was found at Isurdi and the lowest at Rangpur (Fig. 6).

Comparison between the variations of humidity of the two intervals showed that the mean monthly humidity increased remarkably at most of the stations throughout the year but relatively lower increases were found during monsoon. In winter, relative increase in humidity higher than the past might be related to the higher evaporation rate during winter season in the second half.

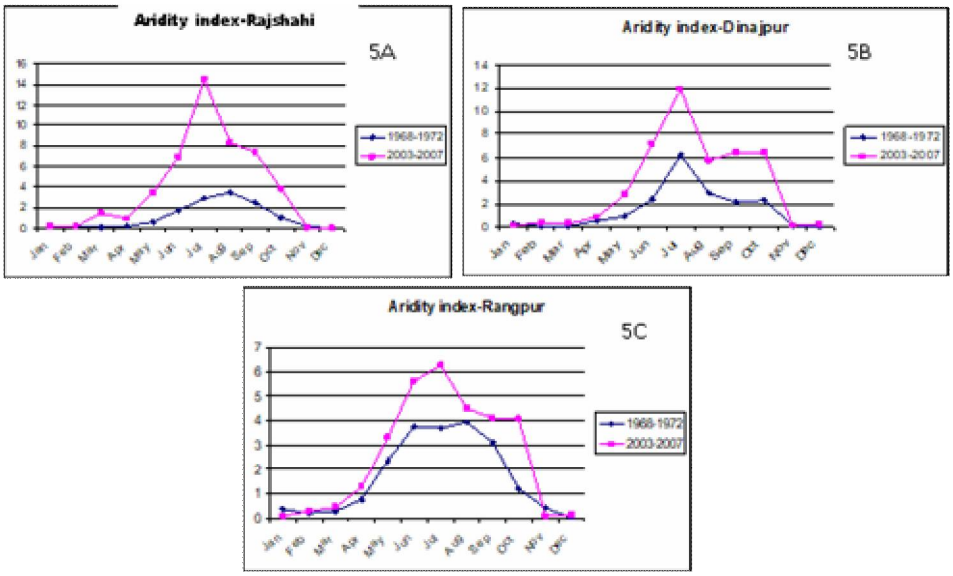

Fig. 5. Aridity Index (AI) curves at selected locations in the studied area - 5A: Rangpur; 5B: Dinajpur; 5C: Rajshahi.

Surface water level (SWL): Construction of dam and significant withdrawal of water at the upstream regions affect the natural flow of transboundary rivers in the NWPB which create scarcity of surface water. It also tends to create negative impact for the replenishment of the upper unconfined aquifer in the studied area. Study showed that the March flows of Ganges River are as much as 57% lower than in the pre-Farakka days (Treadwell and Akanda 2009). Due to the significant withdrawal of water the

downstream riparian country of Teesta barrage are going to be dried up. Karotoa, Fakirni, Buri Teesta, Sonavori, Fulkumar and few other smaller rivers and tributaries in this region are going to be dried up for the same reason (www.probenewsmagazine.com/index).

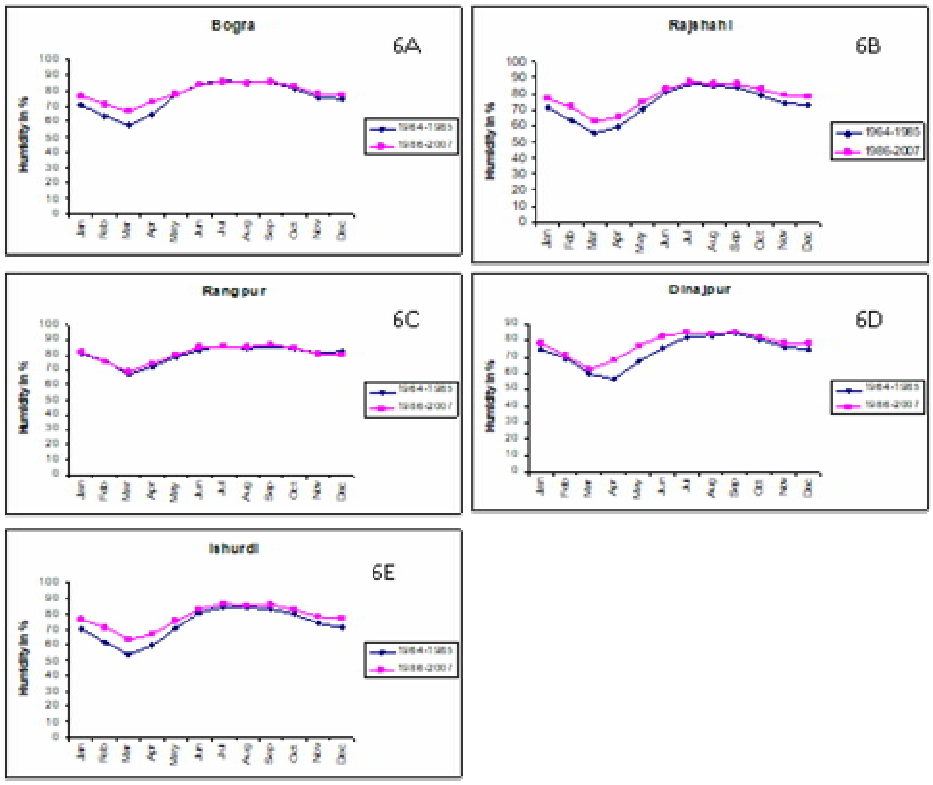

Fig. 6. Changes in mean monthly humidity at different stations - 6A: Bogra; 6B: Rajshahi; 6C: Rangpur;6D: Dinajpur and 6E: Ishurdi.

Long-term hydrographs from five surface water stations were used to determine the long-term variation of SWL at the selected rivers. No significant variations of SWL were observed in Deonair river at Bogra, Ghagoti river at Rangpur and the Korotia river at Dinajpur. Reduction of SWL was observed in Fakirni river at Rajshahi. Declination of SWL is more remarkable at Teesta river at Rangpur (Fig. 7). Both of these two rivers were influenced by the human intervention in the upstream countries.

At Bogra, Rajshahi and Dinajpur the peak of the mean SWL generally started in July during both of the intervals (1995 - 1999 and 2000 - 2004). But at Rangpur the peak of mean SWL started in July during the first half but later the peak shifted to June.

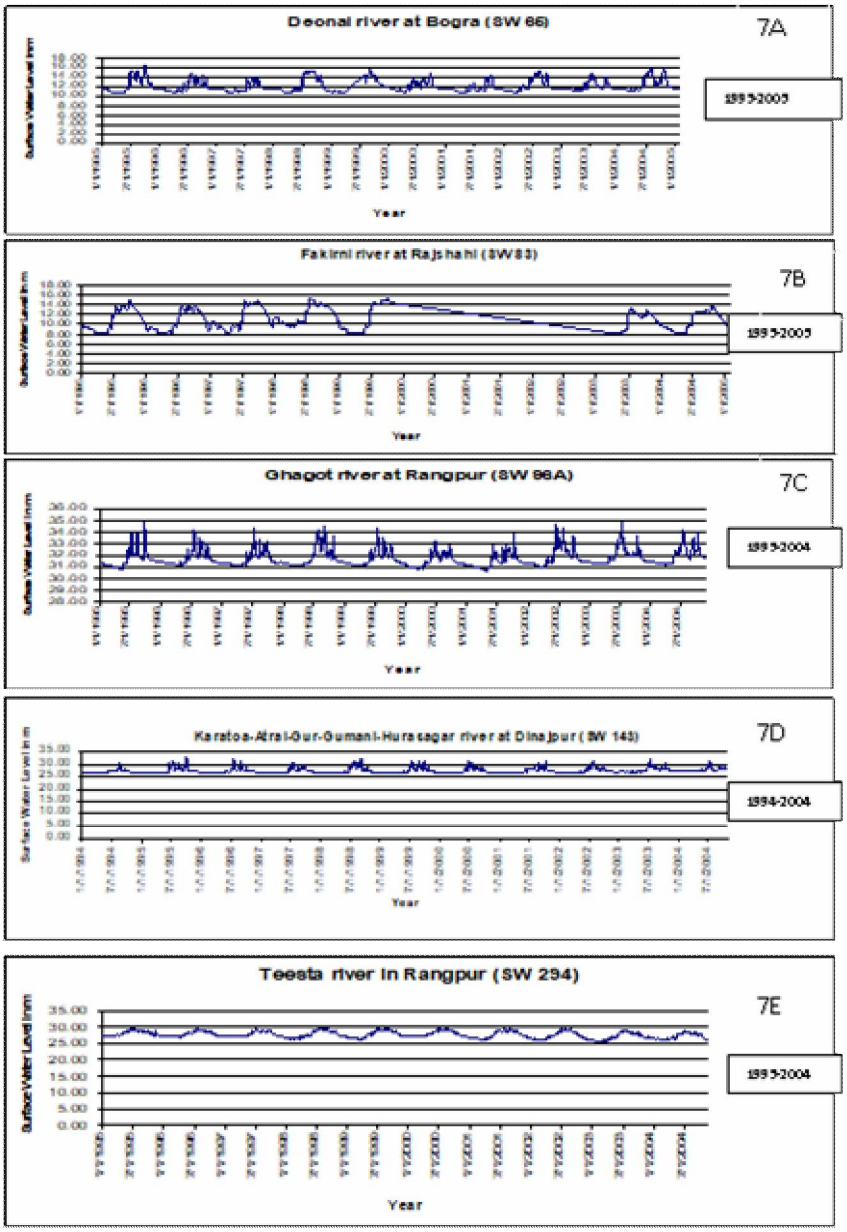

Fig. 7. Long-term changes of surface water level at different rivers in the study area - 7A: Deonair river at Bogra; 7B: Fakirni river at Rajshahi; 7C: Ghagoti river at Rangpur; 7D: Karatoa river at Dinajpur and 7E: Teesta river at Rangpur (Source: BWDB).

Correlating with the rainfall intensity during different months it was found that everywhere the peak of the mean SWL was following the peak of monsoon rainfall. Both of the mean maximum and minimum SWL at station SW 83 in Rajshahi and SW 294 in Rangpur decreased throughout the year. At SW 96 in Rangpur, the mean SWL slightly increased in summer and monsoon months but decreased during the winter. However, the mean SWL slightly decreased during the monsoon but slightly increased during the winter and summer period at SW 65 in Bogra. At SW 143 in Dinajpur, both the mean maximum and minimum SWL increased throughout the year (Table 3).

Table 3. Mean monthly maximum and minimum SWL in m at different year range.

Station name	Location	Ranges of mean monthly SWL (m)			
		1995-1999		2000-2004	
		Max	Min	Max	Min
SW 65	Bogra	11.09 - 15.186	10.7875 - 12.83	11.38 - 14.48	10.97 - 12.8
SW 83	Rajshahi	8.8 - 14.592	8.388 - 13.7	8.36 - 13.425	8.175 - 12.36
SW 96	Rangpur	31.1 - 33.7	30.97 - 31.93	31.16 - 34.19	31.02 - 31.95
SW 143	Dinajpur	26.59 - 31.56	26.52 - 27.62	26.82 - 30.91	26.73 - 27.87
SW 294	Rangpur	27.16 - 29.78	26.7675 - 28.7	26.5 - 29.5	26.202 - 28.5

(Source: BWDB).

At SW 65 in Bogra, the mean minimum SWL was found in April during the two intervals (1995 - 1999 and 2000 - 2004). The mean maximum SWL during the first interval was found in September but in second interval it shifted to October. On the other hand, the mean maximum SWL was found in October for both intervals but the mean minimum SWL shifted from April to May at SW 83 in Rajshahi. Negligible seasonal shifting of mean maximum and minimum SWL was observed at SW 96 and SW 294 in Rangpur and SW 143 in Dinajpur. So, overall seasonal changes of the availability of surface water might negatively affect the seasonal irrigation water requirements in the NWPB.

Ground water level (GWL): According to UNDP (1982), the studied areas were categorized as zone A, D, E and F for groundwater development. Dinajpur district i.e. zone D is characterized by the sediments of mostly coarse detrital piedmont deposits. The clay and silt layers overlying the permeable surface sediment is thin enough to allow maximum infiltration of rainfall. Rangpur district i.e zone A consists mostly of coarse sediments which has the highest transmissivity in the country. The southern districts of the studied area i.e Bogra, Rajshahi and Ishurdi fall in mostly zone E and F, which consists of comparatively thicker layers of overlying clay and silt deposits. As a result,

the rate of infiltration is relatively lower in the southern districts of NWPB (UNDP 1982).

The highest mean monthly GWL was found at DIO-25 in Dinajpur which was 35.72 m and the lowest was found at Rajshahi in RJ-029 which was 5.02 m during the period 1995 - 1999. During the year range 2003 - 2007, highest GWL 36.07 m was observed at the same station of Dinajpurand the lowest 5.82 m in RJ-029 at Rajshahi. Mean monthly GWL showed that its elevation decreased during the second interval (2003 - 2007) throughout the year at B-067, but slight fall was observed at Bogra in B-030, B-009 and B-028. On the other hand, DIO-067 at Dinajpur showed continuously decreasing pattern throughout the year and DIO-025 showed significant reduction during winter and summer but increased higher during monsoon than the past. At both of the stations of Rajshahi, GWL elevation was very low. GWL at RJ-032 was continuously declining but at RJ-029 GWL increased from October to March. GWL was continuously declining throughout the year except the months between April and July at RA-31. No shifting of maximum and minimum GWL was observed in B-028, DIO-025 and RJ-029. At B-03, DIO-067 and RA-031 the minimum GWL was found in April but in all stations maximum GWL shifted from September to October at the second interval. At B-9, minimum GWL shifted from April to March and maximum GWL from November to October. At RJ-32, mean minimum GWL shifted from June to May (Table 4).

Table 4. Mean monthly maximum and minimum GWL in different periods.

Station name	Location	Ranges of mean monthly GWL (m)			
		1995-1999		2000-2004	
		Max	Min	Max	Min
B-030	Bogra	6.78 - 9.4	6.56 - 8.72	6.84 - 8.81	6.58 - 8.4
B-003	Bogra	13.04 - 18.36	12.34 - 17.61	14.05 - 18.1	13.17 - 16.85
B-028	Bogra	10.03 - 13.94	9.76 - 13.08	10.44 - 13.67	10.17 - 12.26
B-009	Bogra	8.97 - 12.99	8.23 - 12.38	9.72 - 14.14	8.84 - 13.43
DIO-25	Dinajpur	33.43 - 35.72	32.87 - 35.41	31.48 - 36.07	30.99 - 35.76
DIO-67	Dinajpur	26.51 - 29.48	27.76 - 30.02	25.18 - 29.25	25.59 - 29.94
RJ-029	Rajshahi	6.29 - 13.1	5.02 - 12.22	6.11 - 13.4	5.82 - 13.16
RJ-032	Rajshahi	9.8 - 11.76	9.62 - 11.63	8.98 - 10.5	8.48 - 10.05
RA-31	Rangpur	28.9 - 31.44	28.57 - 30.54	28.94 - 31.03	28.64 - 30.3

(Source: BWDB).

Conclusion

Significant variation in temperature, atmospheric humidity, evaporation rate and wind speed were observed during different seasons in the NWPB. Increased rainfall in monsoon period and contemporaneous decrease in dry period might aggravate the flood condition during monsoon and drought during the winter period. More changing trend of rainfall pattern than the previous time clearly indicates the changes of climatic condition. Higher annual variability along with unpredictable rainfall shifting than the past might be a reason for the seasonal droughts which badly affect the agricultural production in the NWPB. Comparatively higher AI values during monsoon and lower values during the other seasons than the past shows the higher possibility of flood during the wet monsoon season and drought condition during the dry periods. Remarkable reduction of SWL at Teesta river in Rangpur and also at the Fakirni river in Rajshahi throughout the year was observed. Decrease in SWL and seasonal shifting of peaks may badly affect the agricultural practice. Seasonal shifting of mean maximum GWL at most of the stations with continuous declining of GWL in a few other stations increases the possibility of drought. Finally, the changing pattern of the climatic condition in this study necessitates further vigorous research for better understanding the climatic status in the NWPB.

Acknowledgement

The authors are thankful to Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDB) for providing their valuable hydrometeorological data to carry out this research.

References

Ahmed, R. and I.K. Kim. 2003. Patterns of daily rainfall in Bangladesh during the summer monsoon season: Case studies at three stations. *Physical Geography* **24**(4): 295-318.

Banglapedia, 2003. *National Encyclopaedia of Bangladesh*. Asiatic Society of Bangladesh, Dhaka.

Brammer, Hugh, 1996. *The Geography of the Soils of Bangladesh.* The University Press Limited, Dhaka. 287 p.

Christensen, J.H., B.Hewitson, A Busuioc, A. Chen, X. Gao, I. Held, R. Jones and R.K. Kolli, 2007. *Regional Climate Projections.* In: Climate Change 2007. The Physical Science Basis. Contribution of Working Group to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), 2009. *Characterizing Long term changes of Bangladesh climate in context of Agriculture and Irrigation.* Climate change cell, DoE, MoEF, Component 4b, CDMP, MoFDM, Dhaka.

Islam, Sirajul. 2003. *Banglapedia*. Asiatic Society of Bangladesh, Dhaka.

McIntosh, D.H. 1972. *Meteorological glossary*. Her Majesty's Stationery Office, Met. O. 842, A.P. 897. 319 p.

Rashid er, Haroun. 1991. *Geography of Bangladesh*. The University Press Limited, Dhaka. p. 529.

Shahid, S, X. Chen and M.K. Hazarika, 2005. Assessment aridity of Bangladesh using geographic information system. *GIS Development*. **9**(12): 40-43.

Shamsuzzoha, M., Md. Zahurul Islam, Riaz Hossain Khan and M.N.Amin, 2011. Status of climatic variations in north western region of Bangladesh. *Journal of Agroforestry and Environment*. **5**(2): 57-61.

Treadwell, J. and A.S. Akanda, 2009. *Contributing Factors in the Ongoing Water Conflict Between Bangladesh and India*. https://wikis.uit.tufts.edu/confluence/display/aquapedia. Retrieved on November 21, 2011.

Trewartha, Glenn T 1968. *An Introduction to Climate*. Mcgraw-hill Book Company, New York.

United Nations Development Program (UNDP), 1982. *Groundwater survey, The Hydrogeologic conditions of Bangladesh*. DP/UN/BGD-74-009/1, New York: p. 83-86.

(Revised copy received on 5.11.2018)

J. Asiat. Soc. Bangladesh, Sci. **44**(2): 211-224, December 2018

ASSESSMENT OF FLOOD RISK IN THE EASTERN PART OF JAMUNA FLOODPLAIN

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Abstract

Risk assessment provides the scope to understand the vulnerability situation of any area based on different hazard context. The study has been conducted in the eastern part of Jamuna floodplain area to examine its flood vulnerability. To perform the analysis, the whole study area has been surveyed and examined applying Geographic Information System. The entire hazard, vulnerability as well as the capacity factors are assessed and have been classified into different categories from very low to very high. Individual factor analysis has been considered to realize the specific condition of different factors. Finally, flood hazard map has been prepared to examine the vulnerability of the proposed area. This type of work helps the planners and disaster managers to identify the most risk zone which should receive immediate hazard mitigation measures as well as help to take a decision in an emergency situation when a flood may occur in the study area.

Key words: Flood hazard, Vulnerability, Capacity, Geographic information system

Introduction

Risk assessment is becoming popular in the management and policies of all the major countries especially in disaster management sector like a flood (Meyer *et al.* 2009). In the context of Bangladesh, risk assessment is even more important as she faces different natural calamities on a regular basis and flood is one of them. It noticeably damage humanlives, properties, environments and contributed about 39.26% of worldwide natural disasters and caused about US$ 397.3 billion worth damage between 2000 and 2014 (Em-dat 2010). As Bangladesh is part of the world's most dynamic hydrological and the biggest active delta system, the landscape, position, and outfall of the three major rivers shape the annual hydrological cycle of the land. Too much rain in rainy season and too little water in the dry season is the annual phenomenon in a hydrological cycle. Here regular monsoon event, flood, the depth, and duration of inundation are the deciding factors whether it is affecting beneficially or adversely. Monsoon inflow along with rainfall historically shapes the civilization, development, environment, ecology and the

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economy of the country. Extreme events of flood adversely affect the development, economy, poverty and almost every sector. The quick advancement of satellite-based innovations and the remarkable advancements in spatial data examination and demonstration have empowered various improvements in exact flood risk evaluation and also rational flood management.

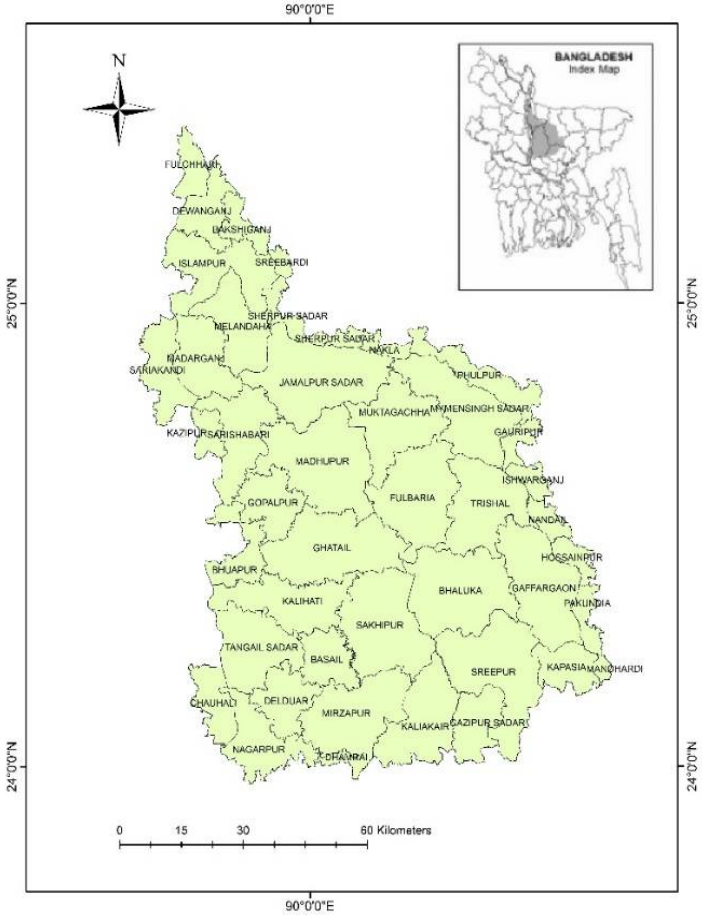

Fig. 1. Study area (Karzakram 2011).

Materials and Methods

The concept of risk: A risk is observed as the likelihood of occurrence or the gradation of loss of a specified element expected from a specific hazard (Schneiderbauer and Ehrlich 2004). While risk measurement varies according to discipline. In hazard research, a risk is equal to the product of two or three factors (Crichton 2002, Wisner *et al.* 2004), though

dissimilar views exist (Chakraborty *et al.* 2005) . For example, (Crichton 2002) summaries chance with a three-way relationship in which risk, presentation, and helplessness contribute freely. On the other hand, Asian Disaster Reduction Center (Shaluf 2007) defines hazard as the coverage areas of three factors - hazard, exposure, and vulnerability - that act simultaneously to generate the risk of natural hazards, which can be expressed as:

$$\text{Risk} = \text{Hazard} \times \text{vulnerability} \qquad \text{(Eq. 1)}$$

$$\text{Risk} = \text{Hazard} \times \text{exposure} \times \text{vulnerability} \qquad \text{(Eq. 2)}$$

While hazards are a probable threat to inhabitants and the surroundings, a risk is an interplay between hazard and vulnerability. Elements at risk, a commonly used term in hazard research, allows the assessment of economic losses from a life-threatening event (Meyer *et al.* 2009). But it is usually not included in the risk equation; it is considered as a part of the vulnerability and exposure analysis.

However, according to the United Nations Disaster Relief Coordinator Office (Peduzzi *et al.* 2009), a risk is the function of elements at risk (e.g., population), hazards, and vulnerability. It varies from the concept of others, who describe risk as a production of hazard and vulnerability (Wisner *et al*. 2004). The risk to a specific community varies over time and time and depends on their socio-economic, traditional, and other characteristics (Cannon 2000, Wisner *et al.* 2004). Moreover the risk of the natural hazards relay on both the hazard and the capability of the community to withstand shocks from disaster.

Risk assessment: Risk assessment refers to the evaluation of the capacity of estimated risks based on the local society's suitability criteria. Processed data and information have been used in the developed model and finally a risk map has been prepared using the following speculation:

$$\text{Risk} = \frac{\text{Hazard} \times \text{vulnerability}}{\text{Coping capacity}} \qquad \text{(Eq. 3)}$$

Concept of flood risk assessment: Flood risk assessment is an interdisciplinary task. It combines various types of source, information and models. Some assessment attempts to estimate many possible hazard factors like flood extent and inundation depth, how probable they are and what may be the consequence (de Moel *et al.* 2015).

Integrated risk assessment model: Risk is the product of hazard, exposure, vulnerability, and coping capacity. Using these measures, hazard (the probability or severity of flood, elevation from sea level), exposure characterizes (structure, population, population

density, distance from river), and capacity (awareness, relief system, economic strength, use of indigenous knowledge, education system), it is possible to determine community's risk to hazards and can take the necessary actions to lessen the risk of disaster. The proposed model was mainly developed to assess the flood risk of the Jamuna Floodplain. Hence, all these above-mentioned components are applicable to single hazard investigation. The model is based on three important principles.

First, a single hazard perspective is used rather than a multi-hazard.

Second, it is only applicable for hazards that have spatial relevance, such as the flood. Spatially non-relevant hazards such as disaster earthquake or cyclone cannot be used.

Third, the model may be useful to determine community risk by integrating hazard and vulnerability. However, it is unable to recognize individuals' risk. An important pitfall of this model is that it requires plentiful data to operationalize the concept.

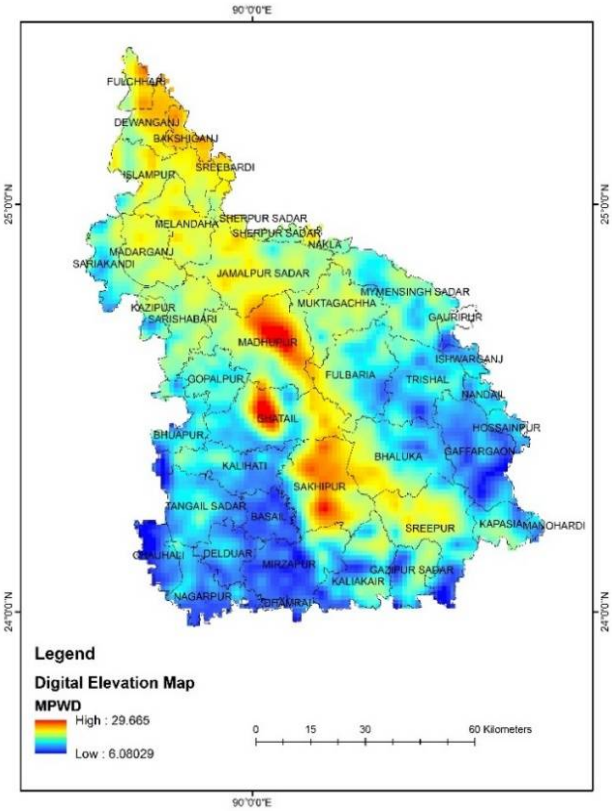

Fig. 2. Elevation map.

Topographic analysis: For the purpose of using geographical data in the planned model, Upazilla map are constructed from an administrative shapefile provided by the Government of Bangladesh. GPX converter (an online open source) has been used to obtain elevation data for a particular area which was later processed and assembled into a spatial database using GIS and image processing (Fig. 2). According to the elevation of the study area elevation rank has been prepared on a map (Fig. 3).

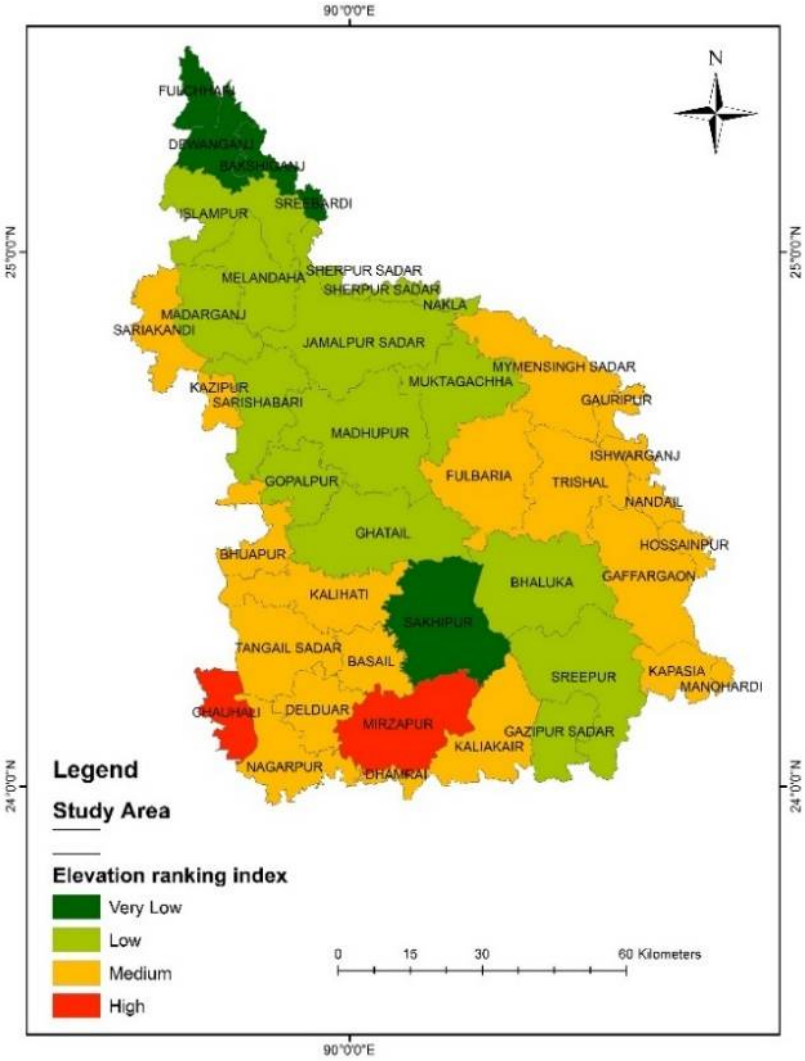

Fig. 3. Elevation ranking.

Analysis of variables of the proposed model

Raster elevation ranked as 20 meters and above height from the sea level is 5 in rank, and 1 is in risk rank while very low in risk index. The estimated values, ranks and risk index are given in the Table 1.

Table 1. Elevation value, rank and index used in the model.

	Values	Rank	Risk index
1 - 5	1	5	Very high
6 - 10	2	4	High
11 - 15	3	3	Medium
16 - 20	4	2	Low
20 +	5	1	Very low

Source: Tingsanchali and Karim 2010.

Table 2. Upazilawise population density in the study area.

SL. no.	Name of the Upazila	Area (sq. km)	Total population	Density/ sq. km	Density rank (*)
1	Basail	157.78	148555	941	2
2	Bhaluka	444.05	264991	596	2
3	Delduar	184.54	175684	952	2
4	Fulbari	402.41	345283	858	2
5	Gafargaon	401.16	379803	946	2
6	Ghatail	451.30	341376	756	2
7	Gopalpur	193.37	252747	1307	3
8	Jamalpur Sadar	489.56	501924	1025	3
9	Kaliakair	414.14	232915	741	2
10	Kalihati	301.22	354959	1178	3
11	Madargonj	225.38	24306	107	1
12	Madhupur	500.67	375295	749	2
13	Melandaha	239.65	262478	1095	3
14	Mirzapur	373.89	337496	902	2
15	Muktagacha	314.71	321759	1022	3
16	Sakhipur	429.63	220281	512	2
17	Sharishabari	263.48	289106	1097	3
18	Tangail Sadar	334.26	680518	2035	5
19	Trisal	338.98	336797	993	2

* Population density index, 100 – 500 = 1, 501 – 1000 = 2, 1001 – 1500 = 3, 1501 – 2000 = 4, 2000+ =5

Source: Bangladesh Bureau of Statistics 2011.

Analysis of population density of human settlement: The population density of the study area provided further evidence of the problems especially in the case of losses of life due to flooding. To assess the flood risk on population settlement, Upazila wise population density statistics has been usedand shown in Table 2. A population density index map has been developed for better visualization (Fig. 4).

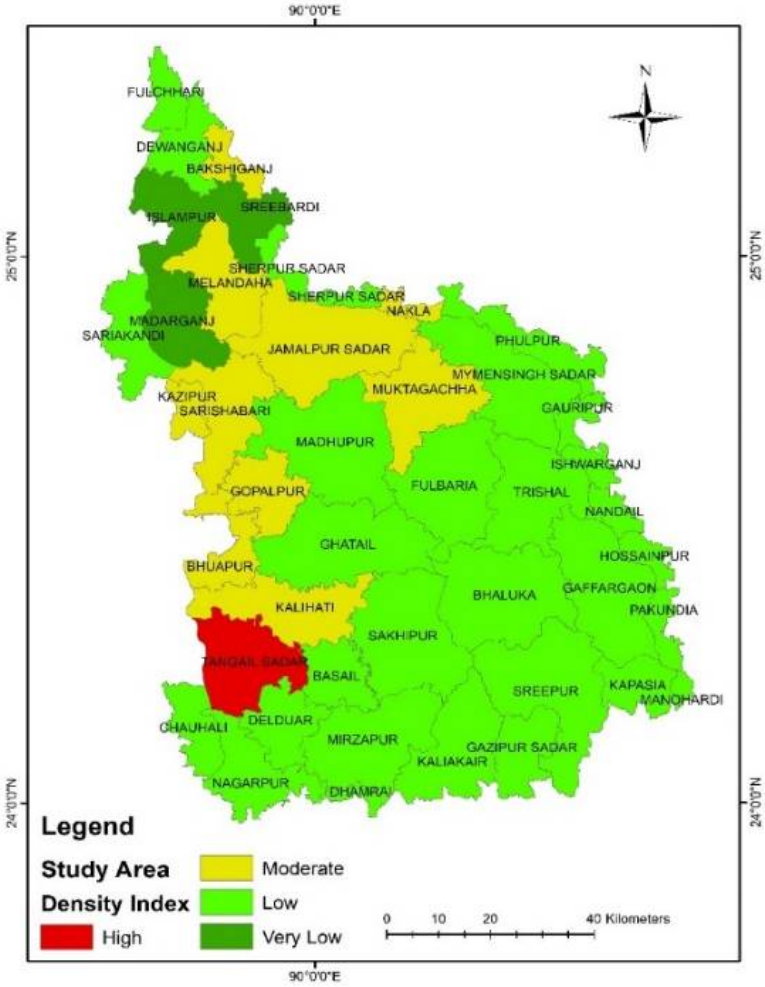

Fig. 4. Population density index.

Hydrological analysis: The vulnerability of flood in any catchment or basin area or floodplain depends on the hydrological characteristics of its own. To determine the actual scenario of hydrological risk, distance from the river of each unit of land (Upazila)

calculated and in this case the river Jamuna has been taken into consideration as a river. Upazila wise distance rank has been prepared on the basis of a distance from the river. The distance has been calculated using proximity toolset in Arcgis 10.1 version. Fig. 5 represents the distant ranking.

Table 3. Hydrological data used in the model.

Sl. No.	Name of the Upazila	Area (Sq. km)	Average distance from the river (Km)	Distance rank *
1	Basail	157.78	38.62	3
2	Bhaluka	444.05	51.49	4
3	Delduar	184.54	24.14	1
4	Fulbari	402.41	54.71	4
5	Gafargaon	401.16	86.90	5
6	Ghatail	451.30	32.18	1
7	Gopalpur	193.37	8.04	1
8	Jamalpur Sadar	489.56	40.23	3
9	Kaliakair	414.14	65.98	5
10	Kalihati	301.22	6.43	1
11	Madargonj	225.38	9.65	1
12	Madhupur	500.67	37.01	2
13	Melandaha	239.65	25.74	2
14	Mirzapur	373.89	41.84	3
15	Muktagacha	314.71	59.54	4
16	Sakhipur	429.63	45.06	3
17	Sharishabari	263.48	14.48	1
18	Tangail Sadar	334.26	17.70	1
19	Trisal	338.98	67.59	5

*Distance index, 0 - 16 = 1, 17 - 32 = 2, 33 - 48 = 3, 49 - 64 = 4, 65+ = 5

Average vulnerability index: To calculate the average vulnerability of the selected area, population density and the distance from the river has been considered because the flood will affect more if it sticks in a densely populated area rather than an area which has less density. On the other hand distance from the river is another parameter as in our country maximum flood occurs when the river cannot contain the excessive water flow coming down from the upward in monsoon period. A vulnerability index map (Fig. 6) has been developed using the average score of the distance from the river and population density.

Coping capacities or coping strategies: Coping capacities or coping strategies are highly complementary since greater resilience is achieved. People of the study area adapted various strategies to cope with the flood of their own and also with the help of different organizations. Focus group discussion (FGD), key informant interview (KII) have been conducted in every Upazilla. Coping strategies of the local people used in the developed model as furnished in the table below: (Table 4) and the map (Fig. 7) symbolize the overall capacity scenario of that specific area.

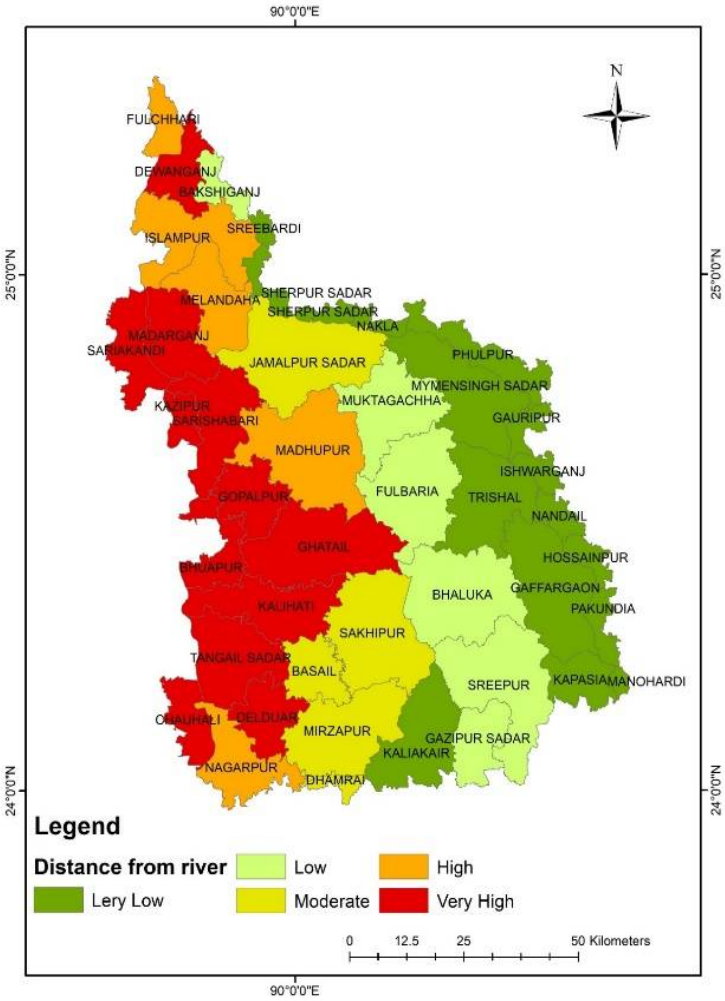

Fig. 5. Distant rank from the river.

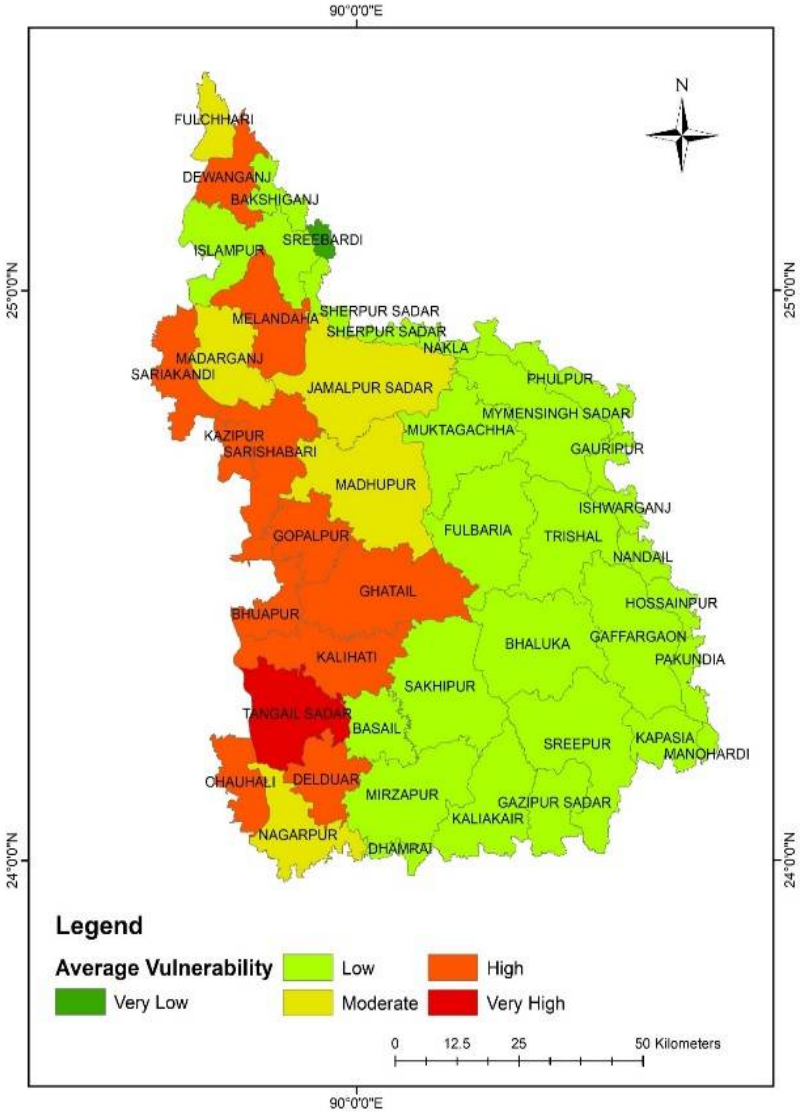

Fig. 6. Average vulnerability index.

Flood risk ranking map: Based on the assessment final risk has been calculated through the equation (Eq. 3). The developed model has run using Arc GIS and final flood risk map have been developed. In the case of the final output of the flood risk map, three major variables like hazard, vulnerability and capacity have been considered. Similarly,

in scheming hazard, vulnerability and capacity both ordinal and nominal values were calculated through the model. Fig. 8 is the final yield of flood rink valuation of the study area.

Table 4. Coping capacity, variables and index (Upazila-wise).

Sl. No.	Name of the Upazila	Variables of measuring coping capacity				
		Awareness	Relief system	Economic strength	Use of indigenous knowledge	Education level
		Index	Index	Index	Index	Index
		Very high = 5 High = 4 Medium = 3 Low = 2	Very good = 5 Good = 4 Satisfactory = 3 Not good = 2 Bad = 1	High = 3 Medium = 2 Low = 1	High = 3 Medium = 2 Low = 1	Very high = 5 High = 4 Medium = 3 Low = 2 Very low = 1
1	Basail	4	4	1	2	2
2	Bhaluka	4	5	2	2	2
3	Delduar	4	4	2	2	2
4	Fulbari	3	3	3	3	3
5	Gafargaon	4	2	2	2	2
6	Ghatail	4	4	2	1	2
7	Gopalpur	3	4	1	1	2
8	Jamalpur Sadar	3	3	3	1	3
9	Kaliakair	4	5	3	2	4
10	Kalihati	4	4	1	2	2
11	Madargonj	4	4	2	1	2
12	Madhupur	5	4	2	3	2
13	Melandaha	4	5	1	1	2
14	Mirzapur	5	3	2	3	2
15	Muktagacha	3	3	2	3	2
16	Sakhipur	4	3	2	2	2
17	Sharishabari	4	4	2	3	2
18	Tangail Sadar	4	2	3	1	2
19	Trisal	3	3	2	2	2

Index of economic based on monthly income taka 15000+ = 3, 10000 - 15000 = 2, 0 - 10000 = 1
Index of education (%), 0 - 20 = 1, 21 - 40 = 2, 41 - 60=3, 61 - 80 = 4, 80+ = 5.

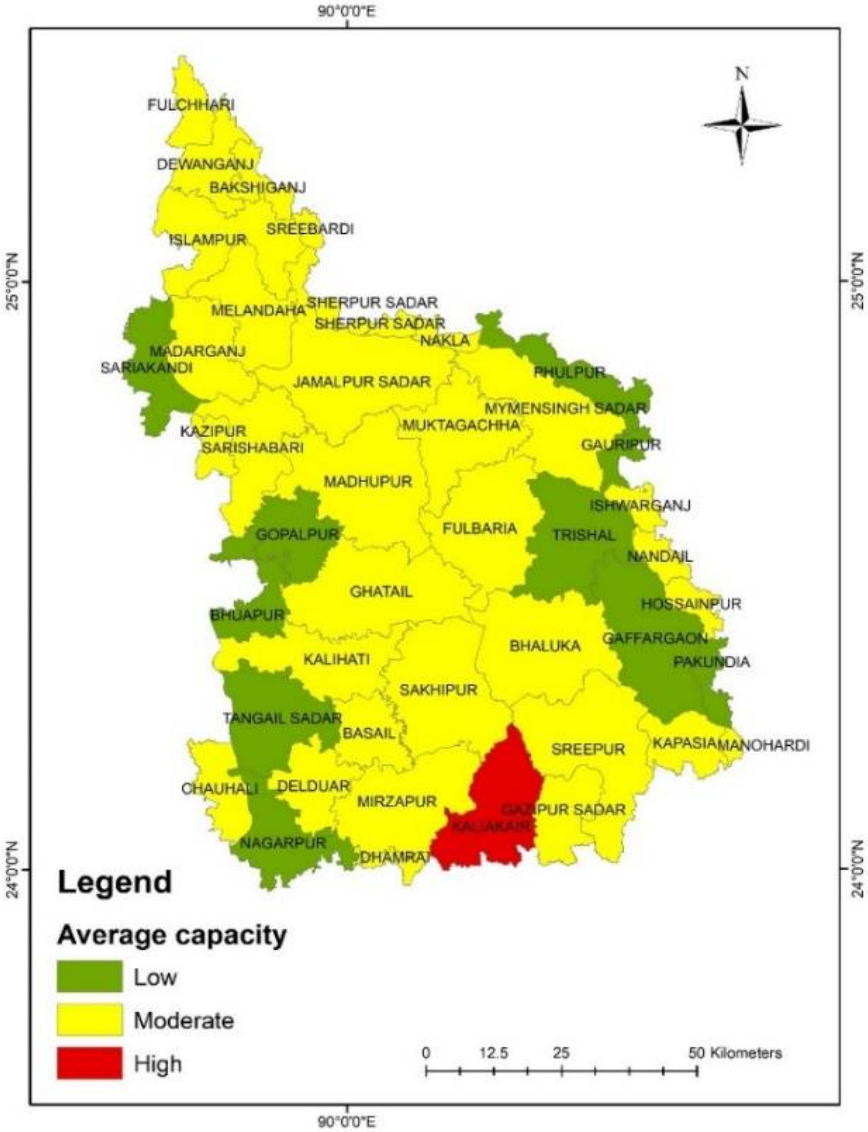

Fig. 7. Average capacity ranking.

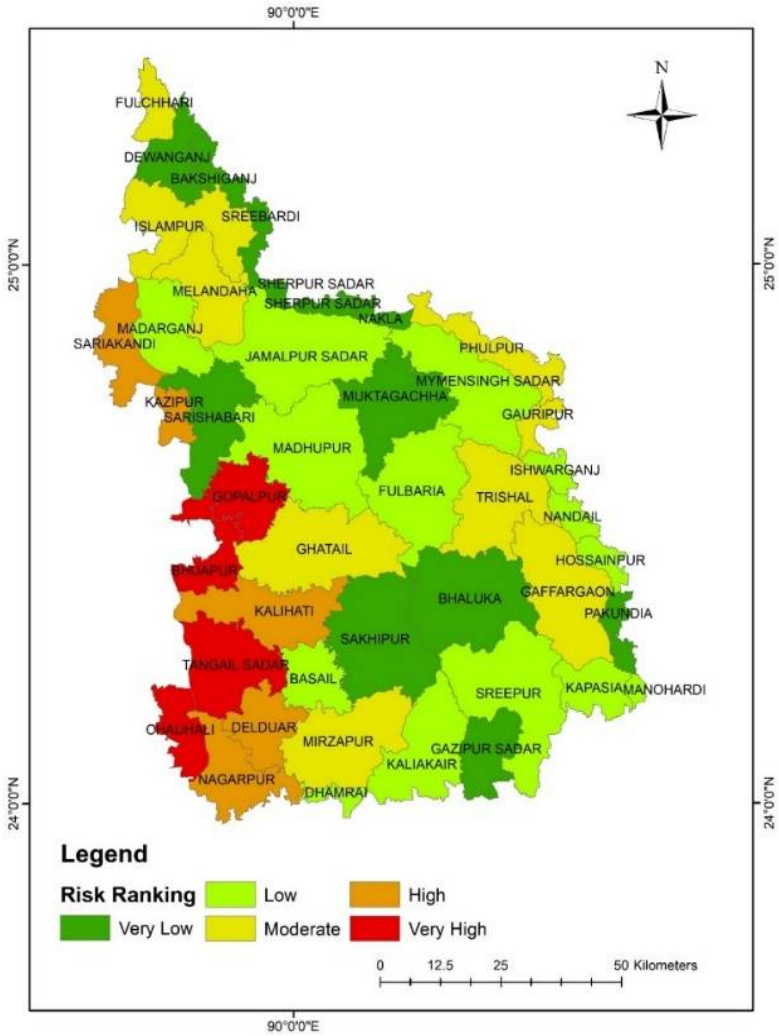

Fig. 8. Flood risk ranking.

Conclusion

After analyzing all variables stated above, final flood risk has been assessed and is shown in the final map (Fig. 8) which shows the index of flood risk of the Jamuna floodplain. The proposed model could also be applicable for the assessment of flood risk for the whole country as both social and topographical factors have been considered here. This assessment has been conducted to identify the priority areas which should give more

emphasis for flood mitigation procedures. This type of work is helpful for the planners, disaster management organizations and also for the government to think about the future plan in the considered area.

References

Bangladesh Bureau of Statistics, 2011. Bangladesh Population and Housing Census 2011.

Cannon, T., 2000. Vulnerability analysis and disasters. *Floods* **1**: 45-55.

Chakraborty, J., G.A Tobin and B.E Montz. 2005. Population evacuation: assessing spatial variability in geophysical risk and social vulnerability to natural hazards. *Natural Hazards Review* ***6***(1): 23-33.

Crichton, D. 2002. UK and global insurance responses to flood hazard. *Water International* **27**(1): 119-131.

de Moel, H., B. Jongman, H. Kreibich, B. Merz, E. Penning-Rowsell and P.J. Ward 2015. Flood risk assessments at different spatial scales. *Mitigation and Adaptation Strategies for Global Change* **20**(6): 865-890.

Em-dat, C.R.E.D., 2010. The OFDA/CRED international disaster database. *Université catholique.*

Meyer, V., D. Haase and S. Scheuer. 2009. Flood risk assessment in European river basins - concept, methods, and challenges exemplified at the Mulde river. *Integrated Environmental Assessment and Management* **5**(1): 17-26.

Peduzzi, P., H. Dao, C. Herold. and F. Mouton. 2009. Assessing global exposure and vulnerability towards natural hazards: The disaster risk index. *Natural Hazards and Earth System Sciences* **9**(4): 1149-1159.

Schneiderbauer, S. and D. Ehrlich. 2004. Risk, hazard and people's vulnerability to natural hazards. *A review of definitions, concepts and data. European Commission Joint Research Centre. EUR*, 21410, 40 p.

Shaluf, Mohamed I. 2007. Disaster types. *Disaster Prevention and Management: An International Journal* **16**(5): 704-717.

Tingsanchali, T. and F. Karim. 2010. Flood-hazard assessment and risk-based zoning of a tropical flood plain: Case study of the Yom River, Thailand. *Hydrological Sciences Journal–Journal des Sciences Hydrologiques* **55**(2): 145-161.

Wisner, B., I. Kelman, T. Monk, J.K. Bothara, D. Alexander, A.M. Dixit, D. Benouar, O.D. Cardona, R. C. Kandel and Petal, M., 2004. School seismic safety: Falling between the cracks? *Earthquakes. London*, 1-56 pp.

(Revised copy received on 18.11.2018)