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Climate change cost upon ecosystem services in the Sundarban mangrove forest in Bangladesh

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Abstract

The Sundarban forest, known as the mangrove protection region by the UNESCO for numerous world endangered species, is located in the southwest of Bangladesh that lies between the delta of the Ganges, Brahmaputra and Meghna rivers. It is the habitat of Royal Bengal tiger (*Panthera tigris*) which is a world largest endangered mammal species and can only be adapted for surviving in the mangrove forests. Also, other endangered species including *Heritiera fomes, Excoecaria agallocha,* and *Ceriops decandra* are largely distributed in the mangrove forest but the rise of mean sea level in 2100 will resulted in 77% decrease of their distributions, so the conservation of the region is so imminent. Thus, ecological service value of Sundarban mangrove with US $ 402 million in 2001 will be reduced by 45% in 2100. In this study, such potential impacts of ecological service on climate change were analyzed on the Sundarban mangrove forest in Bangladesh. The impacts of climate change on the Sundarban mangrove were projected considering various primary resources that are being exploited in the ecosystem and ecological physiography of the mangrove. Secondary information on forest dependent livelihoods degrading condition, reducing ecosystem services and degrading physiographic characteristics of Sundarban mangrove forest were collected and projected the apparent impacts. Further studies should be quantified about long-term impacts of climate change on all the ecosystem services and explore on the potential loss of biodiversity and opportunities in the future for better conservation.

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Introduction

In recent decades, global climate changes have caused impacts on natural and human systems over the whole world (IPCC, 2014). Likewise, Bangladesh is one of the most vulnerable countries to the impact of climate change even if it is low energy consuming country and it is pursuing a low carbon growth path.

The reason behind this situation is the hydro-geological and socio-economic abuses and government policy on the natural resource management along with some geographical factors including its flat deltaic topography with very low elevation. The changes predicted in rainfall and temperature for 2020 were 9.1% and 1.4℃, with a corresponding increase by 22.7% and 2.8℃ , respectively by the year 2050 (Go B, 2006). Even if the massive climate changes are predicted by regional models, little measures of the government are taken in the mangrove.

Mangrove ecosystems are a community of organisms that occur along costal saline and brackish tropical/sub-tropical waters of the world. Dominance of trees, shrubs etc (Yao *et al*., 2000). According to Wetland International Africa (2016).

African mangroves are home to diverse fauna, aquatic mammals include monkeys, antelopes, and manatees, molluscs such as bivalves, oysters and crustaceans. Sundarban is the world's largest single tract mangrove forest, declared as World Heritage site by UNESCO in 1997 located in Bangladesh. It holds greater importance for the local livelihoods, national economy and global environment (Islam, 2003).

Persistency of damaging nature of climate change is dominant. In Nigeria, the loss of mangrove forests has been increasing due to climate change and happened aggressive exploitation of firewood and shellfish procurement (Idowu *et al*., 2011).

Nevertheless climate change participating in melting land ice, mountain glaciers and polar ice sheets that are expanding the water level of the ocean. And even saltwater is intruding into the groundwater, the surface water and soil that severely threatened the health of mangrove forest as well as the wildlife and hydrological parameters (Mahadevia and Vikas, 2012).

It has also been reported that Sundarban mangrove forest is being exploited at a large scale as never seen before manner with climatic disturbances (Uddin, 2013). The study focused on the climate impact on Sundarban ecosystem services and dependent livelihood. Projections of the impact of climate change on Sundarban Mangrove forest are derived from a series of observations.

These are calculated based on factors like reducing ecosystem services and their consequences on livelihoods.

Materials and methods

Study site and the descriptions

The study confined the Sundarban mangrove forest and the neighboring forest dependent livelihoods in Bangladesh (Fig. 1). The Sundarbans mangroves forest is located between the delta of the Ganges, Brahmaputra and Meghna Rivers in southern coast of Bangladesh (Haque *et al*., 2015).

Total area of the Sundarban mangrove forest is 6017 km² where about 69% is terrestrial land and the rest comprises large rivers, small streams and canals (Fig.2).

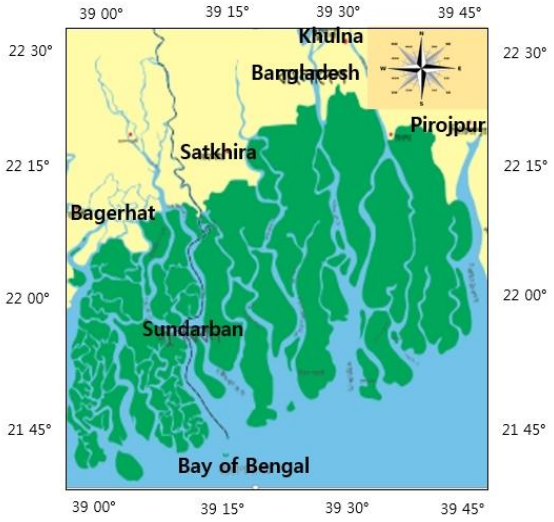

Fig. 1. The regions studied in the Sundarban mangrove forest in Bangladesh.

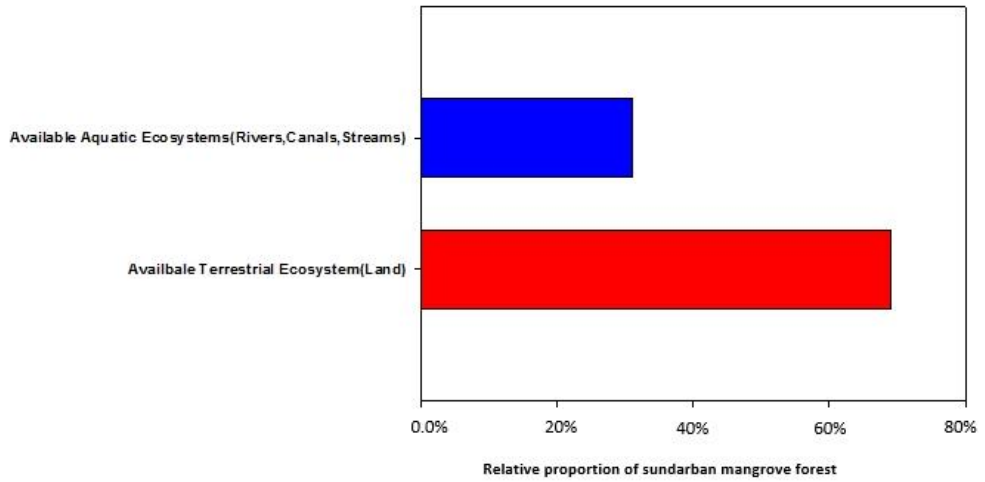

Fig. 2. The area proportions of aquatic ecosystems (river, cannal, stream) and terrestrial ecosystem (land) in the Sundarban mangrove forest.

The 7000 years old mangrove forest is mostly consist of calcareous soil, finely textured, and poorly drained, rich in alkali metal contents. It is a home of diverse floral and faunal resources (Sarkar *et al*., 2016). High biodiversity displayed by Sundarban in the form of hosting 300 species of flora and 425 species of fauna including 291 fish species (Fig.3) where some of them are declared as threatened and endangered in local and global context (Biswas *et al*., 2007). Royal Bengal Tiger (*Panthera tigris)* is the iconic species of Sundarbans (Uddin, 2013). Data were secondary and collected from different website and after collection we modified it.

Regional data collection in the Sundarban region

Fauna and flora data as endangered species were surveyed in the Bangladesh government. Climate change is impacting on Sundarban and its dependent community, ecosystem service simultaneously. Since over 3.5 millions of people living around the Sundarbans are directly or indirectly dependent on ecosystem services (e.g., fodder, fuel wood, tanbarks, fish, honey and medicines). Economic evaluation of the climatic impacts has been considered by estimating two most important timber species - Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*), as indicator. Suitable area of these two species Sundari and Gewa under sea level rise scenario data were collected from CEGIS (2006), whereas available past records of timber stock and price were taken from IRMP (1998).

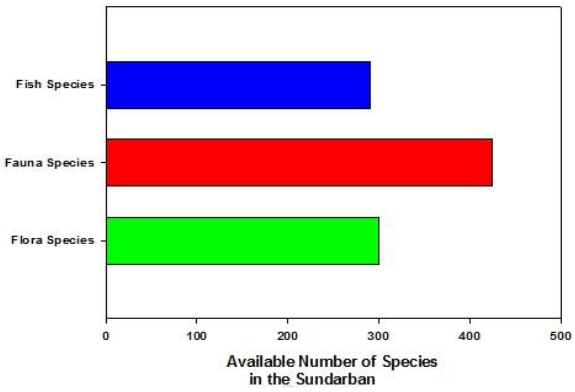

Fig. 3. Biodiversity in the Sundarban mangrove forest; especially fish species as a food source, fauna (all vertebrate animals including fish), and flora (terrestrial plants) for ecosystem services.

Results and discussion

Impact of climate change on the physiography of the Sundarbans mangrove forest

The climate impacts have been examined by secondary data of the Bangladesh government. Data analysis showed that the rise of mean sea level was the greatest threat for disrupting the physiography of Sundarban. The level has been steadily increased by the sea over the years and the occurrence of continuous degrading ecosystem is dominating. Rising sea level participating in the continuous natural decline in the Sundarbans, causing a rise of about 2.2mm per year with net rise rate of 3.1mm per year at Bay of Bengal, the biggest delta of Sundarbans (Siddiqui, 2014).

CEGIS (2006) revealed that by 2100, due to 88 cm sea level rise 77% area of the whole Sundarban will be inundated by more than 1m depth (Fig. 4). Sea level rise altering salinity pattern in the whole Sundarban, consequently it also brings the changes in upstream water flow. As the water level has been increasing day by day due to climate change the aquatic biota composition of the Sundarban area will be altered. The changing physiographical condition would gradually reshape the mangrove ecosystem and its ecosystem services. For instance, the plants are being noted to be shorter and narrower with fewer branches and leaves resulting in lower rates of photosynthesis and regeneration of the mangroves due to continuous submergence in higher water. According to Bangladesh meteorological department (2016), the monthly maximum and minimum temperature pattern of Sundarban area has been changed which greatly affect the physiography of the Sundarban (Fig. 5).

The monthly maximum temperature (°C) in 1995 and 2012 from January to March showed same pattern. The highest maximum temperature was observed in the month of April in 1995 and May in the month of June in 2012. In 1995, after the month of April it showed downtrend whereas in 2012 after May it disclosed decreasing trend up-to August and suddenly increased in the month of October. This trend support that the temperature regime has been changing and affect the biodiversity of the Sundarban (CEGIS, 2006). The monthly minimum temperature (°C) indicated that the temperature profile has been changing which are affecting the physiography of Sundarbans and supported the view point of Haque *et al.*, (2015).

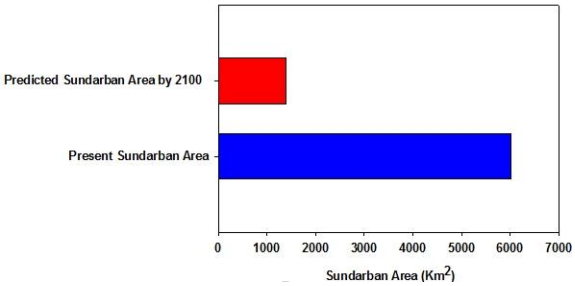

Fig. 4. Present area conditions and the predicted Sundarban area (in 2100) in terms of ecological service, based on the climate change by the rise of mean sea level.

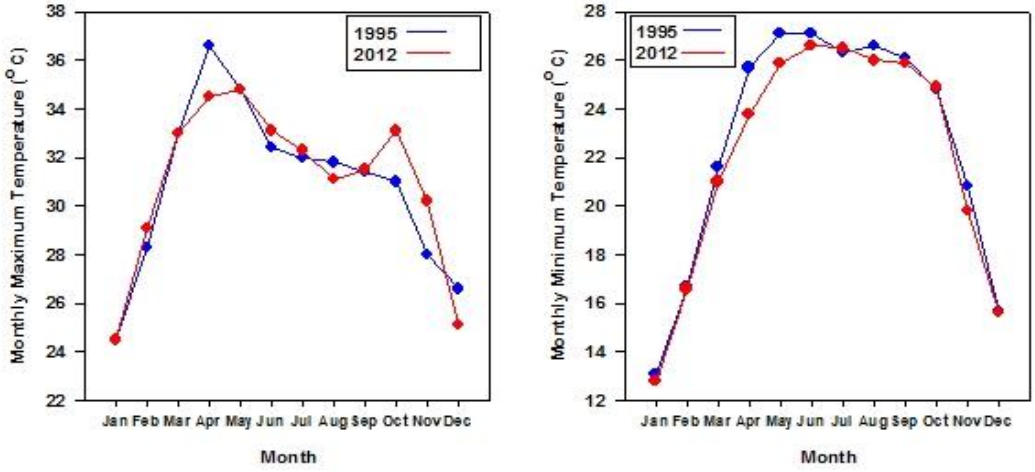

Fig. 5. The comparisons of monthly maximum and minimum temperature in 1995 and 2012 in the Sundarban mangrove region, Bangladesh.

Impact of climate change on the Sundarbans ecosystem services

Due to the Changes in physiographic condition as a potential impact of climate change, the supportive services like plant and animal habitat, nursery ground for fisheries and wildlife of the Sundarban will be greatly affected. Spatial preferences of different species come with differing requirements. CEGIS (2006) analysed the potential suitable area for two major timber tree species – Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*). It was reported that by 2050, under 32 cm sea level rise the suitable

area for Sundari (*Heritiera fomes*) will decrease by 14%whereas by 2100 (Fig. 6), under 88cm sea level rise it will decrease by 45%.

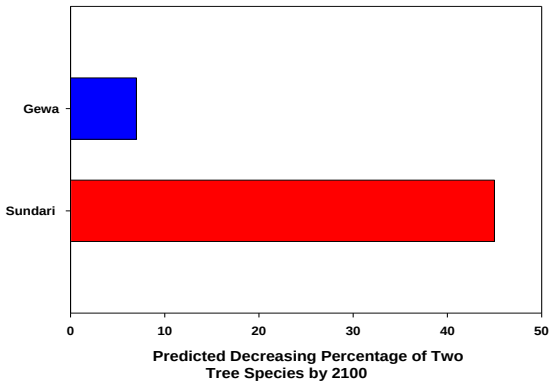

Fig. 6. The predicted decreasing percentage of Gewa (*Excoecaria agallocha*) and Sundari (*Heritiera fomes*)**.**

In the region of Gewa (*Excoecaria agallocha*), the suitable area for ecological service will decrease maximum 7% by 2100. The economic value of Sundari and Gewa were respectively US$ 402 and US$ 29 million in base year 2001 that will be reduced to 45% and 7% by the year 2100. The wildlife depends on the habitat of the forest such as world famous Royal Bengal tiger *(Panthera tigris*) along with other species would be at most risk due to changing hydrological and floristic composition. On the basis of Bangladesh meteorological department dataset (2016), the rainfall pattern has been changed and it has diverse worse impact on the ecosystem (Fig. 7). The Rainfall concentration of the Sundarban area was decreased as compared to 2014 to 1981-2010. Impact of rainfall pattern changes in the fish nursery ground would change the fresh water composition both inside and surrounding fresh water and marine areas which would have negative effect on the local and national economy.

Impact of climate change on Sundarbans dependent livelihoods

The economic profile of local population is directly and indirectly dependent on the Sundraban. Local people are mostly engaged in collection of fish, fuel wood, Golpata (*Nypa* sp.*),* crabs, and honey and wax (IPAC, 2010). According to Fig. 8, Annual income of each household from all sources including forest products was about US$ 559 (range US$ 310 - US$ 945), whereas average annual income of each household from only forest products is US$ 425 (range US$ 156 - US$ 785). The study showed that about 90% collectors earned between US$ 351 and 750per year. About 55% of the respondents were dependent on Sundarbans for 76% to 100% of their total annual income (CEGIS, 2006).

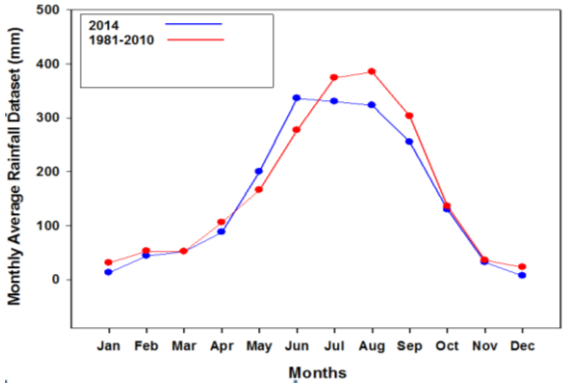

Fig. 7. Rainfall pattern of 2014 and 1981-2010.

The biodiversity dependent livelihoods of Surdarban local inhabitants will be directly affected with respect to the occupation, income level and seasonality if the severely degrading climatic impacts continues with the present rate. Present composition of livelihoods in the neighboring areas might be changed due to change in availability of forest products, such as golpata or honey collector may change occupation into fishing. Lack of diverse resources local people will be more focused on one particular type of resources that will lead to over exploitation and decrease the individual income. In fact migration will be much more dominant due to having high competition in the local market.

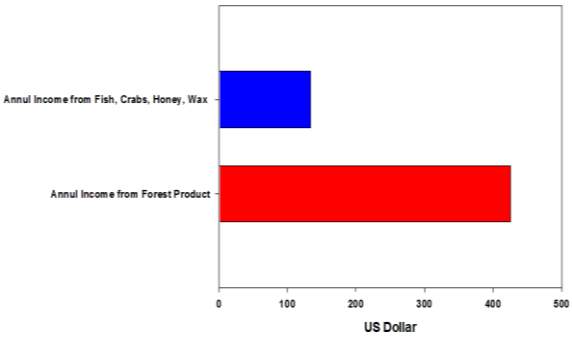

Fig. 8. Annual Income from Sundarban ecosystem services.

Conclusions

Biodiversity degradation through the climatic change or disturbances are rapidly affecting the livelihoods of the people dependent on the Sundarban mangrove forest. Our meta-data analysis addressed some of the key issues that affect such ecological services and what may the future bring and how can we mitigate such effects as to reduce harm. Therefore, efficient management strategies are required to reduce the various impacts of climate change and enhance the potential benefits of the ecosystem services both in the present and future. The visible impact cannot be ignored since if this situation continues to be like the prediction, Sundarban mangrove may be largely destroyed as predicted in 2100. New scheme of effective management strategy including ecological integrity, sustainable harvesting (Carbon emissions need to be cut down sharply) and ensuring the ecosystem services are necessary to protect the pristine mangrove biodiversity from their reversible impact of climate change.

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