*Asian Journal of Conservation Biology*, December 2013. Vol. 2 No. 2, pp. 152–156 AJCB: FP0030
ISSN 2278-7666 ©*TCRP* 2013

# Climate change impacts on the Sundarbans mangrove ecosystem services and dependent livelihoods in Bangladesh

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(Accepted November 12, 2013)

## ABSTRACT

**The Sundarbans mangrove forest of Bangladesh provides ecosystem services having great importance for local livelihoods, national economy and global environment. Nevertheless, the Sundarbans is threatened by various natural and anthropogenic pressures including climate change. This paper presents the potential impacts of climate change on the ecosystem services of the Sundarbans and the forest dependent livelihoods. Both secondary information on climate change impacts and primary data on forest dependent livelihoods were used for the analysis. Recent study revealed that the suitable area of two dominant tree species ofthe Sundarbans - Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) may be decreased significantly by the year 2100 due to sea level rise (88 cm) in the Sundarbans compared to the year 2001, which may be reduce the timber stock of those trees. This indicates the potential loss of economic value of the key provisioning services of Sundarbans. Similarly, the other ecosystem services (e.g. fisheries, tourism, biodiversity, carbon sequestration, etc.) maybe affected by climate change. Consequently, the forest dependent livelihoods would be affected by the degraded ecosystem services of the forest. Further studies should quantify the impacts of climate change on all the ecosystem services and explore the potential loss and opportunities in future. A new paradigm of management should look forward considering climate change, ecological integrity, sustainable harvesting and ensuring continuity of the ecosystem services of the Sundarbans.**

**Key words:** Ecosystem services, mangrove, climate change, sea level rise, Sundarbans, Bangladesh.

the Sundarbans ecosystem services on which they depend. Present status of livelihood dependency on the Sundarbans was harnessed through household survey with semi-structured questionnaires in two adjacent villages of Sundarbans (Uttar Southkhali and South Southkhali under Sarankhola Upazila (sub district) of Bagerhat district, Bangladesh). Annual income of collectors from all sources as well as particularly from forest ecosystem services was estimated and compared with total household income to find the level of dependency on the Sundarbans. Comparing the present livelihoods options with the ecosystem services, the potential changes of livelihood options due to climate change were examined.

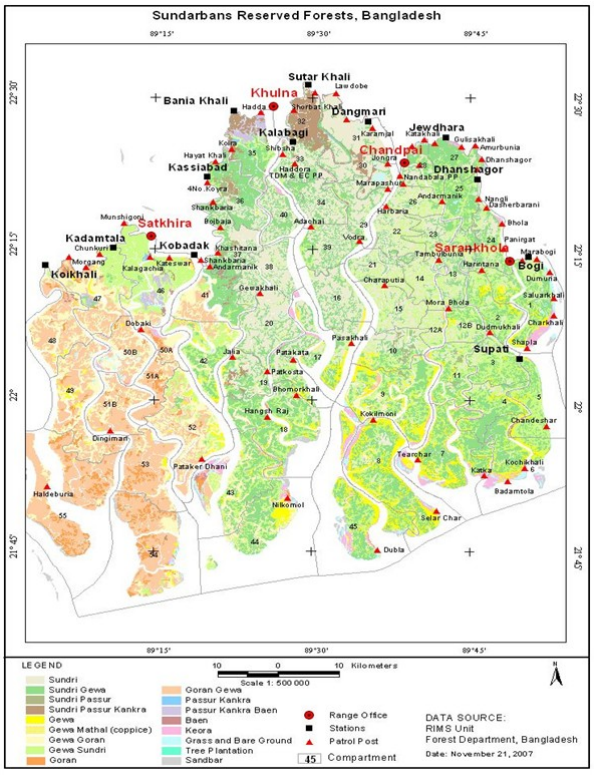


**Figure 1.** Sundarbans Reserve Forest, Bangladesh (Source: Bangladesh Forest Department).

## THE SUNDARBANS MANGROVES AND IT'S ECOSYSTEM SERVICES

The Sundarbans mangroves forest is located in southern coast of Bangladesh and India. Bangladesh part of Sundarbans covers about 6000 sq.km, the other 4000 sq.km of the forest is located in India. This study considers the Bangladesh part of the Sundarbans only.The Sundarbans Reserve Forest (SRF) of Bangladesh (Fig. 1) hosts 300 species of flora and 425 species of fauna, 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 this forest. In addition, there are 291 fish species in the Sundarbans. Around 3.5 million people living around the SRF are directly or indirectly dependent on the ecosystem services of the forest (Giri et al., 2007). Recognizing the ecological and socio-economic importance, the SRF was declared as ' Ramsar site' in 1992

**Table 1.** Suitable area, timber stocks and price of major trees in Sundarbans

| Year | Suitable area (ha) | Timber stocks ($m^3$/ha/yr) | Price (US$/$m^3$) |
|---|---|---|---|
| **Sundri** | | | |
| 2001 (Base) | 80489 | 40 | 125 |
| 2050 (32 cm SLR) | 69571 | 40 | |
| 2100 (88 cm SLR) | 43884 | 40 | |
| **Gewa** | | | |
| 2001 (Base) | 59027 | 21 | 23 |
| 2050 (32 cm SLR) | 58992 | 21 | |
| 2100 (88 cm SLR) | 55021 | 21 | |

*1. From CEGIS (2006)*
*2. Timber stock production rate as estimated in 1995 (IRMP, 1998)*
*3. Price for 2001 is estimated from Forest Department's revenue record.*

and the UNESCO has recognized three wildlife sanctuaries (around 140,000 ha area) of this forest as a "World Heritage Site" in 1997 (Islam, 2003). Further, the Department of Environment (DoE) has declared 10 km buffer zone around the SRF as 'Ecologically Critical Area (ECA)' in 2010, where development activities are restricted.

According to classification of De Groot *et al.* (2002), the ecosystem services of the Sundarbans Reserve Forest can be categorized under four types-provisioning, cultural, regulatory and supporting services. The most common provisioning services are timber, fuelwood, fish, Nypa palm, honey and waxes, medicinal plants;and the cultural services are tourism, recognition as heritage site and Hindu's worship of goddess.The regulatory services of the Sundarbans mangrove includes protecting from cyclone and storm surges, regulating tidal inundation, waste assimilation, nutrient cycling, erosion control and carbon sequestration;and the supporting services includes providing nursery ground to numerous wildlife and fisheries species, andhabitat for flora and fauna (Biswas et al., 2007; Uddin, 2011). Among the ecosystem services, commercially important provisioning (e.g. timbers) and cultural services (e.g. tourism) are of great concern to the Forest Department and the neighboring communities.

## RESULTS

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

The likely impacts of climate change on the physiography of Sundarbans would be mainly due to sea level rise (SLR) that may alter the flooding and salinity pattern in the whole Sundarbans. CEGIS (2006) revealed that dry lands in the Sundarbans would be reduced to 7% in 2100 due to 88 cm sea level rise compared to 43% under base condition in 2001, i.e. about 84% of present dry lands will be lost. About 77% areas of whole Sundarbans will be inu-

ndated by more than 1 m depth due to 88 sea level rise in 2100. In addition to increasing inundation, salinity pattern will be changes in the Sundarbans due to sea level rise and change in upstream freshwater flow. The low saline area (0-1ppt) would decrease from 10.8% in base condition (2001) to 4.0% with 88 cm sea level rise in 2100 (CEGIS, 2006).

Although the impact of climate change induced sea level rise would be visible in the long run, the altered hydrological and salinity pattern would lead to changes in the suitable habitat for plants, wildlife and fisheries. The changing physiographical condition would gradually re-shape the mangrove ecosystem and its ecosystem services.

### *Impact of climate change on the Sundarbans ecosystem services*

As the potential climate change will change the physiographic condition, the supporting services of the Sundarbans (habitat for plants and animals, nursery ground for fisheries and wildlife) will be greatly affected. The changes in the supporting services of the Sundarbans due to climate change and sea level rise would be largely visible on the provisioning services, primarily on the trees and fisheries production. As discussed earlier, sea level rise willchange the inundation and salinity pattern in the Sundarbans that will affect the suitable area for the trees. CEGIS (2006) analysed the potential suitable area for two major timber tree species – Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*)under 32 cm sea level rise (in 2050) and 88 cm sea level rise (in 2100) scenarios. The study revealed that the suitable area of Sundri tree would decrease 14% by 2050 (32 cm SLR) and 45% by 2100 (88 cm SLR) from the base year 2001, whereas the suitable area of 'Gewa' would decrease maximum 7% by 2100 (Table 1) due to sea level rise. As a result, the stock of 'Sundri' and 'Gewa' trees may bedecreased in future similar to change of area (Fig. 2).The economic value of Sundri trees was US$ 402 million in base year 2001, which would decrease about 45% by 2100 if unit price of timber remain constant (Fig. 3). On the other hand, it is found that total value of Gewa timber stock will decrease 7% by 2100 from the present value US$ 29 million at constant unit price of Gewa timber (Fig. 3).

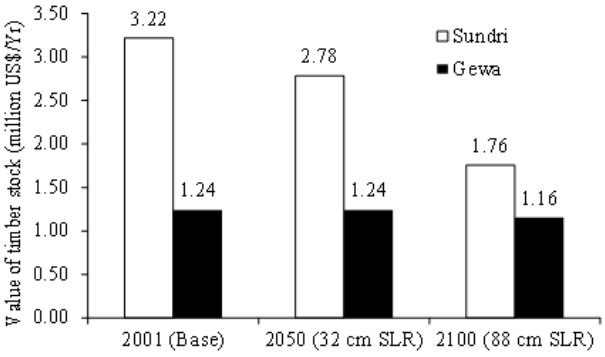


**Figure 2.** Timber stocks (Sundri and Gewa in different SLR scenarios

Further, the changes of tree composition in the Sundarbans due to sea level rise showed that most bio diverse areas with major tree composition in the Sundarbans world be

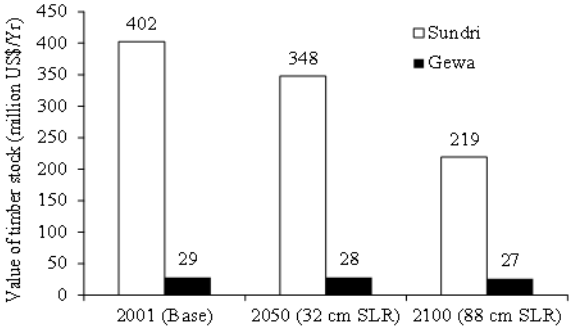


**Figure 3.** Values of Sundri and Gewa timber stock under two SLR scenarios

reduced from 60% to 30% in the year 2100 with 88 cm sea level rise compare to the status in 2001, which would ultimate reduce the production of the provisioning services (forest products) (CEGIS, 2006). The wildlife diversity dependent on the habitat of the forest would be vulnerable due to climate change. World famous Royal Bengal tiger *(Panthera tigris*) found in Sundarbans along with other wildlife may be at most risk (Ahmed, 2006). Changing hydrological and floristic composition will change the food chain in the whole forest that would lead gradual extinction of wild lives, as it happened in the past.

Apart from the timber trees, the fisheries resources, both culture and capture, would be impacted by the climate change and sea level rise. The changes in the fish nursery ground would change the composition of capture fisheries not only inside the Sundarbans but also the neighbouring freshwater and marine areas, which would have impact on the local and national economy. Similarly, production of the other non-timber forest products (honey and wax, Golpata (*Nypa sp.*), medicinal plants,etc.) would be hampered due to climate change.

The cultural services of the Sundarbans entirely depend on the existence of the forest, natural beauty and its wild lives. If climate change and sea level rise greatly change the forest coverage and diversity, the attractive elements in the Sundarbans will be reduced and tourism activities will reduce significantly in the long run. Moreover, the regulatory services of the Sundarbans would be changed due to climate change, although not explicitly investigated yet, a notion can be anticipated as the role of the Sundarbans as carbon sequestration and reducing cyclone impact will be diminished if the forest extent reduces significantly.

### *Impact of climate change on Sundarbans dependent livelihoods*

Presently the forest dependent livelihoods living around the Sundarbans are mainly engaged in collection of fish, fuel wood, Golpata (*Nypa sp.*), crabs, honey and waxes. About 0.74million people are directly engaged inlivelihoods dependent on the Sundarbans (IPAC, 2010). Household survey in the sample sites revealed that, on an average, 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 was US$ 425 (range US$ 156 - US$ 785). The study showed that about 90% collectors earned between US$ 351 and 750 per year. About 55% of the respondents were dependent on Sundarbans for 76% to 100% of their total annual income.

Most of collectors were engaged in fish and fuel wood collection followed by crab, honey and golpata.Each fisher household annually earned nearly US$ 390 from Sundarbans. Fuel wood collection becomes secondary occupation along with fishing or other activities. The fuel wood collector earned an average amount of about US$ 25 per household annually from Sundarbans. In addition, it was noticed that a significant number of people were engaged in crab collection who earned about US$ 290 per household per year.Annual income from honey and golpata were about US$ 220 and US$ 55per household per year.

Since the climate change will have direct impact on the provisioning services (major forest products), the forest dependent livelihoods will be directly affected with respect to the occupation, income level and seasonality. Present composition of livelihoods in the neighbouring areas might be changed due to change in availability of forest products, such as golpata or honey collector may change occupation into fishing. Monotypical occupation of major share of population will lead to overexploitation of one type of resources and decrease of individual income. Some people, who cannot compete in the local labour market, may migrate to urban centers.

## DISCUSSION AND RECOMMENDATIONS

The ecosystem services of the Sundarbans mangrove have great importance in terms of ecological, socio-economic contexts. Future climate change along with other natural and anthropogenic factors is degrading this unique mangrove ecosystem. This study revealed that total stock and economic value of major timbers – Sundri and Gewa will decrease in future due to climate change induced sea level rise. Similar decreasing trend of Sundri and Gewa was observed in past few decades (Forestal, 1959; ODA, 1985), which might be due to climate change or other reasons. Sundri is also threatened by top dying due to salinity and pest infestation (Rahman, 1995). Reduction of Sundri and Gewa indicates that all plant species along with other terrestrial and aquatic species in the Sundarbans could be degraded by climate change. The fisheries resources of the Sundarbans will be impacted, not the production inside Sundarbans only, rather reducing the supply of sufficient commercially important fish larvae to the freshwater and marine zones due to degradation of the quality of the fish nursing ground. Sarwar et al. (2007) urged that the shrimp production can be affected by the sea level rise by overflowing pond by flooding, salinity intrusion, increasing cyclone intensity and frequency. Therefore, it would be worthy to study the potential ecological and economic impact of climate change on the fisheries resources of Sundarbans, which has not done yet. Further, the anticipated impacts of climate change on the other non-timber forest products (honey and waxes, golpata, medicinal plants etc.) could be studied to find out the appropriate linkage and opportunities in future. Also potential loss of economic value of all the ecosystems services due to climate changes can be studied, as currently the Sundarbans generates significant economic value from the provisioning and cultural services (Uddin, et al., 2013).

The forest depended livelihoods are mostly dependent on the provisioning services of the Sundarbans. The livelihoods pattern indicates that most of them were engaged in collecting fish followed by fuel wood, crab, honey and golpata, rather engaged in timber cutting, as because of impose of moratorium on timber felling since 1989 by the Forest Department. Most of the respondents (55%) earned 76%-100% of their total income from the provisioning services of Bangladesh Sundarbans, whereas in Cambodia almost 94% people consider themselves totally dependent on the mangrove forests (Benard, 2007).The impacts of climate changes on the ecosystem services of Sundarbans will directly impact the highly forest dependent livelihoods. Further, the existence of Sundarbans would save the neighbouring community from cyclone and storm surges, as it did in the recent years when Cyclone Sidr hit the area in 2007 (IPAC, 2010). Therefore, necessary management strategies should be taken to reduce the impact of climate change and enhance the potential benefits of the ecosystem services for the forest dependent livelihoods in present and future.

Although historically the management of approach for the Sundarbans focused on the revenue generation from the forest through systematic management (FD, 2010), new paradigm of management should look forward considering the potential impacts of climate change, ecological integrity, sustainable harvesting and ensuring continuing the ecosystem services of the Sundarbans for next generations of human as well as the ecosystem itself.

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