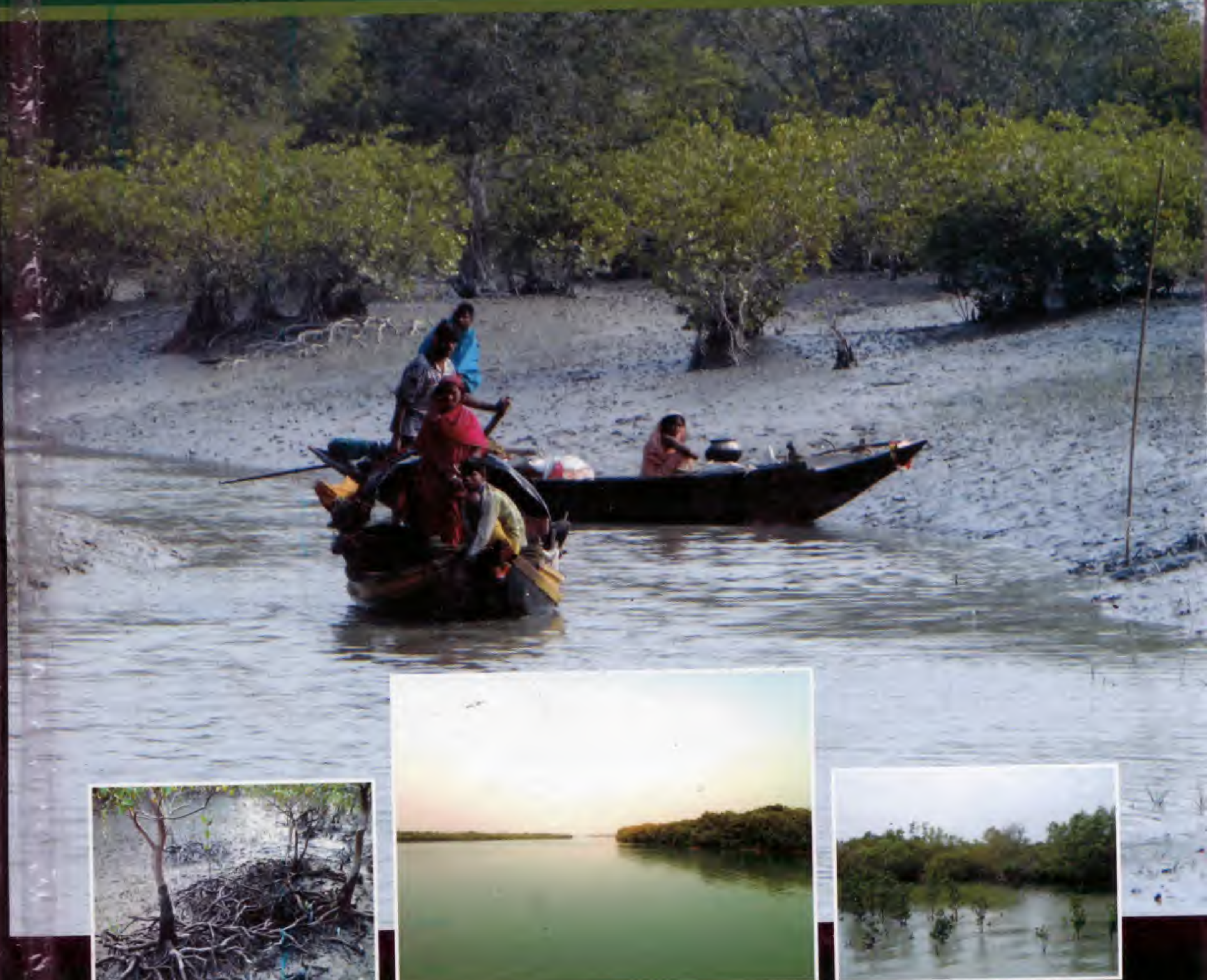
Climate Change Series: 3

Environmental Coastguards

Understanding Mangrove Ecosystem and Carbon Sequestration



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CSIR-National Institute of Science Communication
And Information Resources (CSIR-NISCAIR)

About the Book

"Environmental Coastguards- Understanding Mangrove Ecosystem and carbon Sequestration" is the third book published by CSIR-NISCAIR under the project "Vulnerability Assessment and Development of Adaptation Strategies for Climate Change Impact with Special Reference to Coasts and Island Ecosystems of India (VACCIN)". How mangroves adopted to salty media is the first chapter of the book and there are ten chapters in total. The last chapter is the climate - mangrove bibliography of national and international collection of literature on the various aspects of mangrove studies. This book have extensive review and meta-analysis data on carbon stock and sequestration in context of climate change. Ecosystem services and functions of mangroves are extensively described in the chapter 2 . Presentation on attenuation of wave energy and mitigation of mangroves in response to sea level rise made this book unique among the publications based on mangrove studies. Assessment of stored carbon in 1 year old seedlings of 5 dominant mangrove floral species of Sundarbans is ascribed in Chapter 4 of this book. Mangrove regulates and buffer ocean acidification . The chapter 6 consists detailed discussion on the role of mangroves to regulate and retard coastal hazards such as tsunami. Mangrove centric livelihood like mariculture, traditional extensive methods of culture, oyster culture are a part of this book in Chapter 7. There are a collection of "Cutting edge research articles on role of mangroves in climate change" in this book. Mangrove forests of Sundarbans , the focal theme of the book, also provide a broad spectrum of cultural ecosystem services to coastal populations living close to mangrove forests, ranging from the tangible (tourism, recreation, education) to the abstract (cultural heritage, aesthetics, sense of place). Presence of Bonobibi Goddess in Indian Sundarbans is a symbolic convergence of Hinduism and Islamic religions, who is sincerely worshipped by people of different religions, classes and creeds before entering the dense forest of Sundarbans. Very few people of the world know these facts and figures of mangroves. The present book has highlighted almost all the ecosystem services of mangroves with ground zero level data, which the scientists/researchers have excavated after rigorous field works in the difficult muddy terrains through seasons. The data on carbon sequestration by dominant mangroves of Indian Sundarbans is a pathfinder for global researchers who want to know more about this unique ecosystem of the planet.

ISBN No: 978-81-7236-352-9

Article 2

Carbon storage potential of mangroves along the Mandovi and Zuari estuaries of Goa, India

Contributed by

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Abstract

The increase and accumulation of greenhouse gases in the atmosphere such as carbon dioxide is believed to cause global warming. Effort to decrease accumulation of these gases by increasing the role of mangrove forests as carbon sinks through good management system has become a smart approach in the domain of mitigation of the adverse impact of climate change. To this date, very limited study on the mangrove carbon has been carried out in the Mandovi – Zuari complex of Goa. Purpose of the present research is to estimate the stored carbon in the above ground biomass of the dominant mangrove species along the Mandovi and Zuari estuaries of Goa for which purposive sampling method was performed during February 2015 through the measurement of trunk diameter (DBH) of above ground mangrove biomass without damaging vegetation (non-destructive sampling). The Above Ground Biomass (AGB) and Above Ground Carbon (AGC) values are more along the Zuari estuary compared to the Mandovi estuary, which may be the effect of variation in marine influence (more in Zuari compared to Mandovi).

Introduction

Mangroves constitute an important ecosystem because of their global extent and high productivity. These plants thrive in the intertidal zones of the tropics and subtropics that are characterized by regular tidal inundation and fluctuating salinity. Mangrove species are well adapted, both morphologically and physiologically, to survive under saline conditions. Despite their ecological success in saline environments, however, carbon assimilation capacity and growth are reduced as salinity increases. The carbon storage potential of mangrove floral community has been critically studied and quantified by several researchers (Mitra, 2013; Mitra and Zaman, 2014; Mitra and Zaman, 2015; Murdiyarso *et al.*, 2015; Alongi, 2015; Mitra and Zaman, 2016). The storage of carbon by trees varies spatially and temporally based on abundance of the species, growth rate of the species and site conditions. Net annual carbon sequestration is positive for growing forest with considerable Above Ground Biomass (AGB) of the species.

On this background the primary objective of the present study was to establish a dataset of the stored carbon in dominant mangrove trees in Mandovi and Zuari estuaries located in the coast of Goa. The CO_2-equivalent of each species has also been evaluated to assess the role of the selected trees species in offsetting CO_2.

Materials and Methods

Phase A: Selection of Station

Goa has a coastal stretch of about 100 km and lies between 14°54' N and 15°48' N Latitude and between 72°41' E and 74°20' E Longitude. Nine rivers rise in the Western Ghats and flow towards Arabian Sea through Goa. Mandovi and Zuari are the major rivers among them and these are most important for the economy of the state as they flow through the mining area and grass lands opening up in the Arabian Sea close to Mormugao harbour. The present study was conducted along the Mandovi and Zuari estuaries and three sites were selected for each estuary during February 2015 (Figure 1). Four mangrove

Fig. 1: Map of Study site

species *Avicennia alba*, *Avicennia marina*, *Excoecaria agallocha* and *Rhizophora mucronata* were selected along the Mandovi estuary and five species *Avicennia marina*, *Avicennia officinalis*, *Excoecaria agallocha*, *Rhizophora apiculata* and *Rhizophora mucronata* were selected along the Zuari estuary. The selection criteria focused on the dominancy of the species in the selected plots based on relative abundance of each species.

Phase B: Above Ground Biomass Estimation

AGB in mangrove species refers to the sum total of stem, branch and leaf biomass that are exposed above the soil.

Stem Biomass Estimation

The stem volume of each species in each of the 3 sites per station (n = 5 individuals × 3 sites = 15 trees/ species/ station) was estimated using the Newton's formula (Husch et al., 1982).

$$V = h/6\ (A_b + 4A_m + A_t)$$

Where V is the volume (in m^3), h the height measured with laser beam (BOSCH DLE 70 Professional model), and A_b, A_m, and A_t are the areas at base, middle and top respectively. Specific gravity (G) of the wood was estimated taking the stem cores by boring 7.5 cm deep with mechanized corer. This was converted into stem biomass (B_S) as per the expression B_S = GV. The stem biomass of individual tree was finally multiplied by the number of trees of each species in 15 selected plots (per station) in all the selected stations and expressed in t ha^{-1}.

Branch Biomass Estimation

The total number of branches irrespective of size was counted on each of the sample trees. These branches were categorized on the basis of basal diameter into three groups, *viz.* < 6 cm, 6–10 cm and >10 cm. The leaves on the branches were removed by hand. The branches were oven-dried at 70^0C overnight in hot air oven in order to remove moisture content if any present in the branches. Dry weight of two branches from each size group was recorded separately using the equation of Chidumaya (1990).

$$B_{db} = n_1bw_1 + n_2bw_2 + n_3bw_3 = \Sigma\ n_ibw_i$$

Where B_{db} is the dry branch biomass per tree, n_i the number of branches in the ith branch group, b_{wi} the average weight of branches in the ith group and i = 1, 2, 3, ...n are the branch groups. The mean branch biomass of individual tree was finally multiplied with the number of trees of each species in all the 3 sites for each station and expressed in t ha^{-1}.

Leaf Biomass Estimation

For leaf biomass estimation, one tree of each species per plot was randomly considered. All leaves from nine branches (three of each size group) of individual trees of each species were removed and oven dried at 70⁰C and dry weight (species-wise) was estimated. The leaf biomass of each tree was then calculated by multiplying the average biomass of the leaves per branch with the number of branches in that tree. Finally, the dry leaf biomass of the selected mangrove species (for each plot) was recorded as per the expression:

$$L_{db} = n_1Lw_1N_1 + n_2Lw_2N_2 + \ldots\ldots\ldots n_iLw_iN_i$$

Where L_{db} is the dry leaf biomass of selected urban species per plot, $n_{1..} \ldots n_i$ are the number of branches of each tree of five dominant species, $Lw_1 \ldots\ldots Lw_i$ are the average dry weight of leaves removed from the branches and $N_{1\ldots\ldots} N_i$ are the number of trees per species in the plots. This exercise was performed for all the stations in each region and the results were finally expressed in t ha^{-1}.

Phase C: Above Ground Carbon Estimation

Direct estimation of percent carbon in the AGB was done by CHN analyzer, after grinding and random mixing the oven-dried stem, branches and leaves separately for each species. For this, a portion of fresh sample of stem, branch and leaf from trees (of each species) were oven dried at 70⁰C, randomly mixed and ground to pass through a 0.5 mm screen (1.0 mm screen for leaves). The carbon content (in %) was finally analyzed for each part of each species through a *Vario MACRO elementar CHN* analyzer. The mean of these vegetative parts were considered as the stored carbon in AGB of each species and finally converted to CO_2 – equivalent by multiplyting with a factor of 3.67.

Results

Figure 2 represents the both AGB and AGC values in selected mangrove trees in Mandovi estuary and Figure 3 represents the same for Zuari estuary. The values of CO_2-equivalent of the selected species are depicted in Figure 4 and Figure 5 for Mandovi and Zuari estuaries respectively.

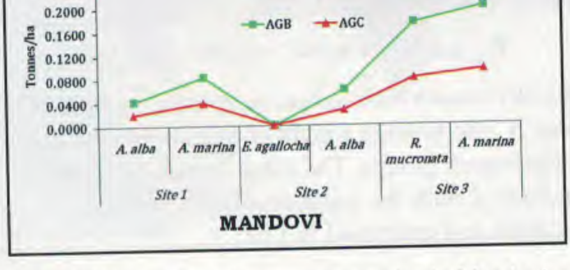

Fig. 2: AGB and AGC in tonnes of mangrove species in Mandovi estuary in Goa

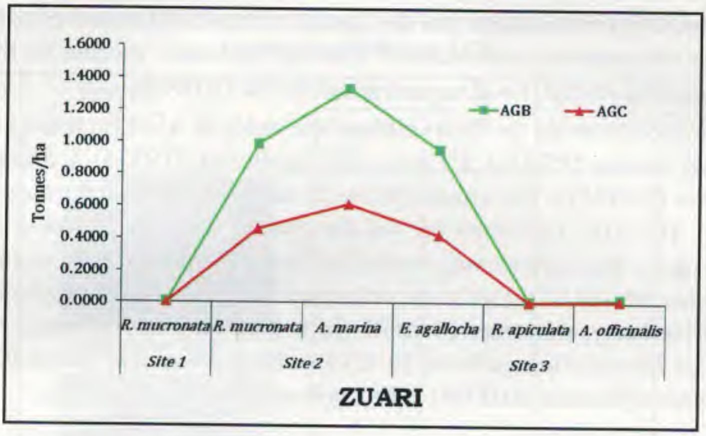

Fig. 3: AGB and AGC in tonnes of mangrove species in Zuari estuary in Goa

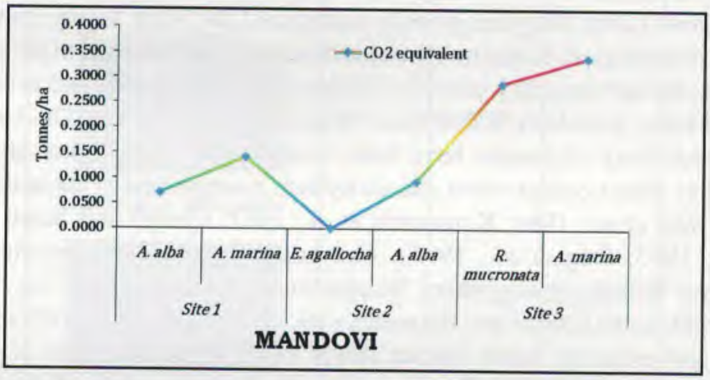

Fig. 4: CO_2-equivalent in tonnes of the mangrove species in Mandovi estuary in Goa

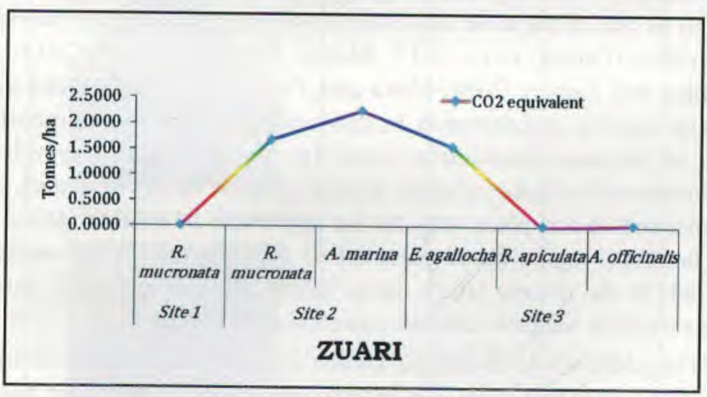

Fig. 5: CO_2-equivalent in tonnes of the mangrove species in Zuari estuary in Goa

The AGB (in tonnes ha^{-1}) of the species along the Mandovi estuary is in the order *Rhizophora mucronata* (0.1734) > *Avicennia marina* (0.1415) > *Avicennia alba* (0.0507) > *Excoecaria agallocha* (0.0005).

For species along the Zuari estuary, the order of AGB (in tonnes ha^{-1}) is *Avicennia marina* (1.3339) > *Excoecaria agallocha* (0.9534) > *Rhizophora mucronata* (0.4955) > *Avicennia officinalis* (0.0218) > *Rhizophora apiculata* (0.0092). The AGC (in tonnes ha^{-1}) of the species along the Mandovi estuary is in the order *Rhizophora mucronata* (0.0784) > *Avicennia marina* (0.0655) > *Avicennia alba* (0.0224) > *Excoecaria agallocha* (0.0002). For species along the Zuari estuary, the order of AGC (in tonnes ha^{-1}) is *Avicennia marina* (0.6102) > *Excoecaria agallocha* (0.4214) > *Rhizophora mucronata* (0.2284) > *Avicennia officinalis* (0.0098) > *Rhizophora apiculata* (0.0042).

Discussion

Mangroves are coastal forest ecosystems occurring in unconsolidated substrata in sheltered intertidal zones of tropical, subtropical and warm temperate regions of the planet Earth. They are globally recognized for being highly important in terms of ecological, economic, social and cultural functions due to the variety of goods and services they provide, reaching an estimated annual economic value of more than US$ 900000/km^2 (UNEP-WCMC, 2006). The biomass and productivity of forests have been studied mainly in terms of wood production, forest conservation and ecosystem management (Putz and Chan, 1986; Tamai *et al.,* 1986; Komiyama *et al*., 1987; Clough and Scott, 1989; McKee, 1995; Ong *et al*., 1995). The goods and services provided by mangroves include, among others, the protection of coastline from the storms, tidal surges, wave actions and the maintenance of fisheries and biodiversity in coastal and estuarine water masses (Ewel *et al.* 1998; Mazda *et al.* 2006; Nagelkerken *et al.* 2008). The contemporary understanding of the global warming phenomenon, however, has generated interest in the carbon-stocking ability of trees. In recent years, carbon storage and sequestration have been recognized as one of the most important environmental services provided by this ecosystem (Donato *et al.* 2011; Alongi, 2014; Lee *et al*., 2014; Mitra, 2013; Mitra and Zaman, 2014; Mitra and Zaman, 2015; Mitra and Zaman, 2016). The carbon sequestration in this unique producer community is a function of biomass production capacity, which in turn depends upon interaction between edaphic, climate, and topographic factors of an area. Hence, results obtained at one place may not be applicable to another (Mitra *et al*., 2011). Therefore, region based potential of different land types needs to be worked out. In the present study, mean values of AGB and AGC data have been presented for the two selected estuarine sites (Table 1).

The regulatory role of edaphic factors is visualized from the contrasting pictures of Mandovi and Zuari sites in terms of species number (4 in Mandovi, while 5 along Zuari estuary), AGB and AGC. Question may arise regarding the variation of carbon sink between these two sites. In Goa, the two rivers,

Table 1—List of dominant tree species in the selected stations with their respective AGB and AGC

Sl. No.	Species	AGB (tonnes ha^{-1})		AGC (tonnes ha^{-1})	
		Mandovi site	Zuari site	Mandovi site	Zuari site
1.	 *Avicennia alba*	0.0507	Ab	0.0224	Ab
2.	 *Avicennia marina*	0.1415	1.3339	0.0655	0.6102
3.	 *Avicennia officinalis*	Ab	0.0218	Ab	0.0098
4.	 *Excoecaria agallocha*	0.0005	0.9534	0.0002	0.4214
5.	 *Rhizophora apiculata*	Ab	0.0092	Ab	0.0042
6.	 *Rhizophora mucronata*	0.1734	0.4955	0.0784	0.2284

Ab: Absent of the species

Mandovi and Zuari, with their interconnecting canal, form an estuarine system on the west coast of India. The flow of the estuarine system is regulated by the entry of seawater with the incoming tide through Zuari which reaches Mandovi through the canal. The flow is reversed during the outgoing tide when the estuarine system is flushed. Mangrove biomass is relatively higher along the Zuari estuary because of its greater marine influence. The carbon dioxide-equivalent data, however, confirms the mangroves of the present geographical locale as a unique sink of carbon. Unlike other vegetation types, mangroves are noted for their carbon sequestering potential. The fact that mangroves have the second highest rate of carbon sequestration in aboveground biomass (2.9 $tC.ha^{-1}.yr^{-1}$), but only the fifth highest carbon stock (78.0 $tC.ha^{-1}.yr^{-1}$) among forest ecosystems is intriguing and indicates an elevated turnover rate of biomass in mangroves. Using the ratio of mean biomass/ mean rate of biomass increment, it has been found that mangrove forests have the lowest turnover time (27 years) of aboveground biomass among the forest ecosystems, while tropical rain forests and tropical moist deciduous forests present renewal times of 43 and 36 years, respectively. The fast turnover rate of aboveground biomass corroborates the high resilience described for mangroves (Vogt *et al.*, 2012), which is, in the view of Alongi (2008), the result of an interaction among factors such as: high nutrient reserves in the substrate; high rates of nutrient flow and microbial decomposition; and the redundancy of key species, although disturbance regimes may also play a role (Duke *et al.*, 2007).

References

1. Alongi, D.M. (2008) Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine Coastal and Shelf Science*, 76 (1), 1-13.
2. Alongi, D.M. (2014). Carbon cycling and storage in mangrove forests. *The Annual Review of Marine Science*, 6, 195-219.
3. Alongi, D.M. (2015). The Impact of Climate Change on Mangrove Forests. *Current Climate Change Reports*, 1, 30-39.
4. Clough, B.F. and Scott, K. (1989). Allometric relationships for estimating aboveground biomass in six mangrove species. *Forest Ecology and Management*, 27, 117-127.
5. Donato, D.C., Kauffman, J.B., Kurnianto, S., Stidham, M. and Murdiyarso, D. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, 4, 293-297.
6. Duke, N.C., Meynecke, J.-O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I. and Dahdouh-Guebas, F. (2007). A world without mangroves? *Science*, 317, 41-42.
7. Ewel, K.C., Twilley, R.R. and Ong, J.E. (1998). Different kinds of mangrove forests provide different goods and services. *Global Ecology & Biogeographical Letters*, 7, 83-94.
8. Komiyama, A., Ongino, K., Aksornkoae, S. and Sabhasri, S. (1987). Root biomass of a forest in Southern Thailand. 1. Estimation by trench method and zonal structure of root biomass. *Journal of Tropical Ecology*, 3, 97-108.

9. Lee, S.Y., Primavera, J.H., Dahdouh-Guebas, F., McKee, K., Bosire, J.O., Cannicci, S., Diele, K., Fromard, F., Koedam, N., Marchand, C., Mendelssohn, I., Mukherjee, N. and Record, S. (2014). Ecological role and services of tropical mangrove ecosystems: a reassessment. *Global Ecology and Biogeography*, 23 (7), 726-743.

10. Mazda, Y., Magi, M., Ikeda, Y., Kurokawa, T. and Asano, T. (2006). Wave reduction in a mangrove forest dominated by Sonneratia sp. *Wetlands Ecology and Management*, 14, 365-378.

11. McKee, K.L. (1995). Interspecific variation in growth, biomass partitioning, and defensive characteristics of neotropical mangrove seedlings: response to light and nutrient availability. *American Journal of Botany*, 82, 299-307.

12. Mitra, A. (2013). In: Sensitivity of Mangrove ecosystem to changing Climate. Springer DOI: 10.1007/978, pp. 323, 81-322-1509-7.

13. Mitra, A. and Zaman, S. (2014). Carbon Sequestration by Coastal Floral Community. published by *The Energy and Resources Institute* (TERI) TERI Press, India.ISBN 978-81-7993-551-4.

14. Mitra, A. and Zaman, S. (2015). Blue Carbon Reservoir of the Blue Planet. Published by *Springer*; ISBN, 2015, 978-81-322-2106-7 (Springer DOI 10.1007/978-81-322-2107-4).

15. Mitra, A. and Zaman, S. (2016). Basics of Marine and Estuarine Ecology. Published by *Springer*, ISBN 978-81-322-2705-2.

16. Mitra, A., Sengupta, K. and Banerjee, K. (2011). Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans. *Forest Ecology and Management*, 261, 1325-1335.

17. Murdiyarso, D., Purbopuspito, J., Kauffman, J.B., Warren Matthew, W., Sasmito, S.D., Donato, D.C., Manuri, S., Krisnawati, H., Taberima, S. and Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. *Nature Climate Change*, 1089-1092.

18. Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A. and Somerfield, P.J. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review. *Aquatic Botany*, 89 (2), 155-185.

19. Ong, J.E., Gong, W.K. and Clough, B.F. (1995). Structure and productivity of a 20-year-old stand of *Rhizophora apiculata* BI. mangrove forest. *Journal of Biogepgraphy*, 22, 417-424.

20. Putz, F.E. and Chan, H.T. (1986). Tree growth, dynamics, and productivity in a mature mangrove forest in Malaysia. *Forest Ecology and Management*, 17, 211-230.

21. Tamai, S., Nakasuga, T., Tabuchi, R. and Ogino, K. (1986). Standing Biomass of Mangrove Forests in Southern Thailand. *Journal Japanese Forest Society*, 68, 384-388.

22. UNEP-WCMC. 2006. Global distribution of mangroves. Compiled by C. Ravilious, courtesy of UNEP-WCMC.

23. Vogt, J., Skora, A., Feller, I.C., Piou, C., Coldren, G. and Berger, U. (2012). Investigating the role of impoundment and forest structure on the resistance and resilience of mangrove forests to hurricanes. *Aquatic Botany*, 97, 24-29.