International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 13-01-2024, Accepted: 28-01-2024, Published: 12-02-2024
Volume 6, Issue 1, 2024, Page No. 10-15

Studies on above-ground biomass and carbon storage in dominant mangroves in Raigad district of Maharashtra

Suresh A Palve*, Ajit B Telave
Department of Botany, Tuljaram Chaturchand College of Arts, Science and Commerce, Baramati, Pune, Maharashtra, India

Abstract
Mangrove forests function as a link between marine and terrestrial ecosystems and provide numerous ecosystem services. Mangrove assumes significance as standing store of sequestered atmospheric carbon and so they are important in mitigation of climate change. This study was aimed to estimate the above ground biomass and carbon sequestration in three dominant mangroves species *viz*. *Sonneratia apetala, Avicenna officinalis* and *Avicennia marina* from Raigad district of Maharashtra. Among the analysed species the above ground biomass (AGB) and above ground carbon (AGC) was maximum in *A. marina* followed by *S. apetala* and minimum in *S. alba*. Correlation coefficient between tree biomass and stored carbon is significantly positive.

Keywords: Above ground biomass (AGB), above ground carbon (AGC), mangroves Raigad district

Introduction

Increasing carbon dioxide level in atmosphere is major environmental concern in the current century. The climate change has adverse impacts like sea level rise, rise of atmospheric temperature, melting of glaciers, and change in precipitation, acidification of sea water, and spread of parasitic diseases, etc. The problems of carbon emissions are increasingly acute in tropical and subtropical forests (Subedi *et al*., 2010) [35] and the forests in these region play a significant role in the global carbon cycle and high primary productivity (Clark *et al.,* 2001) [5]. The coastal ecosystem is more helpful for carbon sequestration and carbon storage in oceanic carbon cycle (Mitra and Zaman, 2014) [27]. Mangroves are a group of trees and shrubs that live in the coastal intertidal zone and mangrove forests store more carbon than other ecosystem per unit area (Alongi, 2014) [1]. These plants have high net primary productivity and typical bottom heavy biomass allocation (Ong *et al.*, 2004) [29] at the rates of approximately 2 to 4 times higher than other mature tropical forests (Nellemann *et al.*, 2009) [28]. There are limited studies on carbon stocks in mangrove ecosystems and meagre data available on carbon sequestration in Indian mangroves (Suresh et al., 2017) [36].

The Indian coastline has a total mangrove cover of 4627.63 km^2, occupying 3% of the global mangroves (FSI, 2013) and the largest mangrove forested area in South Asia. However, India has experienced the greatest mangrove loss (~580 km^2) during 2000 to 2012 (Giri *et al.*, 2015) [9]. The Raigad district is a coastal district situated on the Western Coast of Maharashtra with the largest mangrove forest area as compare with the other coastal district of Maharashtra (IFS, 2017). Mangroves meet the majority of the energy demands of many coastal communities and surrounding urban areas, in addition to providing an important source of timber. However, due to the deforestation, embankments, aquaculture, tourism and urban development, Raigad has experienced slight mangrove loss (~15.71km^2) from 2005 to 2015 (Telave *et al.*, 2017) [38]. The present study aimed to establish a baseline data set of the carbon storage by above ground structures of three dominant mangrove species *viz*. *Sonneratia apetala*, *Sonneratia alba* and *Avicennia marina* in the geographically different locations in coastal area of Raigad district. The carbon content in stem, branch and leaf biomass of selected mangroves and the in soil carbon content variability was analysed from the selected study site.

Material and Methods

Study Site

Raigad district is located in the state of Maharashtra. This coastal district lies between 18º 39' 0" N, 72º 52' 48" E longitude and 18º65' 72º 88' N latitude and covering a geographical area of approximately 222.21 km^2 under mangroves in Raigad district. The five creeks i.e. Uran, Dharamtar, Alibag, Rajpuri, and Srivardhan and three estuaries i.e. Bhagwati, Kundalika and Savitri (Fig.1) are selected for the study purpose an indicator site along the coast of Raigad district.

Collection of samples

Soil and plant samples of three species were collected randomly from dominant sites. Eight sampling plots each of 10 m × 10 m were selected from a particular site. The dimeter of all mangrove species was measured at breast height (DBH, 1.37 m) from the ground level using measuring tape. Tree height was recorded by using laser-based BOSCH height measuring instrument. The biomass of stem, leaf and branch was estimated as per the VACCIN project manual of CSIR (Mitra and Sunderasan, 2016). The carbon content was calculated by multiplying the individual tree biomass with the conversion factor 0.5 (IPCC, 2006).

Estimation of Soil Organic Carbon

Soil samples from the upper 5 cm were collected from all the eight plots from each site and dried at 60^0 C for 48 hrs. For analysis, visible plant particles were handpicked and removed from the soil. After sieving the soil through 2 mm sieve, the samples of the bulk soil (50 gm from each plot) were crushed finely in a mortar pestle. The fine dried sample was randomly mixed to get a representative picture of the study site. Walkley and Black method (1934) was followed to determine the % organic carbon of the soil.

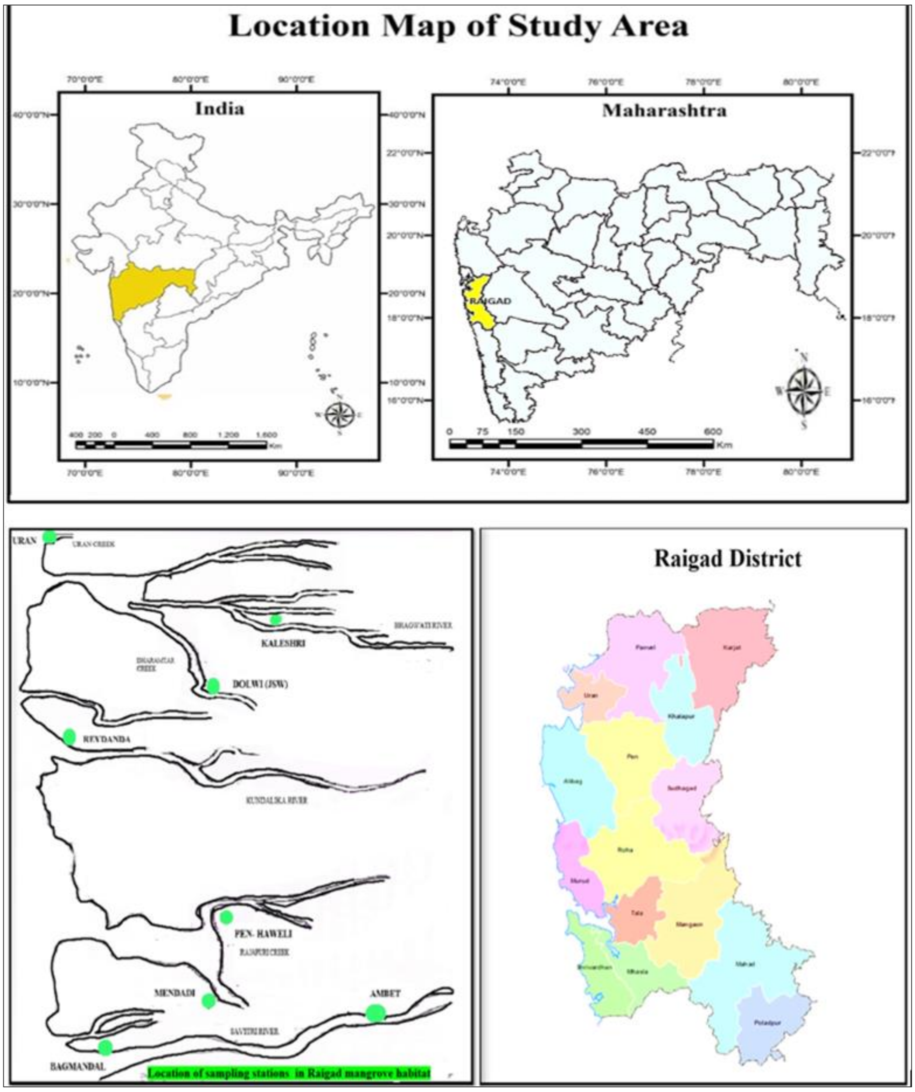

Fig 1: Study Site- Raigad District mangroves Habitat

Results and Discussion

Relative abundance

The relative abundance of *A. marina* was more than *S. apetala and S. alba* in Raigad. The number of individuals of *S. alba* and *S. apetala* are more in southern coastal area of Raigad and *A. marina* dominant towards the north (Table-1).

Table 1: Distribution of mangroves on different creeks and estuaries

Sr. No.	Name of species	Family	Uran creek	Bhagwati estuary	Dharamtar Creek	Alibag creek	Kundalika estuary	Rajpuri creek	Srivardhan creek	Savitri estuary
1.	*Rhizophora mucronata* Poir.	Rhizophoraceae	+	+	+	+	+	+	+	+
2.	*Rhizophora apiculata* Blume.	Rhizophoraceae								+
3.	*Ceriops tagal* (Perr.) C. B. Rob.	Rhizophoraceae	+			+	+	+	+	
4.	*Bruguiera gymnorhiza* (L.)	Rhizophoraceae					+			+
5.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	+				+			
6.	*Sonneratia apetala* Buch. -Ham.	Sonneratiaceae	+	+	+	+	+	+	+	+
7.	*Sonneratia alba* J. Smith	Sonneratiaceae						+	+	+
8.	*Avicennia marina* (Forsk) Virrh.	Avicenniaceae	+	+	+	+	+	+	+	+
9.	*Avicennia officinalis* L.	Avicenniaceae		+				+		+
10.	*Aegiceras*	Myrsinaceae				+	+	+	+	+

	corniculatum (L.) Blanco.									
11.	*Acanthus illicifolius* Linn.	Acanthaceae	+	+	+	+	+	+	+	+
12.	*Excoecaria agallocha* Linn.	Euphorbiaceae	+			+		+		+
13.	*Lumnitzera racemosa* Willd	Combretaceae						+		+
14.	Xylocarpus granatum Koeing	Meliaceae					+			
15.	*Cynometra iripa* Kostel	Caesalpiniaceae								+

+ indicate presence of species

Above ground biomass

In the present study of AGB among the species under study AGB was relatively higher in *A. marina* as compared to other two species (*S. apetala and S. alba*). The AGB value range from 34.39 tha^{-1} to 53.31 tha^{-1}, 36.14tha^{-1} to 92.24 tha^{-1}, 46.18tha^{-1} to 76.432tha^{-1}, 73.09 tha^{-1} to 80.65 tha^{-1}, 50.49tha^{-1} to 77.01tha^{-1}, 51.27 tha^{-1} and 86.33 tha^{-1} to 39.18 tha^{-1} at Uran, Kaleshri, Dolwi (JSW), Revdanda, Rajpuri, Medhadi, Bagmandal and Ambet respectively. The Maximum was recorded in *A. marina* (92.24 tha-^{1}) at Kaleshri and minimum in *S. alba* (39tha^{-1}) at Ambet (Fig.2). The results are similar to the reported above ground biomass values from wildlife sanctuary (BWLS), Odisha (Banerjee *et.al*. 2018) [3] and is nearly similar to the mangrove systems in the oligohaline zones of Sundarbans, Bangladesh (Kamruzzaman, 2017). However, the AGB values varies with the mangrove forest; it was 15.58 t ha−1in *S. alba* (Banerjee *et.al*., 2016) [2], 41.10 t ha^{-1}in *A. marina* (Kandasamy *et al*., 2021) [14] and 79.28 t ha^{-1}in *S. apetala* (Lu *et al*., 2014), 94.8 t ha^{-1} in a secondary mangrove forest of *R. mucronata* and *B. gymnorrhiza* (Suzuki and Tagawa, 1983) [37] and 62.9 t ha^{-1}in a *R. mangle* forest (Golley *et al*., 1962) [10]. The AGB are reported less than 300 tha^{-1}in Malaysia (Putz and Chen, 1986) [31], Indonesia (Komiyama et al. 1988) [19] and French Guiana (Fromard *et al*., 1998) [8]. The AGB is also reported less than 100 t ha^{-1}in most secondary forests and primary forests of high latitude areas (>24°23′N or S) (Mackey, 1993) [22]. The lowest AGB reported is 7.9 t ha^{-1} for a *Rhizophora mangle* forest in Florida, USA (Lugo and Snedaker, 1974) [20]. The greater allocation to above-ground biomass by mangroves was related to it's the biological characteristics of the greater height and DBH and strong colonization ability (Jayatissa *et al*., 2002; Ren *et al*., 2009; Peng *et al*., 2016b). ANOVA results also confirm significant variations in AGB ($p<0.05$).

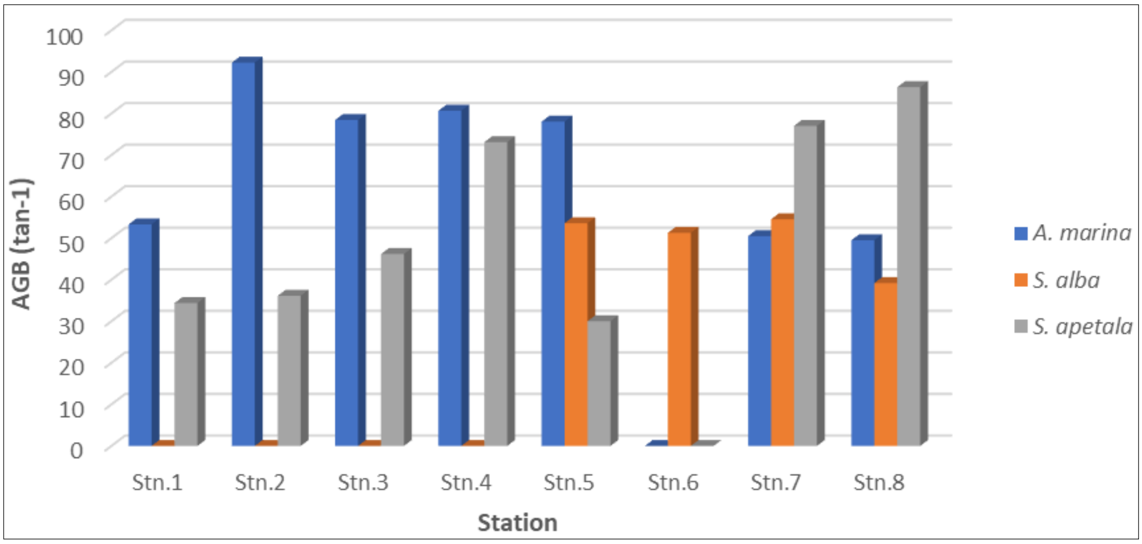

Fig 2: Spatial Variation of Biomass (t/ha) of Dominant Mangrove Trees in Raigad Mangrove Habitat

Stored Carbon in Mangrove Biomass

In this study the stored carbon in AGB (termed as AGC) of the selected site species ranged from 15 tha^{-1} in *S. apetala* at Rajapuri *to* 46.12 tha^{-1} in *A. marina* at Kaleshri. AGC in mangrove species was relatively higher in the *A. marina* as compared to other two species (*S. apetala* and *S. alba*). ANOVA results indicate significant differences in carbon content in AGB from differences site. Species contribution of the different mangrove species to the average carbon stock was in the order of *A. marina*> *S.apetala* > *S.alba*. (Fig.3). The carbon storage of mangrove species vegetation in Raigad is more or less similar to that in other locations reported by Banerjee *et al*., 2018 [3] and Mitra *et al*., 2011 [25], it is higher than the terrestrial forest ecosystems (Donato *et al*., 2011; Alongi, 2014) [6, 1] and other wetland ecosystems (McLeod *et al*., 2011 [23]; Migeot and Imbert, 2012) [24] and is lower than that reported for Micronesia and the Atlantic coast (Kauffman and Bhomia, 2017) [16]. The carbon storage in mangrove ecosystem has large variations may be due to stand age, tree species, geographical environment, tree richness, and species diversity (Kauffman *et al*., 2011 [16]; Kauffman and Bhomia, 2017 [16]; Schile *et al*., 2017) [33].

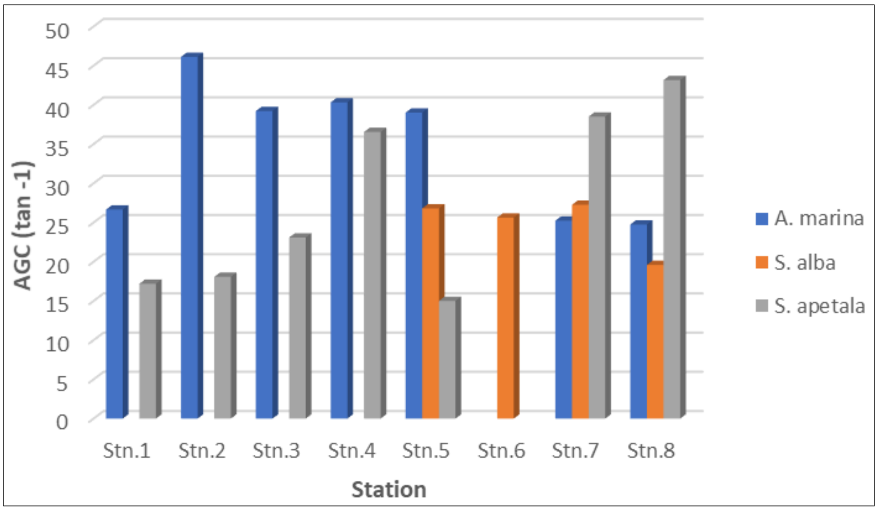

Fig 3: Spatial Variation of stored carbon (t/ha) in Dominant Mangrove Trees in Raigad Mangrove Habitat

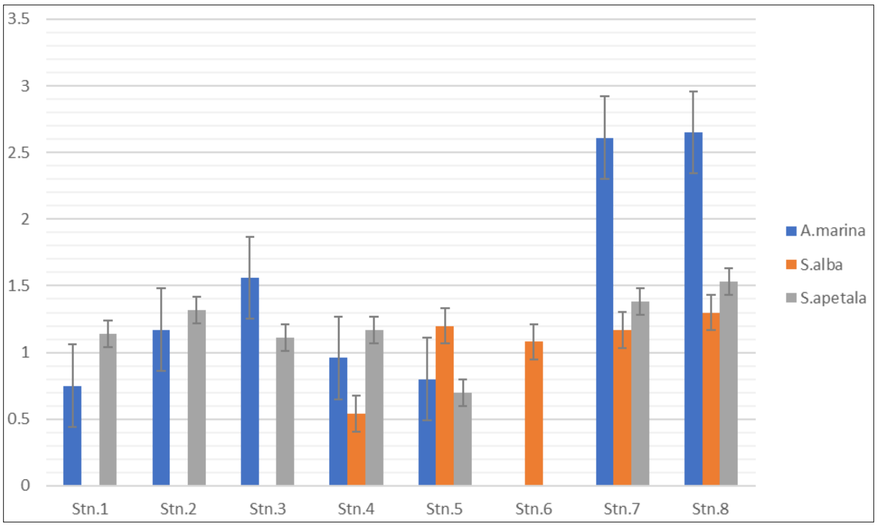

Fig 4: Spatial Variation of SOC (%) in Raigad Mangrove Habitat

Soil Organic Carbon

Soil carbon content also varies with the locations. It ranges from 0.7 to 2.65%. The highest soil carbon content was 2.65% at Ambet and the area was dominated by *A. marina* whereas the lowest soil carbon content was 1.73% under the dominant distribution of *S. alba* at Revdanda. The SOC significantly differs with the site and distribution of the species (Table 3). Several workers reported the soil carbon with many different site characteristics. The height value at Ambet was comparatively similar to the carbon content in soil under *Rhizophora apiculata* and *Xylocarpus granatum* in Forest of Sarawak, Malaysia (Arianto *et al.*, 2015). The soil carbon content of Raigad mangrove forest is almost similar to other report. Shazra *et al*. (2008) [34] reported 0.196 and 0.017% carbon in mangrove forest of Maldives, Ray *et al.* (2011) [32] reported 0.51 to 0.65% carbon in Sundarbans mangrove forest of India, Chandra *et. al.* (2015) reported 1.73 to 6.24% carbon in Awat-Awat mangrove forest of Malaysia. The SOC (%) at the Ambet of Raigad district was 2.9% and the soil found to be the most carbon-rich. The mangrove region indicates a positive correlation between tree density, biomass and carbon storage (Syamani and Susilawati, 2012). The increase in biomass was mainly due to the photosynthetic activities resulting in horizontal and vertical growth (Chanan, 2012). Studies revealed that the soil carbon content varies from one place to another and the distribution of species also play as important role in soil organic carbon.

Conclusion

From the above results it can be concluded that, the mangrove ecosystem of Raigad district has more or less similar potential and role in carbon sequestration. The species like *A. marina* plays a dominant role in carbon accumulation. It is also interesting to note that *A. marina* is the dominant species of Raigad district. It is also evident from the results that the soil carbon content was more at Ambet and the sites has dominant distribution of *A. marina*. The growth variables exhibited significant variation largely between mangrove species rather than mangrove sites. The findings of the present study add to the knowledge gap in the ecosystem functioning dimensions of a major mangrove system in Raigad district of Maharashtra.

Acknowledgement

Authors are thankful to UGC for providing the financial support in the form of JRF to the first author and Principal, Tuljaram Chaturchand College of Arts, Science and Commerce, Baramati for providing the laboratory facility to carry out the research work.

References

1. Alongi DM. Carbon cycling and storage in mangrove forests. Annual review of marine science,2014:6(1):195-219.
2. Banerjee K, Amin G, Fazli P, Pramanick P, Zaman S, Mitra AF. A. Excoecaria agallocha: A Potential Mangrove Species in Context to Carbon Storage in High Saline Zone. Sec. A,2016:5(2):115-120.
3. Banerjee K, Bal G, Paul R. Total Biomass and Carbon Estimates in Mangrove Species of Bhitarkanika Wildlife Sanctuary (BWLS), Odisha. International Journal of Plant and Environment,2018:4(02):27-34.
4. Cebrain J. Variability and control of carbon consumption, export, and accumulation inmarine communities. Limnol. Oceanogr,2002:47:11–22.
5. Clark DA, S Brown, D Kicklighter JQ, Chambers JR, Tomlinson JN, Holland E. A. Net primary production in tropical forests: an evaluation and synthesis of existing field data. Ecological Applications,2001:11:371–384.
6. Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M. Mangroves among the most carbon-rich forests in the tropics. Nature geoscience,2011:4(5):293-297.
7. Fromard F, Higuchi N, Kira T, *et al*. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia,2005:145:87-99.
8. Fromard F, Puig H, Mougin E, Marty G, Betouille JL, Cadamuro L. Structure, above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana. Oecologia,1998:115:39–53.
9. Giri C, Long J, Abbas S, Murali RM, Qamer FM, Pengra B, *et al*. Distribution and dynamics of mangrove forests of South Asia. Journal of environmental management,2015:148:101-111.
10. Golley F, Odum HT, Wilson R. The structure and metabolism of a Puerto Rican red mangrove forest in May. Ecology,1962:43:9–19.
11. Harishma KM, Sandeep S, Sreekumar VB. Biomass and carbon stocks in mangrove ecosystems of Kerala, southwest coast of India. Ecological Processes,2020:9(1):1-9.
12. Forest Survey of India. State of Forest Report. Dehradun: Ministry of Environment and Forest, 2017.
13. Pande HK, Arora S. India State of Forest Report 2013-Forest Survey of India. Dehradun, 2013.
14. Kandasamy K, Rajendran N, Balakrishnan B, Thiruganasambandam R, Narayanasamy R. Carbon sequestration and storage in planted mangrove stands of Avicennia marina. Regional Studies in Marine Science,2021:43:101701.
15. Kathiresan K, Anburaj R, Gomath V, Saravanakumar K. Carbon sequestration potential of *Rhizophora mucronata* and *Avicennia* marina as influenced by age, season, growth and sediment characteristics in southeast coast of India. J. Coast. Conserve,2013:17:397–408.
16. Kauffman JB, Bhomia RK. Ecosystem carbon stocks of mangroves across broad environmental gradients in West-Central Africa: global and regional comparisons. PloS one,2017:12(11):e0187749.
17. Kauffman JB, Heider C, Cole TG, Dwire KA, Donato DC. Ecosystem carbon stocks of Micronesian mangrove forests. Wetlands,2011:31:343–352.
18. Khan MdNI, Suwa R, Hagihara A. Carbon and nitrogen pools in a mangrove stand of Kandelia obovata (S., L.) Yong: vertical distribution in the soil-vegetation system. Wetlands Ecol. Manage,2007:15:141–153.
19. Komiyama A, Moriya H, Prawiroatmodjo S, Toma T, Ogino K. Primary productivity of mangrove forest. In: Ogino K, Chihara M (eds) Biological system ofmangroves. A report of east Indonesian mangrove expedition 1986. Ehime University, Ehime, 1988, 97-117.
20. Lugo AE, Snedaker C. The ecology of mangroves. Annu Rev Ecol Evol Syst,1974:5:39–64.
21. Lunstrum A, Chen L. Soil carbon stocks and accumulation in young mangrove forests. Soil Biol. Biochem,2014:75:223–232.
22. Mackey AP. Biomass of the mangrove Avicennia marina (Forsk.) Vierh. near Brisbane, south-eastern Queensland. Marine and Freshwater Research,1993:44(5):721-725.
23. Mcleod E, Chmura GL, Bouillon S, Salm R, Björk M, Duarte CM, *et al*. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment,2011:9(10):552-560.
24. Migeot J, Imbert D. Phenology and production of litter in a Pterocarpus officinalis (Jacq.) swamp forest of Guadeloupe (Lesser Antilles). Aquat. Bot,2012:101:18–27.
25. Mitra A, Sengupta K, Banerjee K. Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans. Forest Ecology and Management,2011:261(7):1325-1335.
26. Mitra A, Sundaresan J. How to study stored carbon in mangroves, published by CSIR-National Institute of Science Communication and Information Resources (NISCAIR), 2016. ISBN: 978-81-7236-349-9
27. Mitra A, Zaman S. Carbon sequestration by coastal floral community. Energy and Resources Institute, 2014.
28. Nellemann C, Corcoran E eds. Blue carbon: the role of healthy oceans in binding carbon: a rapid response assessment. UNEP/Earth print, 2009.
29. Ong JE, Gong WK, Wong CH. Allometry and partitioning of the mangrove, Rhizophora apiculata. Forest Ecology and Management,2004:188(1-3):395-408.
30. Pregitzer KS, Euskirchen ES. Carbon cycling and storage in world forests: biome patterns related to forest age. Glob Change Biol,2004:10:2052–2077.
31. Putz FE, Chan HT. Tree growth, dynamics, and productivity in a mature mangrove forest in Malaysia. Forest Ecol Manag,1986:17:211–230.
32. Ray R, Ganguly D, Chowdhury C, Dey M, Das S, Dutta MK, *et al*. Carbon sequestration and annual increase of carbon stock in a mangrove forest. J. Atmos. Environ,2011:45:5016-5024.
33. Schile LM, Kauffman JB, Crooks S, Fourqurean JW, Glavan J, Megonigal, *et al*. Limits on carbon sequestration in arid blue carbon ecosystems. Ecol Appl,2017:27:859–874.
34. Shazra A, Rasheed S, Ansari AA. Study on the mangrove ecosystem in Maldives. Global J. Environ. Res,2008:2(2):84-86.

35. Subedi BP, Pandey SS, Pandey A, Rana EB, Bhattarai S, Banskota TR, *et al*. Forest Carbon Stock Measurement: Guidelines for Measuring Carbon Stocks in Community-managed Forests. Asia Network for Sustainable Agriculture and Bioresources (ANSAB), 2010. ISBN: 978-9937-2-2612-7.
36. Suresh HS, Bhat DM, Ravindranath NH, Sukumar R. Carbon stocks and sequestration potential of Indian Mangroves. Trop Ecol,2017:58(3):547-553.
37. Suzuki E, Tagawa H. Biomass of a mangrove forest and a sedge marsh on Ishigaki Island, South Japan. Japanese Journal of Ecology,1983:33(2):231-234.
38. Telave AB, Ghodake SD, Pawar GP. Studies on Area Assessment under Mangroves of Raigad District, Maharashtra, India, *The India Forester*,2017:143:3.
39. Tupan CI, Lailossa GW. "Potential of stock carbon in mangrove Sonneratia alba in Passo coastal waters, Inner Ambon Bay." In *IOP Conference Series: Earth and Environmental Science*,2009:339(1):01.
40. Valiela I, Bowen JL, York JK. Mangrove Forests: One of the World's Threatened Major Tropical Environments: At least 35% of the area of mangrove forests has been lost in the past two decades, losses that exceed those for tropical rain forests and coral reefs, two other well-known threatened environments. *Bioscience*,2001:51(10):807-815.
41. Walkley A, IA Black. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci,1934:37:29-37.