CARBON SEQUESTRATION AND BIOMASS ESTIMATION STUDIES IN MANGROVE RICH WETLANDS OF INDIA - AN OVERVIEW

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ABSTRACT

Mangrove ecosystems, which are highly efficient carbon sinks, naturally reduce the amount of atmospheric carbon dioxide (CO₂) during the cycle of photosynthesis. These unique vegetations sequester large quantities of carbon in their biomass pool (in stems, leaves, branches, wood and roots) and sediment. The present review may help to understand the biomass productivity and carbon sequestration potential of the major mangrove vegetations in India and its astonishing role in global carbon budgets.

KEYWORDS: Mangrove, Carbon sequestration & Biomass

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INTRODUCTION

Mangrove ecosystems are highly efficient carbon sinks and they naturally reduce the amount of atmospheric carbon dioxide (CO₂) during the cycle of photosynthesis. The sequestration of carbon by mangrove wetlands is a function of the potential for biomass production. These unique vegetations sequester large quantities of carbon in their biomass pool (in stems, leaves, branches, wood and roots) and sediment. Biomass of mangroves provides information on their primary production and carbon storing capacity. The total biomass of mangrove forest patches distributed along the different Indian states includes 41.18 Mt (Suresh et al., 2017). Ability of global mangrove species to sequester carbon was assessed to be 4.0 Gigatons and which are basically accumulated as biomass in aboveground and belowground structures (Twilley et al., 1992).

According to historical data of CO₂ emission in India, between the years 1960 to 2016, the CO₂ emissions increased from 120,581.96 to 2,407,671.53 Kilotons. Nearly 48% of CO₂ emissions in India are contributed by biomass combustion and the balance by the combustion of fossil fuel. Due to rapid industrialization, population growth, rising pollution and anthropogenic activities the release of CO₂ and other ozone harming gases has increased multi fold over the last few centuries (Kweku et al., 2017). Mangrove forests play a vital role in the worldwide carbon cycle, by reducing greenhouse gas emissions and moderating the effects of climate change. Mangroves occupy 4740 sq km in India, around 3% of the total global mangrove cover. In India, the protected mangrove forest occupies an area of 1381 sq km (Worthington & Spalding, 2018). However, the destruction of mangroves is at an alarming rate and which in turn resulted in substantial carbon stock losses. Which, in turn, stresses the need of conservation and management of mangrove environments as deforestation will disturb the atmospheric gas equilibrium to immense degree.
The current study is an effort, aimed to summarize the biomass estimation studies and carbon sequestration potential of India’s major mangrove forests. The literature review of selected recently published papers (majority of the papers discussed here are published from the year 2015 to 2020) were conducted with the help of databases and search engines such as Google scholar, Academia, Science direct, Web of science, semantic scholar, and Scopus.

DISCUSSIONS

In order to evaluate the biomass and carbon stocks of Indian mangrove ecosystems, multiple efforts have been made. Most of the studies were conducted in Sundarbans and it emphasizes the role of mangrove habitats in aboveground and belowground carbon storage and the potential for carbon uptake and sequestration of the largest mangrove vegetation block in the world. Indian part of the Sundarban region occupies an area of 9630 sq km and it is a Global Biosphere Reserve, recognised by UNESCO in 2001 (Raha et al., 2013). The quantity of aboveground carbon stored (AGCS) carbon stock of the mangrove ecosystems is usually based on allometric equations either relating to the carbon biomass of plants to diameter at breast height (DBH) or by direct measurement of the vegetative parts through carbon analyzer (Chakraborty et al., 2016). The carbon sequestration rate of mangroves depends on several natural (plant height, age, density of the wood, seasonal and spatial differences) and anthropogenic factors (Mitra et al., 2011 and Ray et al., 2012).

Species wise biomass production and carbon stored in mangroves of Sundarbans were quantified in some studies e.g., Aboveground biomass (AGB) and AGC of *Sonneratia apetala* Buch.-Ham (~18 years old) was estimated at 219.45 t/ha and 61.33–101.76 t C/ha in Western Sector of Sundarban (WS); 37.42 t/ha and 5.76–17.21 t C/ha in Central Sector of Sundarban (CS) respectively (Mitra et al., 2012). Sengupta et al. (2013) estimated the AGB and belowground biomass (BGB) of *Avicennia alba* (~12 year old) in 2012 and the total biomass in the Eastern Sector (ES), WS and CS was 76.95 t/ha, 71.10 t/ha and 60.11 t/ha respectively. In CS and WS, the stored carbon value and sequestration rate of *Exoecaria agallocha* (~12 years old) are calculated to be 0.32 t/ha/month and 0.28 t/ha/month (Bhattacharjee et al., 2013).

Table 1: AGB and AGC stored in *A. alba* and *E. agallocha* distributed in different sectors of Sundarbans.

<table>
<thead>
<tr>
<th>Mangrove Species</th>
<th>AGB (t/ha)</th>
<th>AGC (t/ha)</th>
<th>AGB (t/ha)</th>
<th>AGC (t/ha)</th>
<th>AGB (t/ha)</th>
<th>AGC (t/ha)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. alba</em></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>(~22 years old)</td>
<td>39.78</td>
<td>19.55</td>
<td>50.17</td>
<td>23.80</td>
<td>54.13</td>
<td>26.73</td>
<td>Mitra et al. (2016)</td>
</tr>
<tr>
<td><em>E. agallocha</em></td>
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<td></td>
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</tr>
<tr>
<td>(~22 years old)</td>
<td>12.73</td>
<td>6.15</td>
<td>12.04</td>
<td>5.62</td>
<td>14.83</td>
<td>7.26</td>
<td>Banerjee et al. (2016)</td>
</tr>
</tbody>
</table>

In response to the rise in atmospheric CO₂ in the Sundarbans mangrove forest dominated by *Avicennia* species, Ray et al. (2013) reported an increase in aboveground and belowground/soil stored carbon. The overall AGB of a plantation of mono species (~190 ha) of *A. marina* of Henry Island, Sundarban was measured at 236 tonnes and a carbon stock of 4.9 tonnes, respectively (Manna et al., 2014). Two similar studies have been carried out by Banerjee et al. (2016) in *E. agallocha* and Mitra et al. (2016) in *A. alba*. Estimated the AGB and AGC during 1996, 2005 and 2015 in the WS, CS and ES of Indian Sundarbans. Both of the species shows significant temporal variation in AGB and AGC (Table 1).

A great deal of biomass studies has been carried out in Sundarban mangroves and is focused on its AGB. Mangroves allocate proportionally more carbon belowground. In the Sundarban mangrove forest, overall carbon stored in the AGB and BGB (live) is estimated at 21.13 Tg C (Ray et al., 2011). Carbon stored in individual plants of five dominant species (*Sonneratia apetala, Avicennia alba, A. marina, A. officinalis and Exoecaria agallocha*) from a forest patches
distributed in and around the WS and CS has been estimated to be 130.24 t/ha yr in WS and in CS it was 42.02 t/ha yr (Mitra & Gatti 2015).

The spatial variation of stored carbon according to different types of vegetation (average tree height, basal area, tree crown coverage etc.) and different salinity zones in Sundarbans was investigated by Rahman et al. (2015). Majumder et al. (2016) published a study in Sundarban mangroves which discusses the applicability of RNA leaf level: DNA ratios for determining intra-specific and inter-specific variations in the carbon sequestration of Avicennia, Aegialitis and Bruguiera species. In 2017, it has been reported that the carbon sequestration potential of Prentice island of Indian Sundarbans was 7.58 t/ha yr (Agarwal et al., 2017). Ray and Jana (2017) assessed the ability of the Sundarban mangrove forest to sequester carbon dioxide released from the coal-fired thermal power plant in Kolaghat. Seasonal variation in the AGB and AGCS in dominant mangrove species of Sundarbans in WS and CS were estimated, and it shows that mangrove species like Sonneratia apetala, Avicennia alba, A. marina, A. officinalis and Exoecaria agallocha have considerable carbon storing potential (Mitra et al., 2018). Recently Chowdhury et al. (2019) analysed the cost benefit plantation methods and blue carbon sequestration potential of some selected mangrove species at Sundarban Biosphere reserve. A case study from Satjelia Island by Saha et al. (2019) estimated the aboveground stem biomass of five major mangrove plant species was 19.79 t/ha, 5.83 t/ha, 20.22 t/ha, 21.14 t/ha, and 6.70 t/ha for Sonneratia, Apetala, Exoecaria agallocha, Avicennia alba, A. marina, and A. officinalis respectively.

### Table 2: Rates of Carbon Sequestration in major Indian Mangrove Vegetations

<table>
<thead>
<tr>
<th>Mangrove vegetation in India</th>
<th>Location</th>
<th>Carbon sequestration rate</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhitarkanika wildlife sanctuary</td>
<td>Lat. 20°4’-20°8’N; Long. 86°45’-87°50’E</td>
<td>10.92 tha⁻¹year⁻¹</td>
<td>Banerjee et al. (2017b)</td>
</tr>
<tr>
<td>Mahanadi mangrove wetland</td>
<td>Lat. 20°18’-20°32’ N; Long. 86° 41’ - 86° 48’ E</td>
<td>7.34 tha⁻¹year⁻¹</td>
<td>Agarwal et al. (2017)</td>
</tr>
<tr>
<td>Pichavaram mangrove wetland</td>
<td>Lat. 11° 20’N; Long 79° 55’E</td>
<td>2.33 – 4.44 g cm⁻² year⁻¹</td>
<td>Gnanamoorthy et al. (2019)</td>
</tr>
<tr>
<td>Sundarbans</td>
<td>Lat. 21°32’-22°40’N; Long. 88°05’-89°E</td>
<td>4.71 – 6.54 Mg C ha⁻¹ year⁻¹</td>
<td>Ray et al. (2011)</td>
</tr>
</tbody>
</table>

Several important studies has been carried out along major mangroves of India other than Sundarban were: Pichavaram mangrove forest, Tamil Nadu (Sahu & Kathiresan, 2019; Gnanamoorthy et al., 2019 and Singh et al., 2020), South-eastern coasts of India (Kathireshan et al., 2012; Prasanna et al., 2017) and Mahanadi delta complex and Bhitarkanika mangrove forest of Odisha (Bhomia et al., 2016; Agarwal et al., 2017; Banerjee et al., 2017; Bal et al., 2017 and Banerjee et al., 2020). Carbon sequestration rate of some major mangrove vegetation in India were shown in table 2. In the Mahanadi mangrove wetland, a comparative analysis of carbon stored was estimated in the vegetation and soil of natural mangrove wetlands and new plantations of mangroves. 147.0 +/- 8.1 Mg carbon/ha was the average total carbon stock of natural mangrove forest and plantation area. In the Mahanadi mangrove wetland, the 6651 hectare of mangrove wetlands was calculated to store 0.98 Mt of carbon, equivalent to 3.59 Mt of CO₂ emissions.

Pachpande and Pejaver (2015) estimated the carbon sequestration by Avicennia marina var. Accutissima Stapf & Moldenke ex Moldenke in Thane creek, Maharashtra and with total biomass(AGB+BGB) of 74.6 t/ha and total carbon content up to 37.6 t/ha. A carbon sequestration estimate in mangrove plantations of Avicennia marina, A. officinalis and Sonneratia apetala and naturally regenerated vegetation in the Ayeyarwady Delta, Myanmar were conducted by Thant et
al. (2012). A detailed study of biomass (AGB+BGB), soil organic carbon and sequestration of carbon by Gujarat mangrove forests has been undertaken by Pandey and Pandey (2013). Carbon sequestration by the Gujarat mangroves has been estimated as 8.116 million tonnes of carbon.

Biomass estimation and carbon sequestration potential of mangrove vegetations of Kerala has also been reported from mangroves of Puduvyppu (Kumar & Kumar 1997), Kadalundi wetland, Southwest Indian coast (Vinod et al., 2018) and Thalassery estuarine wetland of Kerala (Vinod et al., 2019). Total AGB production of Puduvyppu, ranged from 36-52 t/ha. The total AGCS and BGCS in Kadalundi wetland were estimated at 83.32±11.06 tonnes of carbon per ha and 34.96±4.30 tonnes of carbon per ha respectively. Kadalundi wetland and Thalassery estuarine wetland have capacity to sequester 2,409.84 t C and 891.11 t C respectively. A report on Kunijimangalam mangroves, Kannur, estimated AGB, BGB and carbon content was published by Bindu et al. (2020). The total carbon stored in the area was estimated at 12.67 tonnes. Harishma et al. (2020) recently carried out a comprehensive estimate of the biomass, carbon stock and carbon sequestration of Kerala mangrove habitats between April 2017 and March 2018. The study shows that the mangrove vegetation of Kerala has a capacity to sequester 139.82 t Carbon/ha.

CONCLUSIONS

All the above studies emphasize the potential of mangrove wetlands to function as carbon sink and propose that the conservation and restoration of this coastal vegetation is an immediate method to alleviate the impacts of environmental change and to reduce the emission of greenhouse gases in addition to all other services that these ecosystems provide to humans. The results may help to understand the biomass productivity and carbon sequestration potential of the major mangrove vegetations in India and its astonishing role in global carbon budgets.

REFERENCES


