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SYSTEMATIC STUDY OF CARBON SEQUESTRATION OF MANGROVE FORESTS AT RAIGAD DISTRICT COAST, MAHARASHTRA, INDIA

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Abstract: *Mangrove forests are highly productive ecosystems with carbon sequestration rate almost equivalent to tropical green forests. Mangroves distribute proportionally more carbon below ground and possess higher below to above ground carbon mass ratio as compared to any other forests (Kathiresen, 2004). Mangrove is amongst the most carbon rich biomes containing more than 950 tC/H. The said study overlooks destructive and non-destructive methods of the carbon sequestration. It is conducted as a comparative assessment of the carbon sequestration potential of mangrove and non-mangrove regions. By means of methodology of calculating Soil Bulk Density (gcm $^{-3}$) and Total Organic Carbon (TOC) in mangroves soils (El Wakeel and Riley, 1956) and Carbon Sequestration Rate (CSR) is estimated based on the sediment rates and TOC content of the soil (Duan Xiaonan et al (2008). The systematic assessment conducted at West Coast of Maharashtra; shows mangrove region with Avicinnia marina species and in non–mangrove region total carbon in soil (%) recorded 17.15% and 4.52 percent respectively. Total Soil Carbon Stock recorded is 431 million g / Ha at mangrove region and 105.7 million g / Ha at non mangrove region. After methodical estimation of biomass and carbon stock of mangroves (English et.al, 1997 and Kaufman and Donato, 2012), total carbon stock of mangrove stand was recorded 393.14 mg/Ha and that of non-mangrove stand was recorded to be 91.7 mg/Ha. It shows that mangroves absorb almost 315.14 percent more carbon than non-mangrove region. In other words, carbon stock in Avicinnia marina stand found to be almost 3 times more than non-mangrove zone.*

Key words: Mangrove, Biome, Carbon Sequestration.

Introduction

The tropical trees and shrubs which grow in inter-tidal region are known as “mangrove.” Mangrove forests are often referred as one of the world’s most productive ecosystems and thus also known as ‘tidal woodlands,’ ‘coastal forests’ or even ‘coastal rainforests. The woody plants those grow in tropical and sub- tropical regions lateral to the land and sea interface, estuaries, backwaters, and in the rivers. They even reach upstream to the point where the water remains saline (Qasim, I998). The word is originated in the year 1613 which is a bi-lingual “mangue” and “grove” originated from Portuguese the English word respectively (Kathirasen, 2001). More often all the salt tolerating plants are referred as mangroves and are also capable to grow in semi saline condition. A criterion was developed by Tomlinson (1986) by which mangroves are designated as a “true or strict mangrove”:

- Follows and grows in coastal environment.
- Forms the structure of the mangrove community and has the ability to form mangrove stands.
- Physical specialization for adaptation to environment.
- Functional specialization for adaptation to saline conditions.
- Taxonomic separation from terrestrial members.

Thus, mangrove is a non-scientific term used to describe an assorted group of plant species those are adapted to saline habitat. Mangrove may usually refer to an individual species, terms such as mangrove forest, mangrove swamp, mangrove community, mangrove ecosystem as well as mangle are used to describe the entire mangrove family.

Socio-economic of Mangroves

Mankind is directly as well as indirectly dependent on the mangrove ecosystem. It brings many economic, ecological, and social values to mankind. Mangrove ecosystems have consistently been undervalued, usually because only their direct goods and services have been included in economic calculations (e.g., forestry resources), but this represents only a minor part of the total value of mangroves. Mangroves ecosystem support one of the richest biodiversity (Ellison, 2008). It is seen that they act as a protective layer during the storms and tsunamis. Mangroves also possess quite a few economic benefits which range from valuable supply of forestry products and products like charcoal and firewood. Mangrove extracts are also used in indigenous medicines and can be used in treatment of diseases like blood pressures leprosy and epilepsy, rheumatic disorders, it is anti-diarrheal. They have also shown properties for the treatment of incurable viral diseases like AIDS (Kathiresan, 2001).

It is observed that Mangrove conversion usually has short-term benefits but it has a greater ecological impact at the longer-term. Some of the non-market values, e.g., species diversity and off-site functions such as nutrient exchange are not easily quantified, but have been significantly important to maintain the ecological cycle. Mangroves stand first in the row as far as the importance in view of their protective and productive values is concerned. They provide numerous tangible and intangible benefits (goods and services) along with the livelihoods to the coastal communities (Vannucci 2004). The socioeconomic importance of natural mangroves has been time and then highlighted addressed by many scholars and scientists (Ruitenbeek, 1994; Walters, 2008; Kathiresen, 2004; Barbier, *et al* 2008). In-fact the over-exploitation of various forest products, including timber, thatching materials and wood for fuel has been degrading Sundarbans mangrove forest (Islam and Gnauck, 2009). Wood is a key resource from the forest which contributes over 80 percent of the revenue generated from the Sundarbans. It acts as an important source of fuel wood for the markets of Bangladesh (Alam, et al 2012).

Threats to Mangroves Ecosystem

In the developing era and fast emerging world, the mangrove regions along with mudflats have often been considered as uncreative and unused land. Their elimination and destruction have been done for short-term utilization for instant economic benefit. One of the main causes of loss of mangrove forests is increase in population and their dependence on coastal resources. Ong (1995) stated that alarming increase in populations is possibly a biggest cause of mangrove destruction and degradation. Study shows that around 60 percent of the global population lives within roughly around 100 km of range from the coastline (WRI). Which means more than 4.6 billion people directly rely on marine habitats and resources for livelihoods, tourism, agriculture, and food, building sites and building materials, as well as recreational areas. The coastal regions and mangrove forests are also seen to be utilised as a dumping site for sewage, garbage and industrial wastes (Jennerjahn et al., 2002)

Moreover, huge population in the non-coastal region resides in agricultural region and urban communities concentrated along the rivers and in the surrounding hills. Pollution and underprivileged land use practices within these low-lying areas bring more and more sediments and pollutants which are ultimately washed into coastal waters affecting the mangrove ecosystem (Breithaupt et al., 1997). Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide or other forms of carbon to mitigate or defer global warming. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels (Brunskil et al., 2002). Carbon dioxide is naturally captured from the atmosphere through biological, chemical, and physical processes. Artificial processes have been devised to produce similar effects, including large-scale, artificial capture and sequestration of industrially produced CO_2 using subsurface saline aquifers, reservoirs, ocean water, aging oil fields, or other carbon sinks (Sanders et al., 2010).

Goal and Objectives

The goal of this study was to assess soil carbon pools and sequestration rates in coastal mangrove ecosystems of West Coast of India with a special reference to Raigad Taluk in the state of Maharashtra. The hypothesis is to assess carbon sequestration potential of mangroves and non mangroves region along a disturbed and non-disturbed tidal creek.

Materials and Methods

The Raigad Coast and Mangroves

Maharashtra has 720 km of a coastline which stretches from district Thane to south region of Sindhudurg till Terekhol creek spread across six districts and Mumbai's urban region. Mumbai sub-urban region forms the longest coastline whereas Thane district contributes the shortest coastline. Raigad district stands fourth as far as length of the coastline is considered. The Konkan coast is indented with number of beaches, fifteen small and large rivers, five major estuaries and more than 30 backwater regions (Jagtap *et al.*, 2001). Raigad coast whereas, is gouged with four major creeks, three creek-lets and five backwater regions. Raigad district is spread over fifteen tehsils which falls in 17^0 51' to 19^0 80' North and 72^0 51' to 73^0 40' East Longitudes, out of which Panvel, Uran, Pen, Alibaug, Murud, Roha Sriwardhan, Mhasala, Mangaon and Poladpur are the coastal tehsils covering about 4100 sq.km. of area with about

1300 villages. Hence, Maharashtra has a strategic central location in the western region of India. Moreover, Raigad falls strategically at the central location at west coast with Thane district at the North and Ratnagairi district down south. The said study was conducted at Dharamtar Creek at four different sites (table 1.1) which is a semi-diurnal, micro-tidal estuarine system located at Northwest region in Raigad district.

Table 01: Sampling Locations along the Dharamtar Creek

Sr. No.	Name of nearest village/town	Latitude	Longitude
1.	Vitthalwadi	18°47'15.70"N	73° 0'47.30"E
2.	Dadar	18°48'19.43"N	73° 2'3.97"E
3.	Khar Devli	18°40'45.12"N	73° 3'4.29"E
4.	Shahapur	18°43'31.77"N	72°58'42.30"E

Sampling

- Sediments sampling using the 1.5 m corer
- Temperature recorded using thermometer with 0.5 ^{0}C accuracy at different depths (0-10-30-50-100-above cms.)
- pH measured using pH meter
- Pour water salinity – hand refractometer
- Soil samples at different depths kept for the sun drying for 48 Hrs.
- Soil Bulk Density using water displacement method

$$\text{Soil Bulk Density } (gcm^{-3}) = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of water displaced (ml) of soil}}$$

El Wakeel and Riley (1956) Total organic Carbon in mangrove soil -

- Soil was dissolved in Chromic Acid
- Chromic Acid digestion and subsequent titration with ferrous ammonium sulphate solution in presence of phenanthroline indicator
- Light pink was an end point
- Same procedure is followed without the soil – blank titer

Calculations –

- Ferrous Ammonium Sulphate consumed (ml) (T) = Titre for blank – Titre for sample
- Total organic carbon (TOC) mgC/g (X) = 1.14 * 0.6 * T (Constant)
- TOC in sediment soil (%) = X / 10
- Total Carbon in sediment soil (%) = TOC / 2
- Carbon Stock in sediment soil (%) = bulk density * Total carbon * soil depth
- CO2 equivalent (%) = carbon stock * 3.67

Carbon Sequestration Rate (CSR) potential of mangrove sediment -

- CSR is estimated based on the sediment rates and TOC content of the soil using Duan Xiaonan *et al* (2008) method.
- CSR = p * TOC * R

Where,

p – Bulk density of soil g/cm^2
R – Sediment rate of mangrove …mm/year
TOC – total organic carbon in %

Similarly, Carbon Sequestration Potential (CSP) of different mangrove areas is made in the area of forest or annual increase in forest cover

CSP = CSR * A (A = distribution area of forest in Ha)

Estimation of biomass and carbon stock of mangroves –

For Mean wood density (p in tm-3) of mangroves: English et al., 1997 and Kaufman and Donato, 2012 method was used in which Girth of mangrove plants was measured in cm at the tree height of 30 cm for Rhizophoraceae members and at 1.3 m for all other mangroves.
Tree diameter is calculated by multiplying girth with the constant factor 0.318.
Calculations –

- Shoot biomass (SB) = 0.251 * p * $D^{2.46}$
- Root Biomass (RB) = 0.199 * $p^{0.899}$ * $D^{2.22}$
- Total Biomass (X) = SB+RB (kg/plant)

Where D – tree diameter; *p – wood density of trunk in ton per* m^3

Observations – Soil *Carbon Stock Mangrove & Non-Mangrove zone*

Results

Table 02: Soil Carbon Stock Mangrove & Non-Mangrove zone

	Zonation	**Soil Carbon Stock (mg/ha)**	**Percentage of control zone (A/B*100)**
A	*Avicennia marina* Zone	426.5	4.03
B	Non Mangrove Zone	105.7	--

It was observed that the soil carbon stock was observed to be four folds than in the non-mangrove zone. Hence, the potential of mangroves in sequestration of carbon is almost four time to the normal climate.

Table 03: Consolidated Data Sheet for Carbon Stock of Mangrove Stand

	Mangrove stand	**Carbon biomass (mg/ha)**	**Soil carbon stock in 1 m soil depth (mg/ha)**	**Total carbon stock of mangrove stands**	
				Mg/ha	% Increase over control (A/B*100-100)
A	*Avicennia marina* stand	33.64	359.5	393.14	315.14
B	Non mangrove stand (control)	0	94.7	91.7	--

It is observed that carbon stock in *Avicinnia marina* stand is almost 3 times more than non-mangrove zone.

Conclusion

The soil carbon stock of non-mangrove zone was calculated to be 105.7 mg/ha and that of *Avicennia marina* zone was found to be 426.5 mg/ha; which is three times more than the non-mangrove zone. From the results of present study, it has been found that mangrove forests absorb more carbon-di-oxide than any other terrestrial ecosystem. Moreover, when compared with *Avicinnia marina* and a non-mangrove area the consolidated carbon stock of mangrove was found to be 33.64 mg/ha; soil carbon stock in one meter depth soil was 359.5 mg/ha and 94.7 mg/ha, respectively and total carbon stock of mangrove stand was 393.14 mg/ha and non-mangrove stand was 91.7 mg/ha. Hence total difference between mangrove and non-mangrove stock was found to be 315.14 mg/ha. Hence the study gives one more reason towards conservation of mangroves towards fighting against climate change, tsunamis and supporting the coast biodiversity.

Table 04: Soil Carbon Stock Mangrove & Non-Mangrove zone

Name of Zone	Depth (cm)	Soil temp	Soil pH	Pour water salinity (ppt)	Dry weight of soil (g) X	Volume of Soil (ml) Y	Soil Bulk Density (g.m3) Z=X/Y	Total organic carbon in soil (%) A	Total carbon in Soil (%) B=A/2	Soil Carbon Stock (milli g/Ha) C=Z*B*soil depth interval (cm)	CO2 equivalent = C*3.67
Avicennia marina Zone	0 – 10	28.3	6.9	69	1	1	1	3.8	1.9	19	71.56
	10 – 30	31.4	6.66	7	1	1	1	10	5	100	367
	30 – 50	31.4	6.65	71	1	1	1	7	3.5	70	256.9
	50 – 100	32.1	6.75	73	1	1	1	6.8	3.4	175	623.9
	➢ 100	31.1	6.78	73	1	1	1	6.7	3.35	67	245.89
Total									**17.15**	**431**	**1565.25**
Non Mangrove Zone	0 – 10	30.1	7.88	11	1	1	1	0.54	0.27	2.7	9.9
	10 – 30	30.9	7.84	15	1	1	1	3	1.5	30	110.1
	30 – 50	31.1	7.78	15	1	1	1	3.2	1.6	32	117.44
	50 – 100	31.1	7.76	15	1	1	1	1.2	0.6	30	110.1
	> 100	30.4	7.73	16	1	2	0.5	1.1	0.55	11	40.37
Total									**4.52**	**105.7**	**387.91**

Table 05: Estimation of Biomass and Carbon Stock of Mangroves

									Carbon Estimation per hector		
#	Spp name	Tree Girth (cm)	Tree Diameter (D) = Girth * 0.318 (cm) D	Wood Density (t.m) p	Shoot Biomass (kg/plant) SB	Root Biomass (kg/plant) RB	Plant Biomass = SB+RB (kg/plant) X	Carbon Biomass = X * 0.42 (kg C/plant) Y	A = Y*Tree density/Ha (kgC/Ha)	B = A/1000 (mgC/Ha	CO2 Equi
1.	A M	43	13.674	0.506	79	35.83	114.83	48.2286			
2.	A M	36	11.448	0.506	50.99	24.13	75.12	31.5504			
3.	A M	33	10.494	0.506	40.72	19.2	59.92	25.1664			
4.	A M	25	7.95	0.506	20.83	10.75	31.58	13.2636			
5.	A M	56	17.808	0.506	151.3	64.38	215.68	90.5856			
6.	A M	56	17.808	0.506	151.3	64.38	215.68	90.5856			
7.	A M	24	7.632	0.506	18.82	9.81	28.63	12.0246			
8.	R M	12	3.816	0.701	4.72	2.81	7.53	3.1626			
9.	R M	14	4.452	0.701	6.92	3.97	10.89	4.5738			
10.	R M	16	5.088	0.701	9.58	5.33	14.91	6.2622			
11.	R M	13	4.134	0.701	5.76	3.36	9.12	3.8304			
12.	R M	12	3.816	0.701	4.72	2.81	7.53	3.1626			
13.	R M	13	4.134	0.701	5.76	3.36	9.12	3.8304	25.88 * 1300	33644 /1000	33.64 *3.67
								336.2268	**33644**	**33.644**	**123.4588**
							336.226 / 13	**25.8636**			

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