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Role of community managed forests in forest biomass & carbon sequestration: A case of Odisha (India)

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Abstract
Tropical forests are known for their huge contribution to terrestrial carbon sequestration and global carbon cycle. Reducing Emissions from Deforestation and Forest Degradation (REDD+) provides incentives to developing countries for positive elements of conservation, sustainable management of forests and enhancement of forest carbon stocks. In view of these roles of forests, a study was conducted in Odisha to estimate the impact of community led management practices on forest biomass and carbon sequestration. The study was conducted in 13 forested villages of 5 selected blocks including community managed/treated sites and natural forest/control sites. Following a quadrate sampling approach, the study found that community managed sites have comparatively higher contribution to total biomass and carbon content. The green tree biomass was found in the range of 10-115 t/ha in case of community managed sites and 7-180 t/ha in case of control sites. The average biomass in case of community managed sites was 63.56 t/ha against 56.73 t/ha for control sites. Similarly, the average carbon content value for treated sites was 32.91 t/ha against 29.49 t/ha for control sites. Overall, the community managed forest sites showed 12% higher biomass and carbon content than that of the control sites.

Keywords: Biomass, carbon sequestration, odisha, REDD+, tropical moist deciduous forest

1. Introduction

Tropical forests are globally considered as the largest terrestrial storehouses of biomass and carbon. It has been estimated that about 193–229 Pg of carbon is stored by the tropical forests in above-ground biomass (Saatchi *et al.* 2011; Baccini *et al.* 2012) [17, 3]. These forests are critical to future climate stabilization (Stephens *et al.* 2007) [20]. With the grounding of REDD+ (Reducing Emissions from Deforestation and Forest Degradation) mechanism, efforts have been furthered to estimate national-level forest carbon stocks in developing countries (Gibbs *et al.*, 2007, Asner *et al.* 2010; Saatchi *et al.* 2011 Baccini *et al.* 2012) [8, 2, 17, 3].

With about 70 mha of area under forest cover and approximately 200 million forest dependent people, India endeavours to conserve, expand and improve the quality of forests (SFR, 2015). In this regard, India has taken a strong course to implement the REDD+ and has developed a comprehensive strategy in this regard. As per one estimation India has the potential to capture more than 1 billion tonnes of additional CO2 over the next 30 years, which will provide it US$ 3 billion as carbon service incentives (Sarkar, 2011) [17]. India is committed to share the financial benefits with the forest dependant, forest-dwelling and tribal communities while safeguarding their rights under Forest Rights Act, 2006. India has. India is hailed as a pioneer in participatory forest management/Joint Forest Management (JFM) in the present world forestry scenario (Balooni, 2002) [4]. It is reported that JFM programme has generated many positive outcomes in different locations (TERI, 2013) [21]. Moreover, flow of financial benefits to the grassroots level community institutions under the REDD+ mechanism will further strengthen the "give and take" relationship, which India has been nurturing over the years. There is a need of national level efforts to quantify the carbon stored in aboveground living forest biomass or carbon stocks). Among the parameters studied, above ground biomass has been the most important visible and dominant C pool in forests and plantations (Wani *et al*, 2012) [22].

In India, There have been efforts to calculate the forest carbon stocks by considering both ground-based and remote-sensing measurements of forest attributes. It is estimated that the values for total carbon storage in Indian forest reported by several researcher range from 1,083.81 Mt C (Manhas *et al.*, 2006) [13] to 3,907.67 MtC (Chhabra *et al.*, 2002) [7] during 1984 to 1994. In Odisha, the authors have made an attempt to estimate the biomass and carbon stocks of two different types of forest areas forest viz. community managed and natural forests. This paper discusses in detail about the methodology and key findings of the study.

2. Materials and Methods

The study covered about 4880 sq. meter of forest area from 13 villages in all 5 blocks of Koraput district of Odisha. Overall, there were 26 sample plots of 20m × 20m size, including 13 treated and 13 control plots. It had a sampling intensity (defined as the ratio of the number of units in the sample to the number of units in the population) of 0.02% (Anonymous, 2002) [1] for estimating biomass and biodiversity. This sample intensity has been found optimum to account for the variability of biomass ranges as per Madugundu *et al.*, 2008 [12] for Tropical Moist Deciduous Forests of the Western Ghats in Karnataka, which are similar to Odisha context.

The authors have used quadrate sampling method to estimate forests biomass in the sample plots. In each sample site, 1 quadrate of size 20 ×20 m for trees was randomly laid out and within that, 4 quadrates of 5m × 5m for shrubs and climbers and 5 quadrates of 1m × 1m for herbs and regeneration along with 4 quadrates of 30cm × 30 cm for green biomass and 1 quadrate of 30cm × 30 cm for leaf litter estimation were drawn. The details of the plant species (common name, botanical name, family, Girth at Breast Height (GBH) found in the quadrates were recorded in the field notes including local land mark and date of collection. Green biomass harvested from 4 plots of 30cm x 30cm (at 4 corners) and leaf litter and detritus collected from one 30cm x 30cm plot (at centre) by sweeping floor respectively were weighed.

The biomass of forest areas were estimated by following the procedure recommended by Murali *et al.* 2005 [14] for tropical forests of India.

Allometric regression model Eq. (2) and Eq. (3) of Murali *et al.* (2005) [14] were used in EAGB estimation of each individual and was extrapolated to per hectare basis (Brown *et al.*, 1997) [5]:

$$\text{Basal area} = (GBH)^2/4\pi \quad (1)$$

$$EAGB = [-73.55 + (10.73 \times \text{Basal area})] \quad (2)$$

$$r^2 = 0.82$$

$$EAGB = [60.33 + 10.73 \times \text{Basal area}] \quad (3)$$

$$r^2 = 0.675$$

Where, GBH= Girth at Breast Height

EAGB= Estimation above Ground Mass

Using, Stand Volume and Yield table of Sal-Coppice (Chaturvedi and Sharma, 1980[6]), volume of timber and small volume were calculated against the observed basal area, and an assumed crop height of 10 m. This was converted into biomass as per the following.

Volume to Biomass conversion factor

Biomass = Volume x 0.728 ----- Singh. (2014) [19] (4)

= Volume x 0.769 ----- Manhash *et al* (2006) [13] (5)

= Volume x 0. 672 ---- Negi (1989) [15] (6)

Therefore, taking average from Eq. 4, 5 and 6, volume was multiplied with 0.723

As mentioned above, GBH was recorded during data collection from quadrate. In all the sample plots, girth (cm) of species was recorded by measuring tape at the breast height of 1.32m. Dry Biomass was calculated by multiplying 0.8 with total tree biomass as per Kishwan, 2009 [10].

The recommendation of IPCC on calculation of BGB (Below Ground Biomass) was considered for estimating below ground biomass in the sample areas i.e. BGB = 25% of above ground mass.

Total Tree Biomass (including below ground) = 1.25 x EAGB

The floor biomass was converted to dry biomass by multiplying an assumed factor of 0.3 and the leaf litter biomass was added to Total Dry Tree Biomass to calculate Total Biomass.

The biomass was then converted to carbon by the following formulae. Carbon from Trees = Dry biomass x 0.47 (Wani *et al.* 2012) [22]

3. Results & Discussion

3.1 Basal Area, Floor Biomass and Leaf Litter

Results on basal area presented in Table 1 illustrate a very narrow difference (6.6 percent) between average basal area of the treated and control plots. Out of the 13 sites, there were three control sites whose performance in terms of basal area found comparatively better than their respective treated sites (viz. Andori 38.93 sq. m /ha; Pipalpadar 38.38 sq. m /ha and Atalguda 30.64 sq. m /ha). Higher variability in basal area of both treated and control sites indicate widely different protection and growth. Given the limitations of the study sites (viz. village degraded forests, highly accessed by local communities, mostly comprised of sal coppice crop) though the average value of basal area seems to be less than that of average basal area reported by Segura and Kanninen (2005) [18], encouragingly certain sites were found at par with the average of 24, 28, 24 m^2 ha^{-1} reported by the said authors for open, dense and ecotone forests respectively.

Table 1: Estimation of Basal area, floor biomass and leaf litter

Village	Basal Area(sq. m/ha)		Floor Biomass(t/ha)		Leaf Litter(t/ha)	
	Treatment	Control	Treatment	Control	Treatment	Control
Andori	22.90	38.93	4.28	4.19	1.33	1.26
Atalaguda	23.53	30.64	3.17	4.50	5.00	5.33
Gandhipadu	6.14	2.11	0.89	0.78	3.11	2.44
Guma	10.32	14.55	3.31	4.03	5.78	5.11
Karaguda	18.01	0.61	0.33	1.58	8.11	5.00
kurumuli	1.18	0.36	0.22	0.36	7.00	9.00
Kusumaguda		3.34	1.75	2.00	10.44	6.22
Pipalpadar	17.19	38.38	0.58	0.56	10.22	8.78
Sorispadar	9.20		0.47	0.44	7.00	8.89
Ramjiput	18.86	0.93	0.69	0.72	2.89	2.67
Rangamguda		7.97	0.44	0.42	6.78	8.11
Rexkanadi	14.03	1.05	0.67	1.72	8.67	3.00
Sanpilcur	7.23		0.19	0.58	7.44	8.22
Mean	13.5	12.6	1.3	1.7	6.4	5.7
Std Dev	7.25	15.71	1.38	1.55	2.77	2.75

With regard to accumulation of biomass on the floor, control sites were reportedly better than the treated sites for most of the cases. Highest floor biomass of 4.5 t/ha was reported in Atalguda control site. The average biomass of leaf litter of the treated areas was 6.4t/ha against 5.7 t/ha for control areas. Among the sites, the treated plot at Kusumaguda reported highest leaf litter biomass of 10.44 t/ha, which was closely followed by Pippalpadar (10.22t/ha). More leaf litter weight could be due to deciduous nature of species. In case of all the three parameters, marginal difference between treated and control areas indicates limited difference in growth, which could be due to the limitations in protection measures undertaken by the communities. Considering the fact that biomass is a function of density of stems, height of the trees and basal area of the trees in a given location, as reported by other researchers, the difference in basal area between the sites indicates the contribution of the above said parameters to above ground biomass, which further differs with sites, successional stage of the forest, disturbance levels, species composition etc. (Whitmore, 1984) [23]. As observed by other researchers (Rai, 1981) [16], the present study also found a strong correlation (0.99) between biomass and basal area of the sites.

3.2 Green tree biomass

In terms of estimated green biomass (Fig. 1), the control site at Pipalpadar showed highest green biomass of 180 t/ha, which was followed by Atalaguda with 143 t/ha of green biomass. However, among the treated areas, highest biomass of 115.25 t/ha was reported in Atalaguda site followed by Andori (105.60 t/ha), while lowest biomass of 10t/ha was recorded in Kurumuli village. Kusumaguda and Rangamguda exhibited no tree biomass because these two sites were dominated by regenerations. Among the control sites, lowest green tree biomass of 7 t/ha was found in Kairaguda. Sanpilcur has recorded no tree biomass due to absence of tree species of suitable girth. The mean green tree biomass of treated sites was 12 percent more than the mean value of the control sites.

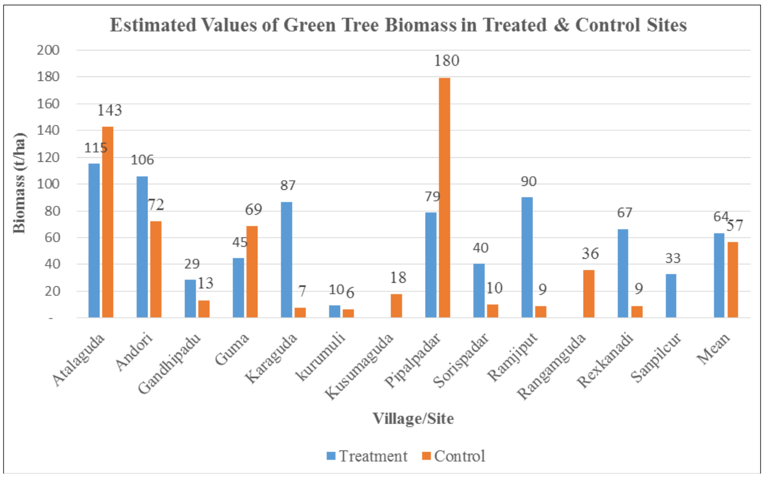

Fig 1: Estimated Values of Green Tree Biomass in Treated & Control Sites

3.3 Dry Tree Biomass, Total Biomass and Carbon Content

The tree dry biomass presented in Table 2 for the treated sites, were in the range of 7.67 t/ha to 92.20 t/ha, with an average of 50.85 t/ha. Atalaguda reported the highest value whereas, lowest value was found in Kurumuli. Similarly, the range of tree dry biomass in case of control sites was 5.13 to 145.37, with a mean of 45.39t/ha. Pipalpadar had highest total tree dry biomass followed by Andori whereas, lowest tree biomass was recorded in Ramjiput. The mean value of total biomass (which was calculated by converting the dry tree biomass values to total tree biomass including below ground biomass by multiplying 1.25 and the values obtained were added with floor and leaf litter biomass of the respective sites) for treated and control sites were 63.56 t/ha and 56.73 t/ha, respectively. Needless to mention, the trend observed in total biomass was more or less similar to that of total tree dry biomass and total dry biomass. Considering the degraded and coppice nature of forests located in proximity to villages in the treated sites, the figures seem comparable with findings of similar studies (mean value of 67.4 t/ha) by Haripriya *et al.*, 2000 [9].

Table 2: Estimated Total Biomass and Carbon Content in Treated vis-à-vis Control Sites

Village	Average Dry Tree Biomass (t/ha)		Total Tree Biomass (t/ha)		Total Dry Biomass (t/ha)		Carbon Content (t/ha)	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Andori	84.48	145.37	105.6	181.71	108.22	184.23	50.86	86.59
Atalaguda	92.2	114.08	115.25	142.6	121.2	149.28	56.96	70.16
Gandhipadu	22.94	10.53	28.68	13.16	32.05	15.84	15.06	7.44
Guma	35.79	54.84	44.74	68.55	51.51	74.87	24.21	35.19
Karaguda	69.42	5.9	86.78	7.38	94.99	12.85	44.64	6.04
kurumuli	7.67	5.13	9.59	6.41	16.65	15.52	7.83	7.29
Kusumaguda		14.31		17.88		24.71		11.61
Pipalpadar	62.96	143.67	78.7	179.59	89.1	188.53	41.88	88.61
Sorispadar	32.34	8.1	40.43	10.12	47.57	19.15	22.36	9
Ramjiput	72.05	6.88	90.06	8.6	93.16	11.48	43.79	5.4
Rangamguda		28.55		35.69		43.92		20.64
Rexkanadi	53.24	7.27	66.55	9.08	75.42	12.6	35.45	5.92
Sanpilcur	26.28		32.85		40.35		18.97	
Mean	50.85	45.39	63.56	56.73	70.02	62.75	32.91	29.49
Std Dev	27.58	55.95	34.47	69.94	34.13	70.05	16.04	32.92

With regard to total carbon content, on an average the performance of treated sites (with a mean of 32.91 t/ha) were slightly better than their respective control sites (mean of 29.49 t/ha). In case of treated sites, highest carbon content of 56.96 t/ha was reported in Atalaguda and the lowest value of 3.25 t/ha was reported in Rangamguda. Similarly, in case of control sites, Pipalpadar registered highest value of carbon content (88.61 t/ha) whereas, the lowest carbon content was recorded in Ramjiput (5.40 t/ha). The result indicates that the carbon content in community managed forests is 12 percent higher than the control forests. The finding of the present study is in line with that of Manhas *et al*, 2006 [13], who has reported that the carbon content in India's Sal forest is 24.07 t C ha−1. As per the field observations, the authors assume that the comparatively higher values of carbon content in the present study sites might be due to inclusion of below ground biomass, particularly in most of the community managed sites.

4. Conclusion
The findings of this study indicate that community managed forests yield comparatively higher biomass and carbon content. The marginal difference in values of several parameters between the community managed forests and natural forests is attributed to the fact that almost all the sites were degraded forest patches and the interventions are only for last 2-3 years. Taking the forecasted CO_2 price of $15 to $25 in 2020 (Luckow, 2015) [11], the average value of these forest sites amount to $92806 to $154,677, which will be a huge amount for the tribal communities, if transferred to them under the REDD+ regime. This incentive will largely contribute in poverty eradication and will support livelihood of the indigenous groups while enhancing and improving quantity and quality of forest resources in the country.

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