Management Regimes, Soil Properties and Carbon Stock in Community Managed Forests

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Date Received: 10-07-2019 Date Accepted: 10-12-2020

Abstract

The study was carried out to understand the management strategies, soil nutrient properties and carbon sock of community managed forests practiced by Jamatia community of Tripura, Northeast India. It revealed that Jamatia people of Tripura are actively involved in conservation and management of the forests under their control. The concept of creating forest and follow an institutional setup for management of forest resources are being noted in this ethnic community. In community forests, maximum numbers of individuals of tree species were represented from the lower girth class while individuals from higher girth class contributed larger biomass and carbon. *Anogeissus acuminata* was the most preferred species in the community forest as it is the source of timber and fuel wood and also contributing high biomass among other species. The total biomass and carbon stock in the community managed forest was found as 40.66 Tha^{-1} and 20.33 Tha^{-1} respectively. The soil of community forests are very fertile and found acidic in nature. The mean SOC is 1.38%, whereas available nitrogen and phosphorus content are 210.79 Kg $ha^{-1}$and 8.36 Kg ha^{-1} respectively. However, a positive and significant correlation of available phosphorus was observed with physical properties like soil temperature, pH and also with total nitrogen content. These forests have potential for future carbon sequestration and to mitigate climate change for longer run as it is managed sustainably by the community.

Keywords: biodiversity, biomass, conservation, institution, Jamatia community, tradition

1. Introduction

Human beings have been relied on forests since long period of time not only for their livelihoods, but also as an integral element in their cultural, spiritual and social systems. Chatterjee et al. (2000) mentioned that the forest provides innumerable tangible and intangible benefits, and its judicious utilisation provides us a sustainable resource. It is proved that the management approaches has improved the condition of forest and enhanced the livelihood of local people (Agarwal and Ostrom, 2001). There is great variability in their management practice, which has evolved under different biophysical and cultural environments (Nongkynrih, 2001).

Northeast India is a mosaic of diverse ecological, social and physiological landscapes. The community conserved areas (CCA) of North-East Indian states were studied by different authors across the regions *viz.*, Assam (Medhi and Borthakur, 2013), Meghalaya (Kharkongor and Tiwari, 2015), Manipur (Khumbongmayu et al., 2005) and Arunachal Pradesh (Murtem and Chaudhry, 2014) and Tripura (Darlong and Barik, 2006). This system was stressed to have deeper level of understanding with proper documentation of its traditional knowledge which needs to be recognised. The ethnic people of this region, through long-term trial and error experiments, have developed an elaborate, functional and democratic system of conservation and management of forests and associated natural ecosystems (Tiwari et al., 2013).

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There is a critical need to understand the ecological and economical potentiality of community managed forests and accordingly strategise conservation of the forests for future generations. Therefore, community conserved areas needs more intensive analyses and conservation. However, there is a lack of scientific research regarding the management practices and other pattern of ownership of community forest, which is very complex and diverse as observed by Tiwari et al. (2010).

It was reported that the tropical forests contributes around 37% of carbon out of the total 90% terrestrial carbon (Houghton, 1996). Due to anthropogenic activity it has now become a source of carbon in atmosphere (Chhabra and Dadhwal, 2004). UNFCCC has recommended in reducing the limit of emission for stabilising the atmospheric greenhouse gases (UNFCCC 1993). The role of community forests in carbon stock enhancement and soil management is not known. It is known that the management strategies in a disturbed forest can potentially meet the current need of stabilising the global warming through soil and carbon management. The community based forest management provides an opportunity to build a sustainable link with ecology to meet future needs. This study aims to document management regimes of community forests practiced by Jamatia and to quantify carbon pool and soil nutrient status in community managed forest areas of Tripura, Northeast India.

2. Materials and Methods

2.1 Study area

Tripura is, one of the land-locked Northeastern states in India, situated between the latitudes of 22°56′ N 24°32′ N and the longitudes of 90°09′ E 92°10′ E. With an area of 10,492 km^2, the state is the third smallest of the country, covers 0.32% of the country's geographical area. The primary sector of the state consists of forestry and agriculture. The present study was conducted in Killa block of Gomati district in Tripura (Figure 1). This block is mainly inhabited by Jamatia community, with combination of *Debbarma*, *Molsom* and other ethnic communities. In total, four villages were selected for the present study *viz*., Wajiy bachai, Warung, Kaipeng bulai and Tairupa bari. It extends between 23°35′28.67″ E 91°29′33.6″ N to 23°36′43.97″ E 23° 57′01.11″ E with an average elevation of 68 m amsl.

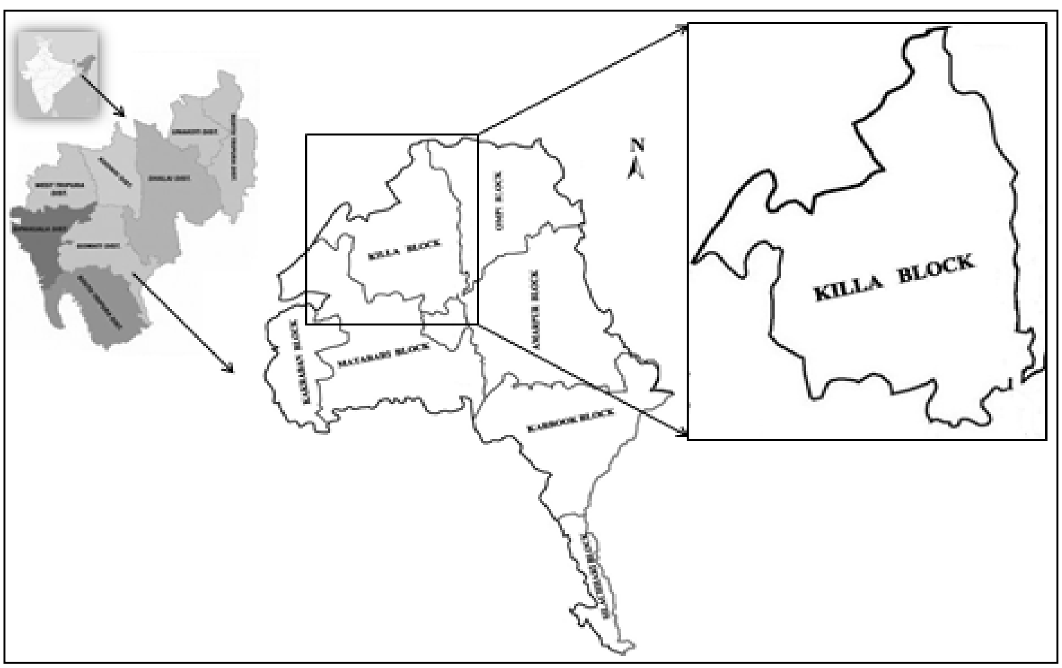

Figure 1. Map of the study area.

2.2 Methodology

The primary data was collected using standard questionnaire method from the households of four different villages during 2016-2017. Some secondary informations were also collected from the head of the local institution. The random sampling method was used, targeting households from each village. Information on literacy, economy, sex ratio, occupation, age structure, fuel and fodder dependency and domestic production were also collected.

Soil samples were collected using soil corer for estimation of physico-chemical properties of soil. The samples were collected from two quadrats from each village up to 1 m depth *viz.*, 0-15, 15-30, 30-45 and 45-100. The soil samples were collected in an air tight zipper bag with proper labeling. A composite sample for each depth was prepared by mixing soils, resulting in one sample per depth level from each study plot for laboratory analyses. Soil texture and water holding capacity were determined according to Anderson and Ingram (1993), while soil moisture content was measured gravimetrically by drying 10 g of field moist soil sample in a hot-air oven at 105° C for 24 h. Soil organic carbon was estimated using wet digestion method (Walkley and Black, 1934). Soil available Phosphorous was determined calorimetrically by Bray and Kurtz (1945). Total nitrogen was estimated following semi-micro Kjeldahl procedure by acid-digestion, distillation and titration (Kjeldahl, 1883). The pH of the soil sample was determined in a soil-water suspension (1:2.5 w/v H_2O) using a digital pH meter.

Tree species in the community forest were measured using randomly placed quadrats of 31.6×31.6 m. At each quadrat, height of all woody species with >5cm DBH and diameter at breast height (DBH) were recorded. The species were identified, mostly through their vernacular names and existing literature (Deb 1981/1983). Biomass and carbon stock was estimated using allometric equation following Chambers et al. (2001): $\exp[-0.37+0.333\times\ln(D)+0.933\times\ln(D^2)-0.122\times\ln(D^3)]$ for aboveground biomass and Cairns et al. (1997): $[\exp(-1.059+0.884\times\ln(AGB)+0.284)]$ for belowground biomass. The total biomass is the summation of above and belowground biomass, carbon was considered 50% of the total biomass following Brown et al. (1989). The statistical analysis was performed using statistical tools. The software used was SPSS 18.

3. Results

3.1 Management implication

There has been a long tradition of community based forest management by the Jamatia community in the hilly regions of Tripura. Four villages were studied (Table 1) to recognise the management strategies of community forest by Jamatia community in Killa block of Tripura. The total forest area managed by this indigenous community is 216 ha (excluding the reserved forest). This is a hilly, partly hilly and plain area with an elevation ranging from 52 to 88 m amsl. Various forest types like mixed forest, mixed forest with rubber and very dense forest were found. The common species like *Ailanthus excelsa*, *Bauhinia purpurea*, *Diospyros* sp., *Microcos paniculata*, *Phyllanthus emblica*, *Schima wallichi*, *Syzigium cumini*, *Tectona grandis*, *Terminalia bellerica*, *Terminalia chebula* were dominant in the study sites. *Hevea brasiliensis* was also raised in the plantation plot. These forests are mainly managed by the local ethnic people of the area. The management activity starts from beginning of the rainy season i.e., from March till the end of November. The management strategy combines to fulfill the objective of conservation as well the overall development of the community.

Villages	Wajiy Bachai	Warung	Tairupa Bari	Kaipeng BFulai
Community forest				
Total Area (ha)	120	16	40	40
Elevation (m)	88	52	63	70
Topography type	Hilly	Hilly	Partly hill	Partly hill
Forest Type	Mixed Forest with Rubber	Mixed forest	Mixed Forest	Very Dense Forest
Dominant species	*Bambusa Hevea,Tectona Diospyros Syzygium, Microcos Bauhinia, Terminalia* sp.	*Schima Albizzia* sp. *Bauhinia* sp. *Microcos Sterculia Diospyros*	*Tectona Anogeissus Schima Microcos*	*Anogeissus Holarrhena Banulai Caryota Flacourtia Bamboo* sp.
Management Practice				
Season of Management	March-November	March-October	March-October	March-October
Establishment Status	Old	Recent	Very old	Old
Income/year	Highly profitable	Minor	Minor	Profitable
Families involved (No.)	72	53	216	145

Table 1: Details of community managed forests in Tripura.

3.2 Institutional arrangement

It was found that the community forest is guarded and administered by the local people of the respective villages. Each village is lead by the Chief called as *Chowdhuri* of the community of a particular village. The Chief is assisted by the *Baya Chowdhuri*, who is selected by the Chief himself and after the consent of the local people. *Chowdhuri* and *Baya Chowdhuri* are supported by other members, such as Secretary, Cashier and other executive members (Figure 2). These executive members are representatives from these four villages. For proper management of the community forests, a group of few members belonging to one or two families from each village are selected. These groups alternatively are involved in management and guarding their respective community forests.

Any major or minor decision for the interest of the people in connection with the community forest is taken after prior permission from the Chief and his selected executive members. The Chief who is the *Chowdhuri* of the village has the absolute authority for decision making in the group or in any family issue. He is also the supreme head of the Village council. He usually presides over any issue raised by the individual or by any group of people. He settles over any issue, if any rights of the community people are violated in any way by any person. He also assists in settling an issue related to any kind of theft of resources from the forest has been reported by the local people. In such case, the guilty is bound to negotiate by paying fine of an amount equivalent to the theft done. Immediate to the *Chowdhuri*, *Baya Chowdhuri* takes the place. He acts on behalf of the *Choudhuri* in his absence and manage over any issue to a solution. In his presence, he assists the Chief for any decision and action. The Secretary help to maintain the official record and assists the *Baya Chowdhuri* for any decision in the absence of the Chief. The cashier takes charges of all the financial matters. He is responsible to collect either monthly or yearly fees to be given by each village. These fund are being utilised for the welfare of the local people such as construction of primary schools, leashing of money to needy ones with low interest rates and during an annual feast that they celebrate in their respective villages.

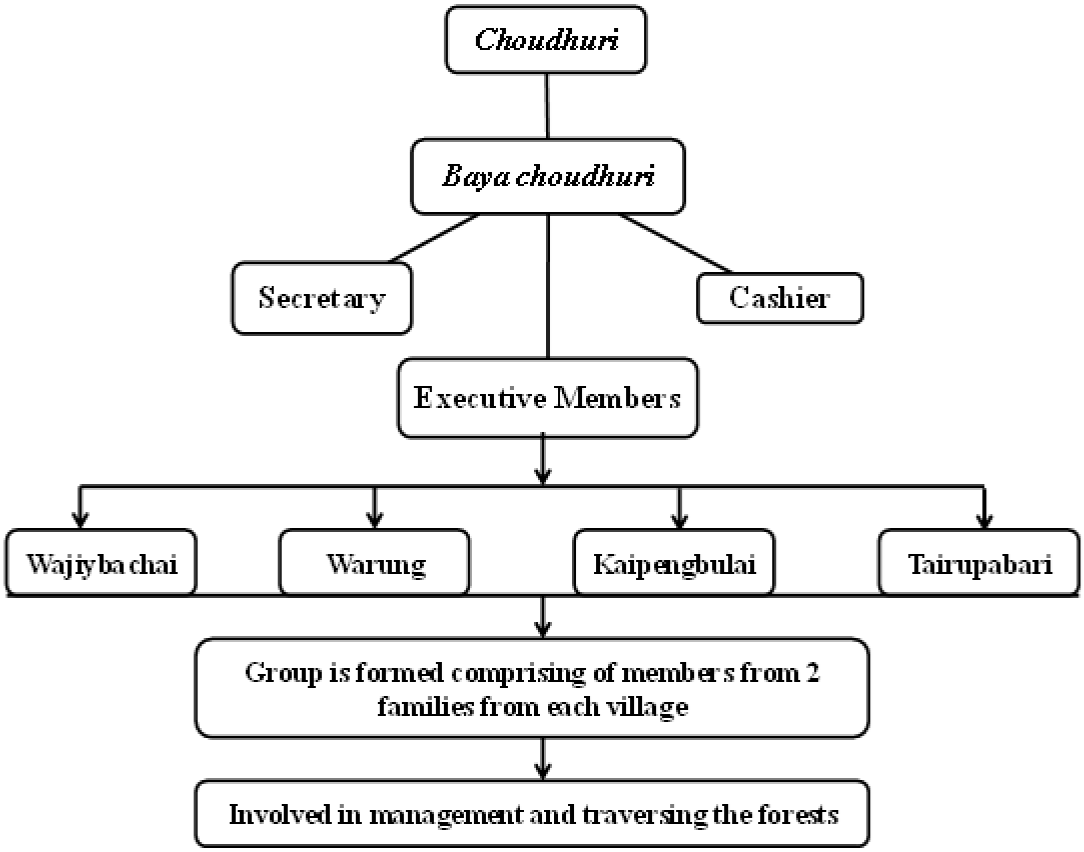

Figure 2. Institutional set up for management of community forest.

A group of 5 to 6 members from each of these four villages are alternatively given charges for traversing their respective community forests mainly in the peak season of probable theft. They help in the proper supervision of the community rules formed for the conservation of the forest. These groups take the responsibility in guarding the forest by an alternative traversing around the forests especially for any illegal activities such as felling and selling of logs and timbers.

3.3 Utilisation pattern

The utilisation of forest resources by the local people is enormous as the daily needs are fairly fulfilled. They use mainly for fuelwood, fodder, timber, medicinal uses, vegetables and fruits. The excess is used for income generating by selling in the nearby local market. Trees were felled as logs after maturity; some important timber species like *Tectona grandis*, *Anogeissus* sp., and bamboos were also harvested for various uses; mainly for selling which are being utilised for construction and furniture making. Various dead wood timber species are also converted to planks for fuelwood and other purposes (pillar, posts and other household purposes). Bamboo shoots are widely extracted for self-consumption and also for selling, which is highly profitable. However, there is restriction in the extraction of bamboo shoots from the same area. Therefore, the extraction procedure is followed in a patch wise, which enables the shoots to regenerate in a sustainable way. Thus, community based forest management offers an alternate approach to sustain the forest resources through the integration of knowledge and skills. This kind of management depends on the community people and their commitment on the conservation and sustainable utilisation. The fuelwood collection and fodder collection is permitted in these areas after prior permission from the *Chowdhuri* or *Baya Chowdhuri* of their respective villages. The community people has devised for equitable benefits by giving preference to the neediest groups. Thus most of the local poor families are given access to collect fuelwood and extract timber for their own purpose. Some multipurpose tree species like *Albizzia lebbeck* is commonly utilised for timber in construction or as fuelwood, whereas *Bauhinia purpure*a is used both as timber and for dyeing. Tree species like *Dillenia indica*, *Garcinia cowa*, *Phyllanthus emblica* and other highly nutritive species are found which are used for consumption and for selling in the market for altering their crisis and meeting their needs. In addition, restrictions are given in case of felling of young woody species and extraction of newly regenerating bamboo shoots. Therefore, only mature dead wood trees could be felled after granting permission from the *Chowdhuri* or *Baya Chowdhuri*. Table 2 shows the list of documented multipurpose tree species recorded in these community managed forests. Further, there are restrictions on the collection of resources from the community forest from each village. The people from other village cannot collect resources other than their own forests and if anyone is found guilty in collection of resources from other forests, he or she is bound to pay fees or give back the resources collected.

Table 2. List of species documented in the community managed forest of Tripura.

Botanical name	Vernacular name	Family	Uses
Ailanthus excelsa Roxb.	Rongeen	Meliaceae	Timber, Fuelwood
Albizzia lebbeck (L.) Benth.	Karai	Mimosaceae	Timber, insecticide
Alstonia scholaris (L.) R.Br.	Shatim	Apocynaceae	Timber, Fuelwood
Anogeissus sp.	Boroswrwi	Combretaceae	Timber
Artrocarpus heterophylus Lamk	Kathal	Moraceae	Fuelwood, edible
Bauhinia purpurea (L.)	Debkanchan	Caesalpiniaceae	Dyes, Timber
*Bombax ceiba (*L.)	Seemul	Bombaceae	Cotton, medicinal
Callicarpa arborea Roxb.	Barmala	Verbenacea	Medicinal
Caryota urens (L.)	Swmal	Arecaceae	Fuelwood
Dillenia indica (L.)	Chalta	Dilleniaceae	Edible, Timber, medicinal
Diospyros sp.	Vanghab	Ebenaceae	Timber, fish poison
Flacourtia jangomas (Lour.) Raeosch	Paniyala	Flaccourtiaceae	Fuelwood, timber
Ficus sp.	Khiychang	Clusiaceae	Fuelwood, edible
Hevea brasiliensis (Wild. Ex A. Juss) Mull. Arg.	Rubber	Euphorbiaceae	Timber, fuelwood
Holarrhena antidysentrica Flem	Kurchi	Apocynaceae	Medicinal, dyes
Garcinia cowa Roxb.	Koksika	-	Edible
Mallotus philippensis H. karst	Kamala	Euphorbiaceae	Edible, medicinal

Microcos paniculata L.	Pisla	Tiliaceae	Fuelwood
Phyllanthus emblica L.	Amlaki	Euphorbiaceae	Edible, medicinal
Botanical name	Vernacular name	Family	Uses
Schima wallichii (Dc.) Kothals	Kanak	Theaceae	Timber, fuelwood
Shorea robusta Gaertn.f.	Sal	Dipterocarpaceae	Timber, fuelwood
Sterculia urens Roxb.	Udal	Sterculiaceae	Edible, fuelwood
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	Edible, fuelwood, medicinal
Tectona grandis L.f.	Teak	Verbenaceae	Timber
Terminalia bellerica (Gaertn.) Roxb.	Bahera	Combretaceae	Timber, fuelwood, medicinal
Terminalia chebula Retz.	Hartaki	Combretaceae	Edible, medicinal
Toona ciliata M. Roem.	Rongeen	Meliaceae	Timber
Vitex negundo L.	Nishinda	Verbenaceae	Medicinal, timber

3.4 Soil physico-chemical properties

Various physico-chemical properties of soil in community managed forests were analysed (Table 3). The average soil temperature was 26.05±1.42^o C and was in decreasing trend towards the lower depth. However, the soil moisture content was highest in the lower layer with 15.82% with an average value of 11.43%. The value shows increasing trend in the lower depths. The soil bulk density shows the compactness of soil. The values recorded are 1.34 gcm^{-3} and 1.82 gcm^{-3} in 30-45 cm and 0-15 cm respectively. Considerably, soil porosity was also found to be large in the upper soil layer than lower layer. The maximum soil water holding capacity was in the 30-45 cm soil depth (47.44%) as compared to upper layer of soil (38.88%).

Table 3. Soil physico-chemical properties in community managed forests of Tripura.

Parameters/Soil depth	0-15 (Mean±SE)	15-30 (Mean±SE)	30-45 (Mean±SE)	45-100 (Mean±SE)	Average value
Soil Temp. (^{o} C)	28.63±1.41	27.10±1.05	2 6.48±1.09	22.00±0.05	26.05±1.42
Moisture Content (%)	8.51±2.19	9.58±2.14	11.81±2.37	15.82±1.99	11.43±1.62
Bulk Density (g/cm^3)	1.82±0.30	1.44±0.16	1.34±0.10	1.55±0.04	1.54±0.10
Porosity	0.31±0.11	0.46±0.06	0.49±0.04	0.42±0.01	0.42±0.04
Water Holding Capacity (%)	38.88±3.36	40.52±2.75	47.44±2.91	41.88±2.62	42.18±1.86
pH	5.75±0.07	5.68±0.03	5.68±0.07	5.62±0.08	5.68±0.03
Organic carbon (%)	1.43±0.19	1.54±0.14	1.35±0.15	1.18±0.13	1.38±0.08
Organic Matter (%)	3.21±0.44	3.45±0.31	3.02±0.34	2.64±0.29	3.08±0.17
Total Kjeldahl Nitrogen (%)	1.11±0.14	1.04±0.07	1.05±0.03	0.94±0.02	1.04±0.04
Available Nitrogen (Kg ha^{-1})	202.50±2.10	207.87±1.33	235.20±2.79	197.57±1.51	210.79±8.41
Available Phosphorus (Kg ha^{-1})	8.59±0.9	10.77±0.40	3.82±0.83	10.27±0.16	8.36±0.58

The soil pH is recorded acidic in all sites with an average of 5.68. The lower soil depth (45-100 cm) was, however, found more acidic (5.62) than the upper layers. The soil organic carbon (%) value ranged from 1.18-1.54%. The average of total Kjeldahl nitrogen was 1.04% with values ranging from 0.94 to 1.11. The available nitrogen was found highest (235.20 Kg ha^{-1}) in 30-45cm soil depth with an average of 210.79 Kg ha^{-1}. The soil available phosphorus ranged between 3.82 to 10.77 Kg ha^{-1}. The correlation matrix shows that soil porosity and soil bulk density are negatively correlated (r=0.998; p=0.01), whereas a positive and significant correlation of available phosphorus was observed with soil temperature (r=0.980, p=0.05) and pH (r=0.974, p=0.05).

3.5 Biomass and carbon stock

The vegetational composition in community forest shows that tree individuals are more in 6-25 cm girth class, whereas only 7% and 9% of the total individual is found under 46-65 cm and <5 cm class respectively (Figure 3). The total biomass stock in the community managed forest was found as 40.66 Tha^{-1} and the carbon content was 20.33 Tha^{-1}. The aboveground biomass (27.06 Tha^{-1}) was 66.55% of total biomass and the rest 33.45% was belowground biomass (13.60 Tha^{-1}). The aboveground biomass ranged from 0.003 Tha^{-1} to 14.49 Tha^{-1}, whereas belowground biomass varied from 0.003 Tha^{-1} to 6.895 Tha^{-1}. The biomass and carbon storage in the top ten tree species is listed in Figure 4 with its total biomass (aboveground and belowground) and carbon content. The carbon content in different species found in community forests are ranging between 0.003 (*Flacourtia jangomas*) THa^{-1} and 10.694 THa^{-1} (*Anogeissus acuminata*). The species with highest biomass and carbon content in this community managed forests includes *Anogeissus acuminata*, *Schima wallichii*, *Tectona grandis*, *Syzygium cumini*, *Ficus* sp., *Holarrhena antidysentrica*, *Diospyrous* sp., *Mallotus phillippensis*, *Bauhinia* sp., *Toona ciliata*, among others.

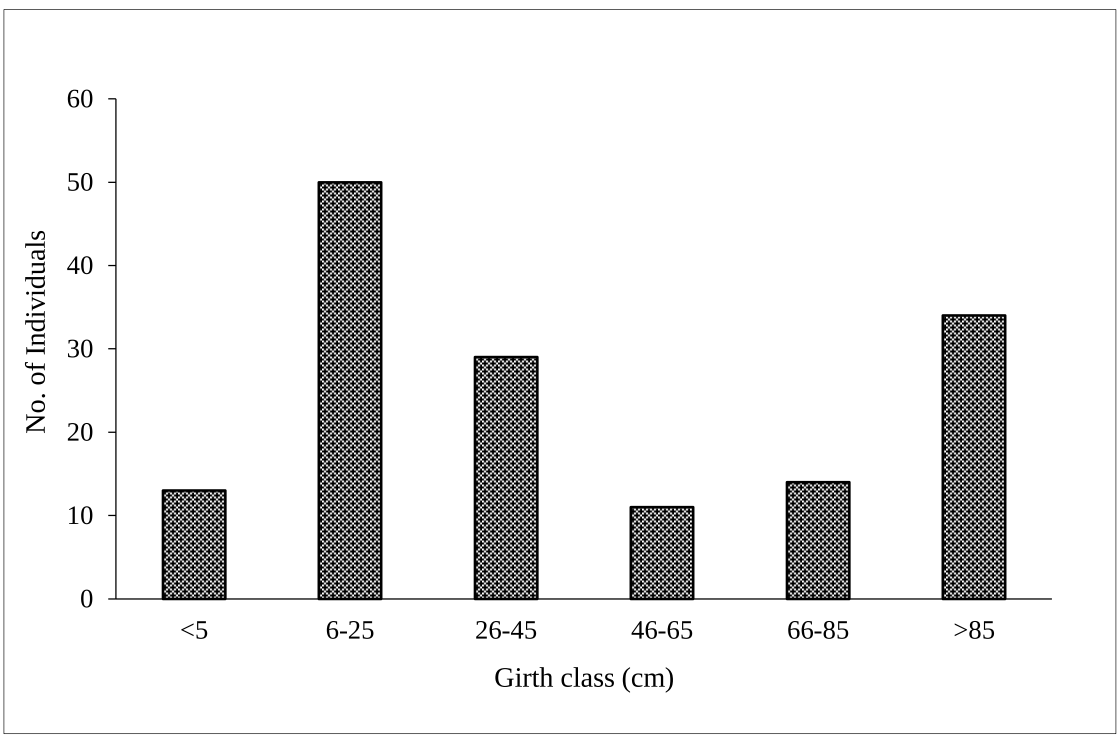

Figure 3. Girth class distribution of tree individuals in community managed forest.

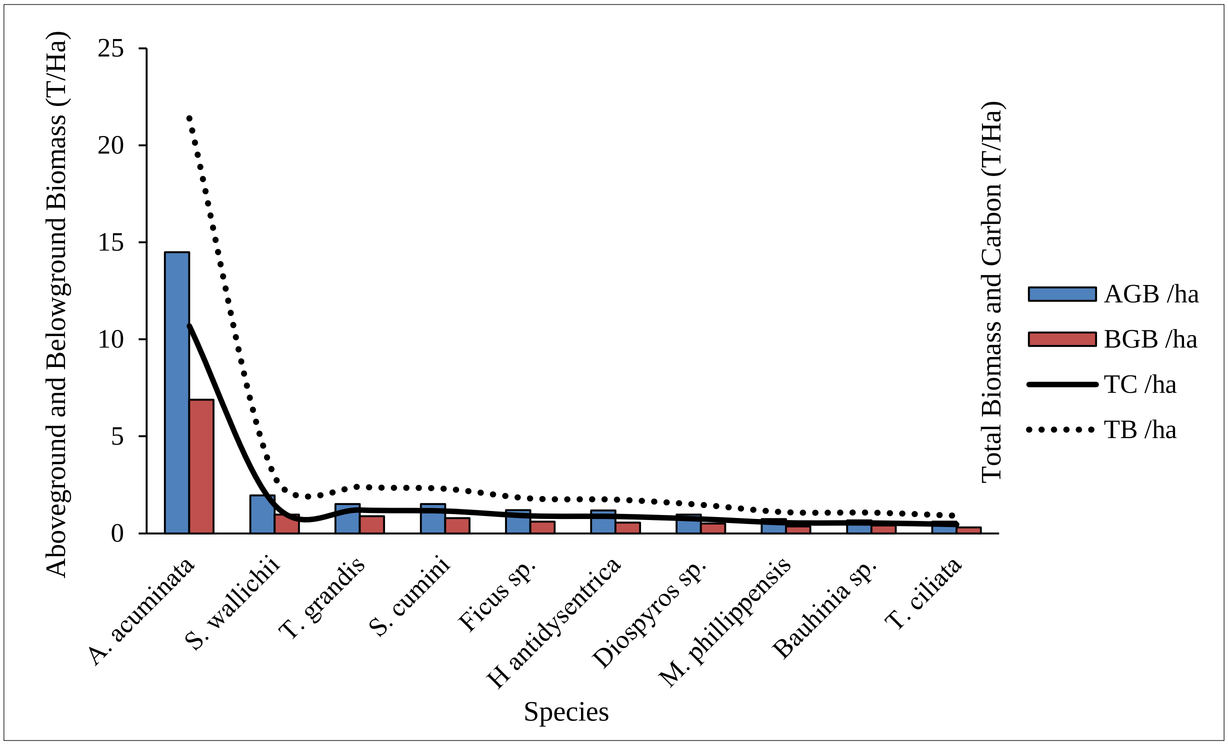

Figure 4. Biomass and carbon in different species.

Figure 5 shows the distribution pattern of biomass and carbon stock in different girth classes of community managed forest in Tripura. It depicts higher girth class (>85 cm) contributing higher biomass and carbon as compared to other girth classes. However, the number of individuals in lower girth class of 6-25 cm was more as compared to higher girth class.

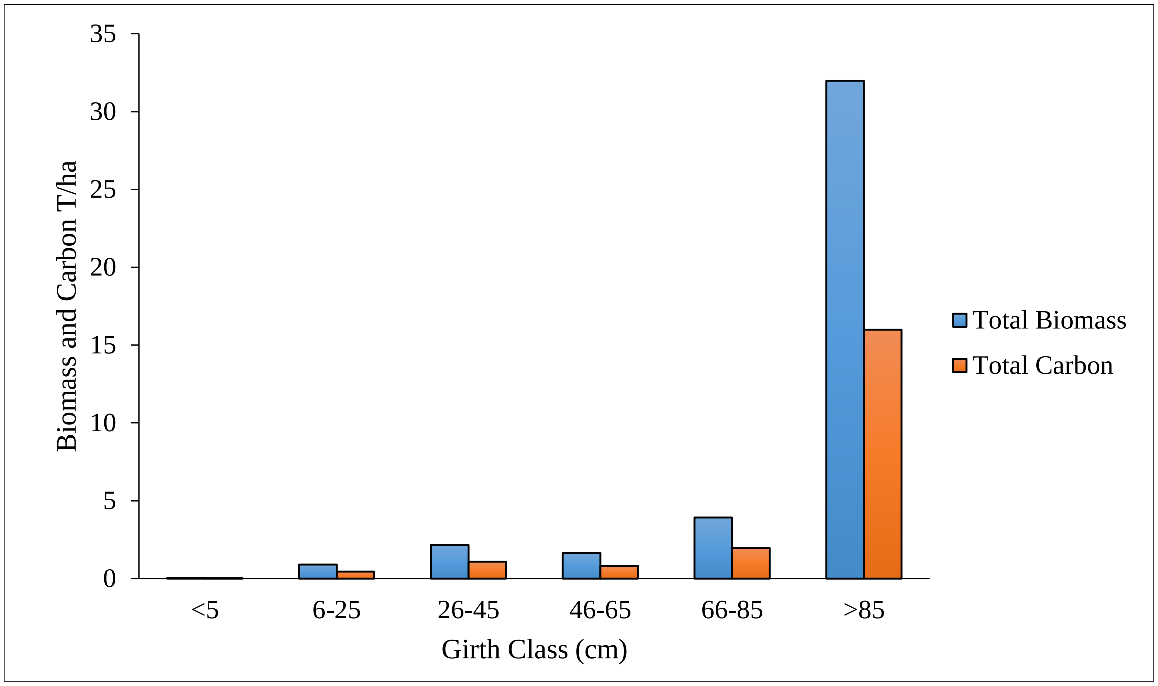

Figure 5. Biomass and Carbon contribution by different girth class of community managed forests.

4. Discussion

4.1 Management implication in community forest

It is revealed that the community forests of Jamatia at Killa block is sustainably managed by the community. It is prevalent through the strong institutional set up made up by the indigenous people to manage the social issues along with village customary laws and rules to conserve the forests. The community forest management practice of Jamatia community was also reported ealier by Darlong and Barik (2006). The traditional institutional setup was earlier called "Hoda" and the head of the "Hoda" was known as the "Hoda Okra", meaning head priest and supreme community leader. The management involved the participation of the ethnic people by local traversing of the forest for checking any disturbances in the forests. Further the fees paid either monthly and yearly give them the sense of belonging and encourage them to feel the forests as their own. The same kind of study was highlighted in the study done by Maharanjan (1998) in Dhankuta district of Nepal where the participation of marginalised forest user groups are given importance to access the forest products. The access to resources by the people in a sustainable way makes them aware of the need to conserve more of the locally available resources. According to the rule, forest resources like NTFPs (bamboo shoots, wild fruits, medicinal plants, fuelwood, fodder and thatch grasses) are collected for bonafide use of the people living under the territorial jurisdiction of those traditional institutions only. This restricts the over-exploitation of resources and put an equal distribution of resources. In fact, forest resources could not be exploited without the prior permission from the traditional authority. This ensures equitable sharing as well as sustainable availability of the resources. Collection of timber is also allowed for domestic use to the poor households with prior permission from the traditional institution. The concept of community forestry has gained much popularity because of its successful conservation, utilisation, management and development of forest resources. Their institutional set up is more convenient than those modern based institutions as it directly involve the participation of the village people. The funds collected are wisely inclined towards the welfare of the society especially the needy ones through flow of fund during marriage or death or during any emergency. Sushenjit and Priya (2014) also emphasised on the direct relation of the household characteristics in defining the provisions subjected towards the local needy ones with low level of education. This allows them to provide incentives in terms of cash or kind and special access to forest reserves which overall check the security of the participation of the local people. During the time of field study, the spirit to conserve the community forest was seen at high stage which is highlighted towards the sense of their own property as they are the custodians of the forest and its resources. However, some constraints still exists in the village but most of the people have taken the role to conserve the forest. Their beliefs, thoughts, faiths and worship have positive interaction with the nature. Likewise, it is being believed that some devils or ill-hearted person presented in those dense forest. So, to alter such kind of problems they take some protective measures simply known as *Mudra*. This is placed inside the boundary of the village for their protection. This is still practiced and is the most common practice in this ethnic community.

4.2 Soil characteristics and carbon stock

Soil physical properties revealed changes according to soil depth in community managed forests. The decreasing trend in the soil temperature across the depth was observed in all the studied sites. This is due to the fact that upper layer of soil are exposed to high atmospheric temperature. The soil moisture content of the community forest was found higher towards the lower depth of soil. Nonetheless, higher soil moisture content recorded in the lower depth might be ascribed to greater clay deposition and humus content. The bulk density value upto 1.82 g cm^{-3} is comparable with reports from natural forest of Bangladesh (Kibria and Saha, 2011) and from pine forests of Meghalaya (Tripathy et al., 2009). The soil water holding capacity is an essential characteristic of soil physical properties. In the present report it was found higher in the lower soil depth as compared to upper depth. This is because the lower depth has high bulk density, low porosity and thereby higher water content. The pH was found more acidic in lower soil depth. Decreasing pH value with depth may be because of the fact that nutrient availability decreases with depth. The pH value 5.50-5.75 in the community forest of Tripura, which is within the ranges as reported in the pine forest of Meghalaya (Tripathy et al., 2009) and the same pattern was also reported by Khanal et al. (2016) in community forest of Palpa districts in Nepal. Except upper soil, the results indicated that with increase in soil depth, bulk density was found to be in increasing trend while the SOC was found to be in decreasing trend.

The number of individuals was observed higher in 6-25 cm girth class as compared to other girth classes. It indicates the new regeneration coming up in the community forest with high anthropogenic disturbances. This also signifies on the need to allow the new regenerations to come up in order to reestablish the stocking of the forest. The quantification of carbon in different girth classes however shows increasing trend across the higher girth class. This is because larger tree has more biomass despite lower girth class having more number of individuals. The total biomass stock in the present study was recorded as 40.66 Tha^{-1} and the carbon content was 20.33 Tha^{-1}, which was quite higher than the *Dipterocarpous* forest of Manipur, where 21.92 t/ha and 18.28 t/ha reported in two different sites (Devi and Yadava, 2015). The present study is comparable with the carbon stock of Hannang forest, Tanzania (Swai et al., 2014) and found higher than the Miombo woodlands (19.2 t/ha) of Tanzania (Munishi et al., 2010). The Above ground biomass recorded in different management regimes of Garo Hills in Meghalaya ranges from 204.15 Mg/ha to 314.02 Mg/ha (Upadhaya et al., 2015), 92.08 tha^{-1} to 276.02 tha^{-1} in community forests of Terai, Nepal (Mandal et al., 2016) which were found quite higher than the present study. This may be because the studies were done in larger area as compared to the present area. *Anogeissus acuminata*, *Schima wallichii* and *Tectona grandis* were found to have higher biomass as compared to other species. This species are mostly used by the local people in meeting the timber and fuelwood demand for their household construction purposes. Hence could be encouraged to maintain the regeneration of these species for meeting the future needs.

5. Conclusions

The present study shows that Jamatia people of Tripura are actively involved in conservation and management of the forests under their control. The concept of creating forest and settling aside forest patches for forest supply revenue within a territorial jurisdiction of the traditional institutions are being noted in this community. The active participation of the community people also encourages them to conserve the resources available to them. The biomass and carbon contribution of community managed forests are much higher than other land use systems. Few plants like *Anogeissus acuminatea*, *Schima wallichii* are important tree species in the community managed forest and stored good amount of carbon in the system. The impact of community managed forest also has significant improvement in soil qualities due to long time management practices. Henceforth, the study has demonstrated that community forest is having the potential to mitigate climate change for longer run through the sequestration of atmospheric C to soil and vegetation and by acting as a natural carbon sink. Thus, this kind of community approaches could be replicated for the management and conservation of any degraded system.

Acknowledgement

The authors are thankful to Department of Science and Technology, Government of India, New Delhi, India for providing financial support (DST/IS-STACE/CO_2-SR-230/14 (G)-AICP-AFOLU-VII) to conduct field study in Tripura.

References

Agarwal, A. and Ostrom, E., 2001. Collective action, property rights, and decentralization in resource use in India and Nepal. *Politics and Society*, 29:485-514.

Anderson, J.M. and Ingram, J.S.I., 1993. Tropical Soil Biology and Fertility-A Handbook of Methods. 2nd edn. CAB International, Wallingford, UK.

Bray, R.H. and Kurtz, L.T., 1945. Determination of Total Organic and Available Forms of Phosphorus in Soils. *Soil Science*, 59:39-46.

Brown, S., Gillespie, A.J.R. and Lugo A.E., 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science*, 35:881-902.

Cairns, M.A., Brown, S., Helmer, E.H. and Baumgardner, G.A., 1997. Root biomass allocation in the world's upland forests. *Oecologia*, 111:1-11.

Chambers, J.Q., Santosdos, J., Riberio, R.J. and Highuchi, N., 2001. Tree damage, allometric relationships and aboveground net primary production in central Amazon forest. *Forest Ecology and Management*, 152:73-84.

Chatterjee, S., Ghosh, S., Sarma, J., Barik, S.K., Tewari, B.K. and Das, K.C., 2009. Community Conserved Areas in North East India: Some observations in Assam, Meghalaya and Arunachal Pradesh. http://www.kalpavriksh.org/images/CCA/Miscellaneous/IndiaRep_CCAs%20North%20East%20 India_20%20July_2009[1].pdf. Accessed 7 December 2018.

Chhabra, A., Palria, S. and Dadhwal, V.K., 2002. Growing stock-based forest biomass estimate for India. *Biomass Bioenergy*, 22:187-194.

Darlong, V.T. and Barik, S.K., 2006. Forests of hope: The Jamatias of Killa district , Tripura. Pp. 40-49 In: *Poffenbenger M, Barik SK, Choudhury D, Darlong V, Gupta V, Palit S, Roy I, Singh I, Tiwari BK, Upadhyay S (Background paper No 12) Forest Sector Review of northeast India.* Community Forest international, Santa Barba, USA.

Deb, D.B., 1981, 1983. The Flora of Tripura State Vols. I & II. Today & Tomorrow Printers & Publishers, New Delhi.

Devi, L.S. and Yadava, P.S., 2015. Carbon stock and rate of carbon sequestration in *Dipterocarpus* forests of Manipur, Northeast India. *Journal of Forestry Research*, 26:315-322.

Houghton, R.A., 1996. Land-use change and terrestrial carbon: the temporal record. In: *Apps MJ, Price DT (ed.) Forest Ecosystems, Forest Management and the Global Carbon Cycle.* Springer-Verlag, Berlin, Heidelberg, New York.

Khanal, Y., Sharma, R.P. and Upadhyaya, C.P., 2010. Soil and vegetation carbon pools in two community forests of Palpa district, Nepal. Banko Janakari. 20:34-40.

Kharkongor, B.M. and Tiwari, B.K., 2015. Sacred Groves of Meghalaya: A Review. *International Journal of Science and Research*, 6:346-349.

Khumbongmayu, A., Khan M.L. and Tripathi R.S., 2005. Sacred groves of Manipur, northeast India: biodiversity value, status and strategies for their conservation. *Biodiversity Conservation*, 14:1541-1582.

Kibria M.G. and Saha, N., 2011. Analysis of existing agroforestry practices in Madhupur Sal forest: an assessment based on ecological and economic perspectives. *Journal of Forestry Research*, 22:533-542.

Kumar, P., 2008. Carbon sequestration strategy of Nubra Valley with special reference to agroforestry. DRDO Technology Spectrum, pp. 187-192.

Maharanjan, M.R., 1998. Flow and Distribution of Costs and Benefits in the Chuliban Community Forest, Dhankuta District, Nepal. Rural development Forestry Network Paper 23e. ODI, pp 1-12.

Mandal, R.A., Dutta, I.C., Jha, P.K. and Karmacharya, S.B., 2016. Carbon sequestration potential in community and collaborative forests in Terai, Nepal. *Tropical Ecology*, 57:655-662.

Medhi, P. and Borthakur, S.K., 2013. Sacred groves and sacred plants of the Dimasas of North Cachar Hills of Northeast India. *African Journal of Plant Sciences*, 7:67-77.

Munishi, P.K.T., Mringi, S., Shirima, D.D. and Linda, S.K., 2010. The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks. *Journal of Ecology and the Natural Environment*, 2:261-269.

Murtem, G., Chaudhry, P., 2014. Sacred Groves of Arunachal Pradesh: Traditional Way of Biodiversity Conservation in Eastern Himalaya of India. *Indian Journal on Biodiversity Management Forestry*, 3:2.

Nongkynrih A.K., 2001. Ka Shnong the microcosm of Hynniewtrep society. lndian Horizon 48:121-151.

Swai, G., Ndangalasi, H.J., Munishi, P.K. and Shirima, D.D., 2014. Carbon stocks of Hanang forest, Tanzania: An implication for climate mitigation. *Journal of Ecology and the Natural Environment*, 6:90-98.

Tiwari, B.K., Tynsong, H. and Lynser M.B., 2010. Forest management practices of the tribal people of Meghalaya, North-East India. *Journal of Tropical Forestry*, 22:329-342.

Tiwari B.K., Tynsong, H., Lynrah, M.M., Lapsam, E., Deb, S. and Sharma, D., 2013. Institutional arrangement and typology of community forests of Meghalaya, Mizoram and Nagaland of North-East India. *Journal of Forestry Research*, 24:179-186.

Tripathy K.P. and Singh, B., 2009. Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat wildlife Sanctuary, North India. *Tropical Ecology*, 50:191-200.

UNFCCC. 1993. The United Framework Convention on Climate Change. UN.

Upadhaya, K., Thapa, N. and Barik, S.K., 2015. Tree diversity and biomass of tropical forests under two management regimes in Garo hills of north-eastern India. *Tropical Ecology,* 56:257-268.

Walkley, A. and Black, I.A. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37:29-37.