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VOLUME YIELD AND CARBON HOARD IN TWO COMMUNITY-MANAGED FORESTS OF EKITI STATE, SOUTHWEST, NIGERIA

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Abstract
This study aimed at evaluating the potential of community-managed forests to sequestration carbon. Systematic line transect was employed in the laying of the plots. A total of 8 sample plots in each community-based forest were used and soil samples were taken from four soil depths for soil carbon determination. Non-destructive method was used in the estimation of volume, above-ground biomass, below-ground biomass and carbon stock. The result also revealed significant difference in tree volume, biomass and carbon stock between the two forests. Tree Biomass and carbon stock were significantly higher in Ogun Onire community forest (48173.07 kg/ha, 30.02 T/ha) than in the community herbal heritage forest (10.745.31 kg/ha, 6.07 T/ha). Soil organic carbon estimated for Ogun Onire community forest (126.59 Tg) was significantly higher than that of community herbal heritage forest (67.95 Tg). Higher tree volume, biomass and carbon stock obtained for Ogun Onire community forest could be traced to the stiffer conservation measure put in place by the community as compared to the community herbal heritage forest where traces of encroachment and cultivation of arable crops were found. For sustainable availability of forest resources in community herbal heritage forest, severe conservation measure is recommended.

Keywords: Above-ground biomass, Soil carbon, Carbon sequestration and Community-based natural, forest

Introduction

Forest ecosystems serve as host for atmospheric carbon dioxide (CO_2) in forest habitat. Plants absorbed carbon dioxide from the atmosphere through the process of photosynthesis into the physiological system as biomass in plants (IPCC 2006). Large volumes of carbon dioxide (CO_2) are removed and stored in plants cell in form of above ground biomass (AGB). The process of carbon sequestration in forest ecosystem occurred in plants, animals and forest soils. Carbon is sequestered into the plants through carbon cycling and taken from plants to the animals as food. Eventually, after the death of the animals, the detritus decomposes into the soil organic carbon by microbial activities. These sequestered carbons in plants acts as carbon sink in forest habitats (Adekunle *et al.* 2014). Climate change effects that influence tree growth will also alter the rates of carbon storage in plants and soils. Increased carbon sequestration would remove more CO_2 from the atmosphere (a negative feedback that lessens climate change), whereas carbon losses through forest disturbances would result in more CO_2 entering the atmosphere (a positive feedback that strengthening climate change).

Loss of biodiversity and environmental degradation has serious negative impacts on ecosystem functioning, carbon sequestration, stability and living organisms' survival. It should be noted that once a stable ecosystem is disturbed or destroyed, it is ecologically and economically very difficult to repair and rehabilitate (Adekunle *et al.* 2014). To promote nature conservation in the developing countries, the concept of community-based forest management should be encouraged. The high rate of deforestation and forest degradation could lead to high rate of Ozone layer depletion and increase in greenhouse gasses but community-managed forest maybe the solution.

Greenhouse gases play an important role on earth's climate changes IPCC, (2007) and these greenhouse gasses include water vapour, carbon dioxide, methane, nitrous oxide and ozone. These are forest reserves that are adequately policed by the local groups, taboos and hunters in order to conserve the biodiversity and the sanctity of the forest. The system of community-based forests is a process by which the local communities organize themselves with support from Federal or State government or non-government organization in the management of forest resources for varying degree and satisfaction of the peoples' livelihood (Bankole 1998; Brosuis *et al* 1998; Olajuyigbe *et al.* 2018). Due to the ecosystem deliverables to the local communities in terms of indigenous access to the forest, herbs collections for health benefits, environmental conservation and economic development, local communities to support the establishment of community forests (Olajuyigbe and Jeminiwa 2018).

These communities managed forest (Community Herbal Heritage, Otun Ekiti and Ogun Onire forest, Ire Ekiti) were selected and inventoried for this study. Several researches have been conducted on forest structure, floristic composition and species richness in government protected forests of tropical ecosystem (Myers *et al.* 2000; Adekoya *et al.* 2003; Onyekwelu *et al.* 2008). However, information on carbon sequestration potential of these community-based forests is scarce. Therefore, this research was designed to determine the volume yield and carbon hoard in two community-managed forests of Ekiti State, Southwest, Nigeria.

Materials and Methods

Study area

This study was conducted in two communities in Ekiti State, (Community Herbal Heritage Forest, Otun Ekiti and Ogun Onire Sacred Forest, Ire Ekiti). Ekiti State is a tropical rainforest ecosystem and the climate is tropical, with distinct rainy and dry seasons and characterized by high mean annual temperature (21 - 34ºC) and well distributed high annual rainfall (1400 mm - 4000 mm). Rainfall begins late March and ends in October while dry season occurs between November and early March. Soils are predominantly ferruginous, typical of the variety found in intensively weathered areas of basement complex formations in the rainforest zone of South-Western Nigeria. Ogun Onire sacred forest is a tropical rainforest in Ire Ekiti, which is geographically located on hilly terrain of Oye Local Government Area, Ekiti State, Nigeria. The town lies within latitudes 7°44'08.69" N and 7°43'57.81" N and longitudes 5°23'38.75" E and 5°23'51.65" E. The community herbal heritage forest is situated in Otun Ekiti, Moba Local Government Area, Ekiti State, Nigeria. Otun Ekiti is a peri-urban settlement that lies within latitudes 7°59'23.05"N and 7°59'24.40"N and longitudes 5°08'15.75"E and 5°08'17.04"E. It is a nodal town which shares boundaries with Kwara State to the North and Osun State to the West. The area falls within the basement complex of south western Nigeria with isolated hills and inselbergs surrounding the town at elevations between 300 to 450 m (Adekoya *et al.* 2003).

Method of Data Collection

Systematic line transect was employed in the laying of the temporary sample plots used for this study. Two parallel transects of 150 m in length with a distance of 50 m between them were used in each of the study sites. Sample plots of 25 × 25 m in size were laid in alternate direction along each transect at an interval of 50 m and thus summing up to 4 sample plots per 150 m transect and a total of 8 sample plots in each of the selected community forest. Within each plot, all living trees with Dbh ≥ 10 cm were identified. Their diameter at breast height, base, middle, top and total height was measured. A sub-plot of 5 m × 5 m was laid at the middle of each 25 m x 25 m plot. A diagonal line was laid within the 5 m x 5 m sub-plot for soil sample collection. Soil samples was taken from four soil depths of 0–15 cm, 15–30 cm, 30–45 cm and 45–60 cm at three points (at the two edges and middle of the line) as done by (Onyekwelu *et al.* 2008). Soil samples from the same depths and from the same plot were thoroughly mixed to form a composite soil sample, from which samples were collected for soil organic carbon determination.

Volume Estimation

The volume of individual trees was estimated using the Newton's formula of Husch *et al.,* (2003): $V = \frac{\pi h}{24}\left(D_b^2 + 4D_m^2 + D_t^2\right)$

Where V = volume of tree (m^3), D_b = diameter at the base (cm), D_m = diameter at the middle (cm), D_t = diameter at the top (cm) and H = height (m).

Total plot volume was obtained by adding the volume of individual trees in the plots. Mean volume per plot was calculated by dividing the total plot volume by the number of sample plots (8 plots). Volume per hectare was obtained by multiplying mean volume with the number of 25 × 25 m plots in one hectare.

Biomass and Carbon Stock Estimation

Above-Ground Biomass (AGB) was estimated using the equation developed by Brown, (1997) for biomass estimation in tropical forests. This equation was adopted in the studies conducted by (Hiratsuka *et al.* 2006; Rajkumar and Parthasarathy 2008; Adekunle *et al.* 2014).

$AGB = 21.297 - 6.953 (D) + 0.740 (D^2)$ Where AGB is biomass per tree in kg and D is diameter at breast height (dbh) in cm. Below ground biomass (BGB) was estimated as 15% of the above ground biomass (MacDicken 1997). Biomass value was converted to carbon stocks using 0.5 carbon fractions as default values and expressed in t/ha.

Laboratory Analysis

Soil samples collected from each layer separately were air dried and sieved through 2 mm sieve. Core cylinder samples were dried for two days at 105 °C to estimate the bulk density as a ratio of oven-dry weight of soil to cylinder volume. The determined bulk density was corrected for percent coarse fractions. The corrected bulk density (gm^{-3}) was used for the estimation of SOC stock. Soil organic carbon was determined by Walkley-Black net oxidation method as:

$SOC = CorrectedSOC \times 100(\%) \rho_b$ (gm^{-3}) ×layer depth (m) x 10^4 ($m^2 ha^{-1}$)

Where ρ_b = bulk density

Corrected bulk density ($g\ m^{-3}$) = bulk density ($g\ m^{-3}$) × 100fraction) coarsecent per - (100

Total SOC storage = SOC density (gha^{-1}) × forest area (ha).

Statistical Analysis Methods

Tree volume, above tree biomass, below tree biomass, carbon stock and soil organic carbon between the two community-managed forests was statistically compared using SPSS version 21.0.

Results

Tree volumes for the two community-managed forests are presented in Table 1 and 2. The total tree volume (319.63 m^3/ha) computed for Ogun Onire community forest was higher than the community herbal heritage forest (248.56 m^3/ha). *Terminalia superba* (20.25 m^3) in the family Combretaceae had the highest volume in Ogun Onire community forest followed closely by *Triplochiton scleroxylon* (15.75 m^3) in the family Malvaceae second highest volume in Ogun Onire community forest; while *Myrianthus arboreus* (14.50 m^3) in the family Urticaceae and *Celtis zenkerii* (13.13 m^3) in the family Ulmaceae. *Millettia thonningii* in the family of Fabaceae and *Morusmeso zygia* in the family of Moraceae had the least volume (0.88 m^3) in Ogun Onire community forest (Table 1). In community herbal heritage forest, *Terminalia ivorensis* in the family Combretceae had the highest volume per ha (26.76 m^3), followed closely by *Gmelina arborea* (18.02 m^3) in the family Lamiaceae and *Steculia africana* (14.65 m^3) in the family Malvaceae. *Allophyllus africana* (2.25 m^3) in the family of Sapindaceae and *Bridelia micrantha* (2.32 m^3) in the family of Bridelieae hadthe least volume in community herbal heritage forest (Table 2).

Carbon stock in tree species differs considerably between one species and another. In Ogun Onire community forest, the species with the highest carbon stock per hectare was *Ficus sycoprorus* (6678.22 kg/ha), followed by *Terminalia superba* (3813.40 kg/ha) and *Celtis zenkerii* (3688.58 kg/ha) as presented in Table 1. In community herbal heritage forest, *Tetrapleura tetreptera* had the highest carbon stock per hectare (1139.12 kg/ha), followed by *Dracaena mannii* (873.77 kg/ha) and *Albizia lebbeck* (570.03 kg/ha) as indicated in Table 2. The total amount of carbon stock in Ogun Onire forest was 48173.08 kg/ha while the corresponding value for community herbal heritage was 10745.31 kg/ha..

Table 1: Estimation of Volume and Carbon stock in Ogun Onire Community Forest

S/N	Species	Family	Vol/ha	AGB/ha	BGB/ha	CS/ha
1	*Afzelia Africana*	Fabaceae	1.38	76.79	11.52	49.91
2	*Albizia ferruginea*	Fabaceae	1.88	26.56	3.98	17.26
3	*Albizia lebbeck*	Fabaceae	1.75	298.07	44.71	193.75
4	*Albizia zygia*	Fabaceae	2.00	54.75	8.21	35.59
5	*Alchorneolaxiflora*	Euphorbiaceae	1.50	54.75	8.21	35.59
6	*Alstonia boonei*	Apocynaceae	11.38	942.92	141.44	612.90
7	*Anopyxis klaineana*	Rhizophoraceae	9.63	686.24	102.94	446.05
8	*Anthonotha macrophylla*	Fabaceae	2.25	82.89	12.43	53.88
9	*Berlinia grandiflora*	Leguminosae	1.88	99.49	14.92	64.67
10	*Blighia sapida*	Sapindaceae	10.25	2720.90	408.13	1768.58
11	*Bomba scecropioides*	Urticaceae	1.25	91.31	13.70	59.35
12	*Brachystegia kennedyi*	Fabaceae	1.88	109.79	16.47	71.36
13	*Canarium schweinfurthii*	Burseraceae	1.25	104.06	15.61	67.64
14	*Ceiba pentandra*	Fabaceae	4.00	422.44	63.37	274.59
15	*Celtis milbraedii*	Cannabaceae	2.25	63.34	9.50	41.17
16	*Celtis philippensis*	Cannabaceae	2.38	106.30	15.94	69.09
17	*Celtis zenkerii*	Ulmaceae	13.13	5674.74	851.21	3688.58
18	*Chrysophyllum albidum*	Sapotaceae	9.75	558.58	83.79	363.08
19	*Cola acuminate*	Malvaceae	1.50	196.83	29.52	127.94
20	*Cola gigantean*	Malvaceae	10.13	574.89	86.23	373.68
21	*Cola hispida*	Sterculiaceae	3.38	53.18	7.98	34.57
22	*Cola milenii*	Sterculiaceae	9.63	1541.80	231.27	1002.17
23	*Diospyros dendo*	Ebenaceae	0.13	25.77	3.87	16.75
24	*Diospyros mobutensis*	Ebenaceae	12.13	1110.51	166.58	721.83
25	*Dracaena arborea*	Dracaenaceae	0.63	109.79	16.47	71.36
26	*Drypetes gossweileri*	Euphorbiaceae	0.38	39.20	5.88	25.48
27	*Entandrophragma angolense*	Meliaceae	8.63	247.45	37.12	160.84
28	*Ficus exasperate*	Moraceae	4.50	239.48	35.92	155.66
29	*Ficus mucosa*	Moraceae	9.13	135.31	20.30	87.95
30	*Ficus sycomorus*	Moraceae	1.50	10274.18	1541.13	6678.22
31	*Funtumia elastic*	Apocynaceae	5.38	118.78	17.82	77.21
32	*Hunteria umbellate*	Apocyanceae	4.88	229.06	34.36	148.89
33	*Khaya grandifoliola*	Meliaceae	11.38	189.28	28.39	123.03
34	*Lannea welwitschii*	Anacardiaceae	1.75	173.74	26.06	112.93
35	*Lecaniodis cuscupanioides*	Sapindaceae	9.63	178.24	26.74	115.85
36	*Lovoa trichilioides*	Meliaceae	2.50	850.47	127.57	552.81
37	*Malachanta alnifolia*	Sterculiaceae	1.63	195.40	29.31	127.01
38	*Mallotus oppositifolius*	Euphorbiaceae	2.00	684.44	102.67	444.89
39	*Margaritaria discoidea*	Phyllanthaceae	1.63	164.92	24.74	107.19
40	*Milicia excels*	Moraceae	10.75	102.86	15.43	66.86
41	*Millettia thonningii*	Fabaceae	0.88	256.64	38.50	166.82
42	*Monodora tenuifolia*	Annonaceae	5.88	74.62	11.19	48.50

39	*Margaritaria discoidea*	Phyllanthaceae	1.63	164.92	24.74	107.19
40	*Milicia excels*	Moraceae	10.75	102.86	15.43	66.86
41	*Millettia thonningii*	Fabaceae	0.88	256.64	38.50	166.82
42	*Monodora tenuifolia*	Annonaceae	5.88	74.62	11.19	48.50
43	*Morusmeso zygia*	Moraceae	0.88	807.51	121.13	524.88
44	*Myrianthus arboreus*	Urticaceae	14.50	86.58	12.99	56.28
45	*Pterygota macrocarpa*	Sterculiaceae	5.63	627.39	94.11	407.80
46	*Pycnanthus angolensis*	Myristicaceae	3.63	127.19	19.08	82.68
47	*Ricinodendron heudelotii*	Euphorbiaceae	6.38	221.40	33.21	143.91
48	*Spathodea campanulata*	Bignoniaceae	1.88	149.01	22.35	96.86
49	*Spondias pinnata*	Anacardiaceae	9.50	58.46	8.77	38.00
50	*Sterculia oblonga*	Sterculiaceae	8.13	618.84	92.83	402.24
51	*Sterculia rhinopetala*	Sterculiaceae	8.00	205.75	30.86	133.74
52	*Strombosia pustulata*	Olacaceae	11.13	312.08	46.81	202.85
53	*Terminalia superba*	Combretaceae	20.25	5866.77	880.02	3813.40
54	*Tetrapleura tetraptera*	Fabaceae	1.88	132.58	19.89	86.18
55	*Trichilia welwitschii*	Meliaceae	4.00	209.42	31.41	136.12
56	*Trilepson madagascariensis*	Moraceae	1.38	494.95	74.24	321.71
57	*Triplochiton scleroxylon*	Malvaceae	15.75	1932.12	289.82	1255.88
58	*Voacanga Africana*	Apocynaceae	7.13	98.82	14.82	64.23

S/N	Species	Family	Vol/ha	AGB/ha	BGB/ha	CS/ha
1	*Albizia ferruginea*	Fabaceae	4.98	116.53	17.48	75.74
2	*Albizia lebbeck*	Fabaceae	3.35	876.97	131.55	570.03
3	*Albizia zygia*	Mimosoideae	5.69	325.17	48.78	211.36
4	*Allophyllus Africana*	Sapindaceae	2.25	32.55	4.88	21.16
5	*Alstonia boonia*	Apocynaceae	8.17	78.04	11.71	50.73
6	*Anthocleasta vogalii*	Potaliceae	11.82	654.41	98.16	425.36
7	*Antiaris Africana*	Fabaceae	3.80	40.95	6.14	26.62
8	*Baphia nitida*	Fabaceae	3.24	67.12	10.07	43.63
9	*Blighia sapida*	Sapindaceae	2.80	32.55	4.88	21.16
10	*Briddia micrantha*	Bridelieae	2.32	30.28	4.54	19.68
11	*Ceiba pentadra*	Malvaceae	12.54	190.87	28.63	124.07
12	*Cleistopholis patens*	Annonaceae	7.82	220.39	33.06	143.25
13	*Dracaena marginata*	Asparagaceae	3.70	74.08	11.11	48.15
14	*Dracaena spp*	Asparagaceae	9.66	1344.26	201.64	873.77
15	*Ficus exasperate*	Moraceae	2.87	19.69	2.95	12.80
16	*Ficus sur*	Moraceae	5.44	41.87	6.28	27.21
17	*Funtumia elastic*	Apocynaceae	6.09	679.38	101.91	441.59
18	*Gmelina arborea*	Lamiaceae	18.02	126.39	18.96	82.15
19	*Hymenocaido acida*	Phyllanthaceae	12.66	288.80	43.32	187.72
20	*Khaya grandifiola*	Meliaceae	5.94	147.27	22.09	95.72
21	*Lecaniodiscus cupanioides*	Sapindaceae	3.40	74.08	11.11	48.15
22	*Marcariteria discoidea*	Phyllanthaceae	4.18	84.91	12.74	55.19
23	*Margariteria discoidea*	Phyllanthaceae	10.52	61.72	9.26	40.12
24	*Milicia excels*	Moraceae	3.54	297.00	44.55	193.05
25	*Millettia thonningii*	Fabaceae	3.45	131.26	19.69	85.32
26	*Napoleonaea imperialis*	Lecythidaceae	2.70	61.72	9.26	40.12
27	*Olax subscorpioidea*	Olacaceae	4.02	41.87	6.28	27.21
28	*Parkia biglobosa*	Fabaceae	3.73	87.75	13.16	57.04
29	*Pterocarpus mildbraedii*	Fabaceae	6.43	89.92	13.49	58.45
30	*Ricinodendron heudelotii*	Euphorbiaceae	12.45	299.76	44.96	194.84
31	*Spathodea campanulata*	Bignoniaceae	2.83	74.73	11.21	48.57
32	*Spondias mombim*	Anacardiaceae	3.80	66.69	10.00	43.35
33	*Steculia Africana*	Malvaceae	14.65	440.87	66.13	286.56
34	*Lannea welwitschii*	Anacardiaceae	3.16	270.14	40.52	175.59
35	*Terminalia ivorensis*	Combretaceae	26.76	53.14	7.97	34.54
36	*Tetrapleura tetraptera*	Fabaceae	3.25	1752.49	262.87	1139.12
37	*Trichilia welwitschii*	Meliaceae	6.52	68.15	10.22	44.29

Table 3 indicated the results of the t-test for comparing volume, soil carbon stock, above-ground biomass, below-ground biomass and carbon stock. Tree volume (319.63 m^3estimated for Ogun Onire community-managed forest was significantly higher when compared with the tree volume computed for community herbal heritage forest (248.56 m^3). More so, soil carbon stock

(126.59 Tg) was discovered to be significantly higher in Ogun Onire than for community herbal forest (67.95 Tg). Significant difference also existed between biomass and carbon stock (AGB=41889.63; 9343.75 kg/ha), (BGB=6283.44; 1401.56 kg/ha), (CS = 30.02; 6.07 ton/ha) for Ogun Onire community forest and community herbal heritage forest respectively.

Table 3: Comparison of volume, soil carbon, above-ground biomass, below-ground biomass and carbon stock of these community forests

Forest	Ogun Onire Community Forest	Community Herbal Heritage Forest
Number of Species	58	37
Volume (m^3/ha)	319.63^a	248.56^b
Soil Carbon (Tg)	126.59^a	67.95^b
AGB (kg/ha)	41889.63^a	9343.75^b
BGB (kg/ha)	6283.44^a	1401.56^b
Carbon Stock (Ton/ha)	30.02^a	6.07^b

Means with the same superscript along the rows are not significantly different (p<0.05)

Discussion

The number of tree species recorded in Ogun Onire community forest was comparably higher than the number of species recorded in other forest reserves in South West Nigeria. For instance, Lawal and Adekunle, (2013) reported 35 species in the SNR of Akure forest reserve, 42 species in Enrichment planting forest of Akure forest reserve and 18 species in the degraded part of Akure forest reserve. Tree species composition in this community-based forest reserves could be attributed to the sacred nature of its management. This community-based forest reserve can serves as biodiversity hot spot if this strict nature of its management is sustained. Volume estimation is a determinant of the tree growth structure and is the most important parameter for forest management (Tonolli *et al.* 2011; Adekunle *et al*. 2013). The estimated volume for these community-based forest reserves can compete favourably with the volume obtained by Adekunle *et al.,* (2013) for Akure strict Nature Reserve (387 m³/ha) and Adekunle *et al*., (2014) for Eda protected forest (287.49 m³/ha).

The carbon sequestration in these community-managed forests varied considerably as revealed in this study. The carbon stock of these community-managed forests were very low when compared with similar study conducted by Adekunle *et al.* (2014) who recorded carbon stock of 156.73 tons/ha for Eda protected forest. Rajkumar and Parthadarathy, (2008); Nebel *et al.,* (2001) reported above-ground biomass between 206-382 mg/ha for Andaman giant evergreen forests and the 259.45 Mg/kg reported by Wittmann *et al*., (2008) for a riparian forest of the Lower Miranda River, Southern Pantanal, Brazil. The carbon content of trees in these community-managed forests is an indication that if biodiversity is well managed and conserved it could contribute significantly to greenhouse gas emission reduction. The low estimated carbon storage obtained for Community Herbal Heritage Forest could be because of the secondary nature of the forest which was established few years ago.

The above-ground biomass (AGB) of tropical forests plays an important role in the global carbon cycle and local AGB estimates provide essential data that enable the extrapolation of biomass stocks of an ecosystem (Wittmann *et al*. 2008). Ramachandran *et al*., (2007) reported that the absorbing of carbon dioxide from the atmosphere and moving it into the physiological system and biomass of the plants and finally into the soil, is the practical way of removing large volumes of this major greenhouse gas from the atmosphere into the biological system.

The carbon storage estimated for this study demonstrated the level of variability of carbon sequestration that could exist within different forest ecosystems. The variation in these values may not only depend on species, climatic condition, anthropogenic disturbances but also could be attributed to model used in estimating biomass and sampling intensity (Adekule *et al.* 2014). Forest soil has the ability of carbon recycling in these two community-based forest reserves. Nutrients in decomposing organic matter are returned to the soil, reabsorbed and stored in aboveground tree components. The difference in soil organic carbon in these two community-based forest reserves could be attributed to the effect of forest disturbances in the forest floor particularly in herbal heritage community forest.

Conclusion

The result of this research indicates the potential of community management method on forest conservation and carbon sequestration. The results also reveal that degraded forests could be restored into their original condition after a long time of restricted anthropogenic disturbances. The soil to store carbon as organic carbon after the death and decomposition of plants and animals should be harnessed as another solution in reducing depletion of ozone layer and subsequently lessen the effect of global warming to the environment. This study has revealed the importance of community partnership in the management of forest ecosystem. Improvement on the management strategies of these community forests would increase tree volume yield and carbon storage potential thereby performing their ecosystems functions to the maximum.

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