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Carbon Stock and Carbon Dioxide Sequestration Potential in a Multi-species Forestry Plot of the Kagyu Nalanda Monastery, Bylakuppe, Mysore District, Karnataka, India

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ABSTRACT

In the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India, during 2010-2011 has established the multi-species forestry plots in the degraded land of the monastery and nurtured them. In one of these plots (2.5 ha in size) aboveground biomass, carbon stock and the potential of carbon dioxide sequestration in the aboveground biomass were assessed. In the study plot, 927 trees belonging to 45 species were recorded. The Gini Index obtained for different species indicated that within a species the inequality is low for tree height when compared to that for tree basal area. The estimated total basal area and total tree volume in the study plot is 33.34 m^2 and 315.73 m^3 respectively. The total aboveground biomass for the plot was 326.39 tonnes with the total carbon stock of 163.18 tonnes. A positive correlation was observed between the carbon stock and total tree volume of the top five species (*Cassia fistula*, *Swietenia macrophylla,* Mangifera *indica*, *Moringa oleifera* and *Spathodea campanulata),* which contributed predominantly (54%) of the total carbon stock ($r=0.812$, $p<0.05$). The study plot sequestrated 598.13 tonnes of carbon dioxide with mean annual rate of 59.81 tonnes. The potential annual economic value of carbon dioxide sequestrated in the aboveground biomass of tree community in the study area ranges from US$ 239.3 to 2,990.7 (Indian Rupees 17,872 to 2,23,402). The scope for selling the carbon credits generated in this multi-species forestry plot to buyers to support further environmental priorities are discussed.

Key words: Tree basal area, tree volume, aboveground biomass, multi-purpose trees, carbon credit, Gini index, carbon trading

INTRODUCTION

Among different types of global ecosystems, forests are of major importance to human society with their several crucial ecosystem services. Tree species richness and tree biomass are regarded as the major contributors of ecosystem services of forests. However, due to several anthropological activities both the quality and quantity of forested lands have been affected and in turn threatening the very existence of mankind. A wide range of human activities, such as deforestation, desertification, industrialization, urbanization and other socio-economic activities are also contributing to climate change. At the global level, deterioration of ecosystem services forests can also be attributed to extensification of agriculture as well as intense conversion of forest lands into land-uses for production of timber, fibre, biofuels and also as for the development of urban areas (Millennium Ecosystem Assessment 2005). In addition, as problems caused by pollution and climate change continue to grow, forest protection is one of the important strategies with us to restore a natural balance (Dorje 2008, 2011). Thus, conservation of remaining natural forests, rehabilitation of degraded forests as well as restoration of degraded forests through tree planting are increasingly important both for sustenance of forested lands and in maintaining ecosystem services of forests.

In the tropics and subtropics, much of the restoration of degraded land has been through afforestation with industrial monocultures involving a limited number of species from very few tree genera. Although these efforts may have been successful in terms of generating goods such as pulpwood, very few of these plantations provide the variety of goods and services to the local people that were once provided by the original forests or even the degraded systems that were replaced (Lamb et al. 2005). However, there is growing evidence that plantations can effectively assume the provision of several ecosystem services, such as maintaining water and nutrient cycles, soil protection and the provision of habitat for biodiversity. In addition, the focus on ecosystem services in restoration efforts does not contradict but may complement socio-economic objectives such as poverty alleviation (Lamb et al. 2005, Mansourian et al. 2005). Different international processes have aimed to define some principles to guide the future development and management of plantation forests to ensure that they meet not only global but also regional and local demands for all the goods and services they can offer. For instance, the Voluntary Guidelines for the Responsible Management of Planned Forests highlighted the fact that intelligent solutions for plantations should feature ecological restoration, aim to achieve optimum productivity of multiple products and services rather than maximum productivity of one product and should be characterized by closed cycles of nutrients and energy conservation (Seufert 2013). Similarly, during the first conference on Environmental Protection for Kagyu Monasteries and Centres it was advised to a) plant at least twice the number of trees that are used in monasteries for different purposes, b) develop groves of trees of different species and use such groves as meditation ground by the monastic community, c) plant suitable tree species and nurture them in severely degraded lands, d) plant the selected area with the tree saplings of different tree species which fall under different successional status, and e) take care of saplings for some time till grow into a tree and long term monitoring of the forested area (Dorje 2008). It may be mentioned here that globally several efforts have also been made for planting trees around temples, churches, synagogues, monasteries etc. However, presently there is a dearth of information on quality, tree species composition, tree characteristics, such as, height, girth, biomass, carbon stock and carbon dioxide sequestration potential in such forested lands. To evaluate the status and trends of forested ecosystems along with the structure and their function, the quantification of stand biomass is essential. Evaluation of storage pattern and production of organic matter in multi-species forestry systems is also critical for better management and climate change mitigation. In the Kagyu Nalanda Monastery in Bylakuppe, Karnataka state, India, during the year 2002, around 5 ha of degraded land has been planted with multipurpose trees in two

Figure 1. Study area

blocks, namely, South Forest Block and North Forest Block (Fig. 1). This paper was aimed to provide details of tree species composition, tree characteristics, such as, height, girth, biomass, carbon stock and carbon dioxide sequestrated in the aboveground biomass in 10-year-old trees in the south forest block (2.5 ha in size) of this multi-species forestry plot.

MATERIALS AND METHODS

Study area and climate

The Kagyu Nalanda Monastery in Bylakuppe (12^0 24' 26" N and 75^0 59' 07" E) has a tropical climate. Here the average annual temperature is 22.5°C with average minimum temperature of 20.7°C during the month of December and average maximum temperature of 25.5°C during the month of April. The mean annual rainfall of 1176 mm with most of the precipitation (around 243 mm) falls in July. While the relative humidity ranges from 49.6 to 89.1% with highest in the month of July and the lowest in the month of February. The soil is slightly alkaline (soil pH around 7.7) with moderate quantity of organic carbon (0.53%), available nitrogen (around 310 kg/ha), available phosphorous (20 kg/ha) and available potassium (around 490 kg/ha).

Methods

The forest south block has a total of 45 tree species planted (Table 1). The monks and other inhabitants of the Monastery received training for tree identification and measurements. All individual trees of each species were numbered with red paint. Tree girth was measured at 1.37 m above the ground level (Gbh). Tree height was measured using a clinometer. In case of individuals with multiple stems, the Gbh was measured for each stem and recorded separately.

Data pertaining to two parameters, namely, Gbh and height of each tree were entered into excel sheets. Tree Volume (m^3) was determined from Gbh, height, and form factor. The following formula was used for tree volume estimation

$$V= (Gbh^2/4\Pi) * h* F$$

where h = tree height (m), Gbh = Girth at breast height (m). and F = Form factor (0.6)

The aboveground biomass of each tree was calculated from the relation of stem volume and basic wood density. The value of wood density was sourced from available literature (IPCC 2006). The following formula was used to calculate stem biomass.

Stem biomass = tree volume × wood density

The tree aboveground biomass was calculated by multiplying stem biomass and biomass expansion factor (BEF). The BEF value for different species were obtained from Henry et al. (2013).

The carbon stock of each tree in the present study was estimated multiplying the value of calculated aboveground tree biomass and conversion factor which is 0.50. This value of conversion factor has been used globally (MacDicken 1997). The carbon stock in a given tree was multiplied by 3.6663 to obtain the carbon dioxide (CO_2) sequestrated in that tree. To determine the annual CO_2 sequestration potential of a given tree, the weight of carbon dioxide sequestered in the tree was divided by the age of the tree.

RESULTS AND DISCUSSION

The results of the present study provide valuable information on tree species composition, individual tree growth, biomass production and carbon sequestration in a multi-species forestry plot established and monitored by the monks of a Buddhist Monastery in Karnataka. A total of 927 trees belonging to 45 species were recorded from the study plot (Table 1). While *Swietenia macrophylla* and *Cassia fistula* each with 97 and 91 trees respectively together contributed for about 20% of total number of trees in the plot, 5 species were represented by 31 to 90 individuals per species. 18 species were represented by 11 to 30 individuals per species and the remaining 20 species in the plot were represented by 1 to 10 trees per species (Table 2). Several studies indicate that reforestation projects very often fail due to several intrinsic factors, including inappropriate species choice; a consequence of inadequate knowledge about the potential of species and their growth and survival rates under different site and environmental conditions and planting and management practices adopted (Wuethrich 2007, Rodrigues et al.2011, Anbarashan et al. 2020). However, in the study plot, trees of all species have established and showing species-specific growth pattern.

Table 1. Tree species recorded in the South Forest Block in the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India.

Species	**Family**	**Common name/trade name**
Acacia auriculiformis Benth.	Fabaceae	Tan wattle
Aphanamixis polystachya (Wall.) R.Parker	Meliaceae	Pithraj tree
Artocarpus heterophyllus Lam.	Moraceae	Jackwood tree
Averrhoa carambola L.	Oxalidaceae	Carambola
Bauhinia purpurea L.	Fabaceae	Camel's foot tree
Bauhinia variegata L.	Fabaceae	Kanchar
Butea monosperma (Lam.) Taub.	Fabaceae	Palash, Flame of the forest
Canthium dicoccum (Gaertn.) Merr.	Rubiaceae	Ceylon Boxwood
Cassia fistula L.	Facaceae	Golden shower tree
Celtis tetrandra Roxb.	Cannabaceae	Eastern nettle tree
Dalbergia latifolia Roxb.	Fabaceae	Indian rosewood
Ficus benghalensis L.	Moraceae	Banyan tree
Ficus drupacea Thunb.	Moraceae	Mysore Fig
Ficus racemosa L.	Moraceae	Cluster fig
Ficus religiosa L.	Moraceae	Bodhi tree, Sacred fig
Gliricidia sepium (Jacq.) Walp.	Fabaceae	Gliriciia
Gmelina arborea Roxb.	Lamiaceae	Gamhar
Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	Silver Oak
Lagerstroemia speciosa (L.) Pers.	Lythraceae	Pride of India tree
Magnolia champaca (L.) Baill. ex Pierre	Magnoliaceae	Champak
Mangifera indica L.	Anacardiaceae	Mango tree
Miliusa tomentosa (Roxb.) J.Sinclair	Annonaceae	Hum
Millingtonia hortensis L.f.	Bignoniaceae	Tree jasmine, Indian cork tree
Moringa oleifera Lam.	Moringaceae	Drumstick tree
Muntingia calabura L.	Muntingiaceae	Singpore Cherry
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Kadam
Olea dioica Roxb.	Oleaceae	Wild Olive tree
Persea macrantha (Nees) Kosterm.	Lauraceae	Large-flowered bay tree
Phyllanthus emblica L.	Phyllanthaceae	Amla
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	False Ashoka
Pongamia pinnata (L.) Pierre	Fabaceae	Pongam tree
Pterocarpus marsupium Roxb.	Fabaceae	Malabar kino
Putranjiva roxburghii Wall.	Putranjivaceae	Putranjiva
Spathodea campanulata P.Beauv.	Bignoniaceae	Fountain tree
Spondias pinnata (Wight & Arn.) Airy Shaw & Forman	Anacardiaceae	Ambara tree
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	Fragrant Padru tree
Swietenia macrophylla King	Meliaceae	West Indian Mahogany
Syzygium cumini (L.) Skeels	Myrtaceae	Jamun tree
Tabebuia pentaphylla Hemsl.	Bignoniaceae	Tabebuia, Trumpet tree
Tabebuia rosea (Bertol.) Bertero ex A.DC.	Bignoniaceae	Rosy trumpet tree
Tecoma stans (L.) Juss. ex Kunth	Bignoniaceae	Yellow trumpetbush
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjun tree
Thespesia populnea (L.) Sol. ex Corrêa	Malvaceae	Portia tree
Vateria indica L.	Dipterocarpaceae	White Damar
Ziziphus rugosa Lam.	Rhamnaceae	Wild jujube

Table 2. Number of trees, tree height (m, mean± SD) and tree Gbh (cm, mean± SD) of different species in the South Forest Block of the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India.

Species	**Number of trees**	**Tree height**	**Gini index**	**Tree Gbh**	**Gini index**
Swietenia macrophylla	97	7.6±1.5	0.10	77.8 ± 45.3	0.30
Cassia fistula	91	8.3±1.4	0.09	89.2 ± 69.4	0.40
Gmelina arborea	82	8.0±1.9	0.12	89.5 ± 40.8	0.23
Syzygium cumini	56	6.1±1.3	0.11	74.2 ± 40.0	0.28
Gliricidia sepium	52	5.7±1.3	0.12	92.6 ± 46.1	0.25
Neolamarckia cadamba	48	7.5±0.9	0.06	72.4 ± 34.7	0.24
Spathodea campanulata	41	7.9±1.1	0.07	94.3 ± 53.6	0.29
Moringa oleifera	33	8.1±1.7	0.10	104.0 ± 56.0	0.28
Magnolia champaca	30	6.4±0.7	0.05	53.2±14.3	0.14
Tabebuia pentaphylla	29	7.1±1.1	0.08	61.6±23.7	0.20
Millingtonia hortensis	28	8.9±2.7	0.15	90.6 ± 54.2	0.31
Pterocarpus marsupium	28	7.6±1.3	0.09	58.2 ± 24.9	0.22
Averrhoa carambola	23	6.6±2.3	0.18	63.3 ± 26.0	0.21
Terminalia arjuna	23	7.4±1.3	0.09	56.5 ± 24.5	0.22
Olea dioica	21	7.5±1.7	0.11	81.6 ± 50.8	0.32
Tecoma stans	21	8.3±1.4	0.09	52.6 ± 26.2	0.25
Tabebuia rosea	18	6.6±1.5	0.11	53.6 ± 21.1	0.20
Pongamia pinnata	17	5.8±1.3	0.12	59.5 ± 24.9	0.21
Aphanamixis polystachya	16	6.3±1.3	0.11	65.3 ± 41.4	0.32
Lagerstroemia speciosa	16	7.0±1.4	0.10	70.7 ± 34.8	0.25
Acacia auriculiformis	15	12.8±3.5	0.14	106.6 ± 54.7	0.26
Butea monosperma	15	8.3±0.8	0.05	87.6 ± 46.4	0.27
Mangifera indica	15	8.0±1.6	0.10	180.4 ± 118.9	0.34
Artocarpus heterophyllus	11	7.2±1.2	0.08	63.8 ± 22.3	0.18
Ficus religiosa	11	8.4±1.3	0.08	67.6 ± 59.2	0.45
Spondias pinnata	10	8.7±2.6	0.15	95.1 ± 53.8	0.29
Celtis tetrandra	8	6.8±1.5	0.12	63.5 ± 22.2	0.18
Ficus racemosa	8	7.0±1.5	0.11	61.6± 19.1	0.16
Phyllanthus emblica	7	7.1±1.5	0.11	79.0 ± 27.7	0.18
Vateria indica	7	7.0±1.6	0.12	61.3 ± 22.6	0.19
Bauhinia purpurea	6	6.9±0.9	0.07	96.2 ± 41.1	0.22
Muntingia calabura	6	5.6±1.3	0.12	64.3 ± 36.4	0.29
Putranjiva roxburghii	6	7.4±1.2	0.08	101.3 ± 64.7	0.33
Canthium dicoccum	5	6.3±1.0	0.08	59.6 ± 31.7	0.27
Thespesia populnea	5	6.1±0.1	0.01	77.6 ± 37.9	0.25
Miliusa tomentosa	3	7.0±1.8	0.13	39.8 ± 9.9	0.13
Persea macrantha	3	7.4±1.1	0.08	54.3 ± 23.6	0.22
Polyalthia longifolia	3	10.7±0.6	0.03	76.3 ± 11.6	0.08
Stereospermum chelonoides	3	7.7±1.6	0.10	60.7 ± 56.6	0.48
Dalbergia latifolia	2	6.2±0.0	—	31.0 ±1.4	0.02
Ficus benghalensis	2	7.5±0.7	0.05	88.0 ± 38.2	0.22
Grevillea robusta	2	8.1±0.1	0.00	48.0 ± 1.4	0.02
Ziziphus rugosa	2	8.6±0.6	0.04	48.5 ± 19.1	0.20
Bauhinia variegata	1	6.0±0.0	—	25.0 ± 0.0	—
Ficus drupacea	1	7.9±0.0	—	38.0 ± 0.0	—

In the study plot, a combination of timber yielding trees, ornamental trees, medicinally important trees, fodder and green manure trees, edible fruit yielding trees and culturally important trees are seen. For instance, *Swietenia macrophylla, Pterocarpus marsupium, Lagerstroemia speciosa, Acacia auriculiformis and Dalbergia latifolia* are primarily planted for their timber values. *Cassia fistula, Spathodea campanulata, Tabebuia pentaphylla, Tabebuia rosea, Tecoma stans* and *Millingtonia hortensis* are known for their ornamental values. In the plot, several edible fruit yielding tree species such

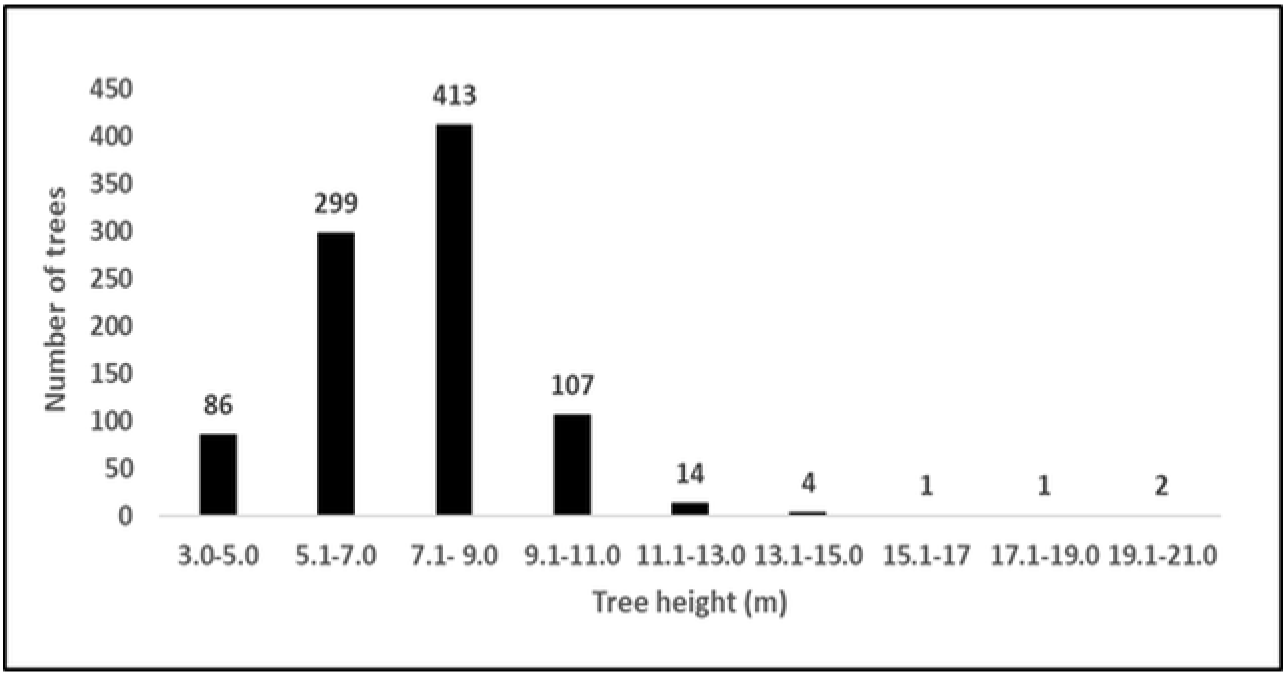

Figure 2. Height class distribution of trees in the South Forest Block of the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India

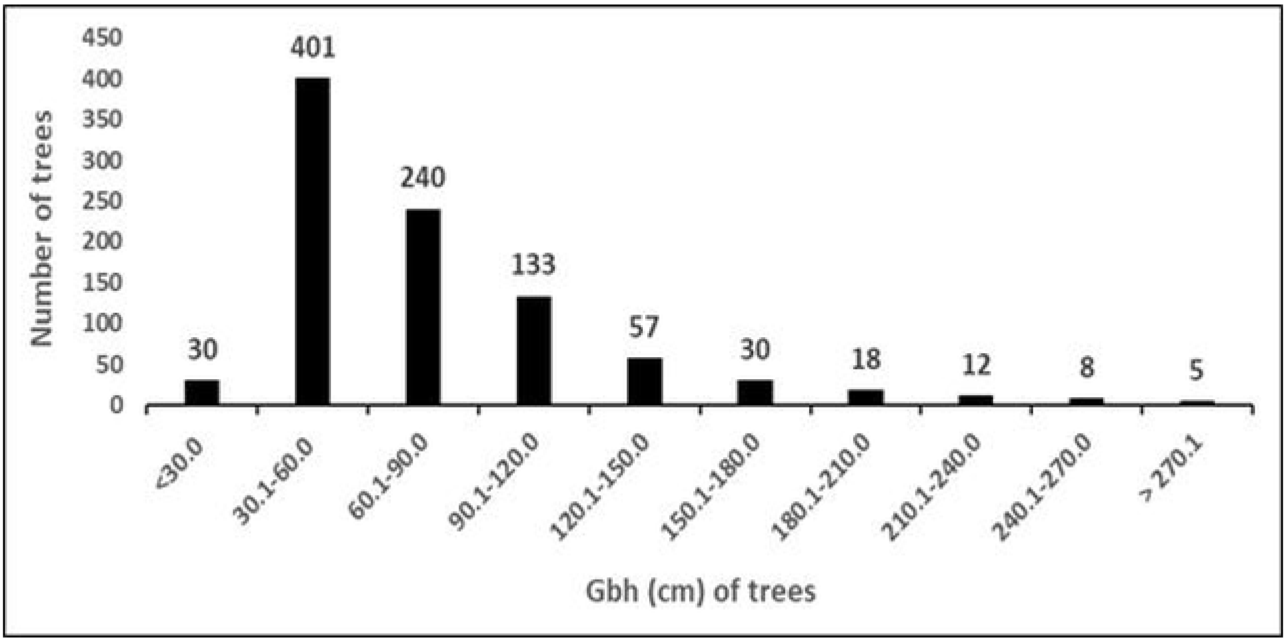

Figure 3. Girth class distribution of trees in the South Forest Block of the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India

as, *Artocarpus heterophyllus, Syzygium cumini, Moringa oleifera, Averrhoa carambola, Mangifera indica, Spondias pinnata* and *Ziziphus rugosa* are also planted. Culturally and religious important tree species like *Magnolia champaca, Ficus religiosa, Butea monosperma* also formed the constituents of tree diversity in the plot. Several tree species, such as, *Aphanamixis polystachya, Terminalia arjuna, Ficus benghalensis, Ficus racemosa, Stereospermum chelonoides, Vateria indica* known for their medicinal values are grown in the plot. Tree species like Glyricidia *sepium* and Pongamia *pinnata* are planted for their green manure, fodder and nitrogen fixing values and trees like *Grevillea robusta a*nd *Polyalthia longifolia* yield poles.

The height of the trees in the plot ranged from 3 to 11 m (Table 2) with 817 out of 927 trees are within the tree height classes from 5.1 to 11 m (Fig. 2). Measurement of tree Gbh indicated that the value ranged from 20 to 465 cm, with multiple stem individuals recorded high Gbh (Table 2). Out of 927 trees 774 fall under the tree Gbh classes between 30.1 to 120.0 cm (Fig. 3). The Gini Index is a measure of statistical dispersion intended to represent inequality among values of given parameter within a given population. A Gini Index of zero expresses perfect equality, where all values are the same. On the other hand, a Gini Index of one expresses maximum inequality among values. In the present study, the Gini Index obtained for tree height in different species ranged from 0 to 0.18 (Table 2). Compared to tree height, the Gbh showed high inequality in each species with the Gini Index for majority of species ranged from 0.19 to 0.40 (Table 2). Available literature also suggested that with the increase in plot age the tree gbh inequality increases when the tree height inequality decreases (Martin and Ek 1984, Binkley et al.2010, Pena et al. 2018, Chandrashekara et al. 2022).

The estimated total basal area and total tree volume of 927 trees in the study plot is 33.34 and 315.73 m^3, respectively (Table 3). Among 45 tree species, *Gmelina arborea*, *Cassia fistula*, *Swietenia macrophylla,* Mangifera *indica*, *Moringa oleifera* and *Spathodea campanulata* together covered about 46 and 55% of the total basal area and total tree volume respectively in the plot. This study also showed a significant difference in individual tree biomass based on tree volume. The total aboveground biomass estimated for the plot was 326.39 tonnes (Table 3). Among the 45 tree species, *Cassia fistula* shared a maximum of 75.66 tonnes (23.2%) to total aboveground biomass followed by *Mangifera indica* (9.1%), *Gmelina arborea* (8.6%), *Swietenia macrophylla* (7.5%) and *Spathodea campanulata* (5.8). In terms of individual tree volume and aboveground biomass accumulation, species like *Swietenia macrophylla*, *Cassia fistula*, *Gmelina arborea* also showed better performance compared. Thus, the multi-species forestry plot possesses a combination of species that accumulate biomass at faster rate in the short term and those which may accumulate more biomass within the system in the long term. Such multi-species systems are regarded as suitable for improving ecosystem resilience, decreasing incidence of pest and diseases and increasing functional diversity (Benayas et al. 2009, Hooper et al. 2005, Rodrigues et al. 2011, Semwal et al. 2013).

The total carbon stock estimated for the plot was 163.18 tonnes (Table 3). Among the 45 tree species in the plot, the contribution of *Cassia fistula* to the total carbon stock was high (37830.2 kg) followed by *Mangifera indica* (14790.1 kg), *Gmelina arborea* (13814.9 kg), *Swietenia macrophylla* (12029.5 kg) and *Spathodea campanulata* (9332.6 kg). A positive correlation was observed between the carbon stock and total tree volume of the top five species which contributed predominantly (54%) of the total carbon stock ($r=0.812$, $p<0.05$).

The aboveground biomass (ABG) and carbon stock in the above ground biomass (ABG C stock) of the Kagyu Nalanda Monetary forestry plot of the present study (ABG Biomass: 118.4 Mg ha^{-1} and ABG C Stock: 59.2 Mg C ha^{-1}) are lower than those in the old growth natural sacred forests, such as, Iringole sacred grove, Kerala, India (ABG Biomass: 701 Mg ha^{-1} and ABG C Stock; 350.5 Mg C ha^{-1}: Chandrashekara and Sankar 1998), Phayeng sacred forest, Imphal West District, Manipur, India (ABG Biomass; 962.94 to 1130.79 Mg ha^{-1} and ABG C Stock; 481.47 to 565.40 Mg C ha^{-1}: Waikhom et al. 2017), and Amba sacred forest, Gedeo Zone, Southern Ethiopia (ABG Biomass; 505.17 Mg ha^{-1} and ABG C Stock; 252.5 Mg C ha^{-1}: Maru et al. 2022), Similarly, the aboveground biomass (ABG)

Table 3. Basal area (m^2) and volume (m^3), Aboveground biomass (kg, dry weight) and Aboveground carbon stock (Kg) of trees of different species in the South Forest Block of the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India.

Species	**Total basal area (m^2)**	**Total volume (m^3)**	**Aboveground biomass (kg)**	**Aboveground carbon stock (kg)**
Swietenia macrophylla	2.95	30.69	24,059.1	12,029.5
Cassia fistula	3.41	49.26	75,660.4	37,830.2
Gmelina arborea	3.66	30.83	27,629.7	13,814.9
Syzygium cumini	1.75	12.12	14,734.1	7,367.1
Gliricidia sepium	1.65	15.39	18,227.2	9,113.6
Neolamarckia cadamba	1.59	11.14	12,122.1	6,061.1
Spathodea campanulata	2.00	18.23	18,665.3	9,332.6
Moringa oleifera	2.30	18.84	7,896.2	3,948.1
Magnolia champaca	0.54	2.80	2,639.9	1,319.9
Tabebuia pentaphylla	0.63	4.32	5,598.2	2,146.9
Millingtonia hortensis	1.23	15.70	11,805.4	2,799.1
Pterocarpus marsupium	0.69	4.33	4,293.9	5,902.7
Averrhoa carambola	0.57	3.38	3,239.4	1,619.7
Terminalia arjuna	0.50	3.17	4,762.4	2,381.2
Olea dioica	0.69	7.27	10,315.9	5,158.0
Tecoma stans	0.42	3.05	2,294.7	1,147.3
Tabebuia rosea	0.36	1.91	1,777.2	888.6
Pongamia pinnata	0.38	2.03	2,077.5	1,038.7
Aphanamixis polystachya	0.39	2.72	2,788.4	1,394.2
Lagerstroemia speciosa	0.43	3.44	3,522.5	1,761.3
Acacia auriculiformis	1.05	15.09	16,416.2	8,208.1
Butea monosperma	0.63	5.78	5,179.9	2,590.0
Mangifera indica	2.32	27.19	29,580.1	14,790.1
Artocarpus heterophyllus	0.26	1.78	1,477.0	738.5
Ficus religiosa	0.34	3.90	2,761.0	1,380.5
Spondias pinnata	0.69	5.48	2,715.5	1,357.8
Celtis tetrandra	0.15	1.12	933.9	466.9
Ficus racemosa	0.17	1.08	659.0	329.5
Phyllanthus emblica	0.18	1.72	1,871.7	935.9
Vateria indica	0.16	0.86	661.5	330.7
Bauhinia purpurea	0.21	2.15	2,480.6	1,240.3
Muntingia calabura	0.14	0.97	467.9	233.9
Putranjiva roxburghii	0.22	3.14	2,865.2	1,432.6
Canthium dicoccum	0.11	0.61	678.6	339.3
Thespesia populnea	0.12	1.04	647.5	323.8
Miliusa tomentosa	0.04	0.18	143.8	71.9
Persea macrantha	0.08	0.37	258.3	129.2
Polyalthia longifolia	0.14	0.91	785.1	392.5
Stereospermum chelonoides	0.05	0.67	643.3	36.5
Dalbergia latifolia	0.02	0.06	72.9	275.9
Ficus benghalensis	0.06	0.58	551.7	90.7
Grevillea robusta	0.04	0.18	181.5	310.1
Ziziphus rugosa	0.03	0.20	212.7	106.3
Bauhinia variegata	0.005	0.02	20.1	10.0
Ficus drupacea	0.01	0.05	18.3	9.2
Total	**33.34**	**315.73**	**3,26,393.0**	**1,63,184.9**

and carbon stock in the above ground biomass (ABG C stock) of the present study site are also lower than those in Church forests in Addis Ababa, Ethiopia (ABG C Stock ; 141± 83: Yilma and Derero 2020), and Urban Sacred forests in Gangtok, Sikkim, India (ABG Biomass; 330.02 – 335.78 Mg ha^{-1} and ABG C Stock; 155.39-156.04 Mg C ha^{-1}: Devi et al. 2021). The present study site is comparatively a young planted forest, and thus its ABG and ABG G stock are lower than those in other sacred forest plots mentioned above.

The study plot sequestrated 598.13 tonnes of carbon dioxide with mean annual rate of 59.81 tonnes. The amount of carbon dioxide sequestrated is directly proportion to the total aboveground biomass. Thus, *Cassia fistula, Mangifera indica, Gmelina arborea, Swietenia macrophylla* and *Spathodea campanulata* have contributed more (53.8%) to total carbon dioxide sequestrated by the tree community in the plot (Table 4).

Based on a study conducted in two urban sacred grove forests in Gangtok, Sikkim, India, Devi and others (2021) reported the annual aboveground vegetation carbon sequestration capacity of 2.10 Mg C ha^{-1} yr^{-1} in 74-year-old Deorali Chorten Monastery Sacred Grove Forest and 1.43 Mg C ha^{-1} yr^{-1} in 111-year-old Enchey Monastery Sacred Grove Forest. On the other hand, the annual aboveground vegetation carbon sequestration capacity of the current study site, which represents a 10-year-old forestry plot established by in Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India is is 5.92 Mg C ha^{-1} yr^{-1}. These two observations suggest that the carbon sequestration potential of young forest is more than in old forests.

It may be mentioned here that, companies in the developed and developing countries are required to meet certain carbon emission targets set by their respective government. However, if these companies are not able to meet their emission targets, they have an alternative of purchasing these carbon credits from the market i.e., from someone who is successful in meeting these targets and who has a surplus of these credits. This process is known as carbon trading. Carbon trading is also advantageous for the companies of the developing world as it provides monetary gains in exchange of carbon credits which help these companies to purchase or change their

Table 4. Carbon dioxide sequestrated (CDS) (kg) in the aboveground biomass and mean annual rate of carbon dioxide sequestration (MARCDS) (kg) in trees of different species in the South Forest Block of the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India.

Species	CDS	MARCDS
Swietenia macrophylla	44103.9	4410.4
Cassia fistula	138696.9	13869.7
Gmelina arborea	50649.4	5064.9
Syzygium cumini	27009.8	2701.0
Gliricidia sepium	33413.1	3341.3
Neolamarckia cadamba	22221.7	2222.2
Spathodea campanulata	34216.3	3421.6
Moringa oleifera	14474.9	1447.5
Magnolia champaca	4839.3	483.9
Tabebuia pentaphylla	10262.3	1026.2
Millingtonia hortensis	21641.2	2164.1
Pterocarpus marsupium	7871.3	787.1
Averrhoa carambola	5938.4	593.8
Terminalia arjuna	8730.2	873.0
Olea dioica	18910.7	1891.1
Tecoma stans	4206.5	420.7
Tabebuia rosea	3257.9	325.8
Pongamia pinnata	3808.4	380.8
Aphanamixis polystachya	5111.6	511.2
Lagerstroemia speciosa	6457.3	645.7
Acacia auriculiformis	30093.4	3009.3
Butea monosperma	9495.6	949.6
Mangifera indica	54224.8	5422.5
Artocarpus heterophyllus	2707.6	270.8
Ficus religiosa	5061.3	506.1
Spondias pinnata	4978.0	497.8
Celtis tetrandra	1711.9	171.2
Ficus racemosa	1208.1	120.8
Phyllanthus emblica	3431.1	343.1
Vateria indica	1212.6	121.3
Bauhinia purpurea	4547.3	454.7
Muntingia calabura	857.7	85.8
Putranjiva roxburghii	5252.3	525.2
Canthium dicoccum	1244.0	124.4
Thespesia populnea	965.9	96.6
Miliusa tomentosa	291.6	29.2
Persea macrantha	473.6	47.4
Polyalthia longifolia	1439.1	143.9
Stereospermum chelonoides	1179.3	117.9
Dalbergia latifolia	133.7	13.4
Ficus benghalensis	1011.4	101.1
Grevillea robusta	332.7	33.3
Ziziphus rugosa	389.9	39.0
Bauhinia variegata	36.8	3.7
Ficus drupacea	33.6	3.4
Total	**598134.2**	**59813.4**

technology. In India, over the past few years, there has been remarkable support for carbon pricing by the private sector. Some of the leading Indian companies have adopted an internal carbon price which ranges from US$ 4 to 50 per tonne of CO_2 (CDP 2020). When we consider these low and high internal carbon prices, the economic value of carbon dioxide sequestrated in the aboveground biomass of tree community in the study area ranges from US$ 2,392.5 to 29,906.5 (Indian Rupees 1,78,720 to 22,34,016; US$ 1= Rs.74.7). Similarly, the mean annual economic value of carbon dioxide sequestrated in the aboveground biomass of tree community in the study area ranges from US$ 239.3 to 2,990.7 (Indian Rupees 17,872 to 2,23,401.6).

CONCLUSIONS

At present, greenhouse gas emissions and increase in global temperature, both due to anthropogenic activities are the two major problems in the world. Extensive deforestation and intensive landuse changes in forested areas are the basic reasons for the global environmental degradation. Due to deforestation not only carbon content is diminishing but also atmospheric carbon dioxide is increasing at an accelerated and alarming rate. Thus, the Karma Kagyu monasteries, centres and communities around the world have undertaken sustainability initiative through several afforestation programmes. In the Kagyu Nalanda Monastery in Bylakuppe, Karnataka, India apart from establishment of a multi-species forestry plot, the monks and other inhabitants also assessed the basal cover, height, aboveground biomass, carbon stock and carbon dioxide sequestration potential of the tree community in the plot. The results of the study give an insight into the value of this forestry plot, not only as a multi-species plantation but also in mitigating the impacts of climate change at a local level. The results of the study, where the mean annual economic value of carbon dioxide sequestrated in the aboveground biomass of tree community is also assessed, can also be considered as a model for assessment of carbon sink potential of forestry plots established by other monasteries of Karma Kagyu and also other institutions and communities in different parts of the world. The forestry plots may explore selling carbon credits and use generated income for nurturing tree communities for their ecosystem services.

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