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Study of Biomass to understand the Carbon stock in some Silvi-cultural important Tree species

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Abstract

Present paper deals the biomass estimation study of some important silvicultural tree species like Gupti, Bhirra, Tinsa, Khirni, Thailand Imli and Rakta Chandan for understanding of carbon sequestration process. Global carbon cycle plays a key role in regulation of earth's climate by controlling the concentration of carbon dioxide in the atmosphere. CO_2 contributes to the greenhouse effects and increased CO_2 in the atmosphere has been responsible for more than half of the climate warming observed in recent decades.

Key words: Agroforestry, Silviculture, Biomass, Carbon Stock, Carbon Sequestration

Introduction

Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere. The idea is (1) to keep carbon emissions produced by human activities from reaching the atmosphere by capturing and diverting them to secure storage, or (2) to remove carbon from the atmosphere by various means and stores it.

The biomass inventory was therefore meant to support the establishment of a carbon sequestration scheme targeting community groups and individuals. Biomass assessments for development of carbon sequestration potential and farm management guidelines for identified land use systems were undertaken. The average net accumulated carbon uptake for the rotation age of trees in the agroforestry systems was quantified. This paper details of the biomass assessments that were done as well as results emanating from the inventory for the state forest research institute, Jabalpur.

Biomass is a mass of live or dead organic matter. It includes the total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass. The quantity of biomass is expressed as a dry weight or as the *energy*, carbon, or nitrogen content. Therefore, a global assessment of biomass and its dynamics are essential inputs to climate change forecasting models and mitigation and adaptation strategies.

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Organic chemicals are characterized by their carbon chains that along with oxygen and hydrogen form their main contents, with smaller additions of nitrogen and sulfur and some metals. However, life can be said to be dominated by the carbon cycle. In the exchange of carbon dioxide (CO2) between terrestrial vegetation and the atmosphere, with net accumulation followed by carbon (C) release, the net balance between sequestration and release shifts from minute-to-minute (for example, with cloud interception of sunlight), to a day-night pattern, across a seasonal cycle of dominance of growth and decomposition, through decadal patterns of build-up of woody vegetation or century-scale build up of peat soils out to the stages of the lifecycle of a vegetation or land use system.

Perennial plants live for more than a year and may live for more than 100 years. They continue to build up carbon stocks, mostly in woody stems and roots. Carbon storage increases during the process of vegetation succession, when woody plants take over from herbs and shrubs, and when large trees take over from smaller ones. Ultimately, however, even big trees die and fall down, creating gaps in the vegetation that allow other trees-awaiting to take over. The C cycle continues, but one has to measure over the life cycle of trees to understand the net balance of sequestration and respiration of natural (or manmade) vegetation.

Forests are critical to mitigating climate change by enhancing the stock of carbon in biomass and in soil or by reducing CO2 emissions. Most land-based developmental projects have the potential to deliver C-benefits (carbon stock enhancement or CO2 emission reduction) as a co benefit of projects that have socioeconomic development or improved management of natural resources as their main goals. Slowing deforestation, combined with changes in forest management as well as reforestation, could curb a significant portion of the emissions that contribute to climate change. In fact, halving deforestation by 2020 would prevent the release of nearly three billion tons of CO2 per year (IPCC, 2007d). Despite this potential, nearly all climate policy frameworks fail to include the full array of forest carbon activities as a critical component of climate change mitigation, due to skepticism about whether these activities generate real benefits to the climate and questions about how those benefits can be measured, monitored and verified.

Contribution to a reduction in greenhouse gases in the short term could be a process known as carbon sequestration. This involves the deliberate removal or storage of carbon in a place (a sink) where it will remain. By signing up the Kyoto Protocol, the developed countries have agreed to reduce their emissions of greenhouse gases collectively by 5.2% from 1990 levels between 2008 and 2012. The risk that carbon reduced or sequestered in forestry projects is release further down the road is in fact undeniable, whoever bears the onus. The merit of the so-called “ton/year approach” is to destroy the fiction of infinity when talking about permanent sequestration (Dutschke M,2001) The Kyoto protocol is a start but definitely more intensive reductions are required in the long term, if climate change is to be stabilized. A whole bundle of so-called “flexible mechanisms” has been foreseen by the Kyoto Protocol in order to help industrial countries to fulfill their agreed reduction targets in the most cost-effective way (Dutschke et al.,1998). According to The Royal Commission on Environment Pollution, the UK will need to reduce its emissions of carbon dioxide from burning fossil fuels by 60% over the next 50 years. Sequestration could have a significant role to play in meeting these targets. The Kyoto Protocol includes, as a strategy for mitigation climate change, the option of removing CO_2 from the atmosphere through biological carbon sequestration. This includes activities such as massive agroforestry systems. Carbon management is a serious concern confronting the world today. A number of summits have been organized on this subject ranging from the stockholon to Kyoto protocol. The current level of carbon in the atmosphere is about 375 ppm. It is estimated that if the carbon increases in the atmosphere at the present rata and no positive efforts are pursued, the level of carbon in the atmosphere would go up to 800-1000 ppm by the end of current century, which may create destruction for all living creatures on earth. Soil may be an important sink for the carbon storage in the form of biomass. This form of carbon is also a matter of serious concern for agriculture scientists across the globe because various researches reveal that the tree under intensive cultivation results in declining the net production area for agriculture crops.

There by proving an obstacle for sustainable agriculture. Tree are the main source of the soil organic carbon, either from the decomposition of aerial plant parts or underground tree parts, e.g. roots in the form of root death, root exudates and root respiration. Thus the aim of this article is to provide an insight on the contribution of tree biomass for transfer of carbon from atmosphere through their significance in sustainable agriculture. Present study is focused to assess the increment in biomass in some silvicultural important tree species

Material and Methods

The present study was conducted on well established farm at krishi vigyan Kendra, Bhind. This activity involved measurement of tree parameters from sample plots in order to obtain single tree weights, quantification of the total standing biomass stock for the surveyed area and ultimately aggregation of standing stock of biomass per ha. The tree parameters that were measured include; diameter at breast height (dbh), bole height, tree height and crown diameter/width.

Biomass estimation

To measure the biomass of trees is not easy, especially in mixed with uneven-aged stands. It requires considerable labor and it is difficult to obtain an accurate measurement given the variability of tree size distribution. It is hardly ever possible to measure all biomass on a sufficiently sample area by destructive sampling and some form of *allometry* is used to estimate the biomass of individual trees to an easily measured property such as its stem diameter.

For biomass estimation of woody vegetation any live plant greater than or equal to 2 cm DBH will be treated as above ground woody plant. Experience to date with the development of generic regression equations has shown that measurements of DBH explains more than 95% of the variation in tree biomass even in highly species rich tropical forests.

Steps

1. Measure the diameter of trees at breast height (DBH) or 1.3 meters or above the buttress of all trees that are above the minimum DBH (≥2 cm) in the sample plot or sub-sample plots. For multiple stems, measure all stems >10 cm diameter at 1.3 m. For multiple stems below 1.3 m, measure collar diameter. For coffee measure collar diameter (30 cm above the ground).

2. Make corrections for buttressed and grooved trees (this can be done subjectively).
3. If there are reasonable numbers of stranglers, Lianas and climbers, take DBH reading.

Total biomass = AGB + BGB

AGB = Aboveground biomass (AGB)- all woody stems, branches and leaves of living trees, creepers, climbers and epiphytes as well as understory plants and herbaceous growth. ◦ Above-ground biomass: all living biomass above the soil including stem, branches, bark, seeds, and foliage.

BGB = Belowground biomass (BGB)-comprises living and dead roots, soil fauna and the microbial community. ◦ living biomass of live roots includes fine roots (< 2 mm diameter), small roots (2 – 10 mm diameter), and large roots (> 10 mm diameter).

Weight loss percentage/ Moisture content percentage

$$\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Carbon content = Dry weight – ash content

Organic content percent

$$\frac{\text{Total dry matter} - \text{Total ash content}}{\text{Total dry matter}} \times 100$$

a. With some of the plots being established on a slope, a correction factor using the formula shown in section 3.6 was used. This is done to avoid over-estimation of the amount of carbon in the plot.
b. The results obtained from each plot were standardized to a hectare using the formula below:
c. EF = ha/A, and 1ha=10000m2, therefore,
EF= A/10000, where EF is the Expansion Factor ; A= Area of sub-plot in m2 Using an allometric equation developed by the national biomass study, the above ground biomass was calculated.
d. The expansion factor multiplied by the total calculated biomass of trees on the sample sub-plot gave an estimate of the aggregate of all the trees on the hectare of land.
e. Below Ground Biomass (BGB) was estimated by multiplying the Above Ground Biomass (AGB) by a constant2 (it is estimated that 25% of AGB is root biomass)
f. Total tree biomass (TB) was calculated by adding Below Ground Biomass (BGB) to the AGB.
g. The total tree biomass was converted to Total Carbon (TC) by multiplying the total biomass by the carbon fraction using the IPCC default value (IPCC 2006).

TC = 0.46* TB

Estimating tree growth rates

To derive the annual increment of the different trees in M3/ha/yr, tree parameters (dbh and height) were used. The procedure used was as follows: Estimating the relationships of dbh:height, dbh:age, height:age and calculated the best fit line. The individual tree stem volume in (M3) was calculated by predicting the stem volume at ages 5, 10, 15 etc. The following formula was used:

$$V1 = \pi \frac{(di/200)2\ h1}{\rho}$$

Where: V1= Volume of tree m^3 , h1= Height of tree in metres, d1= Diameter of tree in cm
ρ = form factor (a form factor of 3 to cater for taper has been used for all tree species). Form factor (*ρ)* is the ratio of the volume of a tree or its part to the volume of a cylinder having the same length and cross section as tree. *ρ = V/Sxh, where V* is the tree volume in cubic units, *S* is the basal area, *h* is the height of the tree The annual increment per tree at age 5, 10, 15, etc. is calculated as the increase in volume between the two ages (e.g. volume at age 15 minus volume at age 10) divided by 5 years. The Current Annual Increment (CAI) per tree is then multiplied by the number of trees as in the technical specification to obtain the annual volume increment per hectare (M3/ha). Appendix ii shows the graphic representation of dbh: age and height: age relationships and CAI.

The growth rates of trees in the area were determined by undertaking tree measurements of known age. This is important to determine the annual stem volume (M3/yr). To determine growth rates, the dbh-age, height-age, volume-age relationships and Current Annual Increment were generated. The methods used to calculate the growth rates are described by ECCM 20083.

Average carbon stock

The carbon sequestration potential is based on the average net carbon storage in biomass (above and below ground). The average carbon stock sequestered over the crediting period is calculated using the following equation: CAvg = Σ(CABG + CAAGB) Where CAvg = Average mass of carbon sequestered over the crediting period; CABG = Average carbon in below ground biomass; CAAGB = Average carbon in above ground biomass

Above ground biomass

The carbon in the above ground biomass is calculated using an allometric equation (NBS 2003). The general equation for tree size dependent equation is as follows: ln(PWF) = a + b*ln(D) + c*ln(HT) + d*ln(CR) where: ln = natural logarithm PWF = predicted wet weight of tree D = diameter at breast height HT = tree height (from the ground) CR = crown width In this equation, constants a,b,c & d are different for two diameter class levels of; below 20 cm, and between 20cm and 60cm. Trees with D < 20cm Wet-wt = Exp**(**0.5*0.09937-0.909575+1.544561*ln(D)+0.50663*ln(HT) + 0.333346 * ln(CR)**)**

Trees with D > 20 AND D < 60cm Wet-wt = Exp(0.5*0.0892-1.795491+1.943912*ln(D)+0.473731*ln(HT)+ 0.245776*ln(CR))

Species specific wood density values obtained from the Africa Agroforestry database were used (Carsan et al, 2012)4. Some of the selected specific wood densities for the identified tree farming systems are shown in Table 4. The carbon stock of all trees was summed and divided by the area sampled and extrapolated to a hectare to give an estimate of carbon density in tC ha-1.This is the estimated Carbon stock before project intervention for the farmland.

Carbon sequestration

The long term average carbon storage was calculated separately for each of the identified tree farming systems i.e. Coffee agroforestry (Figure 7), Boundary planting (Figure 8), alley cropping (Figure 9) and intercropping (Figure 10).

Results and Discussion

About 57 different tree species in varied size classes and some of known age were encountered in the survey plots. Amongst the ten most abundant on-farm trees include; *Albizia coriaria, Markhamia lutea, Cordia millenii, Persia Americana and Premna spp.* were most abundant in the Mt Elgon landscape. *Eucalyptus grandis* and *Pinus caribaea* that are being promoted under the Farm Income Enhancement and Forest Conservation (FIEFOC) project were the most outstanding exotics in the landscape. Indigenous tree species that are amongst the top dominant tree species on surveyed farms across the districts are shown in Figure 6. *Albizia coriaria* and *Markhamia lutea* each accounted for about 14% species composition on-farm tree species, *whilst Cordia millenii*, the third most abundant tree species, accounted for 6%. The 20 most abundant tree species constituted 85% of the total 57 tree species recorded during the survey.

Table 1 shows the average of 20 plants of each species and tabulated in height of stem in centimeter, stem collar diameter, number of leaves, leaves and stem fresh and dry weight.

The above-ground biomass comprises all woody stems, branches, and leaves of living trees, creepers, climbers, and epiphytes as well as herbaceous undergrowth. For agricultural lands, this includes crop and weed biomass. To measure the biomass of vegetation which includes trees is not easy, especially in mixed, uneven-aged stands. It requires considerable labor and it is difficult to obtain an accurate measurement, given the variability of tree size distribution. The focus of this section will be on estimating carbon stocks of forests that are subject to deforestation and degradation. The mean carbon stock in aboveground tree biomass per unit area is estimated based on field measurements in fixed area sample plots or temporary sample points that are selected randomly or systematically.

Table 1: Over ground Biomass

Specieies	**Ht. of stem (cm)**	**Coller Dia. (mm)**	**No.of leaves**	**Fresh wt.of leaves (gm)**	**Dry wt.of leaves (gm)**	**Fresh wt.of stem(gm)**	**Dry wt.of stem(gm)**
Gupti	102	10.3	18	15.3	4.2	24.9	7.7
Bhirra	46	6.2	30	4.5	2	4.1	1.9
Tinsa	34.8	5.5	20	4	1.8	2.9	1.7
Khirni	59.2	8.8	25	16.8	6.4	17.1	6.9
Thailand imli	88.8	8.4	103	6.8	3	15.2	10.4
Rakt chandan	26.6	3.1	11	2.7	1	1.1	0.4
	59.57	**7.05**	**34**	**8.35**	**3.07**	**10.88**	**4.83**

In view of table 1 gupti (102) shows maximum height and Rakt chandan shows minimum height in selected species where as maximum dry weight (Stem) was observed in Thailand imli (10.4 gm) and minimum in Rakta chandan (0.4). Maximum leaves dry weight were observed in gupti (24.9 gm) and minimum in Rakta chandan (1.1 gm).

In view of calculation of difference between fresh and dry weight table 2 shows moisture content percentage of above ground biomass for each selected species.

Table 2: Above ground biomass moisture content in percent

Species	Moisture content (%)	
	leaves	Stem
Gupti	72.55	69.08
Bhirra	55.56	53.66
Tinsa	55.00	41.38
Khirni	61.90	59.65
Thailand imli	55.88	31.58
Rakt chandan	62.96	63.64
	60.64	**53.16**

Table 3: Underground Biomass

Species	Root thickness(mm)	Root Length(cm)	No.of fibrous root	Fresh Wt. of Root(gm)	Dry Wt. of Root(gm)	watee loss (%)
Gupti	11.40	32.20	38.60	13.10	4.30	67.18
Bhirra	7.50	21.00	16.80	8.00	2.50	68.75
Tinsa	4.90	18.30	18.00	4.00	2.00	50.00
Khirni	9.10	32.80	70.80	9.60	4.60	52.08
Thailand imli	9.40	30.60	27.60	11.00	6.30	42.73
Rakt chandan	8.30	21.40	20.40	2.20	0.90	59.09
	8.43	**26.05**	**32.03**	**7.98**	**3.43**	**56.64**

Conclusion

Nowadays, there is a growing demand for reliable information on forest and tree carbon stock at both country and global levels. This implies that monitoring the state and changes of forests carbon pools is an important element. Therefore, measuring and estimating carbon stocks and changes in carbon stocks in various pools are very important to carbon trading and marketing. This requires transparent and verifiable methods, quantification of uncertainties and appropriate monitoring systems for carbon stocks. The change in carbon stock with the dynamics of land use changes may result into either carbon emission or sequestration. This paper outlines the different carbon pools and the concepts of carbon accounting.

Popularization and adoption of carbon sequestration services will help replenish the various ecosystem services e.g. enhancement of watershed management that will make the region stand to benefit mainly downstream water users e.g. of the River Manafwa system and corporate bodies such as the National Water and Sewerage Corporation will incur less expenses in water treatments. In order to supply some of these ecosystem services, upstream land users (who comprise the primary suppliers) may be supported to undertake improved land management practices e.g. on-farm planting and contour reinforcement with agroforestry trees. Strategically, carbon funds can be directed towards enabling land users offset cost of inputs e.g. labour, tools and elite planting materials, which currently hinder use of the land management options.

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