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Estimation of above ground biomass and carbon stock in forests of Prayagraj, Uttar Pradesh

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Abstract
The present study deals with the estimation of above ground biomass and carbon stock of forest sites of Prayagraj by using field measurement method (destructive and non-destructive). Above ground biomass and carbon stock of trees were estimated by non-destructive method and allometric equation whereas destructive method used for shrubs and herbs. In this study maximum total above ground biomass recorded for the site ALD-1 (Koraon range) (27.84 t ha-1) and minimum for the site ALD-4 (Manda range) (8.50 t ha-1) and carbon stock was also maximum at the site ALD-1(Koraon range) (13.08 t ha-1) and minimum at the site ALD-4 (Manda range) (3.99 t ha-1). Basal area and tree density were also maximum at the site ALD- 1(Koraon range) and minimum at the site ALD-4 (Manda range). Trees stored maximum biomass hence trees sequestered maximum carbon and herb and litter layer sequestered minimum amount of carbon. Some external and internal factors affect the wealth of forests which affects the biomass and carbon stock. Study of above ground biomass and carbon stock provide data for forests of Prayagraj which can be use for further study.

Keywords: above ground biomass, carbon stock, field measurement method, allometric equation, basal area, tree density

Introduction

Carbon exists in the atmosphere in the form of carbon dioxide and constitutes about 0.04% of the atmosphere. In the recent years, it has gained a lot of attention as a greenhouse gas and increase in greenhouse gas causes global warming and global climate change. Climate change is one of the most serious problem to the environment as it has influenced the climate pattern of the world. Climate Change (IPCC 2007) [13, 14] report shows that there is continuously increase in average temperature of air and ocean, the melting of snow and ice occur and there is also rise in global sea level.. The main cause of this climate change is continuously increase of green house gases (GHG) in the atmosphere. Due to green house gases the atmosphere warms up. Human activities effectively cause the release of some green house gases into the atmosphere. These green house gases are CO2, CH4, N2O. Out of these gases carbon dioxide (CO2) is the main greenhouse gas which is drastically bringing climate change. Due to increase in population, a large demand for fuel wood, fodder and timber some anthropogenic activities like industrialisation, deforestation, forest degradation and burning of fossil fuel, increased and these activities are responsible for increase in the level of carbon in the atmosphere and disturbed the global carbon cycle. However, nature has its own mechanism of sequestering and storing the carbon in its reservoirs or sinks hence forests have been identified as a potential ecosystem to diminish climate change. So carbon sequestration is a process for removing CO2 from atmosphere by plants through photosynthesis. Plants stored this carbon in vegetation in the form of biomass and organic matter in the soil (Vashum & Jaya kumar 2012) [26]. Carbon sequestration also explains as long-term storage of carbon dioxide or other forms of carbon in the biosphere such as the oceans, terrestrial biomass, soils and geologic formation to diminish global warming and avoid climate change. Different terrestrial ecosystems like forests, grasslands and agricultural ecosystems have different capability for carbon storage but forest ecosystem have more capability for carbon storage per unit area than any other type of ecosystem. So forest plays key role in the global carbon cycle as carbon sinks of the terrestrial ecosystem. The carbon sequestered or stored in the trees of forest are mostly referred to as the biomass of the tree or forest or biomass is the total amount of living organic matter in trees expressed as oven-dry tons per unit area in a forest ecosystem. Analysis of biomass is an important facet in carbon sequestration and also important element in national developmental planning, scientific studies of ecosystem productivity and carbon budgets, etc. Biomass also forms the major source of energy in the ecosystems and it is for nearly 50 % of world's population and forest biomass is the main source of food, fodder and fuel, and its more consumption leads to forest degradation. The amount of carbon is determined by the stored amount of biomass in a forest (Brown *et al*. (1999) [2]. Biomass and carbon (C) naturally stored by forests so the forests are the natural store house for biomass and carbon. Forest biomass contains approximately 80% of above ground terrestrial carbon (C) and 40% of below ground carbon therefore, forests are considered as important sink for atmospheric carbon dioxide

(CO_2) and provide a large potential for temporarily storing atmospheric CO_2 in terrestrial ecosystems.

The Intergovernmental Panel on Climate Change (IPCC) identified five carbon pools of the terrestrial ecosystem involving biomass, namely the aboveground biomass, below- ground biomass, litter, woody debris and soil organic matter. The above-ground biomass constitutes the major part of the carbon pool among all the carbon pools, Estimating the amount of forest biomass is very important for observing and finding the amount of carbon that is missing or emitted during deforestation, and it will also give us an idea about the capacity of the forest that how much carbon sequestered and stored by the forests in the forest ecosystem. So estimation of forest carbon stocks are depended upon the estimation of forest biomass. Carbon stocks of forests are not estimated directly; however, many authors assume that the carbon concentration of tree parts to be 50% or 45% of the dry biomass. This paper, aims to assess the above ground biomass and vegetation carbon stock stored by forests of Prayagraj District.

Materials and Methods

Study Area

a. Geography

Prayagraj district is located between 24° 47' N and 25° 47' N latitudes and between 81° 19'E and 82° 21'E longitudes and it is a height of 90 m above sea level. It covers an area of 5482 km2. This district lies in the southern part of the state in the Gangetic plain and adjoining Vindhyan Plateau of India. Prayagraj district is surrounded by districts Bhadohi and Mirzapur in the East, Kaushambi and Banda in the west, Pratapgarh and Jaunpur in the North and Banda and Madhya Pradesh are in the south. Ganga and Yamuna are the main rivers which are flowing through the District. These rivers divide Allahabad in three different regions, Gangapar, Yamunapar and Dwaba. Allahabad consists of the Gangapar, Yamunapar and the city whereas Dwaba area comes under the Kaushambi district. Northern part of the district is Gangapar region and southern part of the district is Yamunapar region. Gangapar have rich loam soil and more suitable for agriculture and Yamunapar have partly rocky soil which is not more beneficial for agriculture.

b. Climate

A humid subtropical climate occurs in Prayagraj district. There are three different seasons: a hot, dry summer, a cool, dry winter and a hot, humid monsoon occur in this district. Summer lasts from March to September. Winter season spread from middle November to February. The average annual temperature ranges between 5˚ C to 45˚ C with maximum temperature 48 °C. The monsoon spread from June to September. The average annual rainfall ranges between 1000 mm to 1200 mm and the maximum rainfall occurs in July - August.

c. Soil

Mainly four types of soils, are found in Prayagraj: (1). clay loam to sandy loam which is found in 48 % area of the district (Shankargarh, Koraon, Meja and Manda) (2). Loam and sandy loam which is and found in 10 % area of the district (Jasra, Karchhana, Chaka and Kaundhiyara) (3). Sandy loam to sodic which is and found in 15 % area of the district (Pratappur, Handia and Phulpur) (4). Sandy loam and clay found in 27 % of the district (Phulpur, Saidabad and Soraon).

d. Forestry

Forests of Prayagraj cover an area of 129.21 km2 which is 2.36 % of the total geographical area of the district. Forests of Allahabad mostly exist in the Yamunapar region. The forest cover is limited Koraon, Shankargarh, Manda and Meja. The chief varieties of trees found in these forest are *Butea monosperma, Emblica ofbicinalis, Terminalia arjuna, Ziziphus nummilaria, Holoplelea inegrifolia, Madhuca indica, Salmalia malabarica, Boswellia serrata, Ficus religiosa, Ficus racemosa, Ficus virens, Acacia catechu, Terminalia chebula, Buchanania lanzon, Terminalia belerica, Acacia arabica, Dalbergia sissoo, Tectona grandis, Azadirachta indica, Terminalia bellarica, Diospyros melanoxylon* etc.

The study was conducted in Yamunapar region of Prayagraj district and four sites have been selected in Prayagraj district for study named as ALD-1, ALD-2, ALD-3 and ALD-4. Description of the selected sites were given below.

Table 1

S.No.	Site ID	Latitude	Longitude	Elevation(m)	District	Range
1.	ALD-1	24˚ 52' N	82˚05' E	179m	Praayagraj	Koraon
2.	ALD-2	25˚ 13' N	81˚35' E	138m	Prayagraj	Shankargarh
3.	ALD-3	25˚ 07' N	82˚ 08' E	148m	Prayagraj	Meja
4.	ALD-4	25˚ 03' N	82˚15' E	134m	Prayagraj	Manda

Methodology

Forest biomass and carbon stock can be estimated through field measurement, remote sensing and GIS methods. Field measurement method is of two type's i.e. destructive and non-destructive method. Destructive method is also known as harvest method and it is most direct method to estimate above ground biomass and carbon stock accumulated in the forest. In this method all the trees of study area are harvesting and measuring the fresh and dry weight of all the components like tree trunk, leaves and branches of harvested tree. This method is suitable for a small area and small tree and it is resource and time consuming, expensive and not feasible for a large area. This method is not applicable fo degraded forests containing threatened species.

The second method of field measurement is non-destructive method and it is indirect method. In this method biomass of a tree is estimated without felling or harvesting the trees. The above ground biomass is estimated by simply measuring the diameter at breast height (DBH) and height of the tree and then allometric equations was applied for the estimation of above ground biomass and carbon stock. Allometric equations are developed for estimation of the biomass and carbon sequestration in forest ecosystem with the help of forest inventories data. This method is also applicable for degraded forests containing rare species and also for those forests where harvesting is not feasible.

Remote sensing and geographical information system (GIS) methods are another methods for the estimation of biomass in which data is gained from distance with the help of instruments and satellite.

Plant species were identified with the help of Flora of Uttar Pradesh, Flora of Allahabad, and herbarium section at Department of Botany of University of Allahabad.

Sampling Design

In the present study the non-destructive approach was adopted for estimation of the above ground biomass. The study area was identified on the basis of the physical characters and dominance of the vegetation. For the classification of different forest and for identification of sites, satellite data was used. For the study, one super plot of 250 m x 250 m size was laid down at each site and four sample plots, each of 31.6 m x 31.6 m (0.1 ha) size in all the four directions

i.e. NE, NW, SW and SE, respectively were laid in each super plot. Two plots of 5 m x 5 m were laid down for AGB estimation of shrub species, five plots of 1m x1m for AGB estimation of herbaceous layer in each 31.6 m x 31.6 m (0.1 ha) sample plot.

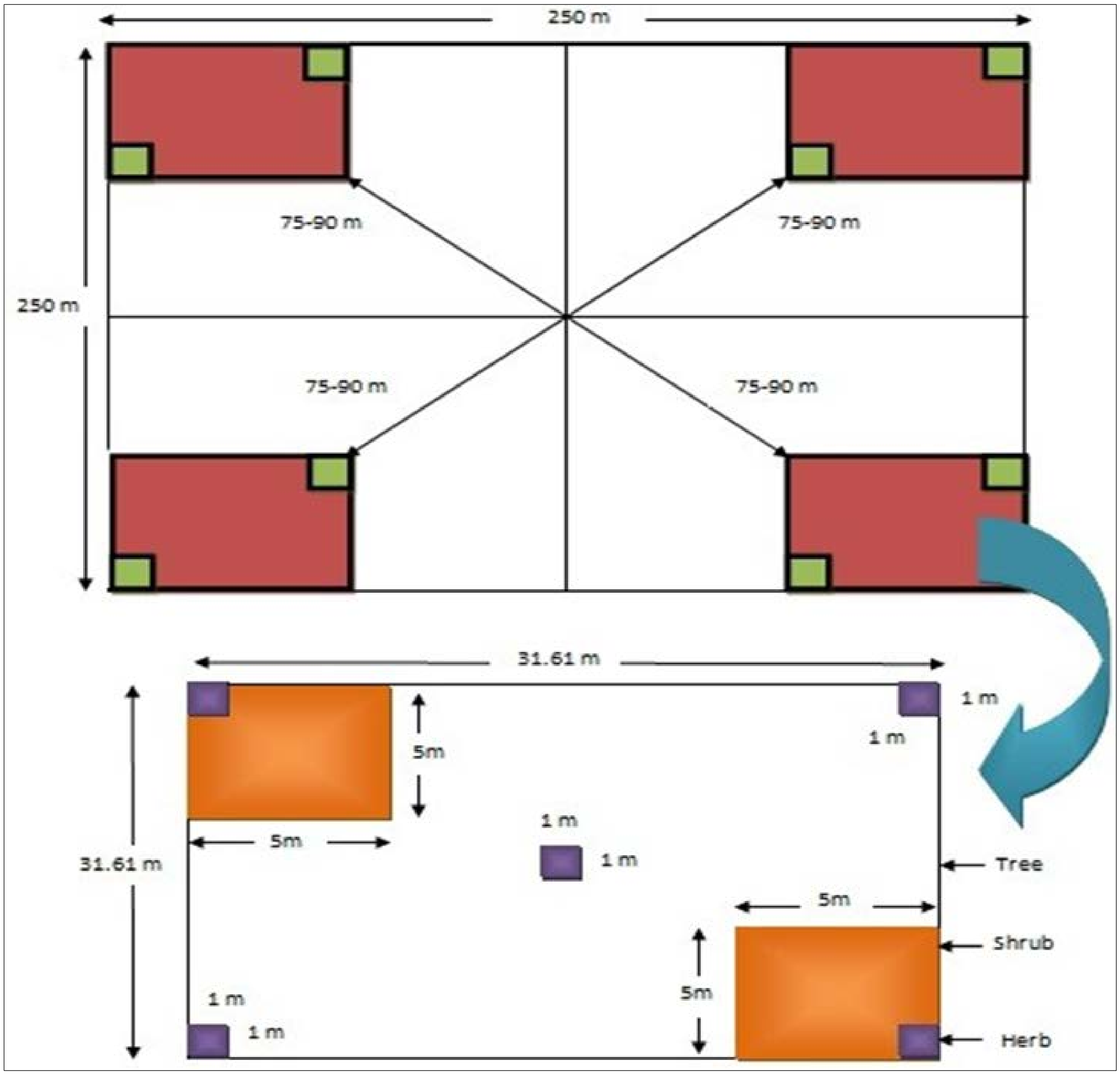

Fig 1: Plot design for tree, shrubs and herbs sampling.

Estimation of volume and above ground biomass of Trees

The height of the tree was measured with the help of Blume Leiss Hypsometer (which is based on trigonometric method) and DBH of the tree was recorded, by using digital tree caliper (Hagl of, Sweden) or measuring tape in 0.1 ha sample plot (31.6 x 31.6m). All trees were marked with number. An allometric equation approach was adopted for non – destructive method to estimate biomass, which requires height and DBH of the tree, volume equations and species specific gravity of every tree. The tree volume of each individual tree species was calculated by using local volume equations as well as general volume equations depending on the availability of each species. Tree volume equation obtained from State Forest Department and Forest Survey of India (FSI, 2006) and species specific gravity obtained from Forest Research Institute (FRI, 1996, FSI, 1996). Tree biomass was calculated by multiplying volume of the tree with species specific gravity. The plants with <10 cm diameter will also be measured for estimation of biomass and carbon stock. For the plants with <10 cm diameter expansion factor obtained by relating biomass and basal area of the components >10 cm diameter and coefficients and obtained value applied for components with <10 cm diameter to assess biomass.

Biomass (t ha-1) = volume of tree × species specific gravity

Estimation of above ground biomass of Shrubs

For the estimation of shrub biomass, total number of thick, medium and thin tillers were counted species wise as well as bush wise in two opposite 5×5 m plot within 0.1 ha plot. A piece of tiller of about 50 cm from each girth class i.e. thick, medium and thin tillers were harvested and after taking the fresh weight, the samples were packed in paper envelope and brought to laboratory for oven drying the samples (at 80o C for 48 hours) and then oven dry weight was taken for estimation of shrub biomass.

Estimation of above ground biomass of Herbs and Litters

For the estimation of herb plants biomass, all herbs were harvested from 1m ×1 m plot of 0.1 ha sample plot and collected all litters from 1m x1m plots. The fresh weight of harvested herbs and litters were taken in the field and then samples were brought into the laboratory and taking dry weight after oven drying the samples at 80o C for 48 hours and the weight showed as biomass.

Biomass Estimation of Bamboo

For estimating the biomass of the bamboo species, number of rosettes in 0.1 ha, number of culms per rosettes, girth, length of the culms etc. will be measured.

Biomass of bamboo species clumps (where ever present) was estimated by using the biomass equation-

Y= -3225.8 + 1730.4 DBH, $R2 = 0.83$, $P \leq 0.001$, where Y= Biomass (kg) clump-1 where, DBH = clump diameter at breast height

Estimation of total above ground biomass (AGB)

Total above ground biomass was estimated by adding the biomass of different components (tree, bamboo, shrub, herb and litter) calculated from four plots (each 0.1 ha) and total above ground biomass denoted by t ha-1 for each plot.

Estimation of Carbon content

The plant biomass of a sampling plot was converted to carbon stock after multiplication with the default value of carbon fraction 0.47 suggested by IPCC (2006) [12].

Carbon (t ha-1) = Biomass (t ha-1) × 0.47

Results

Observations on tree density, basal area, above ground biomass and carbon stock of the study sites were recorded and showed in given table. Maximum tree density was recorded for the site ALD-1 (213 tree ha-1) followed by site ALD-2 (158 tree ha-1), ALD-3 (144 tree ha-1) and ALD-4 (121 tree ha-1). Maximum basal area was recorded at the site ALD-1 (245.72 m2 ha-1) followed by ALD-2 (126.29 m2 ha-1), ALD-3 (91.57 m2 ha-1) and ALD-4 (76.93 m2 ha-1). Above ground biomass was maximum at the site ALD-1 (27.84 t ha-1) followed by the sites ALD-2 (20.66 t ha-1), ALD-3 (12.02 t ha-1) and ALD-4 (8.50 t ha-1) and carbon stock value was also maximum the site ALD-1(13.08 t ha-1) followed by the sites ALD-2 (9.71 t ha-1), ALD-3 (5.64 t ha-1) and ALD-4 (3.99 t ha-1). Tree biomass was maximum at the site ALD-1 (16.97 t ha-1) followed by ALD-2 (10.60 t ha-1), ALD-3 (6.91 t ha-1) and ALD-4 (5.54 t ha-1). Maximum biomass of shrub was recorded at the site ALD-2 (5.46 t ha-1) and minimum at the site ALD-4 (1.87 t ha-1). Herb and litter biomass was maximum at the site ALD-1 (3.01 t ha-1) and minimum at the site ALD-4 (1.09 t ha-1). Bamboo biomass was recorded for the sites ALD-1 (4.11 t ha-1) and ALD-2 (2.46 t ha-1).

Table 2

Sites	Tree density (tree ha-1)	Basal area (m2 ha-1)	Total above ground biomass (t ha-1)
ALD-1	213	245.72	27.84
ALD-2	158	126.29	20.66
ALD-3	144	91.57	12.02
ALD-4	121	76.93	8.50

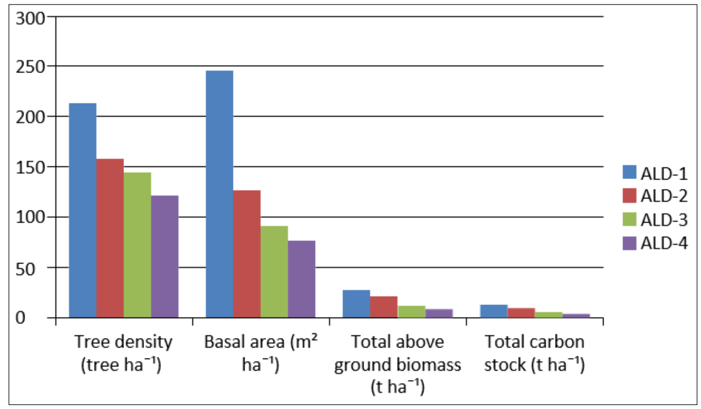

Fig 2: Chart shows tree density, basal area, total above ground biomass and total carbon stock of different study sites.

Table 3

Sites	Above Ground Biomass (t ha-1)				
	Tree	Shrub	Herb and litter	Bamboo	Total
ALD-1	16.97	3.75	3.01	4.11	27.84
ALD-2	10.60	5.46	2.14	2.46	20.66
ALD-3	6.91	3.13	1.98	-	12.02
ALD-4	5.54	1.87	1.09	-	8.50

Table 4

Sites	Total Above Ground Biomass (t ha-1)	Total Carbon Stock (t ha-1)
ALD-1	27.84	13.08
ALD-2	20.66	9.71
ALD-3	12.02	5.64
ALD-4	8.50	3.99

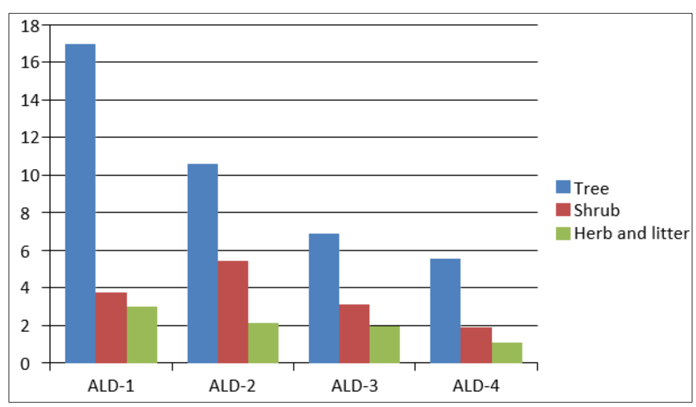

Fig 3: Chart shows total biomass of tree, shrub, herb and litter layers

Discussion

It is founded that the biomass and carbon stock are estimated with the help of destructive and non-destructive method (field measurement method) and tree density, height, diameter at breast height and basal area are the parameters which contributed to the above-ground biomass and these parameters differ at various sites. Some external and internal factors like type of forest, disturbances, total annual rainfall and geographical location of the forests, etc. due to which variation in biomass at various forest sites can be occur (Terakunpisut *et al*. 2007) [24]. Some other factors like deforestation, excessive mining, grazing by the animals, burning, industrialization, etc. also affect the wealth of forests. These all factors affect the biomass of the forests. Such as mining is the big problem for the site ALD-2 (Shankargarh range) and due to this reason day by day forest sequestered less amount of carbon. The size of stem also affects the biomass like small to medium size stems have more capacity to sequester carbon as compared to the big size stem (Upadhaya *et al*. 2015) [25]. Trees sequester more carbon in forest ecosystem and in this study tree species *Butea monosperma* sequestered highest amount of carbon than any other species of tree. ALD-1 (Koraon range) sequestered maximum amount of carbon because of dense vegetation and less damage to the forest however other sites have more damage in the forest and less dense vegetation.

Conclusions

With the help of results it is concluded that for various study sites, values of tree density, basal area, total above ground biomass and carbon stock varied. These values were maximum at the site ALD-1 (Koraon range) and minimum at the site ALD-4 (Manda range). It is also concluded that trees sequestered and stored more biomass and carbon than shrubs, herbs, litters and bamboo in these forest sites. Herbs sequestered and stored minimum amount of biomass and carbon.

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