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Estimation of Carbon Stock of the Trees in the Herbal Garden of Telangana State Medicinal Plant Board, Aziznagar, Hyderabad, India

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Abstract: Carbon staock estimation studies were carried out during November 2019 of the tree species with ≥10-30cm Girth at Breast Height (GBH) and ≥31cm GBH at Herbal Garden of Telangana State Medicinal Plant Board (TSMPB). A total of 1.5-hectare (ha) area was covered 6.39% of the total geographic area of 23.47 ha. The study area is dominated by *Leucaena leucocephala*, *Phyllanthus emblica*, *Azadirachta indica*, *Pterocarpus santalinus, Gliricidia sepium*, *Aegle marmelos*, *Dalbergia sissoo*, *Terminalia arjuna*, *Albizia lebbeck* and *Bauhinia purpurea.* A total of 50 species were documented. Total standing crop biomass was estimated based on volume and specific gravity. Total carbon accumulation was estimated using carbon factor 0.47. A total of 326.388 Megagram **(**Mg tonnes) was accumulated in the sampling plots.

Keywords: Carbon staock, Crop biomass, Geographical area, Herbal garden, Telangana state

The Intergovernmental Panel on Climate Change (IPCC) recommends that actions be taken to limit the earth's temperature increase to no more than 2.0°C, and preferably to no more than 1.5°C above preindustrial levels. An increase of just 1.5 to 2.5ºC could spell extinction for 20-30% of all species, and above 3.5ºC, 40-70% of global species could be wiped out (IPCC, AR6-SCOP/2017). Forest vegetation contains over 350,000 teragrams (Tg) of carbon and plays a major role in the global carbon cycle. Estimation of above-ground biomass (AGB) is an essential aspect of studies of carbon sequestration, carbon stocks and to study the effect of deforestation on global carbon balance because it constitutes about 60% of total phytomass and is involved in the regulation of atmospheric carbon concentration (Ketterings et al 2001). Tree inventories are an efficient way of assessing forest carbon stocks and emissions to the atmosphere during deforestation (Chave et al 2004). Biomass represents the largest organic carbon pool in a mature tropical forest ecosystem. Despite its importance, it is treated as a poorly quantified stock, because changes in biomass are dramatically induced by gap dynamics and succession after natural and human-induced disturbances. Moreover, biomass shows wide variability within and between forest communities (Sarmiento et al 2005). The change in forest biomass has been considered a key characteristic of the forest ecosystem. Biomass variability can be explained by several factors like climate, topography, soil fertility, water supply, and wood density, distribution of tree species, tree functional type, and forest disturbance (Luizao et al 2004, Sicard et al 2006). At present, not much information is available on the estimates of carbon sequestration potential in urban areas. Hence, the study was conducted to estimate carbon stock of tree species at herbal garden, Aziz nagar, Hyderabad.

Study area: The study area is government land located at Aziznagar, Rajendranagar Mandal, Rangareddy district ($17^0$20'03.17" N to $78^0$21'07.58" E and $17^0$21'05.04" N to $78^0$21'05.04" E) of Telangana and measuring 23.47 ha of Telangana State Medicinal Plants Board (TSMPB), Health, Medical, and Family Welfare Department are developing the greenery and maintaining the area. In a portion of this area, more than 500 varieties of medicinal plants are conserved *ex-situ*, with the financial aid of the National Medicinal Plants Board (NMPB), Ministry of Ayush, Government of India and Government of Telangana under various schemes in different years. TSMPB maintains a model nursery in this study area to supply quality planting materials to farmers as well as for distributing medicinal plants to institutions, households, etc. Mother stock groves of 20 medicinal species have been raised in different years. Apart from these, a few trees of *Azadirachta indica, Hardwickia binata, Leucaena leucocephala* are existing in the area naturally. The species existing in the garden are utilised for propagation in model nursery. About 80 varieties of medicinal plants are being raised and maintained at any point of time to distribute to the people to create awareness of medicinal

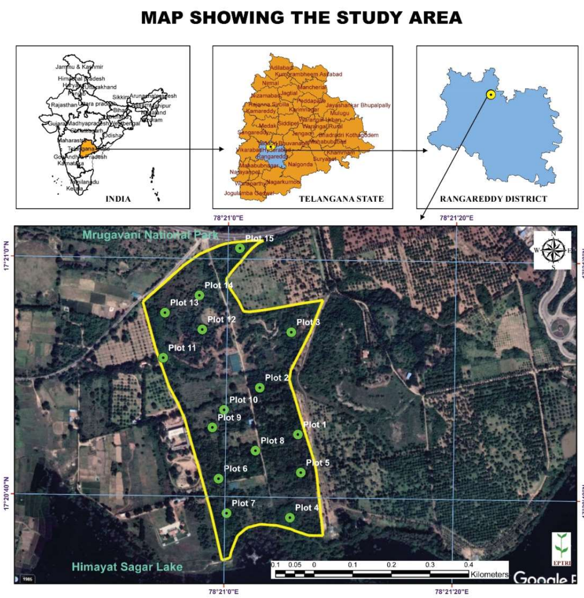

Fig. 1. Map of the study area

plants and implement various schemes like home herbal garden, school herbal garden.

MATERIAL AND METHODS

The primary data was collected from the study area in 15 randomly stratified sample sites as shown in the map. Thus, a total of 1.5 ha area was sampled covering 6.39% of the total 23.47 ha study area. A total of 15 sample sites of 31.62 m x 31.62 m size were identified based on Normalized Difference Vegetation Index (NDVI) values. The said methodology was a comprehensive format design of Vegetation Carbon Pool (VCP) Assessment by National Carbon Project, Indian Institute of Remote Sensing (IIRS) (Singh and Dadhwal, 2008) and the methodology was adopted for the current study.

The following data were collected from each plot

1. A stratified random sampling plot was laid with the size of 0.1 ha (31.62 m x 31.62 m)
2. In the sample plot all tree individuals of more than or equal to 10 cm GBH were documented by measuring girth at the height of 1.3 m.
3. The data for each species was classified based on GBH classes: ≥10-30cm, ≥31-60cm, ≥61-90cm, ≥91-120cm, ≥121-150cm, ≥151-180cm, ≥181-210cm, etc.

Primarily the team has documented the species available in the plots. All the plant taxa present in the sample plots were photographed during the field survey. The total number of individuals of all species together was also recorded. Each species was considered in categories, one between 10cm and 30cm girth class and the other above 30cm girth classes. The estimation of volume, biomass, and carbon stocks of trees in the study area was calculated in 15 stratified sample sites.

Basal area: Basal area of each tree was calculated by using the following standard formula:

$dbh(cm) = gbh(cm) / \pi$, $dbh(m) = dbh(cm) / 100$, Radius(r) $= dbh(m)/2$. Basal Area $(m^2\ ha^{-1}) = \pi r^2$

Volume estimation: Volume of each tree of ≥10cm diameter on above was estimated using the selected volumetric equation developed and compiled by FSI (1996). The formula was selected based on the availability of equations developed by Forest Survey of India.

Criteria 1: Species specific volumetric equation of the same study area.

Criteria 2: If criteria one is not available the species specific volumetric equation of neighboring area of same phytogeographical zone were considered.

Criteria 3: If criteria one and two are not available the volumetric equation belongs to the same species or same genus of the same state or other states has been selected by checking equations of different regions and finally the appropriate equation was selected.

Criteria 4: If criteria one, two and three are not available for those species, the common equation of the same study area is selected.

Specific gravity: Specific gravity values of different species were selected from literature. These values are available for 75-80% of species. For stems with unknown specific gravity, the arithmetic mean of all known species was substituted and used in a particular sample plot.

The estimated volume was converted into biomass by multiplying with specific gravity .Biomass of all the trees was summed up to obtain biomass in a 0.1 ha area.

Biomass (tonnes) = Volume (m^3) × Specific Gravity

Below-ground biomass (BGB): In the present study, 20% of the above-ground biomass was considered as root biomass as per the procedure adopted by Achard et al (2002), Houghton et al (2001), Montagu et al (2002), Ramankutty et al (2007).

Total biomass (TB): Total biomass of each plot was calculated by the addition of total above ground biomass (TAGB) and below ground biomass (BGB).

Estimation of carbon stock : Estimation of carbon stocks from the biomass is done by multiplying the total biomass by a conversion factor that represents the average carbon content in biomass. In the present study, the default 0.47 carbon fraction was used for estimation of carbon (McGroddy et al 2004).

Carbon (tonnes) = Biomass (tonnes) × Carbon %

RESULTS AND DISCUSSION

There are 50 species (41 genera and 23 families) with a total strength of 1936 tree individuals (<30cm GBH 1602 individuals and >30cm GBH 334 individuals) in the study area. The mean stem density is 129 stems ha^{-1}. The top ten dominant tree species are *Leucaena leucocephala* (549) followed by *Phyllanthus emblica*, *Azadirachta indica*, *Pterocarpus santalinus*, *Gliricidia sepium* , *Aegle marmelos* , *Dalbergia sissoo* , *Terminalia arjuna* , *Albizia lebbeck* and *Bauhinia purpurea* which shares 81.06% of the total population of the sampled inventory. However, different sampling plots (0.1ha) showed diversity as per the species as well as total number of individuals is concerned. This ranges from 33 to 282 individuals in different plots.

Trees ≥10-30 GBH: Trees having ≥10-30cm GBH, share 66.39% in all sampling plots. The values range between 1.07-17.41 m^2 ha^{-1} for different sampling plots**.**

Basal area: The basal area ranged between 0.53-9.21 m^2 ha^{-1} in the sampled plots. The top ten dominant tree species are *Leucaena leucocephala* (17.95 m^2 ha^{-1}) followed by *Phyllanthus emblica*, *Azadirachta indica* , *Pterocarpus santalinus*, *Hardwickia binata*, *Gliricidia sepium*, *Aegle marmelos* , *Dalbergia sissoo*, *Terminalia arjuna* and *Bauhinia purpurea* . The top ten dominant tree species shared 84.36% of the total basal area.

Volume: The volume ranges between 2.23-78.16 m^3 ha^{-1} in the sampled plots. The top ten dominant species are *Pterocarpus santalinus* (80.85 m^3 ha^{-1}) followed by *Leucaena leucocephala*, *Azadirachta indica*, *Phyllanthus emblica*, *Terminalia arjuna*, *Gliricidia sepium*, *Aegle marmelos*, *Albizia lebbeck*, *Dalbergia sissoo and Hardwickia binata*. The top ten dominant tree species shared 87% of the total volume.

Biomass: The biomass ranges between 1.5-75.16 Mg ha^{-1} in the sampled plots. The top ten dominant species are *Pterocarpus santalinus* (78.18 Mg ha^{-1}) followed by *Leucaena leucocephala*, *Azadirachta indica*, *Phyllanthus emblica*, *Terminalia arjuna*, *Gliricidia sepium*, *Aegle marmelos*, *Pterocarpus marsupium*, *Dalbergia sissoo* and *Albizia lebbeck*. The top ten dominant tree species shared 90.37% of the total Biomass.

Trees ≥31 GBH: Trees having ≥31cm GBH, share 33.6% in all sampling plots. The values range between 0.8-6.2 m^2 ha^{-1} for different sampling plots while the mean value stands at 3.528±1.78 m^2 ha^{-1}.

Basal area: The basal area ranges between 1.0-10.4 m^2 ha^{-1} in the sampled plots while the mean was 5.56 m^2 ha^{-1}. The top ten dominant tree species are *Azadirachta indica* (31.4 m^2 ha^{-1}) followed by *Hardwickia binata*, *Albizia lebbeck*, *Pterocarpus santalinus*, *Leucaena leucocephala*, *Terminalia arjuna*, *Ficus religiosa*, *Dalbergia sissoo*, *Tamarindus indica* and *Phyllanthus emblica*. The top ten dominant tree species shared 81.42% of the total basal area.

Volume: The volume ranges between 1.3-175.8 $m^3$$ha^{-1}$ in the sampled plots while the mean value stands at 42.23m^3 ha^{-1}. The top ten dominant volume species are *Azadirachta indica* (407 m^3 ha^{-1}) followed by *Albizia lebbeck*, *Leucaena leucocephala*, *Pterocarpus santalinus*, *Hardwickia binata*, *Ailanthus excelsa*, *Terminalia arjuna*, *Ficus religiosa*, *Terminalia bellirica* and *Ficus benghalensis*. The top ten

Table 1. Quantitative attributes of ≥10 to ≤30 cm GBH tree individuals

Plot No.	Tree Individuals	Diameter	BA	Volume	Biomass	BGB	TB	Carbon
1	65	7.33	6.529	14.6539	9.38089	1.876	11.257	5.291
2	117	7.75	4.283	78.1664	75.5869	15.117	90.704	42.631
3	171	7.49	3.161	7.85375	4.78571	0.957	5.743	2.699
4	273	17.41	9.217	16.1594	9.71368	1.943	11.656	5.479
5	38	2.54	1.493	2.23513	1.49565	0.299	1.795	0.844
6	215	12.1	5.858	14.4421	11.1106	2.222	13.333	6.266
7	113	8.1	4.742	11.1184	7.98298	1.597	9.580	4.502
8	67	4	1.979	6.95662	5.18369	1.037	6.220	2.924
9	19	1.07	0.537	4.21967	2.46675	0.493	2.960	1.391
10	115	9.61	4.065	8.61461	5.40523	1.081	6.486	3.049
11	131	8.03	4.099	7.94158	4.81141	0.962	5.774	2.714
12	83	5.27	2.803	7.61789	5.64005	1.128	6.768	3.181
13	109	6.68	3.541	7.6258	5.01832	1.004	6.022	2.830
14	36	2.56	1.524	6.46335	4.13889	0.828	4.967	2.334
15	70	4.61	2.569	6.04083	3.88944	0.778	4.667	2.194
	1602		56.401	200.11	156.61	31.322	187.932	88.328

*BA=Basal Area; ABG=Above Ground Biomass; BGB=Below Ground Biomass; GBH=Girth at Breast Height; TB=Total Biomass dominant tree species shared 96.96% of the total volume.

Biomass: The biomass ranges between 0.9-121.67 Mg ha^{-1} in the sampled plots while the mean value stands at 28.14 Mg ha^{-1}. The top ten dominant Biomass species are *Azadirachta indica* (282.58 Mg ha^{-1}) followed *Albizia lebbeck*, *Pterocarpus santalinus*, *Leucaena leucocephala*, *Hardwickia binate*, *Terminalia arjuna*, *Ailanthus excelsa*, *Pterocarpus marsupium*, *Terminalia bellirica* and *Tamarindus indica*. The top ten dominant tree species shared 94.5% of the total Biomass.

Correlation of basal area and biomass of trees with ≥31cm diameter revealed a determination coefficient of R^2 is 0.9457. Rao et al (2013) reported R^2=0.944, 0.97 & 0.982 for trees outside forests of Kurnool district, Andhra Pradesh. Srinivasa Rao et al (2012a) reported trees outside forests of Kadapa district, Andhra Pradesh (R^2=0.986 & 0.9939). Srinivasa Rao et al (2012b) reported R^2 values from trees outside forests of Prakasam district, Andhra Pradesh (R^2=0.952, 0.986 & 0.871). Bhakthavathsalam (2010) reported R^2 values from Vengalammacheruvu reserved forest of Anantapur district, Andhra Pradesh (R^2=0.961). Patil, (2009) reported R^2 values from forests of Surat district (R^2 = 0.9061), Kashmir Valley (R^2 = 0.9232), Uttarkashi district (R^2 = 0.934) and Panna district (R^2 = 0.903) in North West India. A significant R^2 value of 0.98 by using basal area and 0.94 by using height and basal area was reported from tropical dry evergreen forests of peninsular India by Mani and Parthasarathy (2007). All above R^2 values are greater than obtained in the present study.

Total biomass (TB): The total above-ground biomass of ≥10-30cm (TAGB) and below ground biomass (BGB) ranged between 1.8-90.7 Mg ha^{-1} in the sampled plots with a mean of 12.53Mg ha^{-1}. It accounts for 187.932 Mg in the study area (Table 2). The total above-ground biomass ≥31cm (TAGB) and below ground biomass (BGB) ranged between 1.1-146 Mg ha^{-1} in the sampled plots with a mean value of 33.77Mg ha^{-1}. It accounts for 506.509 Mg in the study area (Table 2). The total biomass in study area (all the individuals) is 694.441 Mg.

Above ground biomass widely varies due to regional differences in stem size distribution, soil fertility, topography and disturbance (Rolim et al 2005, Sarmiento et al 2005, Castilho et al 2006, Malhi et al 2006, Muller-Landau et al 2006, Urquiza-Haas et al 2007). Above ground biomass varies from plot to plot in a forest area due to different stages

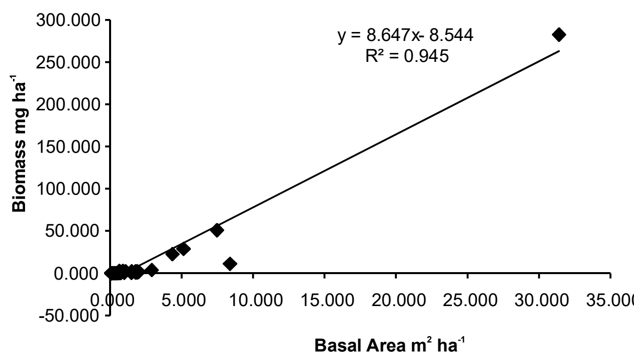

Fig. 2. Correlation between basal area and biomass of ≥31cm diameter

Table 2. Quantitative attributes of ≤31 cm GBH tree individuals

Plot number	Tree individuals	Diameter	BA	Volume	Biomass	BGB	TB	Carbon
1	22	4	6.535	30.471	20.651	4.130	24.781	11.647
2	39	6.2	10.382	82.426	53.113	10.623	63.735	29.956
3	5	0.8	1.193	2.552	1.562	0.312	1.874	0.881
4	9	1.65	3.433	37.407	22.520	4.504	27.024	12.701
5	22	2.91	3.244	2.239	1.433	0.287	1.720	0.808
6	27	4.11	7.414	124.117	85.824	17.165	102.989	48.405
7	15	1.77	1.637	1.297	0.897	0.179	1.076	0.506
8	38	6.22	9.090	20.571	13.738	2.748	16.485	7.748
9	14	3.72	10.191	175.808	121.669	24.334	146.002	68.621
10	27	3.76	5.501	58.083	40.087	8.017	48.104	22.609
11	17	3.17	5.296	21.419	12.064	2.413	14.477	6.804
12	39	6.15	8.763	24.903	18.060	3.612	21.672	10.186
13	5	0.81	0.963	1.818	1.225	0.245	1.470	0.691
14	24	3.24	3.608	6.154	5.004	1.001	6.005	2.822
15	31	4.41	6.146	44.161	24.245	4.849	29.094	13.674
	334		83.395	633.426	422.091	84.418	506.509	238.059

See Table1 for details

of forest growth cycles, habitat variation and tree density. Biomass variability can be explained by several factors like climate, topography, soil fertility, water supply and wood density, distribution of tree species, tree functional type and forest disturbance (Sicard et al 2006).

Carbon stock: The carbon pool ranges between 0.8-42.6 Mg ha^{-1}in the sample plots with a mean value of 5.9Mg ha^{-1} of ≥10-30cm GBH trees the total carbon pool in the study area is 88.328 Mg (A) (Table 1). The carbon pool ranges between 0.5-68.62 Mg ha^{-1} in the sample plots. The total carbon pool in the study area is 238.059 Mg (B) (Table 2). The total carbon pool in the study area (all the individuals A+B) is 326.388 Mg.

CONCLUSION

The study area is dominated by *Leucaena leucocephala*, *Phyllanthus emblica*, *Azadirachta indica*, *Pterocarpus santalinus, Gliricidia sepium*, *Aegle marmelos*, *Dalbergia sissoo*, *Terminalia arjuna*, *Albizia lebbeck* and *Bauhinia purpurea.* A total of 50 species were documented. These species were classified into two girth classes *i.e.* ≥10-30cm GBH and ≥31cm GBH. Total standing crop biomass was estimated based on volume and specific gravity. Carbon accumulations were estimated using carbon factor 0.47 and it estimated that a total of 326.388 Megagrams (Tonnes) (equals to 0.000326 million tonnes) of carbon was found sequestered in the sampling plots and which is equal to 27.2 Mg of carbon dioxide accumulated and release 10.2 Mg of oxygen into atmosphere. India submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) in October 2015, committing to cut the emissions intensity of GDP by 33–35% by 2030 from 2005 levels. In recognition of the growing problem of Climate Change, India declared a voluntary goal of reducing the emissions intensity of its GDP by 20–25%, over 2005 levels, by 2020, despite having no binding mitigation obligations as per the Convention. A slew of policy measures was launched to achieve this goal. As a result, the emission intensity of our GDP has decreased by 12% between 2005 and 2010. To reach the target by 2030 more number of urban parks and should be developed and also other GHG gas reduction systems should be established. With this it concluded that at present, information on the estimation of sequestered carbon potential in natural way in urban areas is not available. Therefore, more detailed studies are needed for assessing the ultimate changes that are happening in both forest and urban areas.

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