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Contribution of Selected Avenue Tree Species to Biomass and Carbon Storage on the University of Ghana, Legon Campus, Ghana

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Abstract: Carbon dioxide (CO_2) is a major contributor to global warming. Thus, carbon emission reduction is of key concern which the Kyoto Protocol seeks to address. In nature, photosynthesis is the unique process through which carbon flows in ecosystems given that plants utilize atmospheric CO_2 by that mechanism. Therefore, trees are important sinks for atmospheric carbon as they store about 50% carbon in their standing biomass and hence contribute significantly by counterbalancing the atmospheric CO_2 levels. In an urban environment, such as the Legon Campus, avenue trees are remarkable 'green pockets' which play very significant role in combatting elevated carbon levels. The study therefore is a first time attempt that provides estimate of the carbon sequestration potential of some selected avenue tree species on the Campus namely *Albizia saman*, *Erythopleum suaveolens*, *Khaya senegalensis*, *Milletia thonningii*, *Millingtonia hortensis* and *Peltophorum pterocarpum*. Non-destructive approach was used for data collection in six (6) 600m x 30m size plots (10.8ha). Biomass estimation, CO_2 sequestration and storage was computed by use of allometric regression equation. Results obtained indicate a total of 666 individual trees sampled; 78 individuals of *Khaya senegalensis* with an average girth (3.48m) & height (26.74m) stored 284.36 tons of carbon per hectare, followed by 132 individuals of *Peltophorum pterocarpum* girth (2.44m) & height (16.95m) stored 125.92 tons/ha, 66 *Erythopleum suaveolens* with girth (2.44m) & height (18.01m) stored 102.24 tons/ha, 72 *Albizia saman* girth (2.96m) and height (15.69m) stored 78.61 tons/ha. The least amount of carbon stock was recorded for 162 individuals of *Milletia thonningii* with average girth (1.64m) & height (15.32m) and 156 *Millingtonia hortensis* girth (1.57m) & height (18.29m) with the values of 69.76 and 69.60 tons of carbon /ha respectively. Present study underscores the carbon sequestration potential of the aforementioned tree species on the Legon campus.

Keywords: Avenue trees, Biomass, Carbon sequestration, Carbon storage, Allometric equations.

INTRODUCTION

In 2007, the Conference of the Parties (COP 13) to the United Nations Framework Convention on Climate Change (UNFCCC) acknowledged the importance of major source of greenhouse gas emissions and has since proposed mechanisms for reducing such emissions. Over the years, increased agriculture and other land use activities have been attributed to the deterioration of natural atmospheric cycles. In addition, other such anthropogenic activities as deforestation, indiscriminate bushfires, burning of fossil fuels, transportation, housing, etc., have caused many harmful effects leading to imbalances in atmospheric conditions [1, 2]. The most dominant of these harmful effects is the alteration of climate conditions caused by the release of greenhouse gases into the atmosphere leading to global warming of the environment [3]. Thus, carbon emission reduction is of key concern, and that is what the Kyoto Protocol seeks to address [4]. The rate at which carbon dioxide is currently being added to the atmosphere is observed to be much faster than at any time in the past 80,000 years [5]. At this rate of carbon dioxide pumped into the atmosphere from the various human-induced activities, the planet would have been overheated if not for nature's own mechanism of rapidly removing all the carbon from the atmosphere and, storing it in such reservoirs as the oceans, forests, soils, rocks, sediments, swamps, wetlands, grasslands, etc. [6]. Pandya *et al.* [7] and, Das and Mukherjee [8] suggests that about two-thirds of the world's sequestered terrestrial carbon are stored or captured in standing forests, forest under-story plants, leaf-soil debris and in forest soil.

As part of ecosystem dynamics, trees are one of the most important elements as they play a significant role in capturing atmospheric carbon through photosynthesis. This accumulation of stored carbon in tissues by photosynthesis results in tree growth and therefore considered as live biomass [9-11] which eventually becomes a part of the ecosystem service; entering the soil as soil carbon and re-entering into the atmosphere upon burning and decomposition [12]. Thus, forest trees are important sinks for atmospheric carbon as they contribute about 50% carbon dioxide in their standing biomass [4]. According to Wilcox [13], urban forestry that contributes significantly to live biomass inputs include trees in streets, gardens and parks which also pay for ecosystem services such as removing air-borne pollutants [14, 15], reducing the urban heat island effect [16] and counterbalancing carbon emissions through carbon storage and sequestration [17- 20]. Thus, apart from forests, there are numerous other identifiable 'green pockets' described as 'avenue' which are planted with trees that contribute significantly to combating greenhouse gas emissions. Hence, according to the IPCC [21] debate on climate change, one of the ways of monitoring greenhouse gas emissions is by determining the average carbon stocks per unit area. Due to the closeness of avenue tree plantations to vehicular emission exposures along driveways, they are considered to play a major role in sequestering carbon and reducing automobile pollution [22, 23]. According to Ferrini and Fini [24], the net save in carbon emissions that can be achieved by urban tree or avenue tree plantings can be up to 18 kg CO_2/year per tree and this benefit corresponds to that provided by 3 to 5 forest trees of similar size and health. Similarly, the shade provided by the canopies of avenue trees influence the microclimate along driveways by rendering cooling effect [25]. Furthermore, avenue trees influence the aesthetics, affective emotions of residents and provide high ecological value to urban dwellers as part of green infrastructure. Thus, avenue trees as part of urban forestry can play a major role in managing the increased levels in CO_2 emission reduction [26].

Given, that avenue trees in our environment play a very significant role as important sinks for atmospheric carbon and because this is related to the Kyoto Protocol [27], it is significant to study them and document their contribution to the climate change debate in Ghana. Several investigations have already been carried out on estimating the carbon stock or storage potential for urban forests in India and many other countries [25- 32, 7] and carbon storage potential of trees in university campuses [26, 33-37]. Apart from Ghana's forests, there are numerous other 'green pockets' which significantly contribute to ameliorating the country's greenhouse gas and consequent climate situation. In view of the beautiful avenue trees planted around the University of Ghana (UG) Main Campus, this study attempts to estimate tree biomass, carbon storage and sequestration potential of six selected avenue tree species on the Legon campus.

MATERIALS AND METHODS

Study Area

The University of Ghana (UG) Legon campus covers an area of about 13km^2 and lies latitude 05°39'03"N and longitude 00°11'13"W at an altitude of 133m above men sea level. It is about 13 kilometers north-east of Accra, the capital city of Ghana. The area experiences a tropical wet and dry savanna climate which is generally characterized by daily minimum and maximum temperatures ranging between 21.0 – 24.0^{0}C and 25.0 – 33.0^{0}C respectively [38]. The variation in average monthly temperature is approximately 4.0 ^{0}C. The annual mean rainfall values ranging from 733 mm to 787 mm is noticeable.

The campus is demarcated into different land use types viz. Residential Area, Academic Area, Botanical Garden and University Farm that has representative habitat types such as thicket, swamp, grassland and forest. The built-up area of the Legon Campus has hostels and halls of residence, lecture theatres, departmental blocks, staff bungalows, lawns and major roads, with low growing grassland. Avenue trees such as *Albizia saman*, *Erythrophleum suaveolens*, *Khaya senegalensis*, *Millettia thonningii Millingtonia hortensis*, *Peltophorum pterocarpum*, *Azadirachta indica*, *Anogeissus leiocarpa*, *Tabebuia heterophylla*, *Leucaena leucocephala* and *Pithecellobium dulce* line up the major roads. This tree is the major shade providers on campus and, adds-on to the aesthetics and beauty while functionally sequestering carbon.

Sample Sites and Selected Tree Species

Since the objective was to determine the carbon sequestration potential of selected avenue tree species on the UG campus, the study was carried out along six major avenues lined with differently aged tree species namely; *Albizia saman* (Jacq.) F. Muell, *Erythrophleum suaveolens* (Guill. & Perr.) Brenan, *Khaya senegalensis* (Desr.) A. Juss, *Millettia thonningii* (Schumach.) Baker, *Millingtonia hortensis* L. and *Peltophorum pterocarpum* (DC) Baker:

Sampling strategy

In terms of cost efficiency and effectiveness in emission accounting, a non-destructive quadrat sampling method was used for data collection. This involved biomass estimation of all the above-listed avenue tree species. To do so, a temporary belt quadrat of 600m x 30m (1.8 ha) size was demarcated along each selected avenue and the following under-listed biophysical parameters were measured to estimate the biomass, hence deriving carbon stock for emission accounting:

Tree Girth Measurement

Standard procedures for the girth at breast height (GBH) measurement; i.e., approximately 1.3 meter from the ground, were followed [40]. Individual trees greater than 10 cm GBH in each sampled plot was determined using a measuring tape. By dividing the measured values of GBH by 3.14 [39], Tree diameter (D) values were obtained.

Tree Height Measurement

In the absence of a clinometer, the isosceles right angled paper triangle method was used to measure tree height (H) in each sampled plot (http://www.wikihow.com/Measure-the-Height-of-a-Tree). To do so, first an A4 size square paper was folded to form an isosceles right angled triangle (one right angle and two 45 degree angles). Next, the triangle was held up in such a way that one tip of the hypotenuse was placed at the eye level and the other to coincide with the tip of sample tree to be measured while the base of the triangle is parallel to the ground level. A backward walk from the tree trunk was taken till the tip of the tree within the canopy coincides with the hypotenuse. The distance was measured and noted as (1). Then, the distance from foot to eye level of the individual holding the triangle was also measured as (2). Finally, the true height of the sampled tree was estimated by adding values of (1) and (2).

Next, live biomass of the selected species was derived using step-by-step application of allometric equations:

Biomass Estimation

The above ground biomass (AGB) and below ground biomass (BGB) of individual sampled tree species were then derived using non-destructive allometric equations as follows:

Above ground biomass (AGB) according to Potadar and Patil [41] consists of the whole shoot, branches, leaves, flowers, and fruits estimated by multiplying the Tree Bio-Volume (TBV) to the wood density of tree species. Meanwhile, Tree bio-volume (TBV) value is estimated by multiplying the factor (0.4) to the square of the diameter and height of sampled tree species where available dataset is limited [42-45].

Tree Bio-volume (TBV) = 0.4 x (D^2) x H ……Eq.-1

AGB=Wood density x (TBV) ....……………...Eq.-2

The values of wood density were obtained from the global wood density database [46]. The standard average density value of 0.6 gm/cm was used for the tree species with density value not available.

Below Ground Biomass (BGB)

For BGB, Hangarge *et al*. [46] root to shoot ratio derived estimate was used,

Where

BGB = AGB x 0.26 ....Eq.-3.

Total Biomass (TB)

The summation of AGB and BGB values (Eq.-2 + Eq.-3) is considered the total biomass (TB) of a sampled tree species [57]

Total Biomass (TB) = (AGB) + BGB) ....Eq.-4.

Carbon Stock Estimation

Generally, carbon stock is estimated by measuring the actual stock of biomass [47] [refer to Eq.-4 above]. Thus, 50% of the biomass of trees is equivalent to the amount of carbon stored according to Pearson *et al*., [40]. Therefore, expressed mathematically,

Carbon Stock or Storage (CS) = Total Biomass (TB) x 50% ………Eq.-5.

In all, a total of 36000 m^2 plots (3.6 ha) were sampled.

Statistical Analysis

The data estimated were subjected to one-way analysis of variance (ANOVA) to determine the significant differences among mean values at the probability level of 0.05.

RESULTS AND DISCUSSION

A total of 666 individual trees from 6 selected avenue species were recorded in 10.8 ha area (1.8 ha x 6). These count number of trees were measured to estimate their biomass, hence potential for capturing and storing organic carbon in tissues.

Density distribution of sampled trees along selected avenue

A notable variation in the density of the sampled trees in 600m x 30m (18000m^2) belt quadrat was recorded. *Milletia thonningii* recorded the highest number of 162 individuals, followed by *Millingtonia hortensis* with 156 trees, *Peltophorum pterocarpum* 132, *Khaya senegalensis* 78, *Albizia saman* 72 and *Erythrophloem suaveolens* recorded least number of 66 individuals (Fig.1).

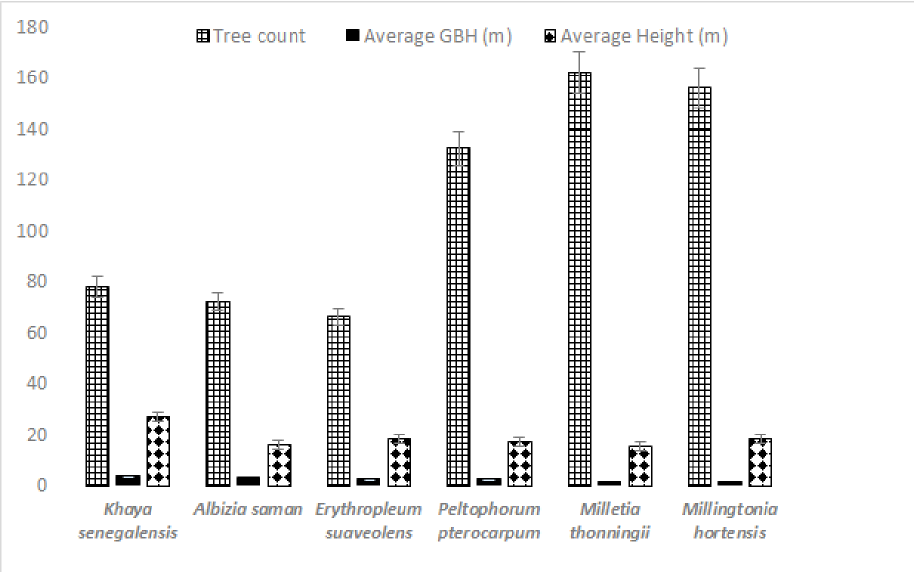

Fig-1: Variation in Tree count, GBH and Height of selected avenue

Variation in GBH and Height distribution

Comparatively, the average girth at breast height of sampled trees in the avenues showed notable differences (Fig 1.). *Millingtonia hortensis* and *Milletia thonningii* recorded smaller average girth sizes of 1.57m and 1.64m respectively whereas *Erythropleum suaveolens*, *Peltophorum pterocarpum* and *Albizia saman* were moderately sized with average tree girth ranging from 2.44m – 2.96m. *Khaya senegalensis* had a relatively higher average girth measure of 3.48m. Similar differences were also noted in the average tree height measures among the sampled avenues (Fig 1.). *Khaya senegalensis* recorded maximum average height of 26.47m and *Milletia thonningii* recorded lowest average of 15.32m. *Millingtonia hortensis*, *Albizia saman*, *Erythrophloem suaveolens* and *Peltophorum pterocarpum* had average height measures ranging from 15.50m – 18.50m.

Biomass and Carbon Stock Estimation in the Selected Avenues

Measured stand biomass and related stock of carbon in each avenue is indicated in Table 1.

Results indicate that an average of ~62 trees per hectare are sampled as avenue trees. However, there are variations in numbers among species (Table 1). Whereas the *Millettia* sp. And *Millingtonia* sp. recorded the lowest total biomass (~139 tons/ha) estimates, *Khaya* sp. (Mahogany) measured four (4) times the same measures (~569 ton/ha), implies that Mahogany trees provide four times more carbon storage compared to the *Millettia* and *Millingtonia*. Similarly, in terms of percent relative contribution to total carbon stock in this study, Mahogany recorded 38.9% while *Millettia* and *Millingtonia* recorded ~9.5%. Thus, of the various avenue tree species sampled, maximum carbon stock was found with *Khaya senegalensis* which sequestered 284.36 tons of carbon per hectare, followed by *Peltophorum pterocarpum* 125.92 tons/ha (17.2%), *Erythopleum suaveolens* 102.24 tons/ha (13.9%), *Albizia saman* 78.61 tons/ha (~10.8%) and the least amount of carbon stock was recorded for *Milletia thonningii* and *Millingtonia hortensis* with the values of 69.76 and 69.60 tons of carbon per hectare respectively. A notable observation is that even though *Khaya senegalensis* captured maximum carbon stock, yet it had a comparative lower individual count (i.e., ½) compared to *Peltophorum pterocarpum*, *Milletia thonningii* and *Millingtonia hortensis.* This can be structurally attributed to woody nature of *Khaya senegalensis* than the other trees. Additionally, the trees that have sizable girth and height are more able to accumulate a substantial amount of carbon over years. Many researchers revealed that above ground biomass is more strongly correlated with higher values of GBH [48-50, 15, 51] which contributes to high biomass. The relationship between GBH and height with volume is nearly linear in all 6 tree species sampled. The study is in accordance Nowak and Crane [52], Maco and McPherson [21]; Nowak and Dwyer 52]; Gough *et al.* [53]; Escobedo *et al.* [54], Timilsina *et al.* [55]; and Potadar and Patil [40] which demonstrated trees with higher girth class and height have high potential of capturing carbon in their biomass and even when managed small conservation areas can have significant impacts on the development of overall carbon footprint.

Table-1: List of Sampled Avenue Trees in study area on the UG Main Campus

Tree Species	Tree count in (1.8) Hectare	Average GBH (m)	Average Height (m)	AGB/ Hectare (tons)	BGB/ Hectare (tons)	Average biomass / tree (tons)	Total Biomass / Hectare (tons)	Carbon Stock/ Hectare (tons)
Khaya senegalensis	78	3.48	26.74	451.37	117.36	13.12	568.73	*284.36
Peltophorum pterocarpum	132	2.44	16.95	119.88	51.97	3.43	251.85	*125.92
Erythropleum suaveolens	66	2.44	18.01	162.29	42.20	5.57	204.49	*102.24
Albizia saman	72	2.96	15.69	124.78	32.44	3.93	157.23	*78.61
Milletia thonningii	162	1.64	15.32	110.73	28.79	2.58	139.52	*69.76
Millingtonia hortensis	156	1.57	18.29	110.48	28.72	1.60	139.20	*69. 60
Total	666						1,461.02	730.49

*Values significant at P 0.05

CONCLUSION

From the findings of the present work, it is clear that CO_2 sequestration potential varies amongst the selected avenues, the best performing being *Khaya senegalensis* successively followed in order of merit by *Peltophorum pterocarpum*, *Erythrophleum suaveolens*, *Albizia saman*, *Milletia thonningii* and *Millingtonia hortensis*. The study provides present status of selected avenue and the total carbon stock as well as percent contribution to sequestration within the UG Campus area.

This study reveals the importance of sustaining urban forests as green pockets for balancing atmosphere carbon otherwise such will release back to the atmosphere if there is human interference [56]. Under the Kyoto Protocol planting of trees with a high carbon sequestration capability is encouraged so as to bring down high concentration of CO_2 in the atmosphere. In fact, the soil-vegetation systems also play an important role in the global carbon cycle by sequestering emitted carbon in the atmosphere thereby mitigating global warming.

In summing up, it can be said that the present work provides useful information on the potential sink of atmospheric carbon by few important avenue trees on campus which will help to reduce the greenhouse effect by providing a safety net for the adverse effects of climate change. The results also offer a pathway to aesthetic rejuvenation through landscape designing collaterally with environmental optimization through CO_2 sequestration with appropriate trees.

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