Eco. Env. & Cons. 27 (3) : 2021; pp. (1031-1042)

ISSN 0971–765X

Ecological studies along highway corridors: A case study of the vegetation pattern and related carbon emission reduction potential along the Accra Tema Motorway, Ghana

Mona Dave*, Vincent Von Vordzogbe and Lord Edem Klukpui

Department of Plant and Environmental Biology, School of Biological Sciences, College of Basic and Applied Sciences University of Ghana, Ghana, West Africa

(Received 3 Decemebr, 2020; Accepted 8 January, 2021)

ABSTRACT

Highways act as concave corridors that thrive unique group of plants which maintain ecological balance. The growing interest in the evaluation of the potential of highway vegetation to climate change mitigation and adaptation as part of IPCC strategies accounts for this research study. The study was conducted along the 19 km stretch of dual carriage, Accra-Tema Motorway in Ghana. Using non-destructive sampling approach in 40-hectare area, biophysical parameters of trees species on either side of this highway was carried out and appropriate allometries used to convert these measures to total biomass and potential carbon dioxide values. 43 different tree species belonging to 18 families from a total of 5976 individual trees were measured. The Fabaceae constitutes the dominant plant family. In terms of spatial tree distribution, 3.0 – 9.0m and 0.30 – 0.90m average tree height and girth ranges respectively were prominent. On the average, 54.94 t/ha of biomass (27.47 tC/ha) from ~149 trees/ha is estimated with *Albizia lebbeck*, *Samanea saman* and *Khaya senegalensis* recording the highest values. In view of that, attention must be paid to the conservation of these and other dispersed trees species due to their ability to sequester and store appreciable amount of carbon.

Key words: *Accra-Tema Motorway, Carbon footprint, Highway corridors, Urban greeneries and green spaces.*

Introduction

Urban greeneries have recently gained popularity as climate change adaptation/mitigation measures and has implications for improving environmental quality (Velasco *et al.*, 2016). Unfortunately, much of the environmental challenge; greenhouse gas emissions, global temperature rises and abnormal climate phenomenon, experienced in urban areas are as a result of ongoing developmental and attendant anthropogenic activities such as construction and broadening of road networks that connects to development of residential and industrial settlements accounting for deforestation. Actually, this has resulted in the disruption of many greeneries leading to reduction in urban ecosystem services. In particular, tree diversity in urban green areas are known to sequester and store carbon. However, it is difficult to quantify the actual amount of carbon sequestered because it involves emissions from other land use activities and therefore, analysis of the carbon footprint would involve an established method for systematically quantifying its sinks and sources (Strohbach *et al.* 2011). Many urban development policies, continue to promote tree-planting, preservation of urban green spaces, and green architecture (i.e. green roofs and facades (US-EPA, 2008; Pataki *et al*., 2011; Demuzere *et al*., 2014) to mitigate carbon. The so called 'green pockets' in the urban areas in the form of avenue trees, trees in home gardens, fruit orchards, arboretum, botanical gardens, etc. acts as hotspots in the urban landscape (Kulkarni *et al.,* 2001). Trees in urban areas therefore, play a key role in maintaining the ecological balance of busy and polluted environment (Chavan and Rasal, 2010). Additionally, trees sequester the accumulated anthropogenic carbon emissions which is utilized in photosynthetic processes mainly for generating multiple compounds that give bulk to the plant body and stored as above and below ground biomass (Litton *et al*., 2007; Gorte, 2009; Munisamy *et al.*, 2011). Urban green pockets also provide other ecosystem benefits such as reducing air and noise pollution, slowing down and trapping sediment, and uptake of nutrients and in some cases heavy metals.

Within urban landscape designs, constructed highways act as concave corridors that thrive unique group of plants that are in constant connect with vehicular and industrial exhaust fumes as well as other anthropogenic pressures. All over the world, highway corridors are usually surrounded by vegetative cover which has this potential to sequester and store carbon. By doing so, woody tree species along highways curtail the greenhouse gas effects to a reasonable extent. There is a growing interest in the evaluation of the potential of roadside/highway vegetation and soils to carbon sequestration. In particular, the emissions of CO_2 generated from combustion of fossil fuel is estimated to comprise approximately 80% of the anthropogenic greenhouse gases, hence contributing to the overall global climate change effect (Alvarez and Plocheck, 2016). According to Kiran and Kinnary (2011), because of the proximity of urban trees to vehicular emissions, such trees contribute significantly in reducing urban air pollution. Beckett *et al.,* (2000) found that trees in close proximity to roadsides capture more large-size particulate matter than trees further away. Scott *et al*., (1999) also reported that roadside trees provide a cooling effect on microclimate directly by shading the ground surface and indirectly through transpiration. Ferrini and Fini. (2011) from similarly related research reported that a net save in carbon emissions that can be achieved by urban tree planting can be up to 18 kg CO_2/year per tree. This benefit he indicated corresponds to that provided by 3 to 5 forest trees of similar size and health. These urban 'green pockets' are therefore a unique ecosystem experiencing different combinations of stressors than many other ecosystems. It therefore requires site- specific research in addition to special strategies and policies to govern its management and design.

The Accra Tema motorway located in the Greater Accra region built in 1964-1965 is part of the Trans West African Highway (Abidjan-Lagos Corridor), linking the city of Accra, the Kotoka International Airport and Tema Port (gipcghana, 2019). This major road network is 19 km stretch that connects Accra to Ghana's Industrial and Manufacturing hub in Tema (Ghana Statistical Service, 2010) and is an excellent road for the transportation of goods and services to facilitate trade and commerce between Tema and other parts of the country. The motorway is a 7.3m 2-Lane dual carriageway with a median divider which separates the two carriageways. The weighted Average Annual Daily Traffic (AADT) volume recorded on the road is approximately 65,200 vehicles per day (vpd), comprising 16% of vehicles in the medium and heavy groups (Gipcghana, 2019). Vegetation along the motorway is made up of several plant life forms (trees, shrub, herbs, climbers etc.). These life forms provide aesthetics, refugia for isolated or relict populations of other exotic plant species as well as increase the water infiltration capacity and reduce erosion and sedimentation of watersheds. Vehicular emissions absorbed from the atmosphere by such plants undergo the biological process of photosynthesis.

Highway development shares the effects with other human related activities that degrade the natural environment. The rate of rapid urban squatter sprawl associated with development of unauthorized structures has resulted in tremendous in road traffic on the motorway since it was built. This now calls for an expansion project. In the near future, the expansion is likely to result in converting the land corridors with different plant species to become concreted land. The most direct effect of highway development on ecosystems is the destruction of a natural habitat through its "conversion" to a transportation land use or "right-of-way". Although natural vegetation may be preserved within the right-of-way, the original natural characteristics of the land is eliminated within the paved area and adjacent roadsides. The clearing of vegetation (trees, shrubs and grasses) and accompanying levelling operations (that destroy the original topography and soil profile) are the principal changes which are likely to happen.

Considering the role of plant diversity along this major highway in combating green-house gases and supporting other biodiversity, it has become significant to study and document their contributions to ecosystem services. Till date, there has been no research on the vegetation and the potential carbon storage along the Accra Tema motorway. This study therefore attempts to provide first-hand information on the 'greenery' and its contribution of woody tree species, hence biomass and carbon stock for evaluating current status of the Accra-Tema motorway.

Materials and Methods

Study area

The study area is the roadside vegetation along the Accra-Tema motorway that lies latitude (5°37'24.98N – 5°40'47.60N) and longitude (0°10'10.55W – 0°01'40.23W) and, located in the southern part of Ghana (Accra), as shown in Fig 1. This motorway begins from the Tetteh Quarshie interchange in Accra and ends at the Tema roundabout expansion.

Climate

The area experiences the tropical wet and dry season climate with an annual mean temperature of 26 ^{0}C. The daily minimum and maximum temperatures range between 21 ^{0}C – 24 ^{0}Cand 26 ^{0}C – 32 ^{0}C respectively with average minimum temperatures ranging from 24^{0}C – 27 ^{0}C. The mean monthly temperatures vary by 4 ^{0}C and the mean diurnal temperature range is 7.5 ^{0}C. Total annual precipitation averages of 787mm with two peaks of rainfall in the months of June and October (Climatemaps, 2015).

Fig. 1. Location of Accra-Tema motorway

Vegetation and Land use

The vegetation along the Accra-Tema motorway is made up of a variety of herbs, shrubs, trees, climbers, lianas etc. on either side of the road. The divider separating the two carriageways thrives various seasonal herbs, shrubs as well as tree saplings (Fig. 2). In recent times, the motorway is seen undergoing various expansion projects which in the future would have adverse impacts on the remaining fragile vegetation along the motorway.

Fig. 2. 2017 Landsat imagery of part of the Accra-Tema motorway stretch showing land use and land cover differences (source: Google Earth Map)

The main land use activities include urban agriculture, illegal settlement, small scale businesses and road construction development. For purposes of agriculture, trees close to the dual carriageway are mostly cleared paving way for use as farmlands for urban agriculture. The common crops farmed are *Zea mays* (maize), *Brassica capitate* (cabbage), *Brassica botrytis* (cauliflower), *Cucumis sativus* (cucumber), *Musa paradisiaca* (banana), *Musa sapientum* (plantain), *Pennisetum glaucum* (perl millet), *Arachis hypogaea* (groundnut), *Abelmoschus esculentus* (okra), *Allium cepa* (onion), *Solanum lycopersicum* (tomato), *Solanum melongena* (eggplant), *Capsicum annuum* (capsicum), *Carica papaya* (papaya), *Lactuca sativa* (lettuce), etc. There are also numerous squatter settlements in kiosks and wooden structures. Settlers in these unapproved structures are illegal. Various infrastructure development in the form of warehouses for industries are a common sight along the motorway. Also, various signages for advertisement of commercial products are also located along the motorway which has replaced previously standing live tree stands. Several illegal small roads also connect to the main highway. These and other anthropogenic activities such as dumping of refuse, laying of electric poles, construction of checkpoints and parking space for heavy loaded vehicles etc. has resulted in a frequent clearing of several patches of the natural vegetation along the motorway causing several notable fragments of the one-time continuous natural vegetation patch along the motorway. These fragments are currently occupied by various woody shrub species and invasive tree species.

Plot Sampling

Ten (10) plots each of 1000m x 20m were demarcated on both the sides (10 plots on each side) of the dual carriage Accra-Tema motorway with an approximate interval of 800m-900m between each plot (Fig.3). In all, an area of appx. 40 hectares was sampled to collect data on live tree species stands. Employing non-destructive approach, biophysical parameters such as the tree height (H) and girth at breast height (GBH) for individual tree species in the sampled plot were measured.

Following Pearson *et al*., (2005) guidelines for GBH measures, and the height of trees were estimated using appropriate tools.

Biomass and Carbon Estimations

A non-destructive approach was adopted and the following parameters calculated by inputing the biophysical measured values into respective allometric equations for estimating biomass pool, organic carbon storage and carbon dioxide sequestered.

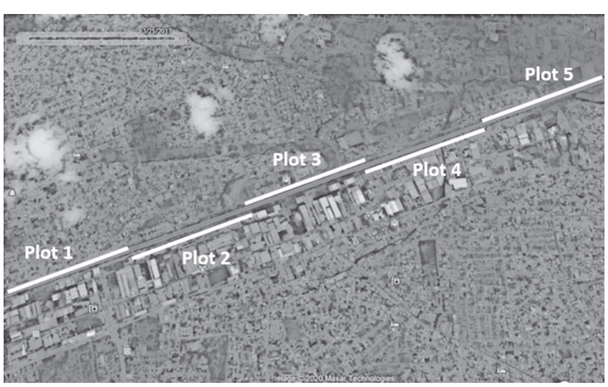

Fig. 3. Sampled plots along the dual carriage Accra-Tema motorway

1. Above Ground Biomass (AGB)

The AGB of trees comprises whole shoot, branches, leaves, flowers, and fruits outside the soil. Allometric equations for biomass usually include information on trunk Diameter at breast height DBH (in m), total tree height H (in m), and wood density (in Kg/m3). The unit of the AGB estimated from the allometric equation is the kilogram (Kg). AGB is calculated using the following formula:

AGB (kg/tree) = Volume of tree (m^3) × Wood density (kg/m^3) (Brown, 1997; Negi *et al*., 2003)

= (πr^2 x H) x Wood density

Radius of the tree is calculated from GBH of tree. The wood density value was obtained from the global wood density database recommended by Zanne *et al*., (2009). The standard average density

of 0.6 gm/cm is applied wherever the density value is not available for tree species.

Below Ground Biomass (BGB)

The Below Ground Biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter. The BGB has been calculated by multiplying AGB by 0.26 factors as the root: shoot ratio.

BGB is calculated by given following formula BGB (Kg/tree) or (ton/tree)

= AGB x 0.26 (Brown, 1997; Negi *et al*., 2003)

Total Biomass

Total biomass of trees was calculated by sum of AGB and BGB of trees. The Total Biomass of trees was calculated by following method (MacDicken, 1997)

Total Biomass (Kg/tree) or (ton/tree) = AGB + BGB

Carbon Storage Estimation

Generally, for any plant species 50% of its biomass is considered as carbon (Pearson *et al*., 2007) i.e. Carbon Storage = Biomass x 50%or Biomass/2 (Kg/tree) or (ton/tree)

Carbon Dioxide Sequestered

CO_2 is composed of one molecule of carbon and 2 molecules of oxygen. The atomic weight of carbon is 12.001115, the atomic weight of oxygen is 15.9994, the weight of CO_2 is C+2*O=43.999915, The ratio of CO2 to C is 43.999915/12.001115=3.6663.

Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663 (Brown, 1997; Negi *et al*., 2003; Pearson *et al*., 2007) expressed in (Kg/tree) or (ton/tree).

Results

A total of 5976 number of individual woody trees with dbh ≥ 10 cm made up of 43 different species and 18 plant families sampled on the Accra-Tema Motorway are shown in Table 1. The plant family Fabaceae was dominant (Fig. 4) and accounted for a total of seventeen (17) different woody tree species, i.e. appx 40%, followed by the Combretaceae and Malvaceae with three (3) species each. Only one or two species belong to the remaining plant families (Fig. 4).

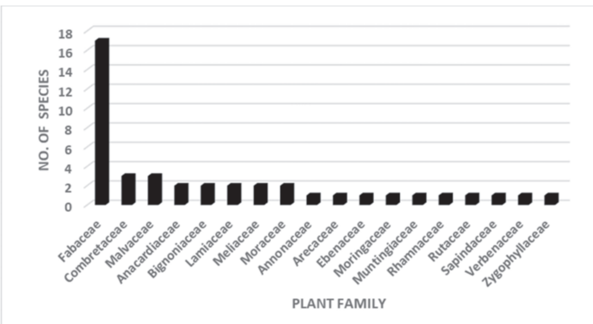

Fig. 4. Ratio of woody tree species to various plant families

Out of 5976 individuals, a total of 3871 trees, appx. 65% of the total accounted for the Fabaceae only on the Accra-Tema Motorway (Fig. 5)

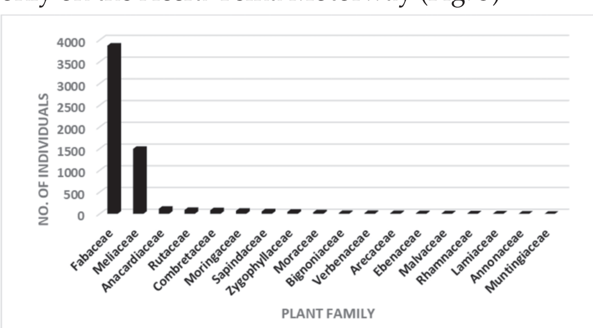

Fig. 5. Ratio of number of tree counts to various plant families

In terms of spatial distribution of sampled tree species, it is noted that aggregation is weaker in number of individual trees with higher heights than those with lower heights (Fig. 6). Boxplot of trees within the height range of 3.0 – 9.0m were dominant across the motorway accounted for appx. 72%. Comparatively, the distribution of number of younger tree sizes, i.e. those with lower height to older trees is highly reduced (Fig. 6).

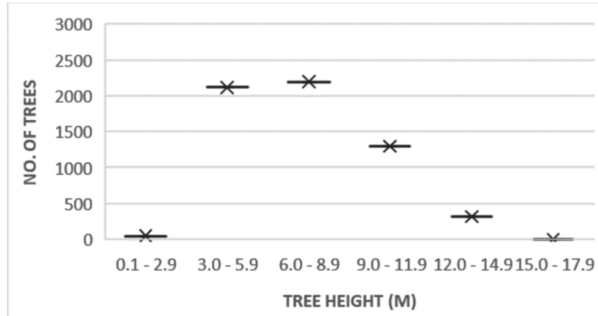

Fig. 6. Boxplot showing pattern of tree height distribution along Accra-Tema Motorway

Similarly, in terms of girth, a 'concave down, decreasing' pattern which implies that spatially, the tree girth sizes do not follow the normal distribution pattern. Rather, more individuals ranged between 0.30 – 0.89m in girth accounting for appx. 79% compared to the larger girth sizes of 0.9 – 2.9m making up 21% (Fig. 7).

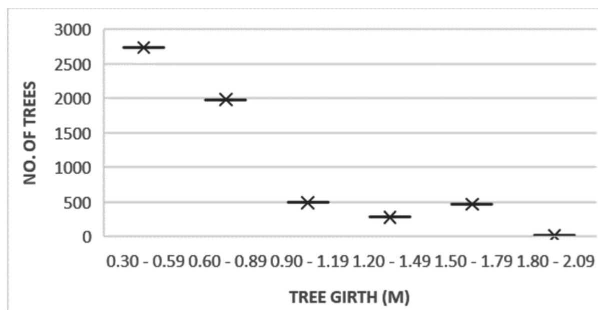

Fig. 7. Boxplot showing pattern of tree girth distribution along Accra-Tema Motorway

In terms of relative frequency distribution, *Leucaena leucocephala* and *Azadirachta indica* recorded the highest percentage followed by *Albizia lebbeck*, *Senna siamea*, *Samanea saman* and *Acacia auriculiformis.* The lowest was recorded for species such as *Tabebuia heterophylla, Cassia fistula, Tectona grandis, Adansonia digitata, Sterculia foetida* and *Muntingia calabura* as shown in (Fig. 8).

Similarly, in terms of relative denisty, *Leucaena leucocephala* recorded the highest value per unit area (32.76%) as shown in (Fig. 9), followed by *Azadiracta indica* (20.03%). These were preceded by *Albizia lebbeck, Acacia auriculiformis, Senna siamea, Khaya* *senegalensis*, and *Samanea saman* withrelative density that ranged between 7.5 to 4.5. The remaining tree species accounted for very low values 1.5 to 0.02. Trees such as *Cassia fistula, Adansonia digitata, Sterculia foetida* and *Muntingia calabura* recorded only an individual each within the entire Accra-Tema motorway stretch.

For total tree biomass in the 40-hectare sampled

Table 1. Bio-physical parameters, biomass and carbon input of sampled tree species

Species Name	Sp. Count	Ave. Ht/M	Ave. Gbh/M	Rel. Density	Rel. Freq.	Total Biomass/ Tons	Carbon Storage/ Tons	CO_2 Sequest-ration/ Tons
Acacia auriculiformis	432	6.7	0.4	7.23	5.08	36.37	18.18	66.74
Acacia mangium	11	7.5	0.7	0.18	1.69	2.06	1.03	3.78
Acacia nilotica	6	4.3	0.5	0.10	0.85	0.39	0.20	0.72
Adansonia digitata	1	11.3	1.1	0.02	0.42	0.42	0.21	0.77
Albizia lebbeck	470	9.3	1.6	7.86	5.93	790.81	395.41	1451.15
Anacardium occidentale	19	8.3	0.9	0.32	1.27	5.63	2.82	10.33
Anogeissus leiocarpa	17	7.2	0.7	0.28	1.69	4.57	2.29	8.39
Antiaris toxicaria	30	9.6	0.6	0.50	1.69	7.84	3.92	14.38
Azadiracta indica	1197	6.5	0.7	20.03	6.78	240.60	120.30	441.50
Balanites aegyptiaca	47	7.3	0.7	0.79	3.81	11.29	5.65	20.72
Blighia sapida	57	8.6	0.6	0.95	1.69	12.25	6.12	22.48
Cassia fistula	1	5.9	0.6	0.02	0.42	0.14	0.07	0.26
Ceiba pentandra	12	9.1	1.9	0.20	1.27	12.22	6.11	22.43
Delonix regia	23	7.3	0.9	0.38	1.69	7.14	3.57	13.11
Diospyros mespiliformis	15	6.7	0.5	0.25	1.27	1.58	0.79	2.90
Elaeis guineensis	17	3.5	0.4	0.28	1.27	0.69	0.34	1.26
Erythrophleum suaveolens	6	6.6	1.0	0.10	0.85	2.94	1.47	5.40
Ficus umbellata	5	10.5	1.3	0.08	0.85	4.53	2.26	8.31
Gmelina arborea	7	9.7	1.2	0.12	0.85	4.58	2.29	8.41
Khaya senegalensis	298	14.7	1.0	4.99	3.81	320.68	160.34	588.46
Leucaena leucocephala	1958	4.6	0.3	32.76	7.20	65.62	32.81	120.41
Mangifera indica	98	7.8	0.7	1.64	2.97	21.03	10.52	38.59
Millettia thonningii	79	6.9	0.7	1.32	2.97	15.28	7.64	28.04
Millingtonia hortensis	18	5.1	0.5	0.30	2.12	1.35	0.67	2.47
Moringa oleifera	69	4.8	0.3	1.15	2.97	1.11	0.55	2.04
Muntingia calabura	1	5.3	0.5	0.02	0.42	0.04	0.02	0.07
Parkinsonia aculeata	67	6.2	0.3	1.12	3.39	2.65	1.32	4.86
Peltophorum pterocarpum	35	11.2	1.0	0.59	1.27	24.00	12.00	44.05
Philenoptera violacea	48	7.7	0.8	0.80	2.54	20.83	10.42	38.23
Piliostigma reticulatum	34	2.5	0.4	0.57	1.27	0.69	0.35	1.27
Pithecellobium dulce	52	6.5	0.5	0.87	2.97	6.19	3.10	11.36
Polyalthia longifolia	5	7.6	0.4	0.08	0.85	0.38	0.19	0.69
Samanea saman	267	11.6	1.3	4.47	5.08	357.13	178.57	655.34
Senna siamea	378	9.0	0.7	6.33	5.93	123.74	61.87	227.07
Sterculia foetida	1	11.7	1.4	0.02	0.42	1.14	0.57	2.08
Tabebuia heterophylla	2	11.6	1.5	0.03	0.42	3.33	1.66	6.10
Tectona grandis	2	14.5	1.0	0.03	0.42	1.68	0.84	3.09
Terminalia catappa	19	13.4	1.0	0.32	1.27	12.21	6.11	22.41
Terminalia mantaly	47	5.3	0.4	0.79	2.97	3.20	1.60	5.87
Tetrapleura tetraptera	4	7.1	0.5	0.07	0.85	0.42	0.21	0.76
Vitex doniana	20	7.5	0.7	0.33	2.97	2.80	1.40	5.14
Zanthoxylum zanthoxyloides	89	10.7	1.0	1.49	4.66	65.98	32.99	121.08
Ziziphus mauritiana	12	2.2	0.4	0.20	0.85	0.22	0.11	0.40
TOTAL	5976					2197.77	1098.89	4032.91

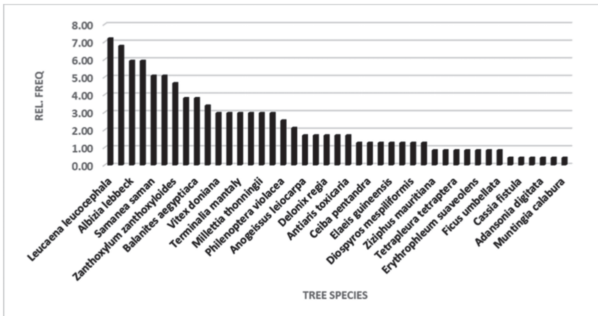

Fig. 8. Relative frequency distribution of sampled species

area, a value of 2197.77 tons is estimated. This implies 54.94 t/ha of accumulated biomass by appx 149 trees/ha. The contribution by individual species such as *Albizia lebbeck* (19.77 t/ha), *Samanea saman* (08.93 t/ha) and *Khaya senegalensis* (08.02 t/ha) recorded the highest estimates. Additionally, species such as *Azadirachta indica, Senna siamea, Zanthoxylum zanthoxyloides* and *Leucaena leucocephala* accounted for biomass values that ranged between 6.00 – 1.00 t/ha. A very low biomass value of less than 1.00 t/ha is recorded for the remaining 36 woody tree species (Fig. 10).

In terms of storage carbon, a total of 1098.89 tons in the 40-hectares sampled area is estimated. This implies 27.47 t/ha carbon stock with *Albizia lebbeck* (9.89 t/ha), *Samanea saman* (4.46 t/ha) and *Khaya senegalensis* (4.01 t/ha) measures as the highest rank order. The remaining woody tree species measured value range between 0.01- 3.00t/ha (Table 1).

Given that, the estimated carbon storage is directly proportional to CO_2 sequestrated, the rank order in terms of potential contribution by individual trees as the major carbon sink include such tree species as *Albizia lebbeck* (36.28 tCO_2/ha) followed by *Samanea saman* (16.38 tCO_2/ha) and *Khaya*

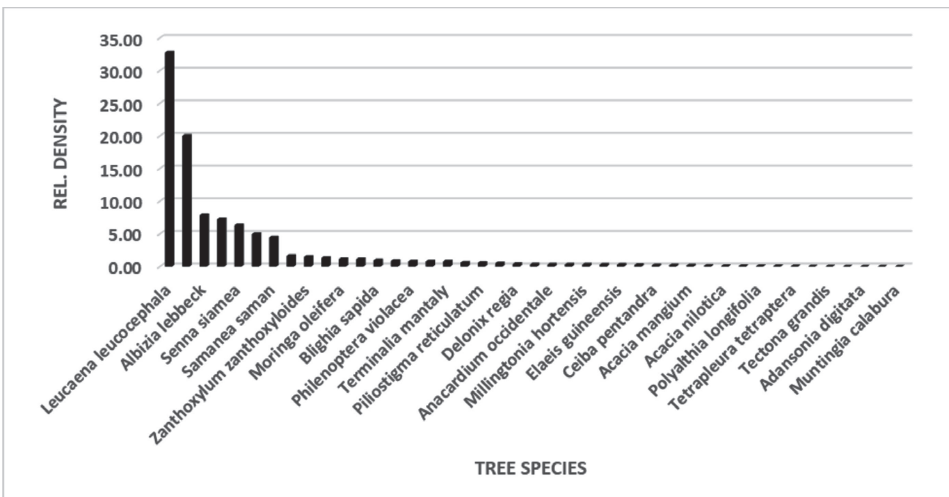

Fig. 9. Relative density distribution of sampled tree species

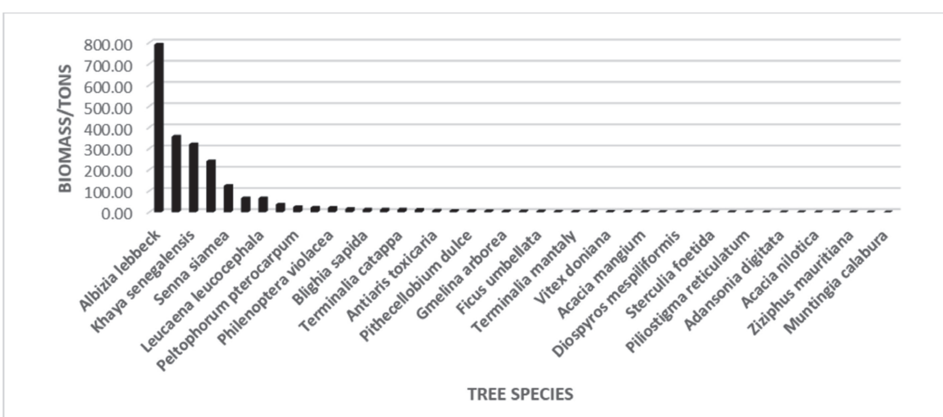

Fig. 10. Estimated biomass accumulation of sampled tree species

senegalensis (14.71 tCO_2/ha). Whereas, the remaining other trees recorded between 0.01-11.00 tCO_2/ha (Table 1).

Discussion

According to Fosu, (2009), the onetime breathtaking landscape of the Accra-Tema Motorway stretch coupled with its serene atmosphere and constant uninterrupted swirling fresh air is fast deteriorating. Steadily, these conditions are vanishing as the adjacent green spaces (trees and vegetative cover) are gradually giving way to brick and mortar, real estate and industrial establishments. A notable observation during the dry season in particular is the burning of brush (shrubs and grasses) annually within the median or divider resulting in brush fires and smoke releases that cause poor visibility to commuters. Thus, evaluating the urban greenery or green space along the Accra-Tema motorway is an important research initiative towards understanding ecological stress of this important resource (tree diversity) for any meaningful future developments of the highway management.

For this study, the vegetation inventory is intended to provide baseline floristic dataset for the existing vegetation and its related biomass and carbon pool estimates towards climate change accounting (mitigation and adaptation). Our record of 43 tree species in 34 genera and 18 families from a sample area of 40 hectares is comparable to similarly related national highway studies by Baral *et al*. (2013) at Nepal and Wang (2011) in Taiwan. In Baral *et al*. (2013) study, 19 different species were recorded from roadside vegetation study whereas, a total of 62 species of woody trees were recorded from another national highway plantation study in Taiwan by Wang (2011). Certainly, these differences reflect geographic and physiographic, environmental gradients and the purpose of management, as noted in Rahmana *et al.,* (2015). Repeated disturbances due to diverse anthropogenic activities such as illegal settlers, farming activities, road expansion, fuel wood harvesting, soil work and others were noted as major land use along the motorway as shown in Fig. 2. Brakenhielm and Liu, (1998) reported that such disturbance activities favor species that grow best in degraded conditions, in particular legume plant species. Indeed, the tree communities in Fig. 4 & 5 were dominated by several species of plants belonging to the Fabaceae family (leguminous plants) in the present study. Legumes accounted for appx 68% of the tree species and 66% of the biomass and related carbon stock for the entire stretch of the Accra-Tema motorway (Table 1). Past research findings in India and also confirm dominance of the legume plant family (Gamble and Fischer, 1934; Muthulingam and Thangavel, 2012).

The spatial dispersion (patchiness or aggregation) of individual live trees sampled in this study is of significance to the overall ecological management of the Accra-Tema highway. According to (Dale, 1999; Folt and Burns, 1999), the degree to which the individual tree species are aggregated or dispersed, is crucial to how a species uses resources, or how it is used as a resource and to its reproductive biology. Condit *et al.,* (2000), reported that spatial patterns of such species distribution are of particularly important theme in tropical ecology because high tree diversity produces low densities in the tropics. Indeed, in this study, the spatio-temporal distribution of the 43 different woody trees sampled do not show uniform distribution pattern for their structural composition (tree height and tree girth distribution) as observed in (Figs. 6 & 7) and along the five sample plots in Fig. 3. Agreeably, this was noted for *Leucaena leucocephala* and *Azadirachta indica*, that recorded comparative high relative frequencies (>50%) and densities (>20%) yet their overall estimated biomass is low despite their large numbers compared to other tree species. Similarly, their overall low average height and girth measures imply that most of these trees are young sizes. Invariably, the high count number recorded is due to their high regeneration ability and invasion in canopy gaps as also noted by many researchers (Lowe *et al*., 2000; Walton 2003; Yoshida and Oka 2004; Hata *et al*., 2010; Kueffer *et al*., 2010; Marques *et al*. 2014; Witt *et al*. 2017). Shelton and Dalzell (2007) and Olckers (2011) also reported that *L. leucocephala* thrives on a wide range of ecological conditions, fire resilience (Idol, 2019) and it quickly spreads to form a dense vegetative cover replacing other native species and once established it becomes difficult to control.

Similar invasiveness as reported for *Azadirachta indica* in this study is also noted in other related studies done in Ghana (Chamberlain, 2004); Togo (Kokou *et al*., 1999; Adjossou; 2009; Radji *et al* 2010); Fiji (PIER, 2007); Australia (Csurhes and Edwards 1998) and in Washington (Richardson *et al*., 2004), where *A. indica* is listed to be an intrusive tree species and spreads profusely in the desolate and canopy gap areas. These studies support the current findings of *L. leucocephala* and *A. indica* as aggressive colonizer within the ruderal sites and canopy fragmented areas due to tree logging for various land use, forming dense monospecific thickets along the Accra-Tema motorway stretch.

On the related biomass measures, Gough *et al*., (2008), Thornton *et al*., (2002), and Timilsina, *et al*., (2013) suggest that older trees have higher capacity to store more biomass as compared to younger trees. Other studies also suggest that the healthier and larger the size of tree, the higher is its capacity to store biomass several times more than tree stands that have small sizes (Escobedo *et al*., 2010; Maco and McPherson, 2003; Nowak, 1993; Nowak and Crane, 2002; Nowak and Dyer, 2007). In this study, *Albizia lebbeck*, *Samanea saman* and *Khaya senegalensis* as shown in Fig. 10 were noted as larger sized tree species with corresponding higher store of biomass. In terms of size and count numbers, these species ranged from 9.0 – 15.0 m height, 1.0 to 1.6 m of girth and appx. 250 – 500 counts. MacDicken (1997) reported that large healthy trees having the diameter more than 1.5 m sequestered approximately 40 times more carbon as compared to the small healthy trees species which have the diameter less than 0.12 m. This implies that, comparatively these averagely large sized trees (appx. 0.4 m DBH) along the motorway sequester appx. 11 times more carbon than the smaller and younger trees. Invariably, large sized trees save nearly 1000 times maximum carbon than smaller trees (MacDicken, 1997).

Clark *et al*. (2001) and Djomoa *et al*., (2010) both revealed that above ground biomass is more strongly correlated with DBH and a good estimator of biomass aboveground (AGB) as shown in Fig.10. Our results highlight the contribution of these sampled younger tree stands to the potential carbon capital. Old trees simply act as negative carbon senescent (Kohl *et al.*, 2017) and hence the Ghana highway authority must ensure that these younger sized trees be maintained for a much longer time to ensure them become efficient at sequestering carbon**.** These trees along the motorway can survive in the urban environment polluted with traffic-related contaminants and may be one of the important green region in the urban and industrial sectors as indicated by (Shannigrahi *et al*., 2004; Govindaraju *et al*., 2011) in similarly related studies.

In summary, the focus of our study is both on aggregated as well as individual tree strength. As large trees determine stand level dynamics as noted by (Newberry and Ridsdale, 2016 and Korner, 2006 and 2017), they play a major role in small-scale carbon accumulation and storage.

Conclusion

Changes in land use have a strong and long-lasting effect on the ground vegetation as well as ecosystem services they provide. With the increasing spatial demands for road network the expansion and encroach of adjacent landscape coupled with the loss of natural and cultural heritage of the Accra-Tema Motorway has become inevitable. Rapid squatter sprawl along the fringes of this dual carriage also contributes greatly to the loss of natural vegetation that must be checked and controlled. The results of the present study show that current tree stands along the motorway act as storehouse of carbon by stocking carbon in their tissues, thereby lowering the levels of atmospheric greenhouse gases. The variation in the biomass and among the younger and small sized trees sampled is due to differences in their age structure, species composition, storage potential, stage of development and site characteristics of the supporting soils. The practice for removal of urban vegetation for various land use and developmental activities at any given time is a continuous disturbance of biomass affecting the stability of highway ecosystems. The study emphasizes that when urban trees are young the standing carbon stock is not substantial, however, the growth of 43 different tree species represents a potential increase in biomass and hence productivity that is dependent on the ability to maintain and conserve these tree resources. Long-term permanent plot data are needed to evaluate this important urban greenery growth, its regeneration and mortality, to improve understanding on carbon emission reduction as part of climate change mitigation and adaptation research along with producing other urban forest benefits. Millions of metric tons of carbon currently stored by urban green spaces is a strong argument for at least maintaining the present urban tree structure.

There is a need for greater attention to be paid to existing tree species such as *Albizia lebback, Samanea saman,* and *Khaya senegalensis* along the motorway and the other inventoried tree species due to their ability to sequester and store reasonable amounts of carbon. The Ghana Highway Authority (GHA) and other relevant authorities should ensure that excessive logging of trees along the motorway is minimized and properly managed as well as protected.

Acknowledgment

Authors would like to thank the Greater Accra Regional Minister, Mr. Henry Quartey and officials of the Ledzokuku Municipal Assembly, lead by the Municipal Chief Executive, Madam Evelyn Twum-Gyamerah for boldly initiating aspects of this research recommendation in support of Policy thoughts on this and other important highway management as reported by Mr. Nii Ayikwei Okine of Citi News Room fame (CNR September 7, 2021)

Conflict of Interest

There is no conflict of interest to declare

References

Adjossou, K. 2009. *Diversity, structure and dynamics of vegetation in the humid forest fragments in Togo: Issues for the conservation of biodiversity*. PhD thesis. University of Lome, Togo, p. 241.

Alvarez, E.C. and Plocheck, R. 2016. *Texas Almanac*. Texas A & M University Press.

Baral, S.K., Malla, R., Khanal, S. and Shakya, R. 2013. Trees on farms: diversity, carbon pool and contribution to rural livelihoods in Kanchanpur district of Nepal. *Banko Janakari*. 23 (1) : 1–63.

Beckett, K.P., Freer-Smith, P. and Taylor, G. 2000. Effective tree species for local air-quality management. *Journal of Arboriculture*. 26 (1) : 12–19.

Brakenhielm, S.and Liu, Q. 1998. Long-term effects of clear-felling on vegetation dynamics and species diversity in a boreal pine forest. *Biodiversity & Conservation*. 7 (2) : 207–220.

Brown, S. 1997. *Estimating Biomass and Biomass Change of Tropical Forest. A Primer FAO Forestry*, paper no. 134. Food and Agricultural Organization of the United Nation, Rome, Italy.

Folt, C. L. and Burns, C. W. 1999. Biological drivers of zooplankton patchiness. *Trends in Ecology & Evolution*. **8** : 300-305.

Chamberlain, J. 2004. Framework for Monitoring Invasive Tree Species in Ghana. CNRD. Available online at http://www.green.ox.ac.uk/cnrd/jo.htm

Chavan, B. L. and Rasal, G. B. 2010. Sequestered standing carbon stock in selective tree species grown in University Campus Aurangabad, Maharashtra, India. *International Journal of Engineering Science and Technology*. 2(7) : 3003-3007.

Clark, D. A., Brown, S., Kicklighter, D.W., Chambers, J.Q., Thomlinson, J.R., Ni, J.and Holland, E.A. 2001. Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological Applications*. 11 : 371-384. DOI: https://doi.org/10.1890/1051-0761(2001)011[0371:NPPITF]2.0.CO;2

Climatemaps. 2015. Accra Climate and Temperature, Accra. Available online at http://www.accra.climatemps.com.

Condit, R., Ashton, P. S., Baker, P., Bunyavejchewin, S., Gunatilleke, S., Gunatilleke,N., Hubbell, S. P., Foster, R. B., Itoh, A., LaFrankie, J. V., Lee, H. S., Losos, E., Manokaran, N., Sukumar, R. and Yamakura. T. 2000. Spatial Patterns in the Distribution of Tropical Tree Species. *Science*. 288 : 1414-1418.

Csurhes, S. M. and Edwards, R. H. 1998. *Potential Environmental Weeds in Australia: Candidate Species for Preventative Control*. Biodiversity Group, Environment Australia.

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. J., Mittal, N., Feliu, E. and Faehnle, M. 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*. 146 : 107–115.

Djomoa, A.N., Ibrahimab, A., Saborowskic, J. and Gravenhorsta, J. 2010. Allometric equations for biomass estimations in Cameroon and pan moist tropical equations including biomass data from Africa. *Forest Ecology and Management*. 260 : 1873-1885.

Dale, M.R.T. 1999. *Spatial Patterns Analysis in Plant Ecology*, Cambridge Univ. Press, Cambridge.

Escobedo, F. J., Kroeger, T. and Wagner, J. E. 2010. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*. 159 (8-9) : 2078-2087.

Fosu, K. 2009. Accra-Tema Motorway: A Reflection of Failed Policies by Institute for Infrastructure Development, available online: https://www.businessghana.com/site/news/technology/101720/Accra-Tema-Motorway-A-Reflection-of-Failed-Policies-by-Institute-for-Infrastructure-Development

Ferrini, F. and Fini, A. 2011. Sustainable management techniques for trees in the urban areas. *Journal of Biodiversity and Ecological Sciences*. **1** (1) : 1-20.

Gamble, J.S. and Fischer, C.E.C. 1934. *Flora of the Presidency of Madras*. Royal Botanic Gardens, Kew, London (1934) : 179.

Gipcghana. 2019. Retrieved from: https://www.gipcghana.com/11-news-and-events/publications/investment-projects/infrastructure/construction-property/road-construction/122-upgrading-of-accra-tema-motorway.html

Gorte, R.W. 2009.*U.S. Tree Planting for Carbon Sequestration*, Congressional Research Service report for congress, Retrieved from: https://digital.library.unt.edu/ark:/67531/metadc689115/

Gough, C. M., Vogel, C. S., Schmid, H. P. and Curtis, P. S. 2008. Controls on Annual Forest Carbon Storage: Lessons from the Past and Predictions for the Future. *BioScience.* 58(7) : 609-622.

Govindaraju, M., Ganeshkumar, R. S., Muthukumaran, V. R. and Visvanathan, P. 2011. Identification and evaluation of air pollution tolerant plants around lignite-based thermal power station for greenbelt development. *Environmental Science Pollution Research.* 19 : 1210-1223.

Hata, K., Suzuki, J. I. and Kachi, N. 2010 Fine-scale spatial distribution of seedling establishment of the invasive plant, *Leucaena leucocephala*, on an oceanic island after feral goat extermination. *Weed Research*. 50 : 472–480.

Idol, T. 2019. A short review of *Leucaena* as an invasive species in Hawaii. *Tropical Grasslands-Forrajes Tropicales.* 7(2) : 290 - 294.

IPCC (Intergovernmental Panel on Climate Change) 2006. *Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Agriculture, Forestry and other land use (AFLOLU). Institute for Global Environmental strategies, Hayama, Japan.

Kiran, G. S. and Kinnary, S. 2011. Carbon Sequestration by Urban Trees on Roadsides of Vadodara City. *International Journal of Engineering Science and Technology*. 3 (4) : 3066–3070.

Kohl, M., Neupane, P. R. and Lotfiomran, R. 2017. The impact of tree age on biomass growth and carbon accumulation capacity: A retrospective analysis using tree ring data of three tropical tree species grown in natural forests of Suriname. *Plos one*. 1-17.

Kokou, K., Caballe, G. and Akpagana, K. 1999. Floristic analysis of forest patches in Southern Togo. *Acta Botanica Gallica*. 146(2) : 139-144.

Korner, C. 2006. Plant CO_2 responses: an issue of definition, time and resource supply. *New Phytologist*. 172 (3) : 393–411.

Korner, C. 2017. A matter of tree longevity. *Science*. 355(6321) : 130–131.

Kueffer, C., Daehler, C.C., Torres-Santana, C. W., Lavergne, C., Meyer, J-E., Otto, R. and Silva, L. 2010. A global comparison of plant invasions on oceanic islands. *Perspectives in Plant Ecology, Evolution and Systematics*. 12 (2) : 145–161.

Kulkarni, M., Dighe, S., Sawant, A., Oswal, P., Sahasrabuddhe, K.and Patwardhan, A. 2001. Institutions: Biodiversity hotspots in urban areas. *In Tropical Ecosystems: Structure, Diversity and Human Welfare*, Oxford and IBH: New Delhi, India, 693–695.

Litton, C. M., Raich, J. W. and Ryan, M. G. 2007. Carbon allocation in forest ecosystems. *Global Change Biology*. 13(10) : 2089-2109.

Lowe, S., Browne, M., Boudjelas, S. and De Poorter, M. 2000. *100 of the world's worst invasive alien species: a selection from the global invasive species database*. Auckland: Invasive Species Specialist Group.

Macdicken, K. 1997. *A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects*. Winrock International Institute for Agricultural Development, Arlington, VA 22209, USA.

Maco, S. and McPherson, E. G. 2003. A Practical Approach to Assessing Structure, Function and Value of Street Tree Populations in Small Communities. *Journal of Arboriculture.* 29(2) : 84-97.

Marques, A. R., Costa, C. F., Atman, A. P. F. and Garcia, Q. S. 2014. Germination characteristics and seedbank of the alien species *Leucaena leucocephala* (Fabaceae) in Brazilian forest: ecological implications. *Weed Research.* 54 : 576–583.

Munisamy, G., Ganeshkumar, R. S., Rajagopalan, M. and Visvanathan, P. 2011. Identification and evaluation of air-pollution-tolerant plants around lignite-based thermal power station for greenbelt development. *Environmental Science and Pollution Research.* 9 (4) : 1210-23.

Muthulingam, U. and Thangavel, S. 2012. Density, diversity and richness of woody plants in urban green spaces: a case study in Chennai metropolitan city. *Urban Forestry & Urban Greening*. 11 (4) : 450–459.

Negi, J.D.S., Manhas, R.K. and Chauhan, P.S. 2003. Carbon allocation in different components of some tree species of India: A new approach for carbon estimation. *Current Science*. 85(11) : 1528-1531.

Newberry, D.M. and Ridsdale, W. E. 2016. Neighbourhood abundance and small-tree survival in a lowland Bornean rainforest. *Ecological Research*. 31(3) : 535–366.

Nowak, D.J. 1993. Atmospheric Carbon Reduction by Urban Trees. *Journal of Environmental Management.* 37(3): 207-217.

Nowak, D.J. and Crane, D.E. 2002. Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*. 116(3) : 381-389.

Nowak, D.J. and Dwyer, J.F. 2007. Understanding the Benefits and Costs of Urban Forest Ecosystems. In: Kuser J.E. (eds) *Handbook of Urban and Community Forestry in the Northeast.* Springer, Boston, MA.

Olckers, T. 2011. Biological control of *Leucaena leucocephala* (Lam.) de Wit (Fabaceae) in South Africa: A tale of opportunism, seed feeders and unanswered questions. *African Entomology*. 19 : 356-365.

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., Pouyat, R. V., Whitlow, T. H. and Zipperer, W. C. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*. 9(1) : 27–36.

Pearson, T., Walker, S. and Brown, S. 2005. Guidebook for the formulation of Afforestation and Reforestation Projects under the Clean Development Mechanism. ITTO Technical series 25.

Pearson, T.R., Brown, S.L. and Birdsey, R.A. 2007. *Measurement guidelines for the sequestration of forest carbon*. Gen. Tech. Rep. NRS-18. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 42 p.

PIER. 2007 Weed risk assessment for *Azadirachta indica* (Neem), www.hear.org/pier/wra/pacific/azadirachta_indica_htmlwra.htm

Radji, R., Klu, K. and Kokou, K. 2010. Forest invasion by alien plant species: The case of neem tree (*Azadirachta indica* A. Juss.) in Southern Togo. *International Journal of Biodiversity and Conservation*. 2(10): 300-307.

Rahmana, M. Md., Kabir, E. Md., Jahir Uddin Akonc, A.S.M. and Andod, K. 2015. High carbon stocks in roadside plantations under participatory management in Bangladesh. *Global Ecology and Conservation*. 3 : 412–423.

Richardson, D., Bingggeli, P. and Schroth, G. 2004. *Invasive Agroforestry Trees: Problems and Solutions*. Agroforestry and Biodiversity Conservation in Tropical Landscapes Publisher: Island Press, Washington, 371-396.

Scott, K.I., Simpson, J.R. and McPherson, E.G. 1999. Effects of tree cover on parking lot microclimate and vehicle emissions. *Journal of Arboriculture*. 25 (3) : 129–142.

Shannigrahi, A. S., Fukushima, T. and Sharma, R. C. 2004. Anticipated air pollution tolerance of some plant species considered for green belt development in and around an industrial/urban area in India: An overview. *International Journal of Environmental Studies.* 61(2) : 125-137.

Shelton, M. and Dalzell, S. 2007. Production, economic and environmental benefits of leucaena pastures. *Tropical Grasslands*. 41 : 174-190.

Strohbach, M. W., Arnold, E. and Haase, D. 2011. The carbon footprint of urban green space : A life cycle approach. *Landscape and Urban Planning.* 104 (2) : 220 – 229.

Thornton, P.E., Law, B.E., Gholz, H.L., Clark, K.L., Falge, E., Ellsworth, D., Goldstein, A.H., Monson, R., Hollinger, D.Y., Falk, M., Chen, J. and Sparks, J.P. 2002. Modeling and measuring the effects of disturbance history and climate on carbon and water budgets in evergreen needleleaf forests. *Agricultural and Forest Meteorology*. 113 (1-4) : 185-222.

Timilsina, N., Escobedo, F.J., Cropper Jr, W.P., Abd-Elrahman, A., Brandeis, T.J., Delphin, S. and Lambert, S. 2013. A framework for identifying carbon hotspots and forest management drivers. *Journal of Environmental Management.* 114 : 293-302.

United States – Environmental Protection Agency (US-EPA). 2008. Trees and vegetation. In Reducing urban heat islands: Compendium of strategies. USA: Climate Protection Partnership Division—EPA's Office of Atmospheric Programs.

Velasco, E., Roth, M., Norford, L. and Molina, L. T. 2016. Does urban vegetation enhance carbon sequestration? *Landscape and Urban Planning*. 148 : 99–107.

Walton, C.S. 2003 *Leucaena (Leucaena leucocephala) in Queensland*. Department of Natural Resources and Mines, Queensland, Australia.

Wang, Y.C. 2011. Carbon sequestration and foliar dust retention by woody plants in the greenbelts along two major Taiwan highways. *Annals of Applied Biology.* 159 (2) : 244–251.

Witt, A. B. R., Kiambi, S., Beale, T. and Van Wilgen, B.W. 2017. A preliminary assessment of the extent and potential impacts of alien plant invasions in the Serengeti-Mara ecosystem, East Africa. *Koedoe.* 59 (1): 1-16.

Yoshida, K. and Oka, S. 2004. Invasion of *Leucaena leucocephala* and its Effects on the Native Plant Community in the Ogasawara (Bonin) Islands I. *Weed Technology*. 18(sp1) : 1371-1375.

Zanne, A.E., Lopez-Gonzalez, G., Coomes, D.A., Ilic, J., Jansen, S., Lewis, S.L., Miller, R.B., Swenson, N.G., Wiemann, M.C., Chave, J. and Lopez-Gonzalez, G. 2009. *Global Wood Density database*.