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Effects of Urban Green Infrastructure on Carbon Storage in Edo North, Nigeria

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Abstract The preceding century has suffered significant changes associated with global warming and biodiversity loss. These environmental problems are triggered by man's anthropogenic activities in the form of land use land cover change and emission of Green House Gases. This lack of respect for the environment has resulted in the increasing effect of climate change, coupled with the countless environmental problems experienced today such as flooding, urban heat, soil erosion and biodiversity loss among others. However, embracing a strategy that will promote green economy can help tackle these challenges. This study assessed the effect of urban green infrastructure on carbon storage. In particular, the study evaluated the contribution of cashew plantations to carbon sequestration across three Local Government Areas in Edo North, Nigeria. Cashew trees were compared with other tree species mostly used in urban green infrastructure (manila palm and false ashoka). Random sampling was used in the selection of LGAs, towns, and sites for the study. Allometric equations was used to estimate the amount of carbon in biomass and soil samples were tested for bulk density and soil organic carbon. Carbon stock varied significantly between the tree species ($p = 0.001 < 0.05$) with cashew accounting for the highest amount of carbon stock at 68.03tC/ha followed by false ashoka (55.8tC/ha) and Manila palm (53.68tC/ha). Result also indicated that the greatest carbon stock in the Above-ground biomass is found in the trunk of the trees which is true for all tree species (cashew = 21.47tC/ha [76.7%]; manila palm = 15.1tC/ha [75.4%] and 17.48tC/ha [80.2%]). The study has shown that cashew plantations are of great benefit to in the effort towards ameliorating the effects of climate change by its high carbon sequestration potential.

Keywords Urban green infrastructure, Cashew tree, Carbon Storage, Biodiversity loss, Climate change

Introduction

The impact of man's anthropogenic activities in the form of land use land cover change has posed severe consequences associated with global warming and biodiversity loss over the last century (Celik, 2013). This situation is further intensified by the growing population of urban areas. According to Aromar, (2013), two thirds of the world population is estimated to reside in urban areas by the year 2050. This increase in urban form (in terms of houses, offices, industries, and markets among others) has drastically changed land use/land cover (LULC) patterns (Andersson et al., 2014), resulting in biodiversity loss, soil fertility loss and decrease in carbon sequestration. This lack of respect for the environment has resulted in the increasing effect of climate change coupled with the countless environmental problems experienced today such as flooding, urban heat island, soil erosion and biodiversity loss among others.

Majority of these environmental crises arises from poor urban designs and how cities have been developed; using up eco-spaces and the upsurge of industrialization. Shu-Yang, Freedman, and Cote (2004) opine that this is basically a problem of not adequately integrating urban green infrastructure into planning. Many of the environmental problems mostly in the urban areas have arisen from design problems which can be resolved by promoting urban green infrastructure in urban settings.

Urban green infrastructure is a vital approach in environmental and urban planning which integrates green infrastructure as a key deciding factor that guides the sustainability of urban development (Cook, 2014). It considers the cultural, biotic, and abiotic components of sustainable development (Ahern, 2007). Urban green infrastructure is aimed at restoring or preserving the integrity of vital natural ecological systems while also giving room for compatible human activities and allowing lands to be used economically. The concept of urban green infrastructure has gained increasing interest in by Architects, civil engineers, urban and regional planners, ecologists, and social scientist among others. This is especially due to the growing awareness that local environmental impacts are usually of global consequence (Cook, 2014; Festus, 2014) and the desire to make cities more habitable. However, achieving an all-round sustainable development requires the inclusion of trees which are known for their high economic value such as cashew (*Anacardium occidentale*). Fruit trees like cashew have proven to have several economic and environmental benefits (Kibira et al., 2015, Lux et al. 2003, Oriola, 2009, Agbongiarhuoyi, Aigbekaen and Akinbile, 2008).

In Nigeria, cashew trees are often grown as a form of plantation forestry and are grown widely due to their environmental friendly nature (Aweto, 1990; Oriola, 2009). Cashew trees are grown in all regions of Nigeria because of its several environmental benefits. Because cashew requires annual rainfall as low as 600ml, it can be grown in the north of the country and the semi-arid regions to ameliorate desert encroachment which greatly threatens the area. It can also be cultivated in the southern part of Niegira to check the effect of gully erosion. From an ecological perspective, the cashew tree possesses great potential to restore of rigorously degraded lands (Dick, Garnett, Jones, Karim, Sundufu, Wadsworth and Okoni-Williams 2015).

There’s been increasing interest in trees in urban areas due to its ability to trap and store carbon in the soil as it is found to be a potential mitigation strategy for greenhouse gases. To these effects, several studies have been carried out to access the potential of cashew trees (Arulselvi, 2011; Noumi et al., 2017; Daouda 2017; Ndiaye et al., 2020; Victor et al., 2021) as effective urban green infrastructure with high carbon sequestration potential. Comparing the carbon sequestration potential of these fruit trees with other widely used tree species in urban ecological design such as manila palm (*Adonidia merrillii*), and false Ahoka trees (*Polyalthia longifolia*) will likely improve the value of cashew farmers in carbon market schemes and policies such as REDD+. Thus, this study evaluates the carbon stock potential of cashew tree (*Anacardium occidentale*), manila palm (*Adonidia merrillii*), and false Ahoka (*Polyalthia longifolia*). This is with the view of determining which tree species contributes most to carbon sequestration.

Methodology

Study area

Edo North is one of the three senatorial districts in Edo State, Nigeria. The district has six (6) Local Government Areas (LGA) (Etsako West, Estako Central, Estako East, Owan South, Owan Central and Owan East). The inhabitants of these communities are people who engage in farming and trading as a source of livelihood coupled with civil/public servants. The study area is relatively characterised by low to medium population density communities, however, Auchi town which is the Local Government headquarter of Etsako West LGA has a high population density. This is due to the influx of people as a result of its strong educational and links. This is so as Auchi town is the seat of a renowned Federal Polytechnic which has encouraged the influx of people to the area for both commercial and educational activities. In addition, Edo North is positioned between latitude 06° 07’N and 07° 06’N of the Equator and between longitude 05°07’E and 06°08’E of the Greenwich Meridian (Fig. 1). Edo North covers a total land mass of about 6169km/sq; home to a total population of 955791 persons. Edo State in general is bounded by Delta State to the South, Ondo State to the West; Kogi State to the North and Anambra State to the East. See Figure 1 showing Nigeria, Edo State and Edo North (the study area).

Sampling of trees technique

Out of the six LGAs in Edo North, three LGAs were selected using random sampling, from each of this three LGAs (Etsako West, Etsako Central, and Akoko Edo), one urban center was randomly selected each (Auchi, Fugar, and Igara), making it a total of three urban centers selected for the study. Three species of trees were purposely selected for this study, they include: cashew, manila palm and false ashoka. From each of these three areas of study, random sampling was used to sample one site each for cashew, manila palm and false ashoka trees within the study area since they are found in scattered locations. A total of 9 sites were selected for all tree species.

Carbon estimation

Generally, the amount of carbon sequestration in an ecosystem is estimated by assessing the biomass contained in the plots because atmospheric CO^2 is accumulated by plants in their cellular components (Tufekcioglu et al., 2003; Sharrow and Ismail, 2004). In this study, the dry biomass present in the aboveground and below-ground components as well as the carbon stock in the soil at a depth of 0 – 30cm were evaluated.

Vegetation data collection

Under each urban green infrastructure or urban ecological component, diverse methods were employed to collect data at every site. Firstly, the carbon stock in tree components was estimated using the allometric equations developed by the FAO (1997) as shown in Table 1. Secondly, data on litter and herbaceous biomass (Above-ground biomass) were collected using a $50cm^2$ quadrant. At every site, the quadrant is thrown to 4 different positions to account for heterogeneity data collected. The litter in the quadrant at all 4 positions are collected and weighed at the site, enclosed in polytene bags, and taken to the laboratory for carbon stock analysis. In measuring the herbaceous biomass, the clear-cut method was employed (see Toko et. Al., 2008). The allometric equation was also employed in calculating the Below-ground biomass (Cairns et. al., 1997).

Table 1: Carbon stock in tree components using allometric equations

Tree component	Adjusted model of carbon stock Estimation (Kg/tree)	R^2
Trunk	$SCT = 191 \times (D^2H)$	0.97
Branch	$SCB = 46 \times (D^2H)$	0.95
Leaves	$SCL = 5.4 \times (D^2H)$	0.96

Where: D = tree diameter at 1.30 m, H = tree height (in meter), SCT, SCB, and SCL = carbon stock in the trunk, branches, leaves respectively.

Soil collection

In each of the sites, 4 soil samples at depth of 30cm were collected and taken to the laboratory for analysis of carbon stock. These samples were collected at 5 random positions on each site in order to account for heterogeneity of various positions at the site. This implies that 45 soil samples were collected under the following ecological component, cashew trees (15), manila palm (15), and false ashoka tree (15). The soil samples were collected using a quadrat of $25cm^2$. In the collection of soil samples, soil samples were collected randomly from four points in the established quadrat and bulked to represent a sample for such area. This is because some points in the quadrat may have high or low concentration than others; hence, the spatial heterogeneity in data collection from many points helps to put that under control. The soil samples collected were stored in polythene bags and labeled; they were also geo-referenced and thereafter air-dried and taken to the laboratory for analysis of carbon stock (using the elemental analysis or dry combustion method) and bulk density.

Estimating the total carbon stock

Total carbon stock at each site equals the summation of all the carbon stock of every component measured. Total carbon stock = AGB + BGB + LC + HC + SOC

Where:

AGB = Above-ground biomass

BGB = Below-ground biomass

LC = Litter carbon

HC = Herbaceous carbon

SOC = Soil carbon

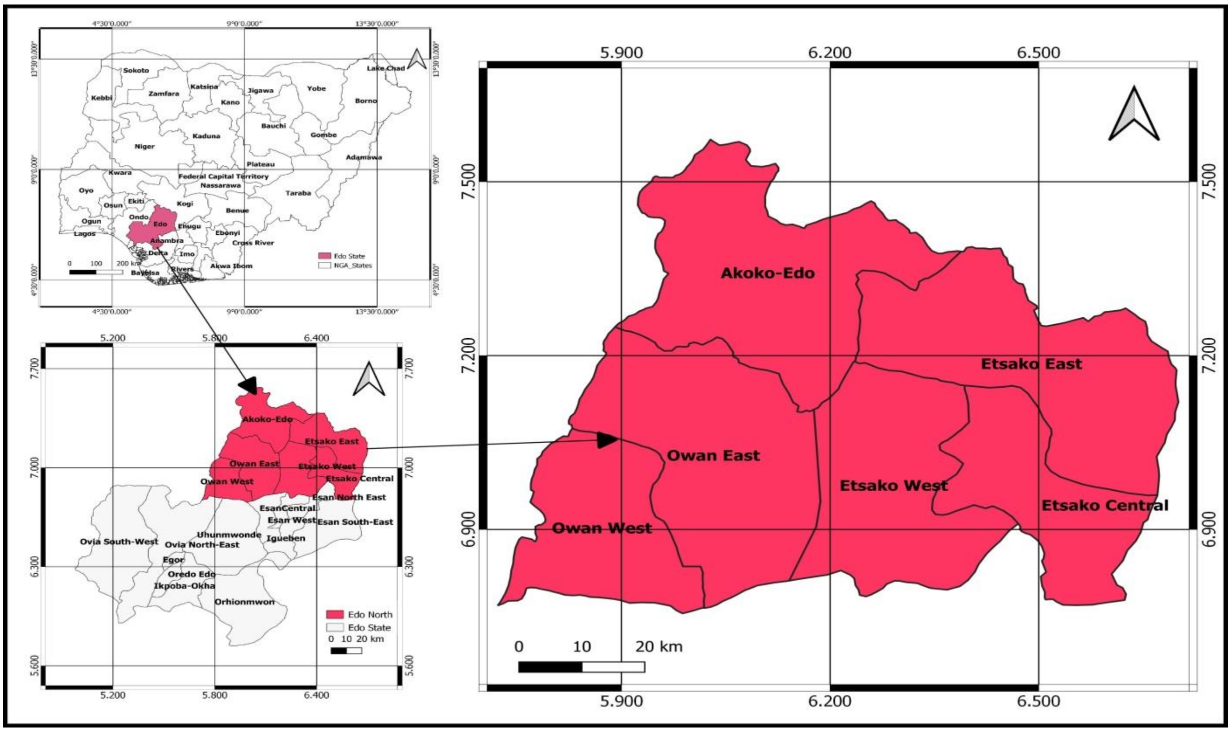

Figure 1: Nigeria showing Edo State and Edo North (The study area)

Method of Data Analysis

Soil and vegetation will be analyzed using varying statistical tools. Data collected were coded into excel spreadsheets and analysis were carried out using STATGRAPHICS and R software. Analysis of Variance was used to test for significance at 5% confidence level.

Results and Discussions

Carbon stocks in the tree components and BGB

Result displayed in Table 2 indicates a significant variation (p<.05) between the different component parts of cashew. Of the three components being measured (trunks, branches and leaves), result shows that the trunk of all the trees under study carries the highest amount of carbon stock at 76.7% of the total carbon stock for the tree component for cashew, 75.4% for manila palm and 80.2% for false ashoka.

Table 2: Mean ± standard deviation of carbon stock (t/ha) in the different tree components

Tree specie	Site	SCT	SCB	SCL	TSC	BGB
Cashew	Auchi	23.71±1.29a	7.14±1.21a	1.24±0.13b	32.09±3.53b	6.19±1.11a
	Fugar	21.3±1.32a	5.17±0.69a	0.83±0.09c	27.3±2.94b	5.11±0.65a
	Igara	19.4±1.38bc	4.34±0.63b	0.79±0.08cd	24.53±2.8cd	4.12±0.51a
	Mean	21.47±2.91A	5.55±0.77A	0.95±0.10A	27.97±3.2A	5.14±0.68A
Manila palm	Auchi	17.29±3.16bc	4.85±1.41a	0.73±0.09b	22.87±1.74a	4.11±1.25a
	Fugar	12.37±3.04c	3.96±0.88c	0.64±0.05cd	16.97±1.69bc	2.98±0.76a
	Igara	15.64±3.11d	4.01±1.07e	0.59±0.02e	20.24±1.83cd	3.21±0.95a
	Mean	15.1±3.16A	4.27±1.11A	0.65±0.07A	20.02±1.58A	3.43±1.13A
False ashoka	Auchi	19.84±4.84ab	4.14±1.21a	0.83±0.10a	24.81±2.64a	2.45±0.96a
	Fugar	16.33±3.98cd	3.36±0.86a	0.78±0.08c	20.47±1.98c	2.13±0.79a
	Igara	16.27±3.84e	3.17±0.74bc	0.69±0.08d	20.13±1.76e	1.98±0.74a
	Mean	17.48±4.21A	3.55±0.97A	0.77±0.12A	21.8±2.11A	2.19±0.88A

This was followed by the branches which holds about 19.8% of the total carbon stock for cashew, 21.3% for manila palm and 16.3% for false ashoka leaving the balance to the leaves. Result further showed that between the different tree species under study, there was a significance difference in carbon stock contained in the trunk, branches and leaves at p value of ($p = 0.001 < 0.05$), ($p = 0.000 < 0.05$) and ($p = 0.000 < 0.05$) respectively. There was also a significant variation in the BGB between the different tree species being studied ($p = 011 < 0.05$). However, there was no significant variation in carbon stock contained in tree trunks, branches and leaves within the same tree species across the LGAs ($p = 0.734 < 0.05$ for trunk, $0.853 < 0.50$ for branches and $0.697 < 0.05$ for leaves). The result also indicates that cashew trees have a higher mean of carbon stock contained in the tree components at 27.97±3.2 followed by false ashoka at 21.8.02±2.11, with manila palm having the lowest carbon stock in tree component at 20.02±1.58.

SCT, SCB, SCL, TSC and BGB: are respectively the carbon stock in trunk, branches, leaves, total carbo stock and below-ground biomass; Carbon stocks are expressed in tons per hectare. Values assigned the same letter are not statistically different ($p > 0.05$; Duncan's test).

Litter and Herbaceous Carbon Stock

Table 3 displays the mean ± standard deviation of the amount of carbon contained in the litter and the herbaceous vegetation across the 3 species of tree being studied. Between the 3 species of tree being studied, result indicated that there was no significant variation in herbaceous vegetation ($p = 0.698 < 0.05$). However, there was a significant variation in the carbon stock contained in the litter ($p = 0.017 < 0.05$). Among the three species of tree being studied, cashew possessed a higher mean of carbon stock contained in the litter at 4.25±0.11 tC/ha

Table 3: Carbon stock in litter and herbaceous vegetation

Tree specie	SCH (tC/ha)	SCLT (tC/ha)	Total (tC/ha)
Cashew	3.21±0.33A	4.25±0.11A	7.46±0.93A
Manila palm	3.18±0.31A	2.51±0.06A	5.69±0.76A
False Ashoka	3.02±0.30A	3.12±0.09A	6.14±0.88A

SCH, SCLT: are Carbon in herbaceous vegetation and litter respectively; Carbon stocks are expressed in tons per hectare. Values assigned the same letter are not statistically different ($p > 0.05$; Duncan's test).

Bulk density, soil carbon content and soil organic carbon stock

The study revealed that there is no significant variation in soil bulk density between the three species of trees under study. There was also no significant variation in soil carbon content ($p = 0.503 < 0.05$). The same trend was noticed with the soil organic carbon. Although cashew hold the highest carbon content at 27.46±2.43, there is no significant variation between the three species of tree being studied ($p = 0.001 < 0.05$).

Table 4: Bulk density, soil carbon content and soil organic carbon

Tree specie	BD	SCC (tC/ha)	SOC (tC/ha)
Cashew	0.98±0.03A	2.95±0.08A	27.46±2.43A
Manila palm	1.01±0.01A	2.86±0.06A	24.54±1.79A
False Ashoka	0.98±0.02A	3.01±0.09A	25.67±1.83A

BD, SCC and SOC: are bulk density, soil carbon content and soil organic carbon respectively; Carbon stocks are expressed in tons per hectare. Values assigned the same letter are not statistically different ($p > .05$; Duncan's test).

Total carbon stock

To obtain the total carbon stock for a site, the total carbon stock contained in tree components, the below ground biomass, the above ground biomass and soil organic carbon were all summed together (Table 5) result indicates that Cashew has the highest carbon stock (68.03tC/ha) among the three species of trees been studied, followed by false ashoka at 55.8tC/ha and manila palm at 53.68tC/ha. Result from the ANOVA indicates that there is significant variation in the total carbon stocks between the three species of trees being studied ($p = 0.001 < 0.05$)

Table 5: Total carbon stock

Tree specie	TSC (tC/ha)	BGB (tC/ha)	SCH + SCLT (tC/ha)	SOC (tC/ha)	Total carbon stock (tC/ha)
Cashew	27.97±3.2A	5.14±0.68A	7.46±0.93A	27.46±2.43A	68.03±10.54A
Manila palm	20.02±1.58A	3.43±1.13A	5.69±0.76A	24.54±1.79A	53.68±8.37A
False Ashoka	21.8±2.11A	2.19±0.88A	6.14±0.88A	25.67±1.83A	55.8A±8.29A

TSC, BGB, AGB, SOC: Total carbon in tree components, below-ground biomass, above ground biomass and soil organic carbon respectively; Carbon stocks are expressed in tons per hectare. Values assigned the same letter are not statistically different ($p > 0.05$; Duncan's test).

Discussion

Overall, the amount of carbon contained in the above ground biomass is showed to be significantly greater than that of the below ground biomass. This is consistent with the result of Montagnini (2004) who reported that in tropical areas, the amount of carbon captured are concentrated in the above ground biomass as opposed to the roots and soils. Similar result was also reported by Bello, (2017); Kooke 2019 and Noumi 2017 which were carried out in Burkina Faso, Senegal and Morrocco; Cameroon and Benin respectively. Cashew trees sequestered the greatest amount of carbon stock among the three species of trees being studied. The average amount of carbon stock in cashew was at 68.03 tC/ha. This was followed by Faslse ashoka (55.8tC/ha) and Manila palm (53.68tC/ha). This falls between the range of carbon stock reported to be contained in cashew by Bello et al. (2019).

Cashew trees have the largest value of Above-ground carbon (35.43 tC/ha) in the study area. This value is greater than that reported by Thiombiano (2010) at 21.7 t/ha and slightly higher than that reported by Noumi et al. (2017) at 32.56 t/ha. Among the three LGAs under study, cashew has the largest carbon in tree components in Auchi, Etsako West LGA at 32.09 t/ha followed by Fugar in Etsako Central (27.3t/ha) and Igara, in Akoko Edo LGA (24.53 t/ha). This is most likely due to the fact that Auchi has a greater urban population compared to the other two areas. Consequently, the amount of carbon present in the atmosphere is likely greater than that found in the other two locations.

The environmental benefits of cashew and its carbon sequestration potential is very encouraging. Aside the numerous economic benefits that it bears as reported in Aweto (1990); Oriola (2009) and Gilleo, Jassey, and Sallah (2011), it has shown to be better at carbon sequestration than the other tree species mostly adopted in urban green infrastructure in the study area. Needless to say, that there is need for more investment by government and NGOs to sensitize cashew farmers of new and improved cashew farming practices and aid in ameliorating some of the challenges of cashew farming in the study areas as reported by (Ifatimehin et al., 2021) which includes price fluctuations, theft of cashew nuts from farm, lack of capital to support cashew farming due to its high demand for large plots of land.

Conclusion

This study has proven that cashew plantations have a great potential at ameliorating the effects of climate change due to its large carbon sequestration potential. It is therefore crucial to incorporate the planting of cashew trees into urban designs, thus creating food, economic benefits and sequestering carbon. This has shown that agroforestry can be used to build new carbon pools not only in rural areas but in urban areas where this is mostly needed. Its potential to sequester carbon can also grant cashew farmers access to carbon credit markets. There were also several species of pre-existent savannah in cashew stands. This form of agroecosystems are not only good for carbon sequestration but also a refuge for endangered species.

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