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Metropolitan Area Adamawa State Nigeria

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SEASONAL VARIATIONS IN CARBON STORAGE AND SEQUESTRATION BY TREES IN JIMETA METROPOLITAN AREA ADAMAWA STATE NIGERIA

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ABSTRACT: This study assessed the seasonal variation in carbon storage and sequestration by trees in Jimeta metropolitan area of Adamawa State, Nigeria. One hundred and sixty (160) trees belonging to eleven (11) species were sampled at different locations along the major streets in the study area. The tree species include: *Ximania americana*, *Delonix regia*, *Eucalyptus camaldulensis*, *Azadirachta indica*, *Mangifera indica*, *Cassia fistula*, *Terminalia catappa*, *Terminalia mentally*, *Gmelina arborea*, *Albizia lebeck* and *Dalbergia sisso*. The experiments were conducted in two seasons (dry and rainy seasons). The leaves, barks and woods samples of each tree were collected from the field by non-destructive method. The samples were analyzed in the laboratory through loss-on-ignition (LOI) method and then allometric equations were used for estimating the percentage organic carbon from the samples. The mean was used to determine the carbon storage quantities in the leaves, bark and wood of the selected tree species during dry and rainy seasons T-test was used to examine the seasonal differences in carbon storage (%) by trees. During dry season, the carbon storage potential by leaves showed highest on *Terminalia mentally* (53.79). On bark, *Gmelina arborea* recorded the highest (54.29). While during the rainy season, the mean square values by the leaves, barks and woods showed highest on *Gmelina arborea* (54.79). Generally, *Gmelina arborea* and *Albizia lebeck* recorded the highest in terms of carbon storage potential both during dry and rainy seasons. The results from t-test showed no significant differences ($P \geq 0.05$) in carbon storage among the leave, bark and wood between dry and rainy seasons. The carbon storage by selected tree species was higher in the rainy season than dry season. From the mean values, the leaves and wood were higher in carbon storage potential in rainy season than dry season. While in the bark sapling, the carbon storage was recorded higher in dry season than rainy season. This indicates that the carbon storage potential by the trees was higher in the rainy season (higher photosynthesis) than dry season (lower photosynthesis) Efforts should also be geared towards enlightenment of the communities on the benefits of trees in offsetting CO₂ from the atmosphere. A strong long-term political commitment by the government to prevent deforestation, to manage and protect the remaining trees is required as a high priority.

Key Words: Seasonal Variation, Climate Change, Tree Components, Carbon Storage, Jimeta

1. INTRODUCTION

Global warming is among the most dreaded problem of this millennium which just represents one aspect of climate change. The global warming is cause mostly by increasing concentration of greenhouse gases in the atmosphere resulting to change in climate pattern. Many

different human activities, or anthropogenic causes, of global climate change have been identified. These include land-use change, development, deforestation, and emission of greenhouse gases that amplify the greenhouse gas effect (Mannion, 1998 Brittany, 2013). The greenhouse gas effect is a naturally occurring phenomenon, in which heat is trapped by gases in the

Earth's atmosphere and radiated back to the earth's surface. It is essential for life to exist on Earth, but increased greenhouse gases in the atmosphere have caused the temperature of Earth's surface to rise rapidly.

Many different greenhouse gases exist, but those of major concern include carbon dioxide (CO₂), methane (CH₄), nitrous and sulfur dioxide (N₂O and SO₂), chlorofluorocarbons (CFCs), hydro fluorocarbons (HFCs), and tropospheric ozone (O₃) (Warrick and Farmer, 1990; Brittany, 2013). Each of these gases affects the atmosphere at different levels of severity and is emitted by human activities. The gas of highest concern is carbon dioxide. Although carbon dioxide is not the strongest greenhouse gas, it is emitted in the greatest amounts from anthropogenic activities.

IPCC (2007); Superales (2016) reported that the concentration of atmospheric CO₂ has increased from 278ppm in the pre-industrial era (1970) to 379ppm in 2005 with an average increase of 1.9ppm per year; largely attributing to human activities like burning of fossil fuels, land use change and deforestation especially in tropical forests. The report has also precisely predicted an increase of 1.8^o C in global temperature at the end of this century. Thus, the provision of article 4 which states that necessitates on preventing and minimizing climate change by limiting anthropogenic emission of greenhouse gases and protecting and enhancing the greenhouse gas sinks and reservoirs (Perschel *et al.*, 2007).

Yang (2008); Superales (2016), in mitigating climate change; the society should immediately take significant step to reduce greenhouse gas emission through energy conservation and improve efficiency in power supply. Forest can also play an important role in mitigating climate change by naturally taken carbon out of the atmosphere there by reducing the impact of CO₂ emissions. Higher temperature, change in precipitation pattern and more frequent and severe disturbances are all the projected result of increased level of atmospheric carbon dioxide.

Trees accumulate more carbon dioxide than the atmosphere and play an important role in global carbon cycle. With the increasing concern for rising CO₂ concentrations, its roles on the long-term carbon pool for assimilation of atmospheric CO₂ are being realized. CO₂ is taken up from the atmosphere during the growing season of vegetation and stored as plant biomass. (Sedjo *et al.* 1998). The fundamental science of carbon sinks is well understood-biological growth binds in the cells of trees and other plants while releasing oxygen into the atmosphere through the process of photosynthesis. Tree sinks have the potential to play a valuable role in carbon

sequestration. Although sinks are only a partial solution to anticipated global warming, they do appear to have the potential to sequester 10 to 20% of the anticipated build-up atmospheric carbon over the next 50 years (Labata *et al.*, 2012; Superales, 2016).

Seasonal variation in CO₂ assimilation was apparent, with rates peaking at different months across the study period. The highest CO₂ assimilation occurred from July to October. Seasonal variation in CO₂ assimilation was also observed: minimum CO₂ assimilation was recorded from January and April. The maximum CO₂ assimilation of a single tree was 6565.99 g in August and 2129.92 g in July.

The CO₂ assimilation from July August and September was 77.15%, 97.05%, and 79.97% of annual CO₂ assimilation respectively (Chung *et al.*, 2016). This result demonstrated that droughts have long-lasting consequences on photosynthesis in *griffithii*, which support previous research indicating that water stress limits tree growth and decreases photosynthetic efficiency (Colom and Vazzana, 2003; Ogaya and Penuelas, 2003). The extended dry seasons in their study period occurred during the early growth season of *griffithii* (March to April). Also, Julia *et al.*, (2014) in their study observed the highest values for organic matter, organic carbon and carbon storage were found during the rainy seasons. Moreover, a previous study had demonstrated that a spring drought may suppress canopy development and exert long-lasting effects on annual ecosystem carbon balance that remains even when soil water availability improves (Noormets *et al.*, 2008).

Despite the wide spread recognition of agroforestry for carbon storage there is still lack of quantitative data on the specific systems and their contribution to climate change mitigation (Brown, 1997; Superales 2016) particularly on the carbon stocks of the tree components (leaves, bark and wood). Presently there no actual baseline data on carbon stocks of the tree components and can be found in literature. In consonance with the concerted efforts of the local community in promoting the reduction of CO₂ emissions, the conduct of this type of study is imperative. Therefore, the carbon storage potential in the components of some selected tree species in Jimeta metropolitan area has to be elucidated to shed light on the contribution of these tree species components in greenhouse gas reduction.

2. STUDY AREA

2.1. Location

Jimeta (Yola North) is located in Adamawa State of the North- Eastern part of Nigeria. Jimeta's geometrical

location is between latitude $9^{\circ} 13'$ and $9^{\circ} 17'N$ and longitude $12^{\circ} 24'$ and $12^{\circ} 28'E$. Zemba (2013) reported that Jimeta had an approximate land area of 111.85km^2 in 2002. The city is located in a flood plain of the Benue valley and is relatively asymmetrical, having possibilities of expansion in only North-West through South as North to South-East are bordered by River Benue and its adjoining marshy lands. It is bordered by Yola South Local Government in the South and West and Girei Local Government Area in the North and East.

2.2. Climate

Jimeta area has a typical tropical climate. The average daily hours of bright sunshine are about 7-8 hours and the wind speed averaging about 76.1Km/hr . It has monthly mean sunshine hours of about 220 from January to April. This decrease to a mean value of 207 hours between May and September was due to increases in cloud. The mean sunshine hours increase again to about 255 for the period between October and December. The average sunshine hours for the year as a whole stand at about 2750 approximately (Adebayo and Umar 1999; Zemba 2010).

Air temperature characteristics in Adamawa state as a whole is typical of West African Savannah Climate. Temperature in this region is generally high throughout the year. In Jimeta, there is a seasonal change, indicating a gradual increase from January to April. This is because at this period the sky becomes clearer leading to more receipt of solar radiation. The seasonal maximum usually occurs in April reaching as high as 43°C . There is a distinct drop in temperature at the onset of rains due to the effects of cloudiness. A slight increase after the cessation of rain (October-November) is common before the onset of harmattan in December when temperature drops further. The minimum temperature value for the area can be as low as 18°C between December and January.

Between January and March, relative humidity is extremely low (20-30%) in Jimeta. It starts increasing as from April and reaches its peak (about 80%) in August and September. This is due to the influence of the humid maritime air mass, which covers the whole area during this time. This could also be attributed to the effect of River Benue and the basin-like terrain of the city. Relative humidity starts to decline again from October following the cessation of rains.

Jimeta has two distinct seasons- the rainy and dry season. The rainy season runs from the months of May through October, while the dry season commences in November and ends in April/May. The average annual rainfall is put at about 960mm with the highest occurrence in August and September, when intensity assumes over 20% of the

annual value. In fact, in the past few years, the highest occurrence of the rainfall has shifted to September, as opposed to August previously, with an intensity of about 15% of the annual value.

The wind direction in the area is characterized by northeast and westerly winds. The northeast trade winds bring harmattan from the north during November to March through the influence of tropical continental air mass while the influence of tropical maritime air mass from the south brings about rains during the period of May to October.

Evaporation is generally high in the area due to high insolation. The monthly distribution pattern is similar to that of sunshine and temperature, which shows significant decline during the rainy season. A record of evaporation in Jimeta shows that, the minimum value of about 2.5ml occurs in August while the highest value is in March (about 15ml) (Adebayo and Umar 1999; Zemba, 2010).

The natural vegetation over a geographical area is essentially a response to the climate and some other parameters such as edaphic and topographic (Adefioye 2013; Olutoyin et al, 2017). Nigeria's vegetation belts reflect this very close link between vegetation and climate, and hence the similarity in the west-to-east zonation of both climate and vegetation. With the south-to-north progressive decline in total rainfall and length of wet season, vegetation belts are demarcated in a west-to-east pattern characterized by transitional zones between one belt and another (Aweda and Adeyewa 2009; Olutoyin et al, 2017). The prevalence of drought and desertification in the northern part of the country and the incessant pastoral clashes resulted in to the depletion of vegetation in the area (FAO 2005; Olutoyin *et al*, 2017).

The climate of the north is drier than that of the south and is marked by a greater range of temperature. The hottest month averages about 32°C (90°F); the coolest, 21°C (70°F). Most of central Nigeria receives 635mm to $1,270\text{mm}$ of rain each year. The natural vegetation of Nigeria varies with the climatic conditions, and particularly the amount of precipitation. The savanna vegetation predominates the sub humid central zone and the drier north. About one-eighth of Nigeria is covered with forests. Rainfall distribution over Nigeria for the study period revealed that the northern part of Nigeria experiences rainfall as low as 500mm , especially at the north-eastern part of Nigeria, with a corresponding low vegetation cover. Therefore, variability in rainfall is a key variable in explaining the spatial variation in vegetation cover (Arome and Ejaro 2012; Olutoyin et al, 2017).

3. MATERIALS AND METHODS

This section discussed the materials and method used in data collection and analysis. It discussed the data and sampling techniques, field data collection procedures as well as laboratory analysis procedures.

3.1. Data and Sampling Techniques

The study used both primary and secondary data. The primary data that was used for this study include; data on the plant community structure, data on the carbon storage potentials of each sampled tree species. The secondary data include; the relevant literatures, maps and some important geographical information regarding the study area which were sourced from publications such as journals, books, bulletins, institution of learning, internets etc.

One hundred and sixty (160) trees belonging to eleven (11) different species were sampled at different locations

along the major streets in the study area (Fig.1). The tree species that were sampled include: *Ximania Americana*, *Delonix regia*, *Eucalyptus camaldulensis*, *Azadirachta indica*, *Mangifera indica*, *Cassia fistula*, *Terminalia catappa*, *Terminalia mentally*, *Gmelina arborea*, *Albizia lebbeck* and *Dalbergia sisso*. These trees are the dominantly planted and good growing species in the study area which justify the basis for their selection. The leaves bark and wood were obtained from each of the sampled tree species. The main objective was to determine the potential of different tree species to sequester and store carbon. The samples were collected in two seasons (dry and rainy seasons). For the rainy season the field work and laboratory analysis were conducted from July to September 2016, while in dry season it was conducted from January to March 2017. All the trees were sampled along the major streets in the study area which was considered to be having the same exposure on the amount of carbon emitted from various sources. Samples were collected from both the exotic and planted trees grown in the study area.

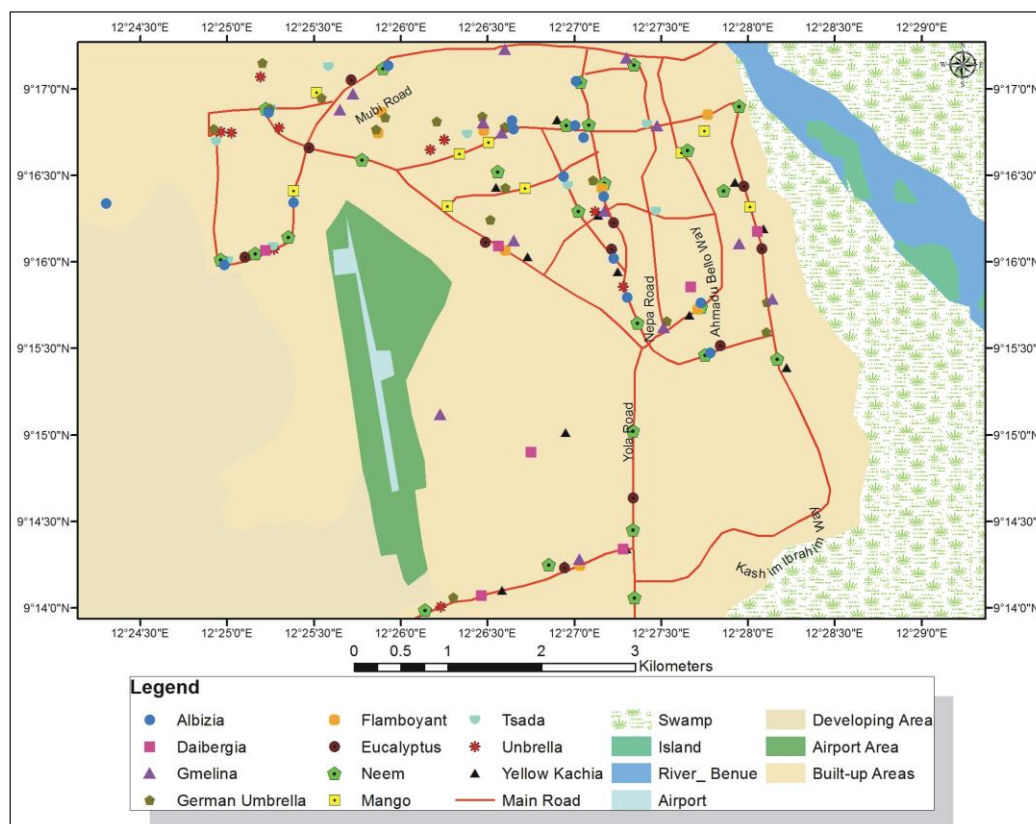


Figure 1: The Locations of the Sampled Tree Species

3.2. Field Data Collection

Diameter at breast height (DBH) was taken using DBH

tape. The Global Positioning System (GPS) was used to get the location of sampled trees. The barks were peeled off using hatchet. The wood was collected using bark

borer. The leaves were also plugged from each sample tree using hands and knife (Jerry, 2016).

3.3. Laboratory Analysis

After the woods, barks and leaves samples of the tree species were collected, they were immediately taken to the laboratory for determination of carbon content percentage using loss-on-ignition (LOI) method in a muffle furnace. LOI method involves combusting samples at high temperature and measuring the weight loss, which is convenient and accurate method to estimate organic carbon. In the laboratory, the samples were further broken into smaller pieces and the fresh weight was taken using weighing balance. After taking the fresh weight, the samples were dried in the oven for 1- 2 hour at 105°C to get dried weights. Oven dried grind samples were taken (11.00g) in pre-weighted crucibles. The crucibles were placed in the furnace at 550°C for 1 - 2 hour. Crucibles were then cooled slowly inside the furnace. After cooling, the crucibles with ash were weighted for calculation of percentage of organic carbon (Arul and Karthick 2013).

Allometric equation was used to estimate the carbon storage contents (%) among the leaves, barks and wood of the sampled tree species. Allometric equations following Allen et al. (1986); Arul and Karthick, (2013) was adopted for estimation of organic carbon percentage. Allometric equations are given in equations 1 to 5 below;

Calculation of ash (%) for estimation of organic carbon:

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \dots \dots \text{eq. 1.}$$

Where W₁ is the weight of crucibles,
W₂ the weight of oven dried grind samples + Crucibles,
W₃ is the weight of ash + Crucibles

Estimation of organic carbon (OC):

$$\text{OC (\%)} = (100 - \text{Ash \%} \times 0.58 \dots \dots \text{eq. 2.}$$

Calculation of Biomass and Properties of the Sample

The biomass properties of the wood, leaf and bark were calculated using the following basic Formula (Brown 2002; Jerry 2016) on the basis of fresh and dry weights of the Samples:

$$\text{MC (\%)} = \frac{\text{Fresh wt} - \text{Dry wt}}{\text{Dry wt}} \times 100 \dots \dots \text{eq. 3.}$$

$$\text{OMC (\%)} = \frac{\text{Dry wt} - \text{Ash wt}}{\text{Dry wt}} \times 100 \dots \dots \text{eq. 4.}$$

$$\text{DMC (\%)} = \frac{\text{Dry wt}}{\text{Fresh wt}} \times 100 \dots \dots \text{eq. 5.}$$

Where MC is the Moisture Content, OMC is the Organic Matter Content, DMC is the Dry Matter Content and Wt is the Weight.

3.4. Statistical Analysis

The mean was used to determine the carbon storage quantities in the leaves, bark and wood of the selected tree species during dry and rainy seasons. T-test was also used to determine the differences in carbon storage between dry and rainy seasons of the tree's components.

4. RESULTS AND DISCUSSIONS

4.1. Biomass and Carbon Storage Potential of the Leaves, Barks and Woods of the Selected Tree Species

This section presents and discusses the results on the biomass as well as carbon storage potential in the leaves, barks and woods of the selected tree species within the context of the study. The biomass and carbon storage potential were estimated using allometric equation presented in chapter three (methodology).

4.2. Biomass Properties of the Leaves, Barks and Woods of the Selected Tree Species

The percentages Moisture Content (MC), Dry Matter (DM), and Organic Matter (OM) from the leaves, barks and woods of the selected tree species are presented in Table 1. The biomass percentage was estimated using equation adopted from Jerry (2016) as stated in methodology. The average MC of the tree parts ranges from 40.10% - 61.55% with DM content of 38.45% - 59.90% and OM content of 86.34% - 95.68%. Among the three (3) parameters (leaves, barks and woods) considered in the study, the leaves appeared to have the highest MC (61.55%) followed by barks (49.47%) and the woods (40.10%) contained the least. This result disagrees with that of Jerry (2016) whose study revealed that, the highest MC (67.38%) was contained in the barks followed by leaves (62.62%) and lastly by the wood of 43.74% respectively.

In terms of percentages OM content of the saplings, the wood is the highest which contained about 95.68%, followed by the leaves (89.79%) and lastly by the bark (86.34%). However, the wood of each sample has the highest estimate on % OM followed by the bark and the

leaves. In the study, the wood has the highest % DM and proportionally captured CO₂ more than the leaves and bark. This means that the raw materials (CO₂) for photosynthesis are mostly stored in the wood among the other parameters considered in sample species.

The percentage DM content of the samples indicated highest in woods (59.90%) followed by the barks

(50.53%) and least in leaves (38.48%). This result is similar to that of Jerry (2016) who discovered from his study that, the wood has the highest OM content (48.21%) and DM (55.66%). However, the result is contrary to that of Jerry whose results recorded least by the leaves (43.55%) in OM and bark (32.39%) in DM.

Table 1: Average Biomass of the Leave, Bark and Wood of the Selected Tree Species

TREE SPECIES	LEAVES			BARK			WOOD		
	%MC	%DM	%OM	%MC	%DM	%OM	%MC	%DM	%OM
<i>Terminalia mentally</i>	56.04	43.96	91.89	44.94	55.06	75.27	41.74	58.26	81.42
<i>Albizia lebbeck</i>	66.61	33.39	91.44	42.90	57.10	91.78	38.22	61.78	97.79
<i>Dalbergia sissoo</i>	57.62	42.38	85.86	43.35	56.65	83.06	28.87	71.13	96.17
<i>Eucalyptus camaldulensis</i>	51.33	48.67	90.65	42.32	57.68	74.74	28.93	71.07	98.06
<i>Delonix regia</i>	58.11	41.89	89.53	36.50	63.50	87.59	42.24	57.76	95.96
<i>Gmelina arborea</i>	61.52	38.48	93.31	59.08	40.92	93.38	48.05	51.95	98.65
<i>Mangifera indica</i>	53.76	46.24	88.12	49.37	50.63	91.25	41.44	58.56	98.39
<i>Azadirachta indica</i>	64.98	35.02	88.46	46.80	53.20	91.50	37.30	62.70	97.11
<i>Ximania Americana</i>	74.55	25.45	87.84	74.13	25.87	89.13	56.40	43.60	96.67
<i>Terminalia catappa</i>	71.35	28.65	88.70	46.36	53.64	85.08	37.13	62.87	97.09
<i>Cassia fistula</i>	61.20	38.80	91.90	58.46	41.54	86.94	40.80	59.20	95.12
TOTAL	677.07	422.93	987.71	544.21	555.79	949.71	441.11	658.89	1052.44
MEAN	61.55	38.45	89.79	49.47	50.53	86.34	40.10	59.90	95.68

Source: Field Survey, 2016 & 2017.

4.3. Carbon Storage Quantities of the Selected Tree Species during Dry and Rainy Seasons

The result for the mean carbon storage of the selected tree species during dry and rainy seasons are presented in Table 2. During dry season, the mean values by leaves showed highest on *Terminalia mentally* (53.79), followed by *Gmelina arborea* (53.59) and thirdly by *Albizia lebbeck* (53.21). *Cassia fistula* came fourth, *Eucalyptus camaldulensis* (fifth), *Azadirachta indica* (sixth), etc. On the bark, *Gmelina arborea* (54.29) recorded the highest, followed by *Azadirachta indica* (53.19) and thirdly by *Albizia lebbeck* (53.14). Others include; *Mangifera indica* (fourth), *Delonix regia* (fifth) and *Ximania americana* (sixth), among others. The mean values by the wood from the table 2 showed highest on *Gmelina arborea* (57.10), followed by *Mangifera indica* (56.81) and thirdly by *Albizia lebbeck*. The fourth tree species was *Azadirachta indica*, fifth (*Eucalyptus camaldulensis*), sixth (*Ximania americana*), seventh (*Terminalia catappa*), eighth (*Dalbergia sissoo*), ninth (*Delonix regia*), tenth (*Cassia fistula*) and lastly by *Terminalia mentally* (40.71).

During the rainy season, the mean values by leaves showed highest on *Gmelina arborea* (54.79), followed by *Cassia fistula* (53.67) and thirdly by *Delonix regia* (53.04). *Terminalia mentally* was the fourth, *Eucalyptus Camaldulensis* (fifth), *Albizia lebbeck* (sixth), etc. For bark part, *Gmelina arborea* (53.99) recorded the highest, followed by *Albizia lebbeck* (53.30), third by *Mangifera indica* (52.94), fourth by *Azadirachta indica*, fifth (*Ximania americana*), sixth (*Delonix regia*), seventh (*Cassia fistula*) among others. The ranking of the wood part from the mean values include; *Gmelina arborea* (first), *Eucalyptus camaldulensis* (second), *Mangifera indica* (third), *Albizia lebbeck* (fourth), *Terminalia catappa* (fifth), *Terminalia mentally* (sixth), *Dalbergia sissoo* (seventh), *Delonix regia* and *Azadirachta indica* (eighth), *Ximania americana* (tenth) and lastly by *Cassia fistula*.

Generally, *Gmelina arborea* and *Albizia lebbeck* have recorded the highest performance in terms of carbon storage potential both during dry and rainy seasons. This indicates that, *Gmelina arborea* and *Albizia lebbeck* are the best tree species that can sequester and store the reasonable amount of carbon all year round.

Table 2: Mean Carbon Storage of the Selected Tree Species during Dry and Rainy Seasons

Tree Species	Dry Season			Rainy Season		
	Leaves	Bark	Wood	Leaves	Bark	Wood
<i>Terminalia mentally</i>	53.79	44.41	40.71	52.81	42.83	56.55
<i>Albizia lebbeck</i>	53.21	53.14	56.61	52.78	53.30	56.89
<i>Dalbergia sissoo</i>	49.03	48.76	55.05	50.99	47.57	56.48
<i>Eucalyptus camaldulensis</i>	52.32	44.22	56.19	52.79	42.48	57.46
<i>Delonix regia</i>	51.25	51.11	54.98	53.04	50.54	56.40
<i>Gmalina arborea</i>	53.59	54.29	57.10	54.79	53.99	57.35
<i>Mangifera indica</i>	50.39	52.83	56.81	51.78	52.94	57.32
<i>Azadirachta indica</i>	51.94	53.19	56.29	50.49	52.93	56.40
<i>Ximania Americana</i>	49.96	51.04	55.98	52.21	52.13	56.15
<i>Terminalia catappa</i>	50.69	49.85	55.93	52.22	48.86	56.70
<i>Cassia fistula</i>	53.01	50.52	54.86	53.67	50.31	55.47
MEAN	51.74	50.30	54.59	52.51	49.81	56.64

Source: Field Survey, 2016 & 2017

4.4. Differences in Carbon Storage between Dry and Rainy Seasons of the Leaves, Bark and Wood of the Selected Tree Species

Results for the differences in carbon storage between the dry and rainy seasons of the tree species parts are presented in Table 3. The results showed no significant differences ($P \geq 0.05$) in the leaves, bark and wood between the two seasons. From the mean values, the wood is the highest followed by leaves and least by the bark in carbon storage potential between rainy and dry seasons. In the leaves and wood, the carbon storage was recorded higher in the rainy season than dry season. While in the bark, the carbon storage was recorded higher in dry season than rainy season. This indicates that the carbon storage potential of the selected tree species was higher in the rainy season (higher photosynthesis) than dry season (lower photosynthesis). This can be attributed to the fact that the rate of carbon storage by trees always increases in the humid and moist condition usually during the process of photosynthesis. Accordingly, McPherson (1998); Nurus (2013) reported that tree is an autotrophic organism which produces their own food during photosynthesis process. To complete photosynthesis, trees need water, carbon dioxide and sunlight (Shively, 2004; Nurus 2013). Chlorophyll which is the green pigment in leaf acts as a site of photosynthesis after carbon enters the leaf from stomata. Therefore, trees play important roles in reducing carbon dioxide in atmosphere because trees assimilate carbon during photosynthesis process and along their life span.

The findings of this study conform to that of Chung et al, (2016), who observed the highest CO₂ assimilation occur from July to October while the lowest was recorded from

January and April in *Fraxinus griffithii*. The maximum CO₂ assimilation of a single tree was 6565.99 g in August and 2129.92 g in July. The percentage annual CO₂ assimilation in July, August and September was 77.15%, 97.05%, and 79.97% respectively. This result demonstrated that droughts have long-lasting consequences on photosynthesis in *Fraxinus griffithii*, which support previous research indicating that water stress limits tree growth and decreases photosynthetic efficiency (Colom and Vazzana, 2003; Ogaya and Penuelas, 2003). The extended dry seasons in their study period occurred during the early growth season of *Fraxinus griffithii* (March to April). Also, Julia et al. (2014), in their study observed that the highest values for organic matter, organic carbon and carbon storage were found during the rainy seasons. Moreover, a previous study had demonstrated that a spring drought may suppress canopy development and exert long-lasting effects on annual ecosystem carbon balance that remains even when soil water availability improves (Noormets et al., 2008).

Table 3: Mean Carbon Storage of Leave, Bark and Wood between Dry and Rainy Seasons

Treatment	Dry	Rainy	T-value	P-value
Leaves	51.74	52.51	1.27	0.281 ^{ns}
Bark	50.30	49.81	0.31	0.757 ^{ns}
Wood	54.59	56.64	1.45	0.162 ^{ns}

Source: Field Survey, 2016 & 2017

5. CONCLUSION

The following conclusions can be drawn from this study;

1. During the dry season, carbon storage was highest in the leaves of *Terminalia mentally* and in the

bark of *Gmelina arborea* recorded the highest. But, in the rainy season, the leaves, barks and woods of *Gmelina arborea* had the highest carbon storage. Generally, *Gmelina arborea* and *Albizia lebbbeck* had the highest carbon storage potential throughout the seasons.

2. Irrespective of the season, there is no significance difference in the carbon storage among the leaves, bark and wood of the tree species.
3. In all the tree species, the bark content had the least carbon storage potential.

REFERENCES

- Adebayo A.A and A.S Umar (1999). Climate 1: Sunshine, Temperature, Evaporation and Relative Humidity. In Adebayo, A.A and Tukur, A.L, 1999(eds). Adamawa State in Maps. Department of Geography, FUTY and Paraclete Publishers, Yola, Nigeria. Pp 20 – 24.
- Adefioye, S.A (2013). Analysis of Land Use/Land Cover pattern along the River Benue channel in Adamawa State, Nigeria. *Academic Journal of Interdisciplinary Studies*, 2, 5: 95-107. DOI:10.5901/ajis.2012.v2n5p95.
- Allen, S.E., Grimshaw, H.M., and Rowland, A.P., (1986), *Chemical Analysis*. In: Moore, P.D., and Chapman, S.B., (eds.), *Methods in Plant Ecology*. America, Blackwell Scientific Publications, pp 285-344.
- Arome T., Ejaro S.P (2012). Dynamics of land use and land cover changes and its implication on food security in Ayingba, North central Nigeria. *Confluence Journal of Environmental Studies*, 7: 42-52.
- Arul P.L and Karthick A (2013). Carbon Stock Sequestration by Tree Plantation in University Campus at Coimbatore, India. Department of Environmental Sciences, Bharanthiar University, Coimbatore – 641 046, India. *Internal Journal of Environmental Sciences Volume 3, N05, 2013*.
- Aweda E. D., Adeyewa Z. D (2009). The usefulness of NDVI in the monitoring of drought in the Guinea Savannah Region of Nigeria. *International Journal of Human Geography and Environmental Sciences*, 1: 39–45.
- Brittany G (2013). An analysis of carbon sequestration on Clarkson University's Campus.
- Brown S, *Estimating Biomass & Biomass Change of Tropical Forests: Primer*, FAO Forestry Paper, FAO, Rome, 1997.
- Chung-IC, Ya-Nan W, Hsueh-When L and Jui-Chu Y (2016). Three –Year Study on Diurnal and Seasonal CO₂ Sequestration of a Young *Fraxinus graffithii* Plantation in Southern Taiwan.
- Colom, M.R. and Vazzana, C. (2003) Photosynthesis and PSII functionality of drought-resistant and drought-sensitive weeping lovegrass plant. *Environ. Exp. Bot.* 2003, 49, 135–144.
- Food and Agricultural Organization (FAO), 2005, Deforestation data for Nigeria, 1990- 2005. <http://news.mongabay.com/2005/1115>.
- IPCC, “Summary for policy makers,” *Climate Change: The Physical Science Basis*, Cambridge University Press, 2007.
- Jerry B.S (2016). Carbon dioxide capture and storage potential of mahogany (*Swieteniamacrophylla*) saplings. *International Journals of Environmental Science and Development*, volume 7, No. 8.
- Julia G.C, Rosa M.C-B, Jaime J.G-S and Ah V.C-Q (2014). Estimation of Regional Carbon Storage Potential in Mangrove Soils on Carmen Island, Campeche, Mexico.
- Labata M.M, Aranico E.C., Tabaranza E.A.C, Patricio J.H.P and Amarado R.F. “Carbon stock assessment of three selected agroforestry systems in Bukidnon, Philippines,” *Advances in Environmental Science*, vol. 4, no. 1, pp. 5-11, 2012.
- Losi, A.J, Siccama, T.G, Condit R. and Morales J. E “Analysis of alternative methods for estimating carbon stock in young tropical plantations,” *Forest Ecology and Management*, vol. 184, no. 1-3, pp. 355-368, 2003.
- Mannion, A.M. (1998). “Global Environmental Change: The Causes and Consequences of Disruption to Biogeochemical Cycles.” *The Geographical Journal*. 164(2): 168-182.
- Noormets, A.; McNulty, S.G.; Deforest, J.L.; Sun, G.; Li, Q.; Chen, J. (2008) Drought during canopy development has lasting effect on annual carbon balance in a deciduous temperate forest. *New Phytol.* 2008, 179, 818–828.
- Nurum N.I (2013). Carbon sequestration by trees species in urban forest in UniversitiTeknologi; Malaysia. A PhD research proposal submitted to the Faculty of Built Environment, Universiti of Teknologi Malaysia 81310 Skudai, Johor.
- Ogaya, R. and Peñuelas, J. (2003) Comparative field study of *Quercus ilex* and *Phillyrea latifolia*: Photosynthetic response to experimental drought conditions. *Environ. Exp. Bot.* 2003, 50, 137–148.
- Olutoyin F, Adeyemi O, Oluwatola (2017). Geospatial Analysis of Changes in Vegetation Coverover Nigeria. *Bulletin of Geography, Physical Geography Series*, No. 13 (2017): 17-28. Department of Geography, University of Ibadan Nigeria. <http://dx.doi.org/10.1515/bgeo-2017-0010>.
- Perschel R., Evans A., and Summers M. (August 2007). Climate change, carbon and the forests of the Northeast. *Forest Guild*. [Online]. p.47. Available: <http://www.forestguild.org/publication/research>
- Sedjo R, Mendelsohn R, Sohngen B. (July 1998). The effectiveness of forest carbon sequestration strategies with system-wide adjustments. [Online]. Available: <http://www.citeseerx.ist.psu.edu/viewdoc/download>

- Shively, G.E., (2004). Carbon sequestration measure its incremental cost., pp.189–197.
- Superales J.B (2016). Carbon dioxide capture and storage potential of mahogany (*Swieteniamacrophylla*) saplings. *International Journals of Environmental Science and Development, volume 7, No. 8.*
- Warrick R and Farmer G (1990). “The Greenhouse Effects, Climate Change and Rising SeaLevel: Implications for Development.” Transactions of the Institute of British Geographers, 15(1)5-20.
- Yang H, “Progress in carbon dioxide separation and capture: A review,”*Journal of Environmental Sciences*, vol. 20, no. 1, pp. 14-27, 2008.
- Zemba A.A (2010) Analysis of Landuse/Landcover Change and Development of Urban Heat Island. PhD Thesis Submitted to the Department of Geography FUTY.
- Zemba A. A, Mohammed S. D & Ishaku T.H (2013). Population Density and Vegetation Fraction as Indices for Urban Land Cover Classification in Jimeta, Nigeria. *International Journal of Environment Ecology, Family and Urban Studies (IJEEFUS) ISSN 2250-0065 Vol. 3 Issue 2, Jun 2013, 79-86 © TJPRC Pvt. Ltd.*