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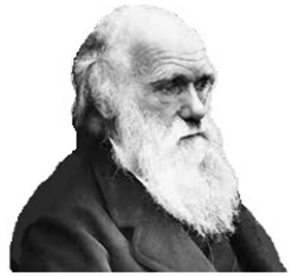

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# Carbon-dioxide sequestration potential of tree species in Nigerian Tertiary Institutions: A case study of Ondo State, Nigeria

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**ABSTRACT**

Carbon dioxide ($CO_2$) is one of the most abundant greenhouse gases and a primary agent of global warming. It constitutes 72% of the total anthropogenic greenhouse gases, causing between 9-26% of the greenhouse effect. This study focused on carbon-dioxide sequestration potential of trees in four tertiary institutions (Federal University of Technology Akure, Adekunle Ajasin University Akungba Akoko, Rufus Giwa Polytechnic, Owo, and Federal College of Agriculture Akure) in Ondo State, Nigeria. Identification of trees located in built up areas, car parks and walk ways of each institution was done with an experienced taxonomists. Tree variables such as diameter at breast height (dbh), diameter at the base ($D_b$), diameter at the middle ($D_m$), diameter at the top ($D_t$) and total height ($H_t$).) were measured using Spiegel relaskop and girth diameter tape. Carbon storage estimation was estimated using non-destructive method. Of the 100% $CO_2$ in the institutions under this study, AAUA had 92.22%, FUTA had 3.40%, RUGIPO had 4.99% and FECA had 0.59% respectively. The amount of carbon-dioxide estimated for each institution in this study were comparably higher than what was obtained for Strict Nature Reserve (593.68 tons/ha) and Enrichment Planting Forest (326.14tons/ha). This study is an eye opener that much more carbon-dioxide could be sequestered if more trees are planted or retained in our tertiary institutions. Therefore, retention and planting of tree species in our tertiary institution is recommended

***Keywords*:** Tree planting, Tertiary Institutions, Climate change

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## 1. INTRODUCTION

Carbon dioxide ($CO_2$) is one of the most abundant greenhouse gases and a primary agent of global warming. According to [11], it constitutes 72% of the total anthropogenic greenhouse gases, causing between 9-26% of the greenhouse effect. There have been predictions of a great increase in average global temperature and an increase in extreme precipitation in the next century [8]. The changes in climate are likely to affect tree growth and increase emissions of greenhouse gases. An increase in temperature leads to more frequent droughts, wildfires, and invasive pest outbreaks [10]. These result in declining tree species and productivity.

There is a need to reduce the amount of carbon dioxide in the atmosphere with the aim of reducing global climate change [20]. Carbon sequestration is the natural means of removing carbon from the air by storing it as biomass [1]. Forest ecosystems in themselves serve as carbon sinks, in which they help store carbon in their vegetation. Many studies have shown that trees planted in urban areas can also store carbon like other forest ecosystems [18]. The trees help to fix carbon during photosynthesis, and as more occurs, there is potential for a reduction of carbon in the atmosphere [6].

The presence of trees in academic institutions has many benefits, including aesthetic and environmental uses. It provides a beautiful landscape for the university environment, providing shade for people to relax under, cars, and pedestrians [6]. Shade provided by trees helps to cool the surroundings by reducing heat buildup and limiting the amount of sunlight that reaches the buildings. There are also many benefits derived from urban trees, such as absorbing carbon dioxide, producing oxygen, reducing the severity of floods, providing windbreaks, and reducing erosion. They also improve air quality and reduce pollution by filtering dust and pollutants in the air [7].

Several studies have been done on the role that forests play in the storage of carbon [3, 5, 13]. However, limited studies are available on the $CO_2$ sequestration potential of tree species in Nigerian tertiary institutions. Since the knowledge of the potential carbon-dioxide sequestration potential in Nigerian tertiary institutions will have a significant impact on the management of tree species on campus. This study therefore became necessary.

## 2. METHODS

### 2. 1. Study Area

The study was carried out in four tertiary institutions (Federal University of Technology Akure [FUTA], Adekunle Ajasin University Akungba Akoko [AAUA], Rufus Giwa Polytechnic, Owo [RUGIPO], and Federal College of Agriculture Akure [FECA] in Ondo State, Nigeria. Ondo State (5°45'N- 8°15'N, 4°45'E - 6°00'E) is located in the South West of Nigeria. It has a tropical wet and dry climate with mean annual rainfall of about 1,500 mm and 2,000 mm in the derived savannah and humid forest zones in the state.

The state has two distinct seasons viz, the rainy season (April - October) and dry season (November - March) while temperature throughout the year ranges from 21 °C - 29 °C and relative humidity is very high [2].

There is vast forest resources comprising a lot of indigenous and exotic tree species and other cash crops like cocoa, cashew, kolanut are also grown. The map of the study area is presented in Figure 1.

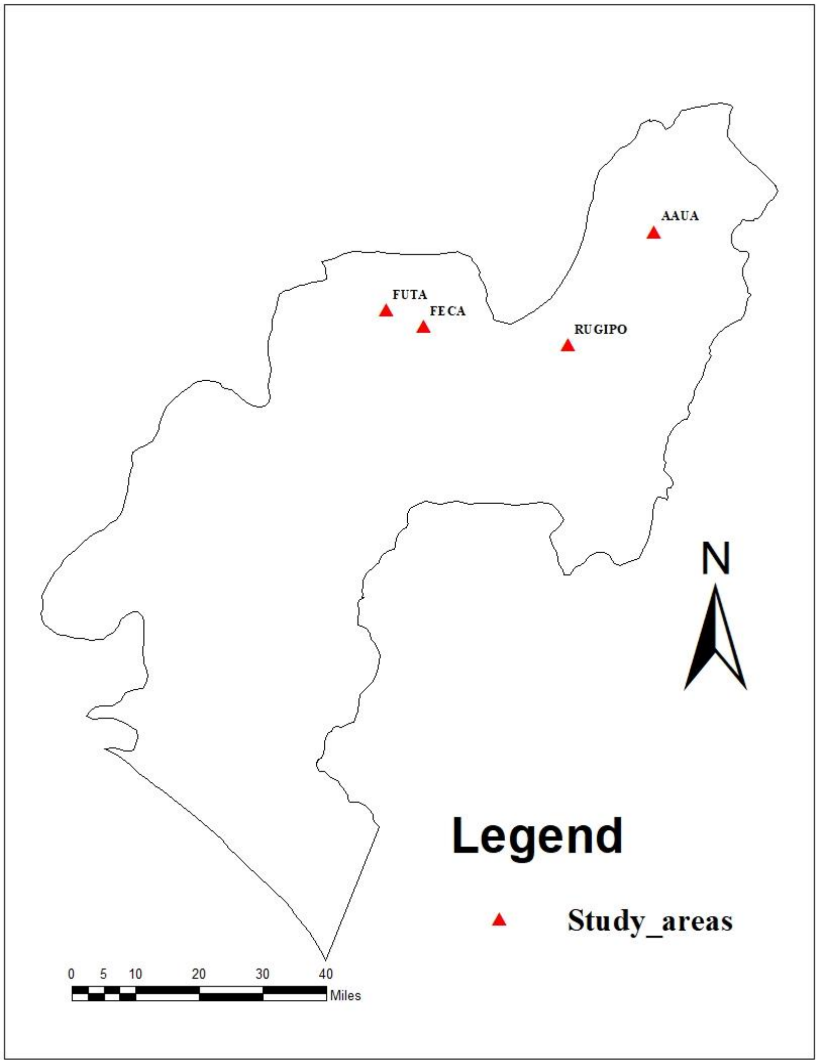


**Figure 1.** Map of Ondo State showing the study areas

## 2. 2. Sampling Procedures and Data Collection

All trees in the built up areas, car parks and walkways of each institution were identified and their diameter at breast height (dbh), diameter at the base ($D_b$), diameter at the middle ($D_m$), diameter at the top ($D_t$), total height ($H_t$), Merchantable height (MH), crown length (CL) and crown diameter (CD) were measured using Spiegel relaskop and girth diameter tape.

## 2. 3. Data Analysis

### 2. 3. 1. Basal Area Estimation

The Basal Area (BA) of individual trees was estimated using the formula in equation 1 [17]

$$BA = \frac{\pi}{4} D^2 \qquad (1)$$

where: BA = Basal area ($m^2$), D = dbh (cm).

#### 2. 3. 2. Volume Estimation

The volume of individual tree was estimated using Newton equation developed for trees volume estimation [4]

$$V=\frac{H}{6}A_b+4A_m+A_t \quad \text{.........(2)}$$

where: V = Stem volume ($m^3$), H = stem height (m), $A_b$ = Tree cross- sectional area at the base, $A_m$ = Tree cross-sectional area at the middle and $A_t$ = Tree cross-sectional are at the middle and $A_1$ = Tree cross-sectional area at the top

#### 2. 3. 3. Determination of carbon stock and carbon dioxide sequestered by the trees in the study areas

Estimation of the Above-ground live biomass was carried out by multiplying the volume of each tree with its respective wood density. Tree densities were obtained from the literature [16] and the internet. Biomass value was converted to carbon stocks using 0.5 carbon fractions as default values [14].

Carbon dioxide $CO_2$ has one molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12 (u) and the atomic weight of Oxygen is 16 (u). The weight of $CO_2$ in trees was determined by the ratio of $CO_2$ to C is 44/12 = 3.67. Therefore, to determine the weight of carbon dioxide sequestered in the tree, we multiply the weight of carbon in the tree by 3.671.

#### 2. 3. 4. Data Analysis

The amounts of carbon-dioxide sequestrated were compared among the study areas using analysis of variance. Where significant differences occur, means were separated with Duncan New Multiple Range Test (DMRT).

## 3. RESULTS

The percentage of carbon-dioxide sequestered in the study areas is presented in Figure 2. Of the 100% $CO_2$ in the institutions under this study, AAUA had 92.22%, FUTA had 3.40%, RUGIPO had 4.99% and FECA had 0.59% respectively. Information on tree density, carbon stock and $CO_2$ estimated in the study institutions are presented in Table 1 and 2 below. In FUTA, a total of 58.62 tons of carbon stock and 215.21 tons of $CO_2$ were recorded. *Gmelina arborea* had the second highest frequency but was found to sequester the highest amount of $CO_2$ (67,455.88 kg). A total of 1,588.35 tons was estimated as the carbon stock in AAUA, which translated to 5,829.26 tons of $CO_2$ in this institution. $CO_2$ recorded for tree species sampled in AAUA ranged from 110.10 kg to 5,721,066.11 kg. The highest $CO_2$ was found in *Terminalia mantali* (5,721,066.11 kg). This was widely followed by *Gmelina arborea* (27,046.62 kg). Tree species sampled in FECA had a total of 10.19 tons of carbon stock and 37.39 tons of $CO_2$ respectively. *Delonix regia* was found sequestrated the highest amount of

$CO_2$ in this institution. This was followed followed by *Azadirachta indica* (7,743.99 kg) and *Bauhinia purpurea* had the least $CO_2$ (36.88 kg). In RUGIPO, 86.00 tons of carbon stock and 315.63 tons of $CO_2$ were estimated for the sampled tree species as presented in Table 2. *Tectona grandis* stored the highest $CO_2$ (181,280.38 kg) followed by *Gmelina arborea* (59,998.73 kg) and *Azadirachta indica* (34,527.36 kg) respectively. Also, the statistical variation in the amount $CO_2$ estimated for tree species among the studied institutions is presented in Table 3. The result was in this order: AAUA > RUGIPO > FUTA < FECA.

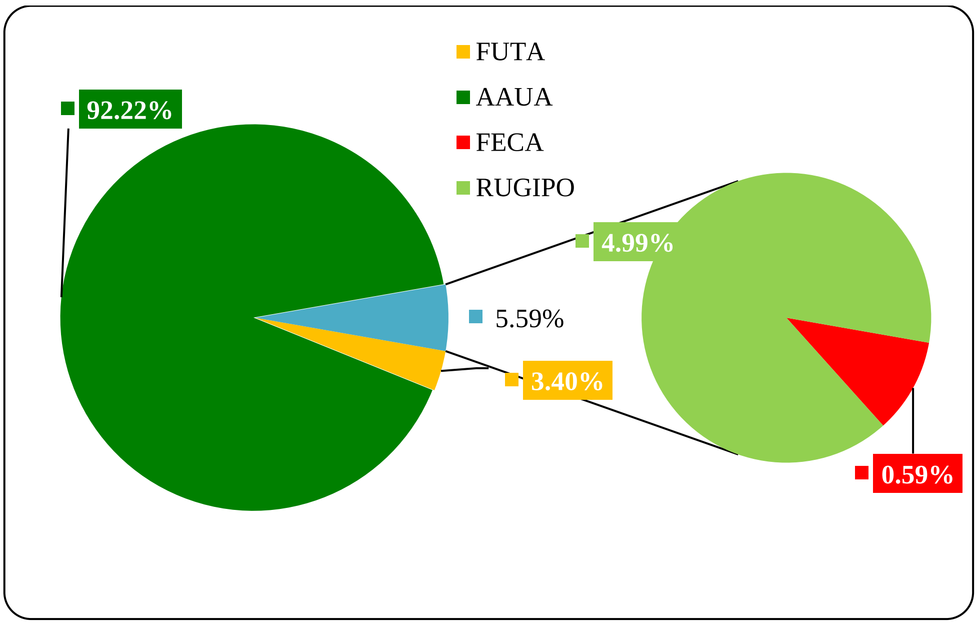


**Figure 2.** Percentage of $CO_2$ sequestered in the study areas

**Table 1.** Tree density, carbon stock and $CO_2$ estimation in FUTA and AAUA

| | Institutions | FUTA | | | | | AAUA | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Species | Tree frequency | Tree density (kg/m$^3$) | Vol. (m$^3$) | Carbon stock (kg) | $CO_2$ (kg) | Tree frequency | Vol. (m$^3$) | Carbon stock (kg) | $CO_2$ (kg) |
| 1 | *Acacia auriculiformis* | 21 | 575 | 7.23 | 4157.25 | 15261.26 | 31 | 5.48 | 3151.00 | 11564.17 |
| 2 | *Acacia fistula* | 12 | 790 | 2.73 | 2156.70 | 7917.25 | | | | |
| 3 | *Albizia lebbeck* | | 508 | | | | 4 | 0.75 | 381.00 | 1398.27 |
| 4 | *Albizia zygia* | 9 | 610 | 5.67 | 3458.70 | 12696.89 | | | | |
| 5 | *Anthocleistia djalonensis* | 1 | 686 | 0.38 | 260.68 | 956.96 | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | *Azadirachata indica* | 9 | 672 | 1.90 | 1276.80 | 4687.13 | 17 | 2.65 | 1780.80 | 6535.54 |
| 7 | *Bauhinia forficate* | | 670 | | | | 2 | 0.48 | 321.60 | 1180.27 |
| 8 | *Bauhinia monandra* | 1 | 670 | 0.25 | 167.50 | 614.89 | | | | |
| 9 | *Bauhinia purpurea* | 1 | 67 | 0.12 | 8.04 | 29.51 | | | | |
| 10 | *Blighia sapida* | | 883 | | | | 1 | 0.07 | 61.81 | 226.84 |
| 11 | *Casia siamea* | | 700 | | | | 2 | 0.25 | 175.00 | 642.25 |
| 12 | *Cassia fistula* | | 790 | | | | 1 | 0.12 | 94.80 | 347.92 |
| 13 | *Cola gigantean* | 1 | 460 | 0.85 | 391.00 | 1435.36 | | | | |
| 14 | *Delonix regia* | 28 | 970 | 6.97 | 6764.54 | 24832.62 | 7 | 2.25 | 2182.50 | 8009.78 |
| 15 | *Erythrina senegalensis* | | 686 | | | | 2 | 0.19 | 130.34 | 478.35 |
| 16 | *Eucalyptus camadolensis* | | 720 | | | | 31 | 4.11 | 2959.20 | 10860.26 |
| 17 | *Ficus benjamina* | | 650 | | | | 6 | 0.96 | 624.00 | 2290.08 |
| 18 | *Ficus exasperata* | | 600 | | | | 1 | 0.57 | 342.00 | 1255.14 |
| 19 | *Gliricidia sepium* | 1 | 686 | 0.35 | 240.10 | 881.41 | | | | |
| 20 | *Gmelina arborea* | 72 | 515 | 35.69 | 18380.35 | 67474.26 | 15 | 14.31 | 7369.65 | 27046.62 |
| 21 | *Hildegardia barteri* | | 686 | | | | 13 | 1.67 | 1145.62 | 4204.43 |
| 22 | *Hura crepitans* | | 880 | | | | 1 | 0.49 | 431.20 | 1582.50 |
| 23 | *Khaya senegalensis* | | 760 | | | | 2 | 0.29 | 220.40 | 808.87 |
| 24 | *Leucaena leucocepahala* | 8 | 800 | 0.85 | 68 | 249.63 | 7 | 0.78 | 624.00 | 2290.08 |
| 25 | *Margaritaria discoidea* | 1 | 857.5 | 0.24 | 205.80 | 755.49 | | | | |
| 26 | *Mouringa olifera* | 7 | 600 | 0.13 | 78.00 | 286.34 | | | | |
| 27 | *Nauclea diderrichii* | 2 | 790 | 1.64 | 1295.60 | 4756.15 | | | | |
| 28 | *Pinus caribaea* | 23 | 630 | 7.11 | 4479.30 | 16443.51 | 1 | 0.08 | 50.40 | 184.97 |
| 29 | *Polyalthia longifolia* | | 772.5 | | | | 6 | 0.62 | 478.95 | 1757.75 |
| 30 | *Pterocarpus osun* | | 775 | | | | 1 | 0.32 | 248.00 | 910.16 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 31 | *Seena fistula* | 4 | 686 | 0.74 | 507.64 | 1863.55 | | | | |
| 32 | *Spondias mombin* | 1 | 600 | 0.27 | 160.27 | 588.35 | 1 | 0.05 | 3 | 110.10 |
| 33 | *Sterculiar setigera* | | 686 | | | | 1 | 0.27 | 185.22 | 679.76 |
| 34 | *Tectona grandis* | 7 | 640 | 3.33 | 2132.44 | 7828.19 | 30 | 7.33 | 4691.20 | 17216.70 |
| 35 | *Terminalia catappa* | 141 | 520 | 10.74 | 5584.31 | 20500.01 | 5 | 3.12 | 1622.40 | 5954.21 |
| 36 | *Terminalia mantali* | 63 | 640 | 10.71 | 6851.23 | 25150.88 | 38 | 2435.74 | 1558873.60 | 5721066.11 |
| 37 | *Tetrapleura tetraptera* | | 686 | | | | 1 | 0.26 | 178.36 | 654.58 |
| | *Total* | 414 | | 97.9 | 58624.25 | 215,209.88 | 227 | 2,483.21 | 1,588,353.05 | 5,829,256 |

**Table 2.** Tree density, carbon stock and CO2 estimation in FECA and RUGIPO

| | **Institutions** | **FECA** | | | | | **RUGIPO** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Species | Tree freq | Tree density (kg/m$^3$) | Vol . (m$^3$) | Carbon stock (kg) | $CO_2$ (kg) | Tree freq | Vol. (m$^3$) | Carbon stock (kg) | $CO_2$ (kg) |
| 1 | *Acacia auriculiformis* | | 575 | | | | 1 | 3.07 | 1765.25 | 6478.468 |
| 2 | *Cacia fistula* | | 790 | | | | 5 | 1.32 | 924.00 | 3391.08 |
| 3 | *Albizia zygia* | 1 | 610 | 0.38 | 231.80 | 850.71 | | | | |
| 4 | *Azadirachata indica* | 5 | 672 | 3.14 | 2110.08 | 7743.99 | 29 | 14.00 | 9408.00 | 34527.36 |
| 5 | *Bauhinia purpurea* | 1 | 67 | 0.15 | 10.05 | 36.88 | | | | |
| 6 | *Casuarina equisetifolia* | 2 | 1000 | 0.56 | 56 | 2055.20 | | | | |
| 7 | *Delonix regia* | 15 | 970 | 5.16 | 5005.20 | 18369.08 | | | | |
| 8 | *Eucalyptus camadolensis* | | 720 | | | | 2 | 0.97 | 698.40 | 2563.13 |
| 9 | *Ficus benjamina* | 1 | 650 | 0.18 | 117.00 | 429.39 | | | | |
| 10 | *Gliricidia sepium* | | 686 | | | | 1 | 0.20 | 137.20 | 503.52 |
| 11 | *Gmelina arborea* | 1 | 515 | 0.57 | 293.55 | 1077.33 | 19 | 28.57 | 14713.55 | 53998.73 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 | *Irvingia gabolensis* | 2 | 686 | 0.25 | 171.50 | 629.41 | | | | |
| 13 | *Laguncularia racemose* | | 857.5 | | | | 14 | 4.17 | 3575.78 | 13123.09 |
| 14 | *Pinus caribaea* | 2 | 630 | 0.90 | 567.00 | 2080.89 | 7 | 3.92 | 2469.60 | 9063.43 |
| 15 | *Tectona grandis* | 2 | 640 | 1.13 | 723.20 | 2654.14 | 92 | 77.18 | 49395.20 | 181280.38 |
| 16 | *Terminalia catappa* | 3 | 520 | 0.52 | 270.40 | 992.37 | 8 | 0.71 | 369.20 | 1354.96 |
| 17 | *Terminalia mantali* | 1 | 640 | 0.20 | 128.00 | 469.76 | 14 | 3.98 | 2547.20 | 9348.22 |
| | *Total* | 36 | | 13.14 | 9683.78 | 37389.15 | 193 | 138.09 | 86,003.38 | 315,632.39 |

**Table 3.** Analysis of variance (ANOVA) for comparing $CO_2$ sequestrated in the study areas

| **Locations** | **Mean $CO_2$ (kg)** |
|---|---|
| AAUA | $224,202.14^{a}$ |
| RUGIPO | $28,693.85^{b}$ |
| FUTA | $10,248.08^{c}$ |
| FECA | $3,115.76^{d}$ |

Note: Means with the same superscript are not significantly different.

## 4. DISCUSSION

Carbon sequestration is the process by which the atmospheric carbon dioxide is captured and stored for a very long-term in trees [19]. [9] mentioned that long-term storage of atmospheric $CO_2$ is an important mitigation option to reduce the largest portion of green house gas emissions. Clearing and burning of forest estates for agricultural purposes could lead to the depletion of the ozone layer by greenhouse gasses. [13] highlighted these greenhouse gasses to include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6), and nitrogen trifluoride ($NF_3$).

When sunlight reaches the surface of the Earth, some are absorbed and warm the Earth. In turn, the Earth emits long wave radiation towards the atmosphere, a fraction of which is absorbed by the greenhouse gasses. The Greenhouse gasses then emit long wave radiation both towards space and back to the Earth. The energy emitted downward further warms the surface of the Earth. When the concentration of greenhouse gasses in the atmosphere increased, the earth's surface temperature is also expected to increase [12].

The high rate of deforestation and forest degradation could lead to high rate of Ozone layer depletion and increase in greenhouse gasses but maintenance of avenue trees in our institutions maybe a solution [15]. In this study, carbon sequestration in the institutions varied considerably as revealed. The amount of carbon dioxide estimated for tree species was higher in AAUA than other institutions. The highest number of species recorded in this institution could be responsible for the highest $CO_2$ in AAUA. The $CO_2$ storage estimated for this study demonstrated the level of variability of carbon sequestration that could exist within different institutions.

The amount of carbon-dioxide estimated for each institution in this study were comparably higher than what was obtained for Strict Nature Reserve (593.68 tons/ha) and Enrichment Planting Forest (326.14 tons/ha) in Akure Forest Reserve, Ondo State [13]. Similarly, [5] revealed that the total amount of carbon stock in Ogun Onire forest was 48173.08 kg/ha while the corresponding value for community herbal heritage was 10745.31 kg/ha. Although the present study could not compute carbon stock per hectare as done in the previous studies due the built-up nature of the areas, the results clearly indicate that much more carbon could be sequestered if more trees species are planted or retained in our institutions.

## 5. CONCLUSION AND RECOMMENDATIONS

Substantial amount of carbon dioxide was sequestered in the studied tertiary institutions. The highest carbon dioxide was found in the tree species sampled in AAUA. RUGIPO had the second highest carbon dioxide, followed by FUTA and FECA had the least $CO_2$. This study is an eye opener that much more carbon could be sequestered if more tree trees are planted or retained in our tertiary institutions. Therefore, retention and planting of tree species in our tertiary institution is recommended. This is to further mitigate the effect of climate change in Nigeria. Also, proper management of the green cover in tertiary institutions should be maintained for biodiversity conservation and other service functions.

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