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Role of Urban Zoological Park in Woody Species Conservation and Carbon Sequestration: Insight from Funaab Zoo Park in Abeokuta, Nigeria

Adeleye Afeez Olukunmi [1], Moussa Soulé [2*], Hamidou Taffa Abdoul-Azize [3], Atanda Toyeeb Abidemi [4], Osoba Akolade Emmanuel [5]

[1] Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta, Nigeria
Email : s.moussa@futminna.edu.ng
[2] Laboratoire de Biologie Garba Mounkaila, Faculté des Sciences et Techniques, Université Abdou Moumouni, Niamey, Niger
[3] Istanbul Gelisim University, Faculty of Applied Sciences, Istanbul Turkey
[4] Institute of Environmental Sciences, Jagiellonian University, Kraków, Poland
[5] Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta, Nigeria,

Corresponding author: Moussa Soulé, s.moussa@futminna.edu.ng, Telephone: +22796801125

ABSTRACT— This study determines the role of FUNAAB zoo park Abeokuta, Ogun State in tree biodiversity conservation and carbon sequestration of Abeokuta city in Nigeria. A systematic sampling approach was used and the tree biodiversity inventory was conducted. Accordingly, the study identified 30 plant species and 15 families with *Fabaceae* as the dominant family (6 species). Shannon diversity index (H′) was 3.29 and Pielou's evenness (J') was 0.97 in the park. There were more native woody species (80%) than exotic (20%) in the park. Tree species were the dominant growth form in the park. Additionally, the trees with a diameter greater than 11 cm had the higher carbon sequestration potential with 1009776 kgCha^{-1}, above-ground biomass of 2456.795 kg and below ground biomass of 272.33 kg. The study proved the role of the zoological park in woody plant conservation and carbon sequestration potential in a city under rapid urbanization and completes the effort of the city managers to determine the City Biodiversity Index. Consequently, the management of FUNAAB Zoo Park should consider native woody plants conservation and big size trees.

Keywords—Carbon sequestration, zoological park, Shannon diversity index, biological conservation, Nigeria.

I.INTRODUCTION

Biodiversity loss poses many socio-economic and ecological problems in the world (Cardinale et al., 2012; Roe, 2019), which can lead to the occurrence of many diseases, food insecurity, conflict, poverty, and loss of cultural values (Cardinale et al., 2012). The loss of biodiversity jeopardizes also the capacity of the ecosystems to provide socio-economic and ecological benefits to society. The key drivers of biodiversity loss are agricultural expansion, urbanization, logging activities, hunting practices, inappropriate agricultural practices such as the use of fire for land clearance, etc. In Nigeria, biodiversity is under threat due to human activities such as the use of wood for energy purposes, rapid urbanization, conflict, overgrazing, roads constructions and climate change (Nwankwo, 2020; Sobere and Ihua-madunenyi, 2019).

Nature is a city that provides many ecosystem services such as biodiversity conservation, local climate regulation, socio-economic wellbeing of the urban people such as health benefits (Borelli and Conigliaro, 2018). For instance, Zoo Park or zoological garden plays a crucial role in areas such as a site for tourist attraction and tourism industry, a site for biodiversity conservation, site of research and education in urban.

Over the last 50–60 years, Conservation Biology has worked through several different framings of the relationships between people and nature. The observation that natural areas supply ecosystem goods and services (ES) to people has provided a useful link between ecosystems and human well-being (De Groot *et al*. 2002; MA 2005). The practicalities of quantifying and modeling this link are still a work in progress (Carpenter *et al*. 2009; Seppelt *et al*. 2011; Reyers *et al*. 2013;

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Mace 2014). Explicitly connecting change in ecosystems to human well-being requires a comprehensive approach that considers both tangible and intangible benefits (Russell *et al*. 2013). Many tangible ecological benefits are readily quantified through economic measures, such as the costs of water purification and the market values of food and fuel. Intangible benefits, or cultural ecosystem services (CES), are harder to measure through approaches that recognize the difficulties of aggregating human values and deliberately maintain a plurality of perspectives and epistemologies (Chan *et al*. 2012a; Satz *et al*. 2013). The assessments of CES cover recreation (Driver *and* Knopf 1977; Chan *et al*. 2006), culture and heritage (Tengberg *et al*. 2012; Nahuelhual *et al*. 2014), sense of place (Trentelman 2009; Ardoin *et al*. 2012), and mental health (e.g., Bratman *et al*. 2012; 2015), and contribute to more resilient strategies for ecosystem management (Chan *et al*. 2012b).

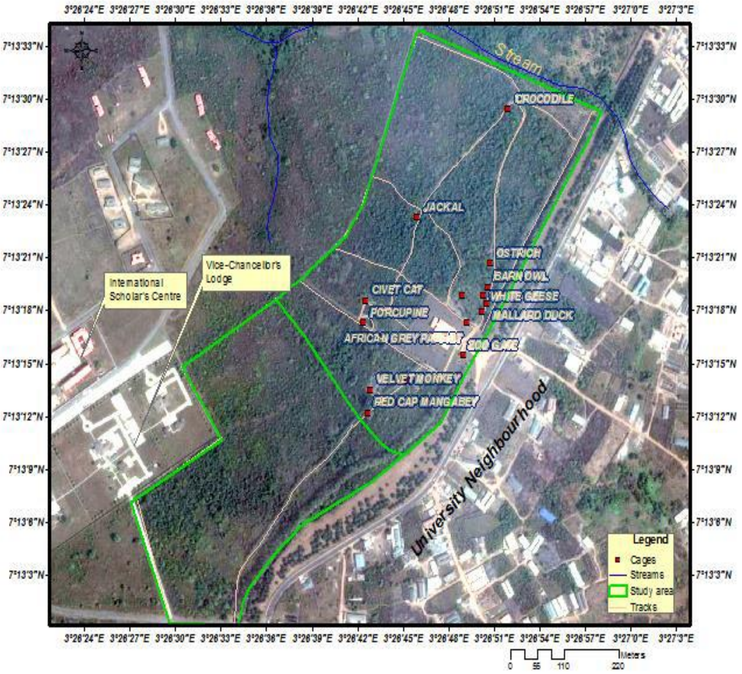
The concept of ecological services has become a new tool that conservationists use to reduce the global loss of biodiversity in human-created ecosystems (Perrings *et al*., 2010). Therefore, natural areas around urban and suburban areas could provide spaces for sport and spiritual activities and could maintain a small sample of wildlife and lend more intangible services such as carbon sequestration and water supply according to the level of disturbance (Bolund *and* Hunhammar, 1999).

However, the role of urban and peri-urban Zoo Park areas in carbon sequestration and socio-economic well of the urbanite in Nigeria's cities has not been up now well captured. For instance, there is a lack of study that demonstrates the role of urban zoological parks in woody species conservation and atmospheric carbon dioxide reduction. Consequently, this study hypothesizes that FUNAAB Zoo Park has high woody plants diversity that plays a key role in carbon sequestration. Specifically, the study seeks to (1): identify the woody species diversity of the FUNAAB zoo park and (2) determine its carbon sequestration potential.

II.METHODOLOGY

Study Area

The study area is Abeokuta which is located in the sub-humid tropical region of Southwestern Nigeria (Lat 7º5'N to 7º20'E and Long 3º17'E to 7º27'E). Abeokuta and the surrounding area had a population of 593140 (Wikipedia, 2010; NPC, 2010) spread over about 125,600 hectares of land at present and dredging. The study was conducted in the Federal University of Agriculture, Abeokuta (FUNAAB) Zoo Park which is



located along Latitude 7.2209º N; Longitude 3.4466ºE (Figure 1).

Figure 1. Satellite Imagery of FUNAAB Zoo Park

The Federal University of Agriculture, Abeokuta, Nigeria zoological park lies geographically within latitudes 7o 12' to 7o 20' and longitudes 3o 18' to 3o 27' was established in the year 2010 by the institution for fund generation and as recreation, teaching, and learning resource. FUNAAB Zoo Park is being managed by the Zoo Directorate and was commissioned on 23 May 2012. The Study is constrained to both the feral i.e. free-living animals and the Zoo animals i.e. the animals under captivity in the FUNAAB Zoo Park. It is located in the derived Savanah zone of southwest Nigeria, a few kilometers north of Abeokuta city. The zoo park offers a balanced mix of nature's gifts to man. The Zoo Park combines forestry and other wildlife all in a natural habitat. The park serves as a leisure garden for the public to appreciate nature and see different animals in their natural habitat. A tour guide

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is available at the request of a visitor. It has different animal groups such as the primates, duckers, cats, birds and reptiles that are just representative of the games found in the wild in this part of Nigeria (IFSERAR, 2010). The forty-hectare zoo has now become a haven to several free-ranging wildlife including, monkeys, antelopes and birds of all types because it is near to nature (Vconnect, 2016). Figure 2 show also the location of animal pens.

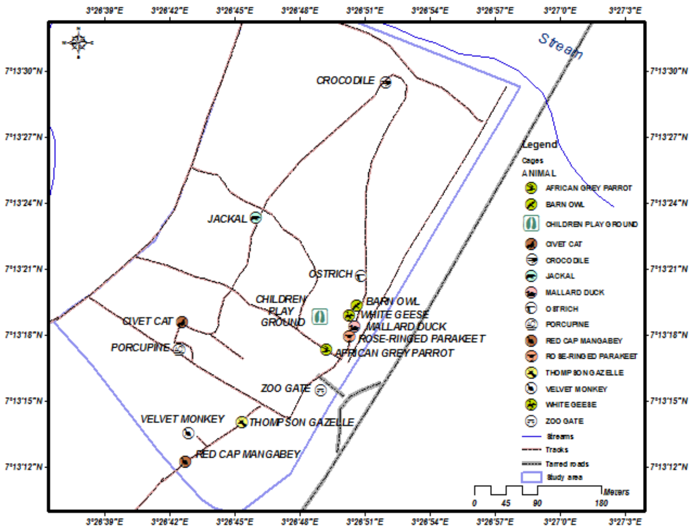

Figure 2. Map of the location of Animal Pens in FUNAAB Zoo Park

Sampling technique and data collection

Biodiversity inventory

A systematic sampling technique was used and four plots (10 m×10 m) was placed close to the major animal sections in the park. Complete enumeration was conducted within each plot to determine the name of flora and fauna species and dendrometric measurements (girth and height of the tree) were conducted. Accordingly, the girth of each tree species was obtained with the aid of girthing tape 1.3 m for the tree base, and the diameter at breast height was computed. The initial unit of measurement was centimeter, which was converted to the meter by timing the recorded values by a correction factor of 0.3 (Hamilton, 1975).

Besides, the height of the tree species was measured using the Haga altimeter. Initially, the Haga altimeter was standardized to 9 m for very tall trees and 3 m for short trees away from the tree (Hamilton 1975). Angiosperm Phylogeny Group 4 (APG IV) was used for the classification systems and new subfamily classification of the Leguminosae according to Legume Phylogeny Working Group (LPWG), 2017)

III. DATA ANALYSIS & RESULTS

Biodiversity analysis

Scientific and local names of the identified plants and animals, species richness and number of families were determined. Shannon and Pielou diversity indices were used for the dominant families and species in the park. Accordingly, the Shannon diversity index was determined by the formula: $H' = -\sum [(ni/N)*Ln\ (ni/N)]$. Furthermore, Pielou's evenness (J') was calculated by the formula: $J = H'/Ln(S)$. Where ni refers to the number of individual species i, N is the total number of individuals, S the total number of species recorded in the park, and *Ln* is the natural logarithm.

Biomass estimation

The above-ground biomass (ABG) of a tree was estimated by Allometric equations. Therefore, for the trees with diameter less than 11 cm: $AGB = 0.25D^2H$ (Chave et al., 2005)) and for those with diameter greater than or equal to 11 cm: $ABG\ (Kg) = 0.15D^2H$. ABG refers to the above-ground biomass of the tree in kilogram, D = Diameter at breast height (DBH) of the trunk (m) and H refers to the height of the tree (m). Additionally, the root shoot ration developed by (Cairns et al., 1997) was used to estimate the below ground biomass (BGB): $BGB = \exp(-1.3267 + 0.8877 \times \ln(AGB) + 0.1045.\ln(AGE)$.

Carbon Sequestration Potential

Trees Carbon dioxide (CO_2) sequestration potential was estimated by combining the ratio derived from the atomic weights of the elements making up the CO_2 molecule to that of carbon (C), i.e. 3.7 (Assah et al., 2012). The ratio (3.7) was timed to the (AGB) and the Below Ground Biomass (BGB) of the different trees to estimate CO_2 sequestrated: Total CO_2 sequestrated = 3.7 * (AGB + BGB).

Results

Woody floristic composition of FUNAAB Zoo Park

Table 1 showed that 30 woody plant species, 15 families and 15 genera were recorded within the park and *Fabaceae with* 6 species was dominant in the park.

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Accordingly, the Shannon diversity index (H′) was 3.29 while Pielou's evenness (J') was 0.97 in the park. *Anacardium occidentale* (12 stems) was the dominant tree species in the park. Native woody plants represent 80% of recorded in the park and exotic woody plants accounted for 20% (table 1).

TABLE 1. LIST OF WOODY PLANT SPECIES RECORDED

Species	Common Name	Local name (Yoruba)	Forms	Families	Origins
Albizia adianthifolia (Schumach)	Flat crown	-	Tree	Fabaceae	Exotic
Albizia ferruginea (Benth)	Albizia	-	Tree	Fabaceae	Native
Albizia zygia (Benth)	Albizia	-	Tree	Fabaceae	Native
Alchornea cordifolia (Mull-Arg)	Christmas bush	-	Shrub	Euphorbiaceae	Native
Alchornea laxiflora (Benth)	Lowveld bead-string	-	Shrub	Euphorbiaceae	Native
Alstonia boonei (De Wild)	God's tree	-	Tree	Apocynaceae	Exotic
Anacardium occidentale (Linnaeus)	Cashew	Kasu	Tree	Anacardiaceae	Exotic
Anthocleista vogelii (Planch)	Planch tree	-	Tree	Gentianaceae	Native
Antiaris Africana (Lesch)	Mull berry	-	Tree	Moraceae	Native
Bambusa vulgaris (Schrad)	Bamboo	Oparun	Grass	Poaceae	Native
Baphia nitida (Lodd)	Camwood	-	Tree	Fabaceae	Native
Blighia sapida (Koenig)	Achee	-	Tree	Sapindaceae	Native
Blighia unijugata (Baker)	Triangle tops	-	Tree	Sapindaceae	Native
Bridelia atroviridis (Mull-Arg)	Bredelia	-	Tree	Euphorbiaceae	Native
Ceiba pentandra (Gaertn)	Kapok	-	Tree	Malvaceae	Native
Celtis zenkeri (Linnaeus)	African celtis	-	Tree	Ulmaceae	Native
Chrysophyllum albidum (George)	Cherry	Agbalumo	Tree	Sapotaceae	Native
Cola millenii (K. Schum)	Kola	Obi	Tree	Malvaceae	Native
Cola nitida (Schott &Endl)	Kola	Obi	Tree	Malvaceae	Native
Delonix regia (Raf)	Royal tree	-	Tree	Fabaceae	Exotic
Diospyros dendo (Welw)	Yellow persimmon	-	Tree	Ebenaceae	Native
Elaeis guineensis (Jacq)	Oil palm	-	Tree	Arecaceae	Exotic
Entandrophragma angolense (Welw)	Utile	-	Tree	Meliaceae	Native
Ficus exasperata (Vahl)	Sandpaper tree	Ipin	Tree	Moraceae	Native
Funtumia elastica (Stapf)		-	Tree	Apocynaceae	Native
Gliricidia sepium (Jacq.) Steud	Gliricidia	-	Tree	Fabaceae	Exotic
Guarea thomsonii (Clarke)	Black guarea	-	Tree	Meliaceae	Native
Holoptelea grandis (Hutch.) Mildbr		-	Tree	Ulmaceae	Native
Homalium africanum (Hook.f.) Benth.		-	Tree	Salicaceae	Native
Mangifera indica (Linnaeus)	Mango	Mangoro	Tree	Anacardiaceae	Exotic

SOURCE: FIELD SURVEY, 2018

Biomass and carbon stocks

For above-ground biomass of tree species < 11 cm DBH

Table 3 showed that the total below ground biomass of the tree species < 11cm DBH was 71.681 kg for a CO_2 sequestrated of 227310 kgCha^{-1}.

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TABLE 3: ABOVE-GROUND BIOMASS OF TREE SPECIES < 11CM DBH

Species	No of stem	Mean DBH (cm)	Mean height (m)	Model	AGB (kg)
Delonix regia	3	7.8	11.1	W = $0.25D^2H$	43.29
Bridelia artroviridis	3	10.7	19.9	W = $0.25D^2H$	106.47
Ceiba pentandra	10	7.8	17.7	W = $0.25D^2H$	69.03
Cola millenii	7	7.8	23.8	W = $0.25D^2H$	185.64
Diospyros dendo	8	10.8	25.6	W = $0.25D^2H$ Total	138.24 542.67

SOURCE: FIELD DATA

FOR ABOVE-GROUND BIOMASS OF TREE SPECIES >11CM DBH

Table 4 showed that the above-ground biomass of the species with a diameter greater than or equal to 11cm and the height of the trees calculated by Model 1 and the below ground biomass and carbon sequestration estimate by sing Model 3 and 4. The total AGB of the tree species with diameter > 11 cm was 2456.795 kg, a total BGW was 272.33 kg and the total CO_2 sequestered by the tree species with diameter > 11 cm was 1009776 $kgCha^{-1}$ (Table 4).

TABLE 4. ABOVE GROUND BIOMASS OF TREE SPECIES >11CM DBH

Species	**No of stem**	**Mean DBH**	**Mean height**	**Model**	**AGB(kg)**
Ficus exasperate	9	11.8	9.3	W = $0.15D^2H$	32.92
Anacardium occidentale	12	12.0	10.4	W = $0.15D^2H$	37.44
Albizia adianthifolia	5	13.0	11.7	W = $0.15D^2H$	45.63
Albizia ferruginea	7	12.4	9.2	W = $0.15D^2H$	34.22
Albizia zygia	4	24.1	11.0	W = $0.15D^2H$	72.22
Alstonia boonei	8	18.0	18.2	W = $0.15D^2H$	98.28
Antiaris Africana	9	16.0	16.5	W = $0.15D^2H$	79.2
Anthocleista vogelii	2	14.4	20.5	W = $0.15D^2H$	88.56
Bambusa vulgaris	10	26.1	24.2	W = $0.15D^2H$	189.49
Baphia nitida	10	40.0	18.4	W= $0.15D^2H$	220.8
Blighia sapida	5	18.1	16.9	W = $0.15D^2H$	91.77
Blighia unijugata	7	21.9	18.0	W = $0.15D^2H$	118.26
Celtis zenkeri	9	12.0	31.5	W = $0.15D^2H$	113.4
Chrysophyllum albidum	5	13.0	20.6	W = $0.15D^2H$	80.34
Cola nitida	8	11.8	16.1	W= $0.15D^2H$	56.99
Entandrophragma angolense	11	12.0	22.7	W = $0.15D^2H$	81.72
Elaeis guineensis	6	13.0	22.5	W= 0.15D2H	87.75
Funtumia elastica	8	12.4	32.0	W=0.15D2H	119.04
Guarea thomsonii	10	24.1	34.5	W=0.15D2H	249.435
Gliricidia sepium	11	39.0	17.8	W=0.15D2H	208.26
Holoptelea grandis	11	17.1	24.2	W = 0.15D2H	124.15
Homalium africanum	6	20.0	24.2	W = $0.15D^2H$	145.20
Mangifera indica	8	12.2	15.9	W = $0.15D^2H$	81.72
				Total	2456.795

SOURCE: FIELD DATA

IV. DISCUSSION

The study determined the biodiversity and showed the existence of high species diversity in FUNAAB Zoo Park. With Shannon's diversity index greater than 2.0, this showed a range of medium to high diversity in for the park (Magurran, 2004). This indicates that the zoo park is an area of high diversity of woody plants and presents a great in tree biodiversity conservation. Similarly, Trichon (1997) noted that diversity is an indicator of richness and abundance of individuals' tree species and reflects the degree of heterogeneity or stability of the park ecosystem. The high tree species diversity in FUNAAB Zoo Park showed a potential for conservation and maintenance of the ecological integrity of the park ecosystem. Tree diversity is an important attribute of the resilience of urban systems (Jacobi et al. 2015) and climate change adaptation (Bandanaa et al. 2015).

With regards to the nature-based solution, high tree species diversity can contribute to urban sustainability through the promotion of inter-and intra-generational equity, protection of the natural environment, minimization of natural resource use, and community and individual well-being. These results are aligned with Conde et al. (2011), Rabb (1994) and Maclaren (1996) who reported that zoological parks play a major role in conserving biodiversity.

However, the study highlighted the role of the urban zoological park in tree biodiversity conservation. Therefore, it completes the knowledge gaps about the role of zoological parks in tree biodiversity conservation rather than animal conservation, which is in essence its first role. Besides, the study shows that FUNAAB zoo park is housing some endangered tree species such as *Albizia ferruginea* (Guill. & Perr) Benth, *Entandrophragma angolense* (Welw.) C. DC. and *Guarea thompsonii* Sprague & Hutch that are in the red-listed threatened plants species of IUCN Red-in Nigeria (Borokini, 2014). The dominance of native tree species in FUNAAB Zoo Park indicates the remnant vegetation with those patches of native trees. It also emphasizes the role of the zoological park in native trees conservation. Among the species recorded, there was a tree with a huge canopy, which could protect the FUNAAB zoo park from various damages such as floods and winds. The tree diversity recorded in FUNAAB Zoo Park would have great implications in biological conservation because as stay in the zoo as long as will remain the trees except for the natural extinction. Furthermore, this high diversity could play a key role in carbon conservation and climate change mitigation so that FUNAAB zoological park may contribute to ecosystem resilience.

On the other hand, the study revealed the existence of exotic food trees (mango, cashew) that could provide fruit to the frugivorous animals of the park. Besides, the Park dominated indigenous woody species due to the conservation of local flora in urban areas like FUNAAB Zoo Park. These results controvert those of Raoufou et al. (2011), Ganaba (2020) and Moussa et al. (2020) who reported that the woody flora of West African cities is dominated by exotic woody species. The study showed there was a dominance of *Fabaceae* in the park. Likewise, Agbelade et al. (2017) and Moussa et al. (2020) reported the existence of a high number of species of *Fabaceae* in the cities of Ibadan, Maradi, and Niamey. Also, Raes et al. (2013) indicated that Fabaceae is an indicator of botanical diversity of a given area and Mudzengi et al. (2014) explained that the dominance of Fabaceae in the FUNAAB could be due it is worldwide distributed and it supports various types of soils and climate.

Fabaceae is a plant family that plays a key role in fixing biological nitrogen and therefore it could have great importance for the vitality of FUNAAB park. Additionally, it would enhance the carbon sequestration potential of the park. Urban and urbanizing areas were usually considered as sources of carbon emissions. The vegetation of urban and peri-urban areas has been largely ignored in the carbon cycle study (Churkina, 2008, 2016; Churkina et al., 2010). The findings of this study suggest that tree species in Funaab Zoo Park are carbon sinks and can play a vital role in climate change mitigation and adaptation. The total CO_2 sequestrated (CO_2e) for the tree species with < 11cm DBH was 227310 $kgCha^{-1}$ while the total CO_2 sequestrated (CO_2e) for the tree species with > 11cm DBH was 1009776 $kgCha^{-1}$. The result of this study also corroborates with Timilsina et al. (2014) who reported that Public parks, cemeteries, institutional compounds in peri-urban areas store more carbon compared to other urban green spaces except in the natural forests. Well functioning ecosystems are likely to be more resilient to both the direct effects of climatic change and to indirect impacts such as GHG emission reduction, disease prevalence, invasive species, changing hydrology and fire regimes (Folke, 2010; Folke *et al.*, 2004).

Also, woody species with (BDH > 11 cm) showed more important carbon sequestration potential in the park and native species contributed about 80% to the total carbon stocks in the park. Likewise, Thomas et al. (2007) reported that the native tree species have a great carbon sequestration potential and Schlaepfer et al (2020) underlined that the dominance of native tree species in the park may provide various services such as biodiversity conservation.

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V. CONCLUSION

The study revealed the level of woody species diversity and carbon sequestration potential of FUNAAB Zoo Park in Abeokuta in Nigeria. In addition, the findings showed that FUNAAB Zoo Park has high woody species diversity while 80% of the woody flora is native species. Furthermore, Woody species with BDH > 11 cm were more important for carbon sequestration potential than other species, which exist in the park. Accordingly, the management of FUNAAB Zoo Park should consider native woody plant conservation, woody species with (BDH > 11 cm) and further studies could focus on the perception of evaluation of ecosystem services by woody species to the visitors and the FUNAAB Zoo Park.

The study showed that FUNAAB Park stores considerable amounts of carbon through its woody species. Furthermore, it provides the role of the zoological park in climate change mitigation through the estimation of the carbon stock. This is the first attempt as at present, no study estimated the carbon stock of zoological parks and therefore it completes the international effort of providing nature-based solutions from urban areas to fight climate change. Therefore, for sustainable carbon storage, the management of the park should consider the above-mentioned tree species in the zoological park because of the important roles they play in climate change mitigation.

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BIOGRAPHY

This work was carried out in collaboration among all authors. Author Afeez Adeleye Olukunmi gives the idea and collected data for the research, author Osoba Akolade Emmanuel performed the preliminary analyses, author Atanda Toyeeb Abidemi managed the literature searches and performed the final analysis, and author Moussa Soulé read the first draft and gives technical advice to the research while author Hamidou proofread the manuscript and participle in the writing of the paper. All authors read and approved the final manuscript.