VASCULAR PLANT DIVERSITY AND CARBON STOCKS OF SELECTED SACRED GROVES IN SOUTHWESTERN, NIGERIA

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ABSTRACT
Sacred groves are hotspot areas for tree species diversity and rare woody plants. Tree species composition have not been evaluated for its contribution to carbon in sacred groves. This study was designed to investigate influence of stand structure on variation of biomass and soil carbon stocks in the selected sacred sites in Southwestern, Nigeria. Ten (0.09ha) plots were randomly demarcated in each sacred grove. Tree ≥5cm Diameter-at-Breast Height (DBH) were identified and species diversity indices (Shannon-Weinner, H´; Simpson, 1-D) were computed. Total height (TH) and DBH were measured for volume and carbon estimation. Soil samples were collected with cores at three depths in each plot. Core samples were oven-dried at 105^{o}C and 100g of soil was separated into >2.0, 2.0-1.0, 1.0-0.5, 0.5-0.05 and<0.05mm aggregates and carbon proportion determined. Data were analysed using descriptive statistics and ANOVA. A total of 28 tree species representing 18 families, 23 tree species representing 14 families, 8 tree species representing 6 families and 16 tree species representing 12 families were identified in Ori-Oke, Bilikisu-Sugbo, Olumo rock and Osun-Osogbo groves, respectively. The H´ ranged from 2.61 (Ori-Oke) to 1.67 (Olumo-rock), while 1-D ranged from 0.94 (Bilikisu) to 0.74 (Olumo-rock). Biomass carbon ranged from 24240.00 (Bilikisu-Sugbo) to 7998.36 kg/ha (Ori-Oke). Carbon content increased with decrease in aggregate size in soil depths of Ori-Oke and Bilikisu-Sugbo while decreased with decrease in Olumo-Rock and Osun-Osogbo Groves. Bilikisu-Sugbo ontained the highest tree species diversity and carbon storage. Therefore, Bilikisu-Sugbo should be considered for plant diversity and carbon storage conservation schemes.

Keywords: Carbon sequestration; Cultural sites; Religion sites; Above-ground carbon; Biomass Carbon

INTRODUCTION
Sacred groves are small patches of forest that are maintained for spiritual and religion purposes (Rath *et al.*, 2020). Most times, sacred groves harbour remnant of climax vegetation and pristine floral composition of the community. Therefore, sacred groves are local hotspot areas for tree species diversity and several rare woody plants. Hence, sacred groves contribute to climate change mitigation through sequestration of tree stem carbon and storage of soil carbon. However, conservation strategies based on religion belief and emphasize strict restriction of rights to livelihoods of local communities (Rath *et al*., 2020) have not yielded a desirable results because belief alone cannot longer conserve these local heritages (Ballullaya *et al.*, 2019). Forests where local communities are strictly restricted to have access to livelihood are often perceived as public properties and often treated destructively (Ballullaya *et al.*, 2019). Also, erosion of religious beliefs has weakened the local institutions and beliefs system. Therefore, rapid urban annexation has reduced the number and size of sacred groves (Barik *et al*., 2018 and Ballullaya *et al.*, 2019)..

Perception of the local communities is important for management and conservation of sacred groves (Ballullaya *et al.*, 2019). Therefore, conservation is less difficult when the local people are aware of the monetary benefit for providing ecosystem services through Payment for Ecosystem Services (PES) scheme (Brandt *et al* 2015). The role of private sector is growing among PES scheme at local and international level. The quality and quantity of ecosystem service determine its inclusion in conservation priority and decision of the government. Therefore, quantification of ecosystem services is required in selected sacred groves in Southwestern, Nigeria. However, studies on biomass and soil carbon estimation are scarce in these sacred groves because of local restrictions. Therefore, carbon sequestration potentials of these sacred sites have not been studied extensively.

However, presence of size and species diversity of vascular plants composition influence the variation of soil carbon stock and flux. The tree species composition and size have not been comprehensively evaluated for its contribution to stem and soil carbon in sacred sites. Estimation of carbon stock of vascular species and sizes is required to understanding the contribution of structure to sequestration of biomass carbon. This study is designed to investigate the stem and soil carbon stocks of four selected Sacred Groves in Southwestern, Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in four sacred groves which are Ori-Oke Amule (Latitude 3° 24′; Longitude 5° 75′), Bilikisu Sungbo (Latitude 3° 94′; Longitude 6° 88′), Olumo rock (Latitude 3° 34′ Longitude 7° 16′) and Osun-Osogbo (Latitude 4° 55′; Longitude 7° 75′) sacred groves. The four sacred groves were located in Osun and Ogun States.

Data collection

Ten (30m x 30m) sample plots were demarcated in the grove of each sacred site. Tree stems with ≥10cm diameter-at-breast height (DBH) > 5cm were enumerated and identified to species level. The stem DBH and total height were measured and categorized into diameter and height classes. Also, the diameter-at (-base, -middle and –top) and total height were measured using Spiegel Relaskop (Bitterlich model). Shannon-Weiner, Simpson and Margalef indices of diversity were used to evaluate tree species diversity of the selected sacred groves.

Shannon-Wiener species diversity index was expressed as:

$$H = -\sum_{i=1}^{n} P_i ln P_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, ln is natural logarithm; P_i is the percentage of individual trees represented by species *i* and is estimated by;

The Simpson species diversity index was expressed as:

$$D = 1 - \left[\frac{\sum_{i=1}^{n} n_i(n_i-1)}{N(N-1)}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $n_i$is the number of individuals of the i^{th} species and *N* is the total number of individuals

Margalef's index of species richness (*Ma*) is expressed as:

$$Ma = \frac{(S-1)}{\ln N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, *S*is the total numbers of species in each grove, *N*is the total number of individual trees, *ln*is the natural logarithm

Stem diameter distribution of the selected sacred groves

The stem DBH of trees sampled in each sacred grove were categorized into 20 size classes with a width of 7.50cm DBH, starting from the smallest to the largest. Also, the stem diameter distribution curve of 20 classes was produced for each sacred grove.

Estimate of above- and below- stem biomass and carbon at the four sacred sites

The measured tree stem diameter-at (-base, -middle and –top) and total height of individual species were used to compute the above-ground stem volume and the stem volume was converted to stem biomass and carbon stock. It was assumed that below-ground biomass is 20.0% of the above-ground biomass.

Stem volume of individual tree species was computed using Newton wood volume equation (Fonwebau, 1997). Newton's formula is expressed as:

$$Stem\ wood\ volume = \frac{D_b + 4D_m + D_t}{6} xh \quad \text{.....(4)}$$

Where, D_b=Diameter-at-base
D_m= Diameter-at-middle
Dt= Diameter-at-top
h=tree height

The volume of individual tree species was multiplied with individual wood density to obtain stem biomass/ha. According to Malhi *et al* (2004), stem carbon about 50% of tree biomass. The wood density of individual tree species were obtained from Wood Density Database (Zanne *et al*., 2009).

Stem carbon of each tree species was estimated using this expression (IPCC, 2006 and Malhi et al., 2004):

$$Stem\ carbon = stem\ volume\ x\ Wood\ Density\ x\ 0.5 \quad \text{.....(5)}$$

Data analysis

Stem diameter distributions of vascular plant of sacred groves were presented using line graph of 20 classes with class interval of 7.50. Vascular species diversity in the sampled quadrats of sacred sites were assessed using the Shannon-Weiner, Simpson and Margalef richness indices. Wood volume and biomass carbon stock of each tree species was computed and estimated per hectare. The significant difference in carbon contents among five soil aggregate sizes in each sacred grove was tested using two-way analysis of variance (ANOVA) at 0.05 probability level. Mean separation was done using Duncan Multiple Range test.

RESULT

The tree species diversity of four selected sacred groves in Southwestern, Nigeria

A total of 62 tree species representing 34 families was identified in the four selected sacred groves. Twenty eight (28) tree species representing 18 families were identified in Ori-Oke Amule sacred grove. A total of 23 tree species representing 14 families was identified at Bilikisu-Sugbo sacred grove (Table 1). A total of Eight (8) tree species representing 6 families were identified at Olumo-Rock grove and 16 tree species representing 12 families were identified at Osun-Osogbo sacred groves. *Milicia excelsa* was common to Bilikisu-sugbo, Olumo rock and Osun-Osogbo

sacred groves while *Funtumiaelastica* was common to Ori-Oke Amule, Bilikisu Osugbo and Osun-Osogbo sacred groves. Also, *Milicia excelsa* and *Newnouldia Laevis* were common to Olumo and Osun-Osogbo sacred groves.

The value of Simpson index ranged from 0.941 (Bilikisu) to 0.746 (Olumo Rock). Also, the value of Shannon-Weinner index ranged from 3.103 (Bilikisu-Osugbo) to 1.677 (Olumo Rock) (Table 1). Conversely, the value of Evenness ranged from 0.762 (Osun-Osogbo) to 0.487 (Ori-Oke Amule).

Table 1: Values of diversity indices of selected Sacred Groves in Southwestern, Nigeria

Diversity indices	Ori-Oke Amule	Bilikisu	Olumo Rock	Osun-Osogbo
Number of tree species	28.00	24.00	8.00	17.00
Number of tree families	18.0	14.0	6.0	12.0
Number of stems	274.00	181.00	52.00	59.00
Simpson index (1-D)	0.898	0.941	0.746	0.912
Shannon-Weinner	2.613	3.103	1.677	2.619
Evenness	0.487	0.718	0.668	0.762
Margalef index of richness	4.81	5.771	1.772	4.169
Equitability	0.784	0.903	0.806	0.906

Diameter distribution of tree stems at Ori-Oke sacred site expressed inverse-J shape curve while other expressed rotate sigmoid curve. Highest number of tree stems occurred at 0.0-7.50cm DBH, followed by gradual decrease at 7.51-15.01 and 15.02-22.52cm DBH classes and few representation at intermediate classes at Ori-Oke sacred grove. The diameter distribution of Olumo and Osun-Osogbo sacred groves extended til 142.69-150.19cm DBH. There was un-usual high stem density at 37.55-45.05 to 67.59-75.09cm DBH.

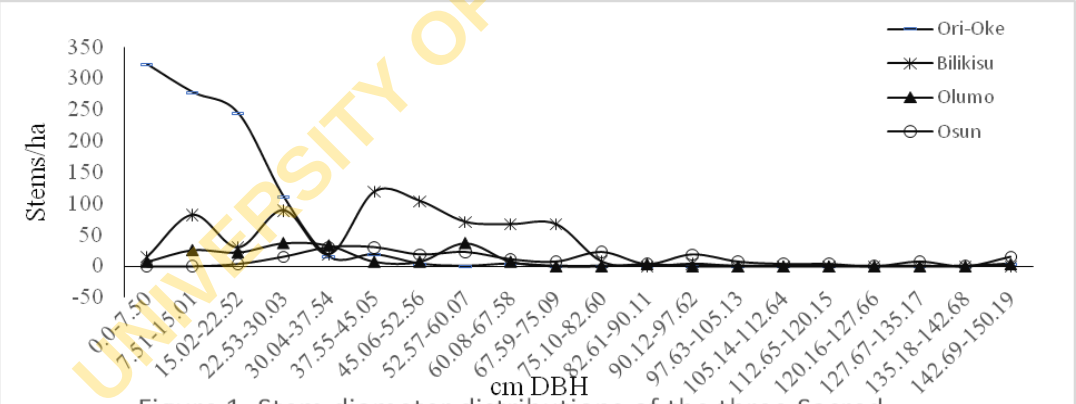

Figure 1. Stem diameter distributions of the three Sacred Groves

The above- and below-ground stem carbon stock obtained at Ori-Oke sacred site was 7998.36 kg/ha. The *Pterocarpus erinaceus* contained the highest amount of carbon (15.8%), followed by *Terminalia macroptera* (13.5%), *Parkia biglobosa* (12.9%) and *Lophira alata* (12.2%) at Ori-Oke sacred site (Table 2). The total amount above-ground and below-ground stem carbon were 6651.87 and 1330.37 kg/ha. Respectively, at Ori-Oke sacred grove.

Table 2. The five tree species with highest stem carbon stock at Ori-Oke sacred site

Tree species	DBH range	Stems /ha	AGBC (Kg/ha)	BGBC (Kg/ha)	Total carbon
Isoberliniadoka	4.30-32.2	24.0	445.41	111.35	556.76
Lophira alata	2.00-144.00	16.0	777.36	194.35	971.71
Parkia biglobosa	2.00-43.5	20.0	827.23	206.81	1034.04
Pterocarpus erinaceus	5.10-26.50	35.0	1007.90	251.98	1259.88
Terminalia macroptera	3.30-23.10	15.0	864.46	216.12	1080.58

Above-Ground Biomass Carbon, AGBC; Below-Ground Biomass Carbon, BGBC

The above- and below-ground stem carbon stock obtained at Bilikisu-Sugbo sacred grove was 24240.43 kg/ha. The *Albizia adianthifolia* contained the highest amount of carbon (18.5%), followed by *Spondia mombin* (10.6%), *Daniella ogea* (9.4%) and *Ricinodendron heudelotii* (6.2%) at Bilikisu-Sugbo sacred grove (Table 3). The total amount of above-ground and below-ground stem carbon were 20200 and 4040 kg/ha, respectively, at Bilikisu-Sugbo sacred grove.

Table 3: The five tree species with highest stem carbon stock at Bilikisu-Sugbo sacred site

Tree species	DBH range	Stems/ha	AGBC (Kg/ha)	BGBC (Kg/ha)	Total carbon
Albizia adianthifolia	9.80-63.8	25.0	3584.28	896.06	4480.31
Daniella ogea	7.10-72.10	13.0	1816.31	454.08	2270.39
Ricinodendronheudelotii	43.40-76.20	15.0	1204.53	301.13	1505.66
Spondia mombin	5.00-52.90	22.0	2046.89	511.72	2558.61
Tetrapleura tetraptera	50.20-72.10	4.0	751.13	187.78	938.91

Above-Ground Biomass Carbon, AGBC; Below-Ground Biomass Carbon, BGBC

The above- and below-ground stem carbon stock obtained at Olumo-Rock sacred grove was 8238.33 kg/ha (Table 4). The *Adansonia digitata* contained the highest amount of carbon (40.0%), followed by *Azadirachta indica* (36.5%), *Adansonia digitata* (8.0%) and *Milicia excelsa* (5.8%) at Olumo-Rock sacred site. The total amount above-ground and below-ground stem carbon were 6865.27 and 1373.05 kg/ha, respectively, at Olumo-Rock sacred grove.

Table 4: The five tree species with highest stem carbon stock at Olumo Rock sacred site

Tree species_Olumo	DBH range	Stem/ha	AGBC	BGBC	Total carbon
Adansonia digitata	85.00-150.00	2.0	523.67	130.92	654.59
Albizia lebbeck	5.100-58.50	2.0	2639.19	659.80	3298.98
Azadirachta indica	18.50-58.50	12.0	2402.92	600.73	3003.65
Ficus thonningii	32.00-36.20	3.0	329.22	82.31	411.53
Milicia excelsa	8.60-45.00	4.0	381.16	95.29	476.45

Above-Ground Biomass Carbon, AGBC; Below-Ground Biomass Carbon, BGBC

There was significant difference in the proportion of carbon among the aggregate sizes. Soil fractions of size 0.0-0.05mm contained the highest proportion of soil carbon, followed by fractions of ≥2.00mm while fractions of ≤0.05mm contained the least proportion of carbon at the five (5) soil depths in Ori-Oke sacred groves. The mean separation test showed that proportion of carbon of 0.5-0.05mm (31.82gC/100g of soil) was significantly higher than ≥2.0mm (23.54gC/100g of soil) and 2-1.0 (19.18gC/100g of soil), 1-0.5 (16.82gC/100g) and ≤0.05mm

(8.59gC/100g) in Ori-oke sacred site. Conversely, there was no significant difference in the mean proportion of soil carbon among the five soil depths.

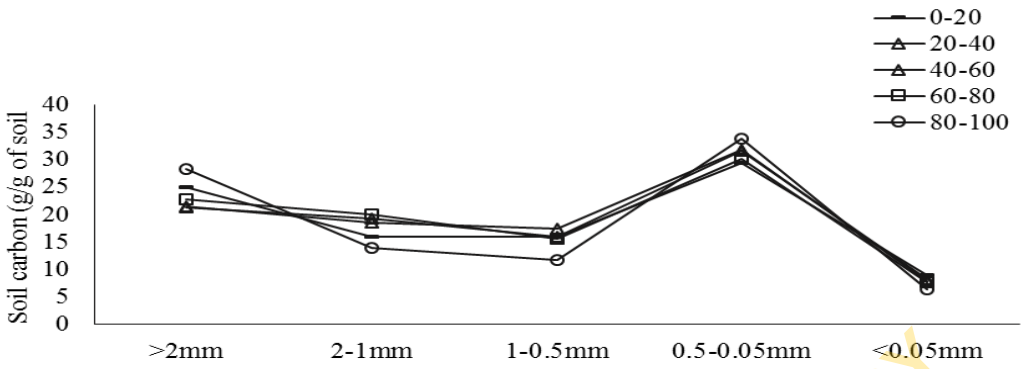

Figure 1. Soil carbon content on aggregate sizes at five depths in Ori-Oke sacred grove

There was significant difference in the proportion of carbon among the aggregate sizes. Carbon content increased with increase in aggregate size, except for fractions of size ≤0.05mm. Soil fractions of size 0.5-0.05mm contained highest proportion of carbon, followed by 1-0.5mm fractions while fractions of 2-1.0mm contained the least proportion of carbon at 5 soil depths in Bilikisu-Sugbo Sacred site. The mean separation test showed that proportion of carbon of 0.5-0.05mm (38.23gC/100g of soil) was significantly higher than 1-0.50mm (22.18gC/100g of soil) and ≤0.05 (15.76gC/100g of soil), ≥2.0 (13.36gC/100g) and 2-1.0m (11.31gC/100g) in Bilikisu-Sugbo sacred grove. Conversely, there was no significant difference in the mean of soil carbon among the five soil depths.

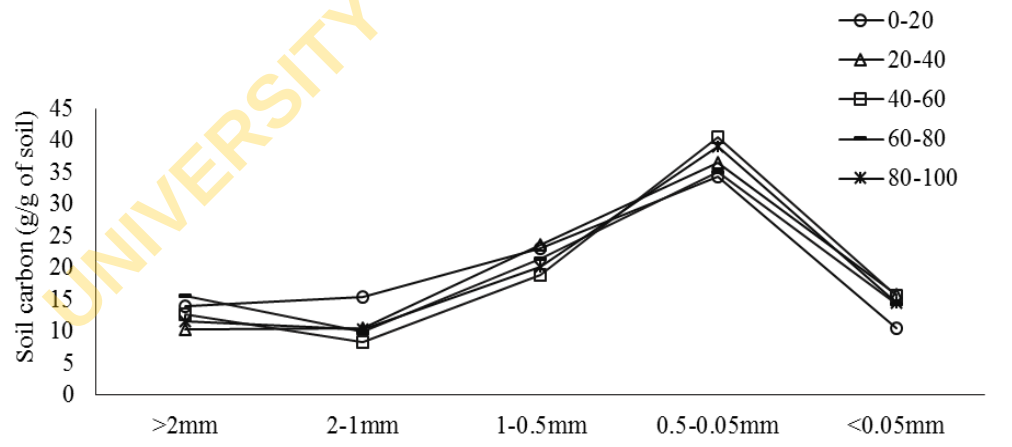

Figure 2. Soil carbon content on aggregate sizes at five depths in Bilikisu=Sugbo sacred grove

Soil fraction of size ≥2.0mm contained highest proportion of carbon, followed by 0.5-0.05mm while fractions of size 1-0.5mm contained the least proportion of soil carbon in Olumo-Rock Sacred grove.

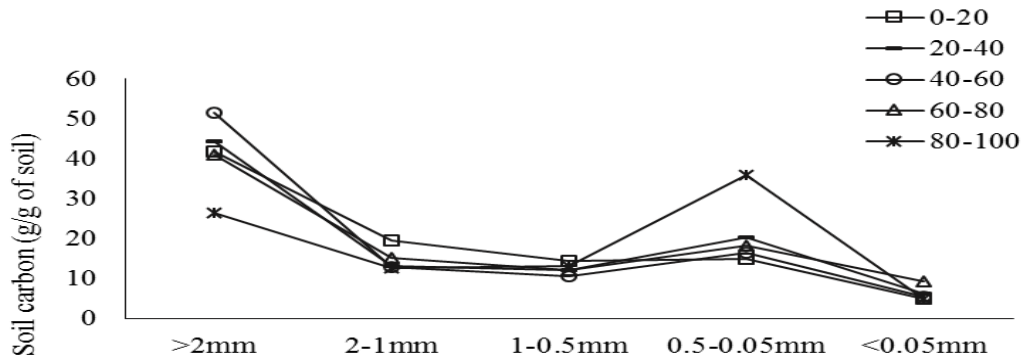

Figure 3: Soil carbon content on aggregate sizes at five depths in Olumo rock sacred grove

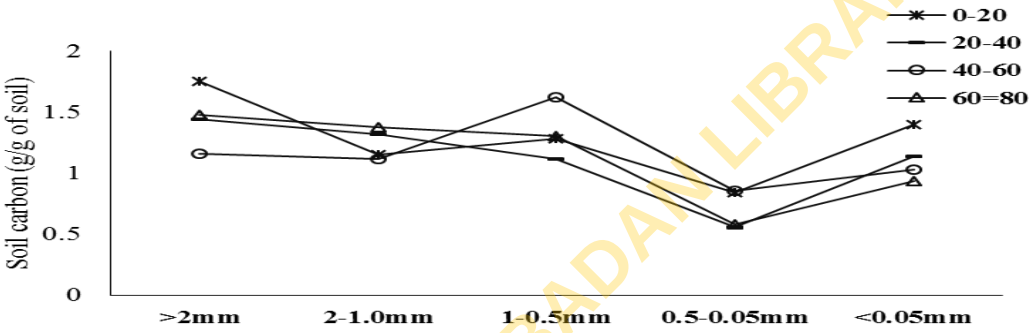

Figure 4. Soil carbon content of aggregate sizes at five depths in Osun-Osogbo sacred grove

DISCUSSION

There was no tree species similarities between the sacred groves. Only *Milicia excelsa, Funtumia elastica* and *Newnouldia Laevis* were common to two or three sacred groves**.** The seeds of three tree species are mostly dispersed by animal, especially bats and birds. Bilikisu had high value of indices of tree species diversity and contained highest number of tree species. Therefore, high tree species richness results in large range of size, genetic variation and complex canopy structure (Hui and Pommerening, 2013). Stem size variability contributes to structural diversity of the grove which is important for many ecological functions (Metsaranta and Lieffers, 2008). It is known that structural diversity affects quality of ecosystem service provided by the forest. Shannon-Weinner index takes into account tree species richness and evenness of the distribution (Magurran, 1988). It is also sensitive to changes in rare tree species (Pielou, 1966). Simpson index of diversity consider the richness and abundance of individuals. This reflects the degree of stability of individual Sacred Grove.

Extension of diameter distribution to 150.19 cm DBH in Olumo rock and Osun-Osghbo indicated the presence of large trees while the moderate stem density at intermediate classes indicated high reproductive potential and sustainability of the groves. Limited number of big trees in groves could be attributed to effect of natural disaster and soil conditions.

The amount of carbon accumulated varied among tree species because carbon in the stem biomass dependent on stem size and wood density. Also, the carbon accumulated in above-ground stems was higher than the below-ground tree roots.

Isoberlinidoka and *Pterocarpus erinaceus* contributed high stem carbon due to high stem density.

The potential of Bilikisu-Sugbo sacred site for large carbon accumulation was due to presence of large trees and high tree species diversity. This showed the contribution of Bilikisu-Sugbo sacred grove to carbon sequestration and climate change mitigation. Day *et al*. (2013) found significant correlation between species diversity and improved carbon sequestration potential in tropical forests.

CONCLUSION

Fabaceae and Apocynaceae families contained highest number of tree species in most of the sacred groves due to seed dispersal mechanisms. Also, Fabaceae and moraceae families contained tree species with optimum carbon storage include *Albizia adianthifolia, Albizia lebbeck, Antiaris africana*. Bilikisu-Sugbo sacred grove should be prioritized for both tree and soil carbon storage among the sacred groves in Southwestern, Nigeria. Therefore, Bilikisu-Sugbo should be considered hotspot area for tree species diversity and carbon storage in Southwestern, Nigeria.

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