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Species Diversity and Carbon Accumulation of Two Golf Courses in Makurdi, Benue State

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ABSTRACT

Background and Objective: There is an increasing trend in anthropogenic activities in the destruction of natural habitats of plants and less awareness of conservation measures, including the consequence of actions on the ecosystems. A survey was conducted to investigate the species diversity and carbon stock potential of trees, herbs, and soil at NASME and New Bridge Golf Course, Makurdi, Benue State. **Materials and Methods:** Each Golf course was divided into two plots of 100×100 m, and each plot had three quadrats was resulting in a total of twelve quadrats for both Golf courses. The biomass and carbon stock of 50 dominant trees and shrubs, 12 species of trees, and 78 species of herbs from 28 families were evaluated. Above and below ground trees and shrubs' biomass was determined using allometric equations, and herbs and grasses biomass was estimated using the stable oven dry weight method. **Results:** *Parkia biglobosa* had the highest SCO_2E (7655.17 kg) and TSC/Tree (2085.88 kg) in both study locations. *Parkia biglobosa* also had the highest record in above-ground (5348.40 kg) and below-ground (3476.46 kg) biomass, lowest above-ground biomass recorded in *Polyanthia longifolia* and *Tectona grandis* (71.74 kg). Diversity index (Shannon-Weiner) (2.15), species evenness (0.93), and richness (10.00) were evaluated highest in the NASME Golf course. *Vernonia cinerea* had the highest relative frequency (0.122), relative density (12.25), relative abundance (0.061), and IVI (12.44). The FVI was highest in Cyperaceae (24.27) and least in Cucurbitaceae (0.2) at the NASME golf course. *Mitracarpus villosus* had the highest relative frequency (0.127), relative density (12.72), relative abundance (0.06), and IVI (12.91), while Poaceae had the highest FVI (26.22). **Conclusion:** In both study sites, the total number of trees, herbs, and soil collected demonstrates that there are differences in carbon stock in both sampled sites based on the degree of disturbance.

KEYWORDS

Important value index (IVI), family value index (FVI), NASME, total sequestered carbon (TSC), sequestered carbon estimation (SCO_2E)

INTRODUCTION

Species diversity and carbon accumulation are two important components of ecosystem functioning[1]. Species diversity refers to the number and variety of species found in a particular ecosystem, while carbon accumulation refers to the amount of carbon stored in the ecosystem. The relationship between these two components has been extensively studied as they both contribute to the overall health of the ecosystem and have important implications for global carbon cycles. Higher species diversity is positively correlated

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with ecosystem stability and resilience, as well as higher rates of primary productivity[2]. Carbon accumulation in an ecosystem provides important benefits such as carbon sequestration, which contributes to climate change mitigation. In recent research of tropical forests, high species diversity was found to be positively associated with higher levels of above-ground carbon storage[3]. Another study found that communities with higher tree species diversity were associated with higher carbon storage in both aboveground and belowground biomass[4].

The relationship between species diversity and carbon accumulation highlights the importance of protecting biodiversity in order to address climate change. By protecting and restoring natural ecosystems, we can simultaneously maintain and increase biodiversity as well as contribute to carbon sequestration. This can be facilitated through sustainable land management practices, as well as conservation and restoration efforts[5]. Trees are arguably the most efficient sequester of carbon[6]. During photosynthesis, trees absorb carbon dioxide from the atmosphere and convert it into carbohydrates for energy. The remaining carbon is stored in the wood and bark of the tree. Growing more trees, particularly indigenous species, in an area is one of the most effective ways of sequestering large amounts of carbon in an ecosystem.

Grasses also play a vital role in sequestering carbon, although on a smaller scale than trees. Grasses absorb carbon dioxide through photosynthesis and use it to form glucose and other organic molecules[7]. The glucose is used for energy production, and some of the carbon is stored in the root and leaf tissues. Planting or restoring grasslands can be an effective method for increasing carbon sequestration, especially in the guinea savanna region, where Benue State belongs.

Soil is another major sink for atmospheric carbon dioxide. This happens during microbial respiration, soil microorganisms break down plant material, releasing the stored carbon dioxide in the form of carbonic acid. This dissolves in water and is absorbed by minerals or used by plants, storing the carbon in the soil[8]. Carbon enhances soil health, and introducing new crop varieties that aid in carbon sequestration can help increase the amount of carbon stored in this manner[9]. All trees, grasses, and soils have their natural mechanisms for sequestering carbon dioxide from the atmosphere and mitigating the effects of climate change. Uptake of carbon dioxide through these methods is crucial for reducing global warming. Achievement of full carbon mitigation potential requires estimation of country-level carbon stocks through statistically validated methods[10].

Carbon sequestration is the process of reducing carbon from the atmosphere and depositing it in reservoirs[11]. Carbon sequestration by plants, particularly in the terrestrial ecosystems, entails the absorption of carbon dioxide from the atmosphere during photosynthesis[12]. The carbon dioxide obtained is converted to biomass, consequently reducing atmospheric carbon and storing it in plant tissues above and below ground. Forest ecosystems play an important role in the sustenance of the total global carbon bank and cycle, as they are reported to sequester about 80% to 40% of terrestrial organic carbon[13].

The build-up of carbon dioxide and other greenhouse gases in the atmosphere captures heat and consequently results in climate change implications[14]. The evaluation of strategies for mitigation of climate change impacts through investigations on how carbon can be captured is a significant step towards defying the consequences of global warming[15]. This research is particularly relevant since there is an increasing trend of anthropogenic activities in the destruction of natural habitats of plants and less awareness of conservation measures, including the consequences of actions on the ecosystems. The quantification of carbon sequestered in a particular ecosystem or region will assist policy makers, researchers, and entrepreneurs to advocate for emission reduction, especially from developed nations[16].

Carbon uptake estimation, afforestation, and grazing exclusion support the reduction of carbon escape to the atmosphere and favour carbon sequestration through reduction of organic carbon deposition and soil erosion in the presence of higher ground cover[17].

This study was based on tree species diversity, herbs and grasses biomass, and also the soil organic carbon, on two Makurdi golf courses (NASME golf course and the New Bridge golf course).

The specific objectives in this study include:

- Estimation of the dry and wet biomass of grasses, herbs, and shrubs in the two golf courses studied
- Evaluation of species diversity indices, abundance, percentage frequency, and important value indices of species in the study location

MATERIALS AND METHODS

Study area: The research was conducted in two golf courses: NASME golf course and the New Bridge golf course, court 5 located in Makurdi. Makurdi town is the headquarters of Makurdi Local Government Area and the capital of Benue State. The town is located between Latitude 7°38'-7°50'N, and Longitude 8°24' and 8°38'E[18]. It is situated in the Benue valley in the North Central Region of Nigeria. Located in Central Nigeria and is part of the middle belt region of Central Nigeria. The city is situated on the South bank of the Benue River. It is traversed by the second-largest river in the country, the Benue River.

Data collection methods

Description: Data was collected from Makurdi golf course, which includes: Sappers golf course, NASME, and The Makurdi golf course, new bridge, court 5. Each Golf course was divided into two plots of 100×100 m, and each plot, three quadrats was thrown for each plot, having a total of twelve quadrats for both Golf courses.

Tree species: The data collection on woody vegetation, herbs, grasses, and soil samples was carried out between the 13-20th of December, 2022. Trees measuring greater than or equal to 15 cm in diameter at breast height (DBH), using the Girth diameter (measuring tape). Tree height was taken with the Haga Altimeter. The canopy diameter was also taken using the 30 cm measuring tape. The biomass and carbon stock of dominant trees and shrubs were estimated using allometric equations developed for tree and shrub species[19].

Herbaceous and grasses biomass: A destructive sampling method was used for measuring the biomass of grasses and herbs by harvesting whole parts of fresh samples of grasses or herbs within each quadrat, a size of 1×1 m, using a cutlass or sickle. All grasses emerging within the quadrat's areas were cut at the ground level, weighed, and a composite sample was obtained for oven-dry mass determination. The oven drying was set and observed for 24 hrs or until the samples reached their stable weight[20].

Soil organic carbon stock: Soil samples were collected in each quadrat along the transect line at a soil depth of 10 cm from the centre of each quadrat for soil bulk density (SBD) determination. A total of 12 soil samples were collected from both fields and taken to the laboratory for oven drying to get the soil organic carbon[21].

Data analysis: The data that was obtained study locations were analysed using the Statistical Package for the social Sciences (IBM SPSS Statistics 25).

The Shannon-Weiner diversity index, which specifies the comparative occurrence of many species' abundance and relative richness amongst species[22].

Species richness, evenness, and diversity were taken. Species richness is simply the number of species present in an area[23]. Species evenness refers to the proportion that each species comprises of the whole[24]. The Shannon-Weiner species diversity index is calculated by taking the number of each species, the proportion each species is of the total number of individuals, and summing the proportion times the natural log of the proportion for each species. Since this is a negative number, we then take the negative of the negative of this sum. The higher the number, the higher the species diversity. In the ideal situation, one should compare populations that are the same size in numbers of individuals Pielou[24] and Goswami *et al.*[25]. The formula is as follows:

$$H' = \sum_{i=1}^{s} Pi \ln Pi$$

where, H' is the species diversity index, s is the number of species, and pi is the proportion of individuals of each species belonging to the ith species of the total number of individuals.

The cover value indices (CVI) were used for evaluating. The CVI was calculated by adding the relative density (RDe) and relative dominance (RDo) of species[26]. The importance value index (IVI) was calculated by adding CVI and relative frequency (RF)[27]:

$$CVI = RDe+RDo$$

$$IVI = CVI+RF$$

RF, RDe and RDo were obtained using the following equations:

$$\text{Relative frequency (RF)} = \frac{\text{Number of individual of species A}}{\text{Total number of individual}} \times 100$$

$$\text{Relative density (RDe)} = \frac{\text{Number of individual of species A}}{\text{Total number of individual}} \times 100$$

$$\text{Relative dominance (RDo)} = \frac{\text{Total basal area of species A}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative abundance (AbR)} = \frac{\text{Abundance of species}}{\text{Total abundance of all species}} \times 100$$

Family value index (FVI) = Sum of IVI of all species in each family.

Measurement of tree height and Diameter at Breast Height (DBH): Tree height was measured using a Haga altimeter; height classes range from 0-5, 6-10, 11-15, and 16-20. While DBH (cm) was measured using a measuring tape at approximately 1.3 m above ground on each tree, and it ranged from 0-50, 51-100, 101-150, 151-200[28].

Biomass determination: Data was collected on plant height (m), Diameter at Breast Height (DBH, cm), while species above-ground biomass (AGB) was estimated non-destructively using equation[29]:

$$AGB = \exp(-2.977+\text{Ln}(pD^2H)) = 0.0509\times pD^2H$$

where, AGB is aboveground biomass, D is diameter at breast height, H is total height, and p is wood density (wood specific gravity), p = 0.56, $D^2 = (DBH)^2$, and H = Height.

- Dry above ground biomass (DAGB)= 65% of AGB
- Below ground biomass (BGB) = 20% of AGB
- Dry below ground biomass (DBGB) = 65% of BGB
- Total biomass (TB) = DAGB+DBGB

Total sequestered carbon (TSC):

- TSC/tree =50% of TB
- Sequestered carbon dioxide equivalent, SCO_2E (kg) = TSC×3.67
- SCO_2E (Tonnes/Tree) = SCO_2E (kg)×0.001[30]

RESULTS

Tree species distribution: A total of 22 trees, belonging to 10 species, were recorded in the NASME golf course, and 28 trees, belonging to 6 species, were recorded in the New Bridge golf course. Making it a total of 50 trees, belonging to 12 species, were recorded from both sampled sites. *Elaeis guineensis* had the highest number of plants (5), representing 23.81% in NASME and 18 plants (64.29%) in New Bridge golf course (Fig. 1).

In general, the total number of *Elaeis guineensis* is 23 plants (46.94%) of the percentage occurrence from both sampled sites (Fig. 1).

Herbs species distribution: A total of 73 herbs and grasses, belonging to 46 species and 19 families, were sampled from NASME golf course (Table 1). Also, a total of 70 herbs and grasses, belonging to 53 species and 21 families, were sampled from the New Bridge Golf course (Table 2).

Vernonia cinerea had the highest relative frequency (0.122), relative density (12.25), and relative abundance (0.061), followed by *Cyperus esculentus* (0.089, 8.89, 0.44) and *Kyllinga pumila* (0.087, 8.70, 0.04), respectively. Furthermore, *Vernonia cinerea* had the highest IVI (12.44; Fig. 2). The FVI was highest in Cyperaceae (24.27) and least in Cucurbitaceae (0.2), Solanaceae, and Sapindaceae (0.39; Fig. 3), respectively.

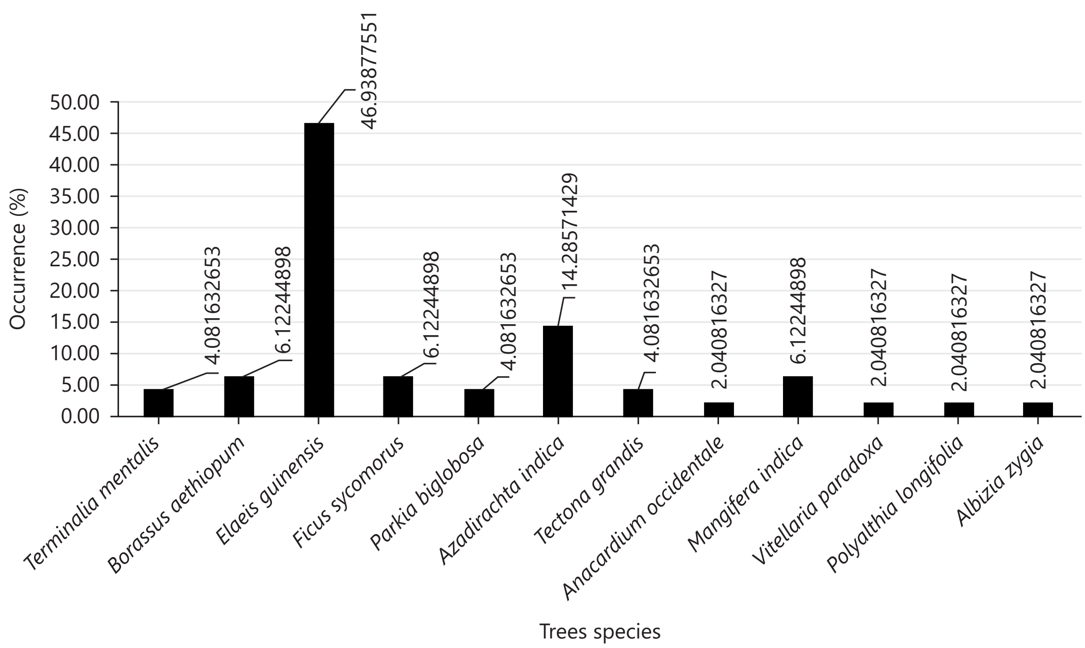

Fig. 1: Percentage occurrence of trees in sampled sites

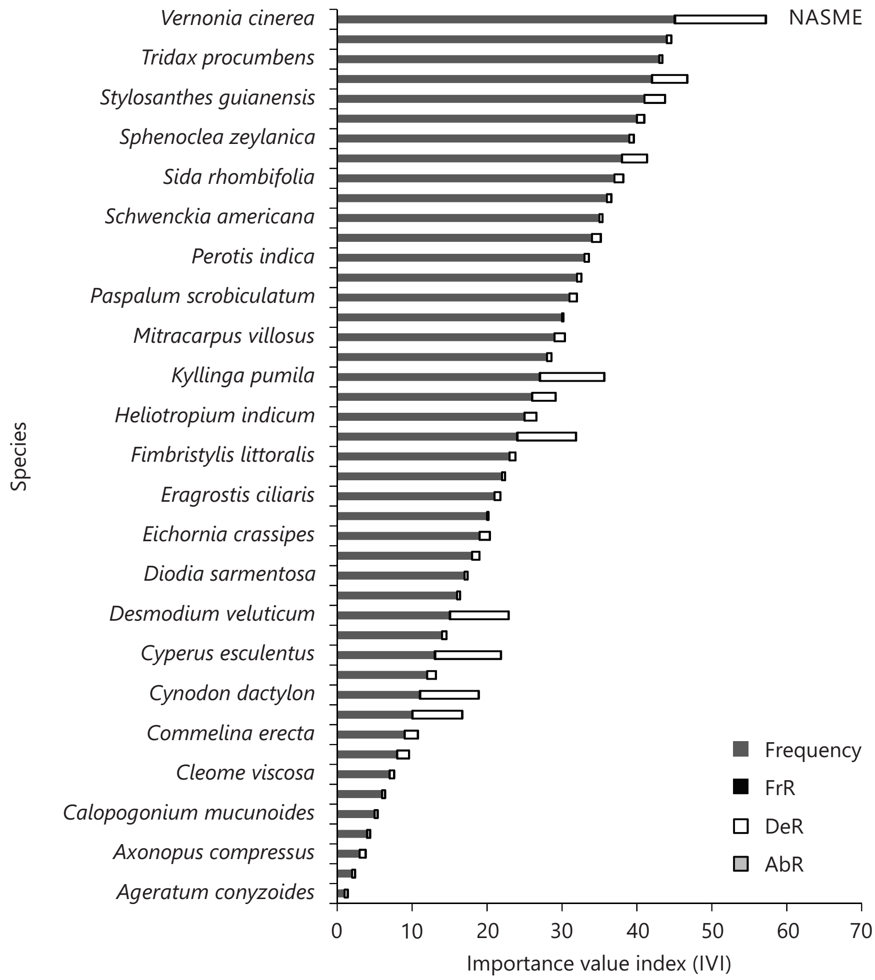

Fig. 2: Relative frequency, relative density and relative abundance of 46 herbs species in NASME golf course

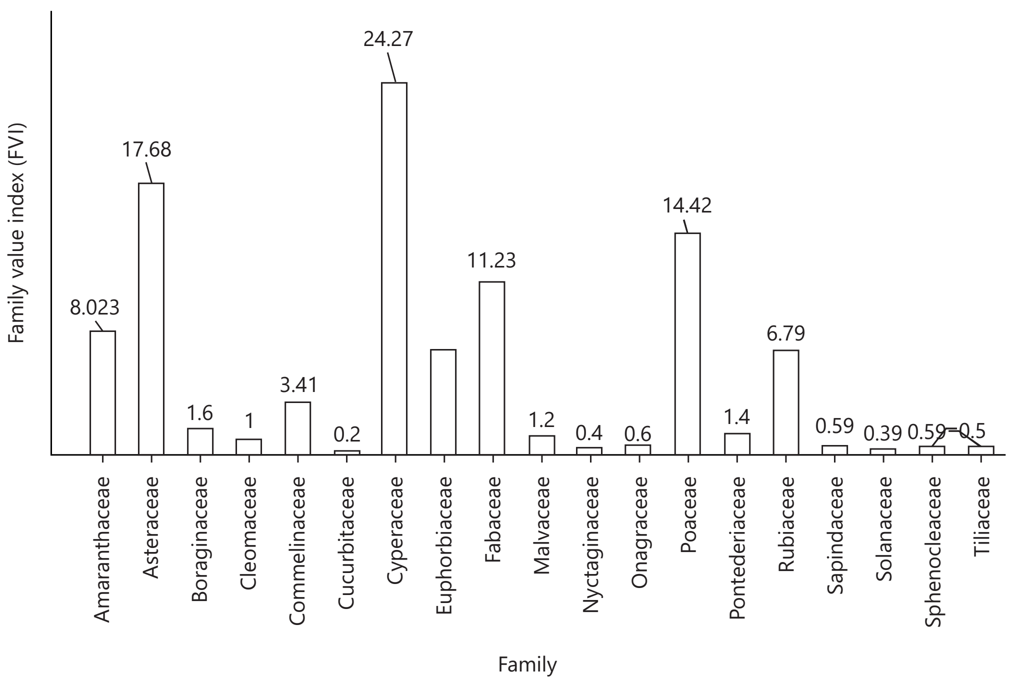

Fig. 3: Family value index (FVI) of herbs species collected in NASME golf course

Table 1: Herbs and grasses found in the NASME golf course

Sr/N	Scientific name	Family	Number of plot occurrence	Number of individuals per species
1	*Ageratum conyzoides*	Asteraceae	1	2
2	*Antropon gayanus*	Poaceae	1	2
3	*Axonopus compressus*	Poaceae	1	4
4	*Boerhavia erecta*	Nyctaginaceae	1	2
5	*Calopogonium mucunoides*	Fabaceae	1	2
6	*Cleome rudidospermae*	Cleomaceae	1	2
7	*Cleome viscosa*	Cleomaceae	1	3
8	*Commelina benghalensis*	Commelinaceae	1	8
9	*Commelina erecta*	Commelinaceae	1	9
10	*Croton hirtus*	Euphorbiaceae	2	34
11	*Cynodon dactylon*	Poaceae	2	40
12	*Cyperus eragrostis*	Cyperceae	1	6
13	*Cyperus esculentus*	Cyperaceae	1	45
14	*Dactylocterium aegyptium*	Poaceae	1	3
15	*Desmodium veluticum*	Fabaceae	2	40
16	*Digitaria longiflora*	Poaceae	1	2
17	*Diodia sermentosa*	Rubiaceae	1	2
18	*Echinochloa colona*	Poaceae	1	5
19	*Eichornia crassipes*	Pontederiaceae	1	7
20	*Eleusine indica*	Poaceae	1	1
21	*Eragrostis ciliaris*	Poaceae	1	4
22	*Eragrotis tremula*	Poaceae	1	2
23	*Fimbristlylis littoralis*	Cypraceae	1	4
24	*Gomphrena celosoides*	Amaranthaceae	2	40
25	*Heliotropium indicum*	Boraginaceae	1	8
26	*Kyllinga bulbosa*	Cypraceae	1	16
27	*Kyllinga pumila*	Cypraceae	2	44
28	*Ludwingia hyssopifolia*	Onagraceae	1	3
29	*Mitracarpus villosus*	Rubiaceae	1	7
30	*Momordica charantia*	Cucurbitaceae	1	1
31	*Oldenlandia corymbosa*	Rubiaceae	1	8
32	*Paspalum scrobiculatum*	Poaceae	1	5
33	*Paullina pinnata*	Sapindaceae	1	3
34	*Perotis indica*	Poaceae	1	3
35	*Pycreus lanceolatus*	Cypraceae	1	6
36	*Schwenckia americana*	Solanaceae	1	2
37	*Setaria barbata*	Poaceae	1	3
38	*Sida rhombifolia*	Malvaceae	1	6
39	*Spermacoce ocymoides*	Rubiaceae	1	17
40	*Sphenoclea zeylanica*	Sphenocleaceae	1	3
41	*Sporobolus pyramidalis*	Poaceae	1	5
42	*Syllosanthes guianensis*	Fabaceae	1	14
43	*Synedrella nodiflora*	Asteraceae	2	24
44	*Tridax procumbens*	Asteraceae	1	2
45	*Triumfeta cordifolia*	Tiliaceae	1	3
46	*Vernonia cinerea*	Asteraceae	1	62

Mitracarpus villoscus had the highest relative frequency (0.127), relative density (12.72), and relative abundance (0.06), followed by *Cyperus esculentus* (0.10, 10.37, 0.05), respectively. *Mitracarpus villoscus* had the highest IVI (12.91; Fig. 4) while Poaceae had the highest FVI (26.22; Fig. 5). The most abundant species include: *Mitracarpus villoscus*, *Cyperus esculentus*, and *Leersia hexandra*, respectively.

Height and DBH classes

Distribution of trees: Height class 11-15 m had the highest frequency, representing 42.90% (Table 3). The DBH class (cm) 0-50 had the highest frequency, followed by class 51-100, with class 101-150 being the least (Table 4).

Table 2: Herbs and grasses found in the New Bridge golf course

Sr/N	Scientific name	Family	Number of plot occurrences	Number of individuals per species
1	*Ageratum conyzoides*	Asteraceae	1	2
2	*Alternanthera sessilis*	Amaranthaceae	1	5
3	*Andropogon virginacus*	Poaceae	1	13
4	*Biophytum petersianum*	Euphorbiaceae	1	5
5	*Brachiaria lata*	Poaceae	1	2
6	*Calopognium mucunoides*	Fabaceae	1	1
7	*Celosia leptostachya*	Amaranthaceae	1	2
8	*Cleome vicosa*	Cleomaceae	2	3
9	*Conyzia sumatrensis*	Asterceae	1	13
10	*Croton hirtus*	Euphorbiaceae	1	3
11	*Cynodon dactylon*	Poaceae	1	27
12	*Cyperus esculentus*	Cyperaceae	2	53
13	*Cyperus iria*	Cyperaceae	1	17
14	*Desmodium scorpiurus*	Papilionoideae	1	3
15	*Digitaria longiflora*	Poaceae	1	7
16	*Echinochloa pyramidalis*	Poaceae	1	14
17	*Eclipta alba*	Asteraceae	1	5
18	*Eichorania crassipes*	Pontederiaceae	1	3
19	*Eragrostis atrovirens*	Poaceae	1	3
20	*Euphorbia heterophylla*	Euphorbiaceae	1	2
21	*Euphorbia hirta*	Euphorbiaceae	1	5
22	*Euphorbia hyssopifolia*	Euphorbiaceae	1	2
23	*Fimbristylis littoralis*	Cyperaceae	1	2
24	*Gomphena celosoides*	Amaranthaceae	1	6
25	*Hyptis lanceolata*	Lamiaceae	1	2
26	*Ipomoea aquatica*	Convolvulaceae	1	1
27	*Kyllinga pumila*	Cypraceae	1	19
28	*Leersia hexandra*	Poaceae	1	32
29	*Ludwingia abyssinica*	Onagraceae	2	4
30	*Ludwingia hyssopifolia*	Onagraceae	1	2
31	*Mariscus longibracteatus*	cyperaceae	2	12
32	*Melochia corchorifolia*	Sterculiaceae	1	1
33	*Mitracarpus villoscus*	Rubiaceae	1	65
34	*Nelsonia canenscens*	Acanthaceae	2	11
35	*Panicum maximum*	Poaceae	1	2
36	*Paspalum scrobiculatum*	Poaceae	1	13
37	*Pentodon pentandrus*	Rubiaceae	1	27
38	*Phyllantus amarus*	Euphorbiaceae	1	14
39	*Physalis angulata*	Solanaceae	1	1
40	*Polygonum lanigerum*	Polygonaceae	1	3
41	*Portulaca oleraceae*	Portulaceae	1	7
42	*Rottboellia cochinchinensis*	Poaceae	1	1
43	*Schwenkia americana*	Solanaceae	1	4
44	*Scorparia dulcis*	Scrophulariceae	2	21
45	*Setalia pumila*	Poaceae	1	6
46	*Sorghum arundinaceum*	Poaceae	1	8
47	*Spermacoce ocymoides*	Rubiaceae	1	17
48	*Sphenoclea zeylanica*	Sphenocleaceae	1	2
49	*Spigelia anthelma*	Loganiceae	2	16
50	*Sporobolus pyramidalis*	Poaceae	1	4
51	*Tephrosia bracteolate*	Papilionoideae	1	1
52	*Tridax procumben*	Asteraceae	2	6
53	*Vernonia cinerea*	Asteraceae	2	11

Diversity index (Shannon), evenness, and species richness: The Shannon-Weiner index of diversity was used to get the diversity index, and the results show that the diversity index of NASME is higher (2.15) than the diversity index of New Bridge (1.14). Also, in the species richness, NASME had the highest (10.00), than New Bridge (6.00), which proves that NASME has the highest measure of the number of different types of species. While in the species evenness, NASME also had the highest (0.64), meaning NASME has the highest measure of relative abundance of each species (Fig. 6).

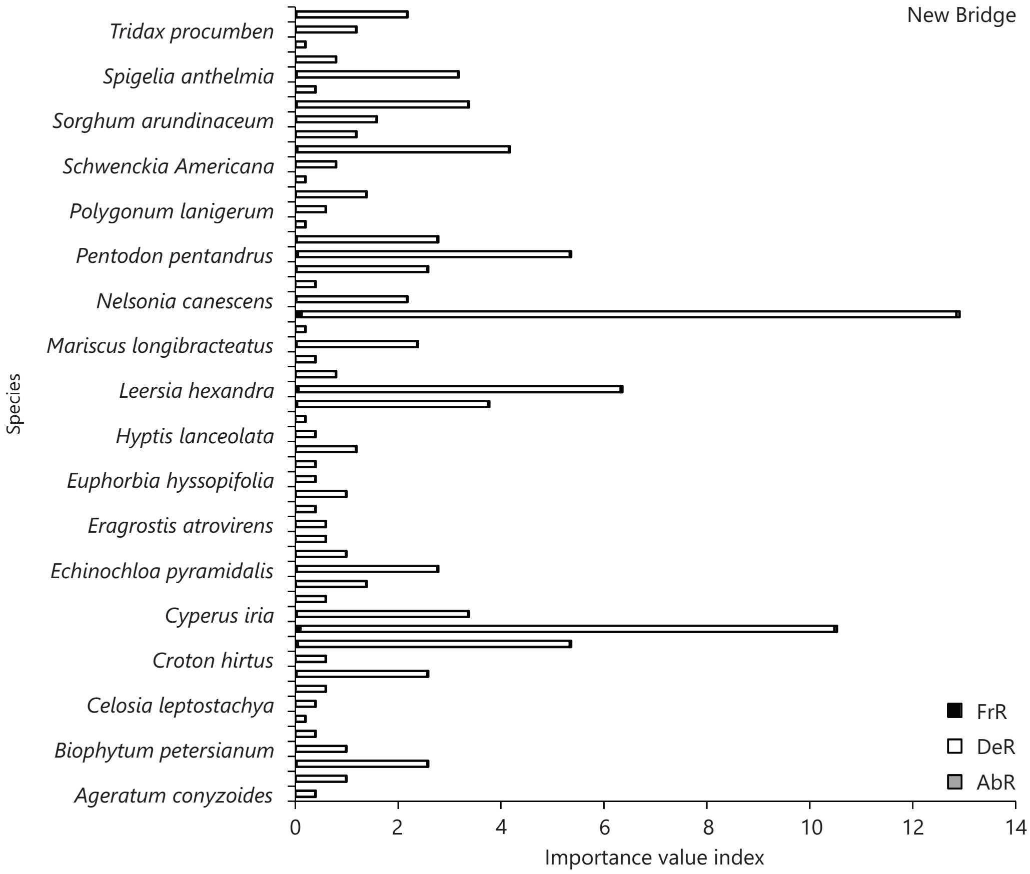

Fig. 4: Relative frequency, density, and abundance of herbs in New Bridge golf course

Table 3: Height class distribution of species

Height class	Frequency (number)	Percentage (%)
0-5	4	8.20
6-10	20	40.80
11-15	21	42.90
16-20	4	8.20

Table 4: DBH class distribution of species

DBH class (cm)	Frequency (number)	Percentage (%)
0-50	31	63
51-100	16	33
101-150	2	4

Species frequency, CD, BA, R. F, R. De, R. Do, and IVI in trees: Table 5 and 6 shows species DBH (cm), DBH^2, tree height (m), canopy diameter, basal area, frequency, percentage of occurrence, relative frequency (RF), relative density (RDe), relative dominance (RDo), and importance value index (IVI) in NASME and New Bridge, respectively (Fig. 7a-b) shows the IVI of species in NASME and New Bridge, respectively.

In the NASME Golf course, *Parkia biglobosa* had the highest DBH (1.03) and the DBH^2 (1.07), and had the highest tree height (17.55), with the highest canopy diameter (20.18) and highest basal area (0.84), and also the highest in relative dominance (0.25). While *Elaeis* guineensis had the highest frequency (5), representing 23.81% of the percentage occurrence, and the highest IVI (24.10) and highest CVI (23.86).

Azadirachta indica had the lowest DBH (0.25) and DBH^2 (0.06), and had the lowest tree height (5.50). Furthermore, *Azadirachta indica* had the lowest basal area (0.05), and also the lowest relative

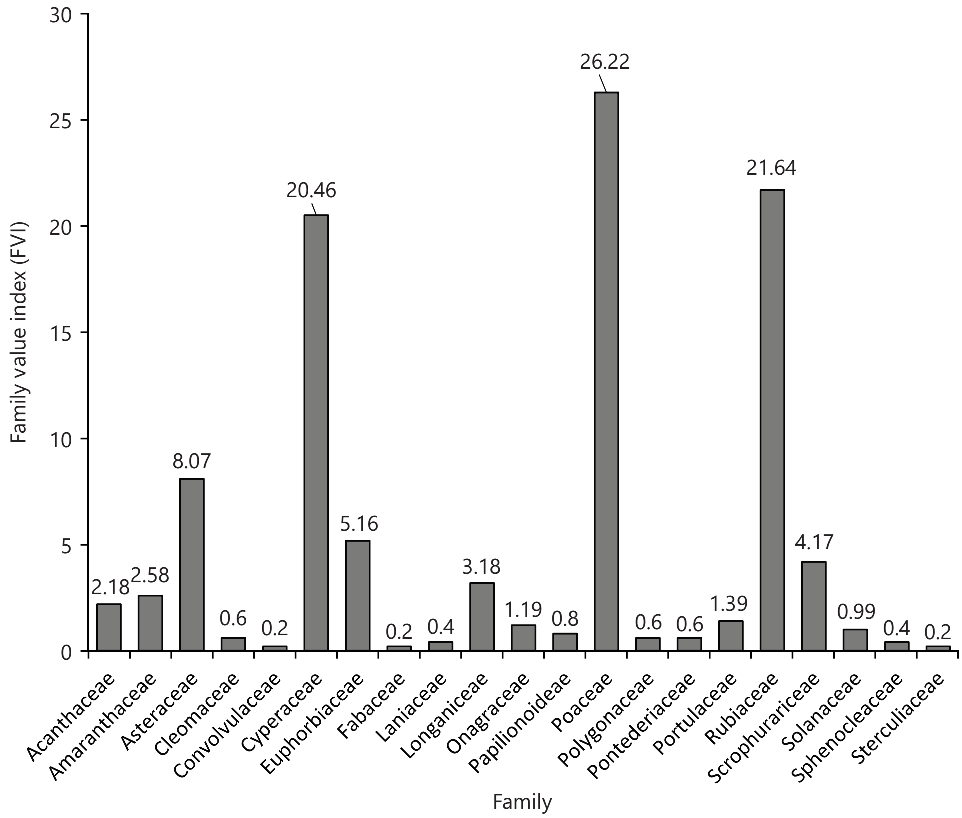

Fig. 5: Family value index (FVI) of 21 herb families collected in the New Bridge golf course

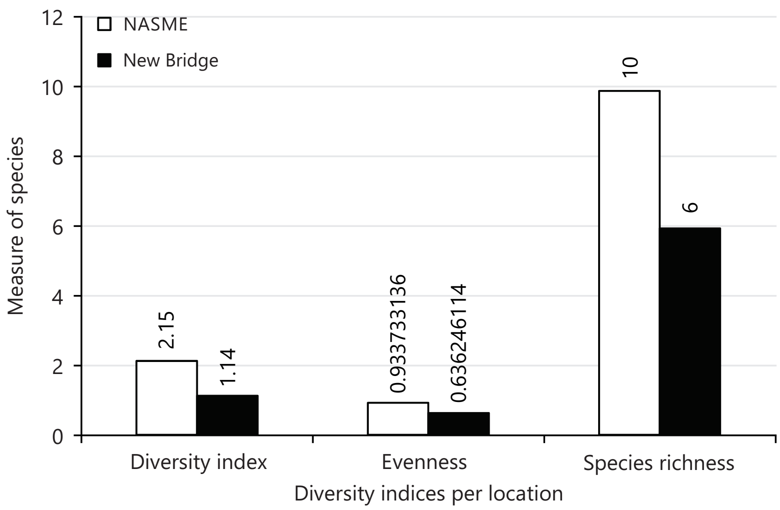

Fig. 6: Diversity index (Shannon) evenness and species richness

dominance (0.01). *Anacardium occidentalis*, *Bitellaria paradoxa*, *Mangifera indica*, and *Tectona grandis* all had the lowest frequency (1), representing 4.76% of the percentage occurrence, relative frequency (0.05), and relative density (4.76), respectively (Table 5).

In the New Bridge golf course, *Elaeis guinensis* had the highest DBH (m) and DBH^2 (0.4007 and 0.161), respectively. It had the highest tree height (11.38). Furthermore, *Elaeis guineensis* had the highest frequency (18), representing 64.29% percentage occurrence and the highest IVI and CVI (65.06, 64.42), respectively. While *Albizia zygia*, *Polyanthia longifolia* and *Tectona grandis* had the lowest frequency (1), representing 3.57% of the percentage occurrence with relative frequency (0.04) and relative density (3.57), respectively (Table 6).

Table 5: Species frequency, DBH, TH, CD, BA, percentage occurrence, RF, RDe, RDo, IVI, and CVI of trees in NASME Golf course

Sr/N	Tree	DBH (m)	DBH^2	Tree height (m)	Canopy diameter	Basal area	Frequency	Percentage occurrence	Rel. freq	Rel. den.	Rel. dom.	CVI	IVI
1	*Anacardium occidentalis*	0.63	0.39	8.50	9.75	0.31	1	4.76	0.05	4.76	0.09	4.85	4.90
2	*Azadirachta indica*	0.25	0.06	5.50	5.95	0.05	2	9.52	0.10	9.52	0.01	9.53	9.63
3	*Bitellaria paradoxa*	0.47	0.22	10.50	8.50	0.17	1	4.76	0.05	4.76	0.05	4.81	4.86
4	*Borassus aethiopum*	0.60	0.36	12.13	9.88	0.28	3	14.29	0.14	14.29	0.08	14.37	14.51
5	*Elaeis guinensis*	0.46	0.21	11.28	5.28	0.16	5	23.81	0.24	23.81	0.05	23.86	24.10
6	*Ficus sycomorus*	0.92	0.84	12.03	13.47	0.66	3	14.29	0.14	14.29	0.20	14.49	14.63
7	*Mangifera indica*	0.77	0.59	10.10	10.75	0.47	1	4.76	0.05	4.76	0.14	4.9	4.95
8	*Parkia biglobosa*	1.03	1.07	17.55	20.18	0.84	2	9.52	0.10	9.52	0.25	9.77	9.87
9	*Tectona grandis*	0.42	0.18	11.10	8.75	0.14	1	4.76	0.05	4.76	0.04	4.8	4.85
10	*Terminalia mentalis*	0.54	0.29	15.00	17.50	0.23	2	9.52	0.10	9.52	0.07	9.59	9.69

Table 6: Species frequency, DBH, TH, CD, BA, percentage occurrence, RF, RDe, RDo, IVI, and CVI of trees in New bridge Golf course

Sr/N	Tree	DBH (m)	DBH^2	Tree height (m)	Canopy diameter	Basal area	Frequency	Percentage occurrence	Rel. freq	Rel. Den.	Rel. Dom.	CVI	IVI
1	*Albizia zygia*	0.463	0.214	10.50	6.05	0.17	1	3.57	0.04	3.57	0.18	3.75	3.79
2	*Azadirachta indica*	0.346	0.12	8.76	8.30	0.09	5	17.86	0.18	17.86	0.10	17.96	18.14
3	*Elaeis guineensis*	0.4007	0.161	11.38	8.21	0.13	18	64.29	0.64	64.29	0.13	64.42	65.06
4	*Mangifera indica*	0.798	0.637	11.00	9.68	0.50	2	7.14	0.07	7.14	0.53	7.67	7.74
5	*Polyanthia longifolia*	0.22	0.048	8.00	6.60	0.04	1	3.57	0.04	3.57	0.04	3.61	3.65
6	*Tectona grandis*	0.15	0.023	5.90	4.60	0.02	1	3.57	0.04	3.57	0.02	3.59	3.63

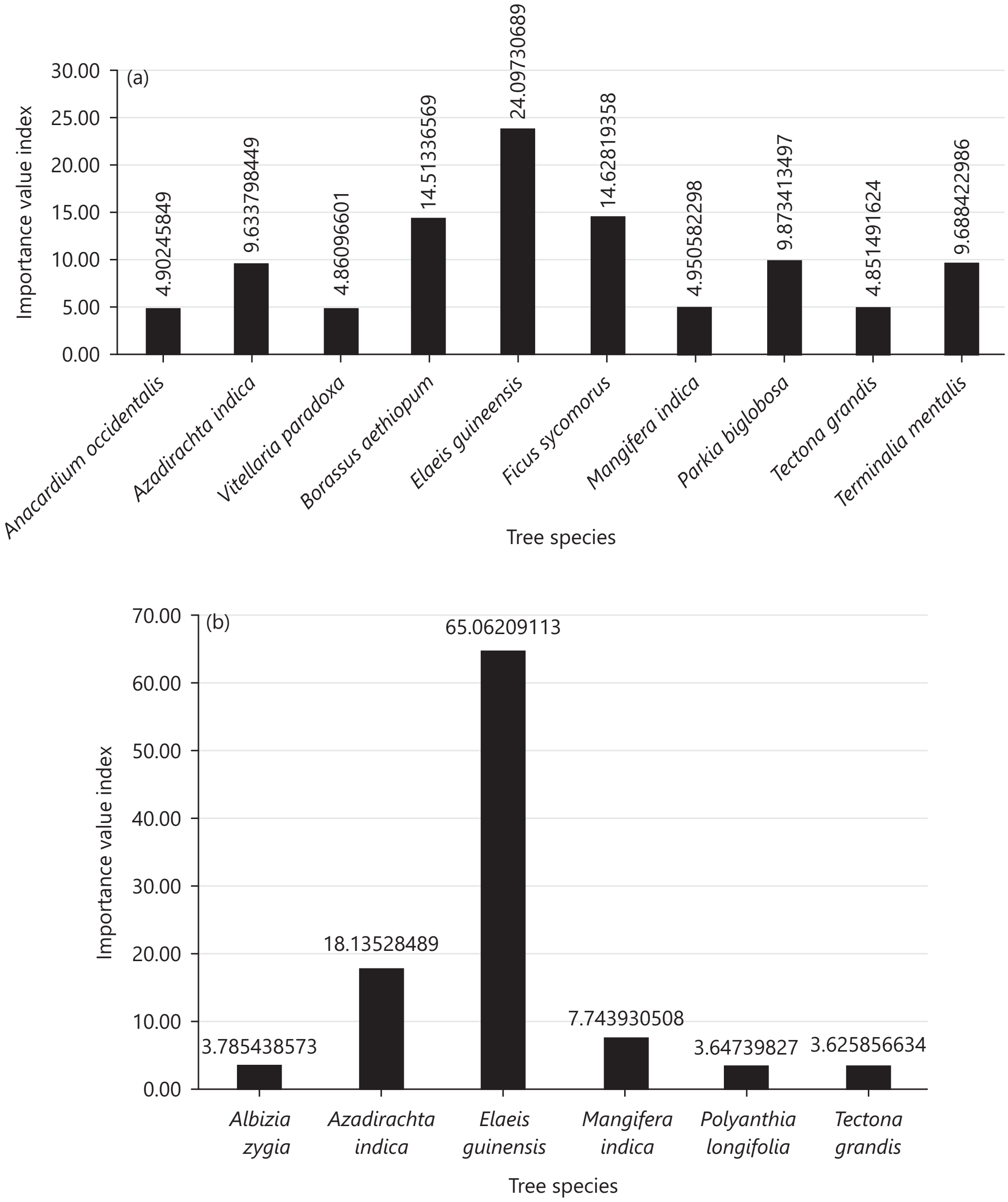

Fig. 7(a-b): Showing the IVI of tree species in the (a) NASME golf course and (b) New Bridge golf course

Plant biomass and total sequestered carbon of trees

Above and below ground biomass estimation: The result shows that *Parkia biglobosa* had the highest above-ground biomass (5348.40), dry above-ground biomass (3476.46), and *Polyanthia longifolia* and *Tectona grandis* had the lowest above-ground biomass (71.74).

Additionally, *Parkia biglobosa* had the highest below-ground biomass (1069.68), while *Polyanthia longifolia* and *Tectona grandis* had the lowest below-ground biomass (22.07), dry above-ground biomass (14.35) in both sampled sites (Table 7).

Furthermore, by location, *Parkia biglobosa* still had the highest above-ground biomass (5348.40), dry above-ground biomass (3476.46), and *Azadirachta indica* had the lowest above-ground biomass (97.0) in the NASME golf course. *Mangifera indica* had the highest above-ground biomass (1996.66), dry above-ground biomass (1297.83), and *Tectona grandis* had the lowest above-ground biomass (37.84) in the New Bridge golf course (Table 8).

Table 7: Biomass, total sequestered carbon and sequestered CO_2 equivalent of trees species in NASME and New Bridge golf course

S/N	Tree	DBH (cm)	TH (m)	AGB	BGB (kg) (20% of AGB)	Total biomass (DAGB+DBGB)	SCO_2E (kg) sequestered	SCO_2E (kg) (Tones/Tree)
1	*Albizia zygia*	46.30	10.50	641.59	128.32	500.44	918.31	0.92
2	*Anacardium occidentalis*	62.50	8.50	946.42	189.28	738.21	1354.61	1.35
3	*Azadirachta indica*	31.83	7.83	226.06	45.21	176.33	323.56	0.32
4	*Bitellaria paradoxa*	46.50	10.50	647.14	129.43	504.77	926.26	0.93
5	*Borassus aethiopum*	59.70	12.13	1232.64	246.53	961.46	1764.27	1.76
6	*Elaeis guinensis*	41.29	11.36	551.91	110.38	430.49	789.95	0.79
7	*Ficus sycomorus*	91.60	12.03	2877.95	575.59	2244.80	4119.20	4.12
8	*Mangifera indica*	78.87	10.70	1897.04	379.41	1479.69	2715.23	2.72
9	*Parkia biglobosa*	103.40	17.55	5348.40	1069.68	4171.75	7655.17	7.66
10	*Polyanthia longifolia*	22.00	8.00	110.37	22.07	86.09	157.97	0.16
11	*Tectona grandis*	22.00	8.00	110.37	22.07	86.09	157.97	0.16
12	*Terminalia mentalis*	54.00	15.00	1246.76	249.35	972.48	1784.49	1.78

Table 8: Biomass by location, total sequestered carbon and sequestered CO_2 equivalent of trees species in NASME and New Bridge golf course

Location	Tree	DBH (cm)	DBH^2	TH	AGB	DAGB (kg) (65% of AGB	BGB (kg) (20% of AGB)	DBGB (kg) (65% of BGB)	Total biomass (DAGB+DBGB)	TSC/Tree (50% TB)
NASME	*Anacardium occidentalis*	62.50	3906.25	8.50	946.42	615.17	189.2844	123.03	738.21	369.10
NASME	*Azadirachta indica*	24.90	620.01	5.50	97.20	63.18	19.44004	12.64	75.82	37.91
NASME	*Bitellaria paradoxa*	46.50	2162.25	10.50	647.14	420.64	129.4288	84.13	504.77	252.39
NASME	*Borassus aethiopum*	59.70	3564.09	12.13	1232.64	801.21	246.5271	160.24	961.46	480.73
NASME	*Elaeis guinensis*	45.70	2088.49	11.28	671.50	436.48	134.3004	87.30	523.77	261.89
NASME	*Ficus sycomorus*	91.60	8390.56	12.03	2877.95	1870.67	575.5893	374.13	2244.80	1122.40
NASME	*Mangifera indica*	77.00	5929	10.10	1706.90	1109.49	341.3804	221.90	1331.38	665.69
NASME	*Parkia biglobosa*	103.40	10691.56	17.55	5348.40	3476.46	1069.68	695.29	4171.75	2085.88
NASME	*Tectona grandis*	42.00	1764	11.10	558.12	362.78	111.6239	72.56	435.33	217.67
NASME	*Terminalia mentalis*	54.00	2916	15.00	1246.76	810.40	249.353	162.08	972.48	486.24
New Bridge	*Albizia zygia*	46.30	2143.69	10.50	641.59	417.03	128.3179	83.41	500.44	250.22
New Bridge	*Azadirachta indica*	34.60	1197.16	8.76	298.92	194.30	59.78498	38.86	233.16	116.58
New Bridge	*Elaeis guinensis*	40.07	1605.338	11.38	520.63	338.41	104.1261	67.68	406.09	203.05
New Bridge	*Mangifera indica*	79.80	6368.04	11.00	1996.66	1297.83	399.3321	259.57	1557.40	778.70
New Bridge	*Polyanthia longifolia*	22.00	484	8.00	110.37	71.74	22.0735	14.35	86.09	43.04
New Bridge	*Tectona grandis*	15.00	225	5.90	37.84	24.60	7.567812	4.92	29.51	14.76

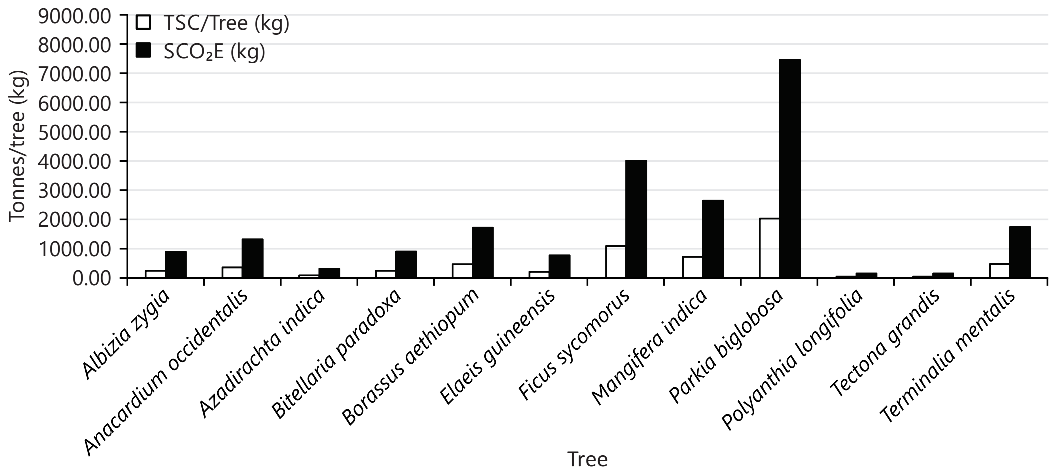

Fig. 8: Total sequestered carbon and sequestered carbon equivalent estimate

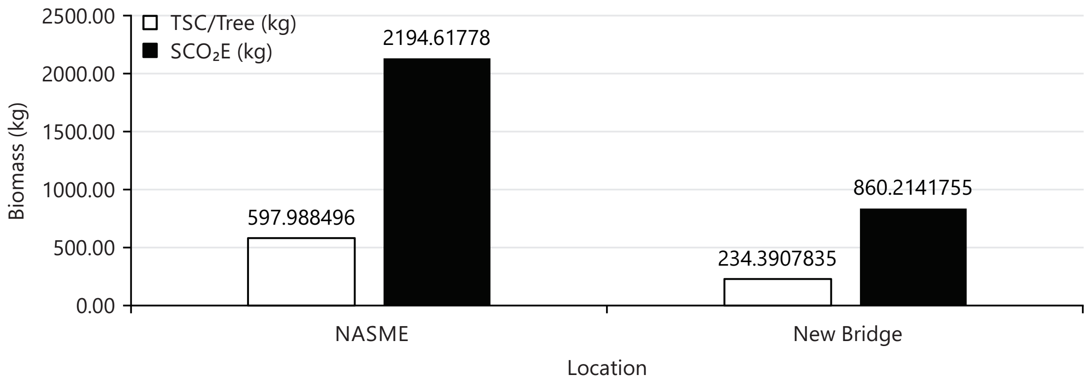

Fig. 9: Biomass by location of the total sequestered carbon and sequestered CO_2 equivalent of trees species in NASME and New Bridge golf course

Also, *Parkia biglobosa* had the highest below-ground biomass (1069.68), dry below-ground biomass (695.29), and *Azadirachta indica* had the lowest below-ground biomass (19.44004), dry below-ground biomass (12.64) in the NASME golf course. *Mangifera indica* had the highest below-ground biomass (399.3321), dry below-ground biomass (259.57), and *Tectona grandis* had the lowest below-ground biomass (7.567812), dry below-ground biomass (4.92) in the New Bridge golf course (Table 8).

Total plant biomass estimation: *Parkia biglobosa* had the highest total biomass (4171.75) while *Polyanthia longifolia* and *Tectona grandis* had the lowest (286.17). In both sampled sites (Table 7).

In the NASME golf course, *Parkia biglobosa* had the highest total biomass (4171.75), while in the New Bridge golf course, *Mangifera indica* had the highest total biomass (1557.40). *Azadirachta indica* had the lowest total biomass (75.82) in the NASME golf course, and *Tectona grandis* had the lowest total biomass (29.51) in the New Bridge golf course (Table 8).

The TSC/tree (kg) in NASME (597.99) is higher than the TSC/tree (kg) in New Bridge (234.39). The SCO_2E (kg) in NASME (2194.62) is higher than the New Bridge (860.21) (Fig. 9).

Sequestered carbon and CO_2 equivalent estimation: Carbon storage varied with species (Table 7). *Parkia biglobosa* had the highest total sequestered carbon (2085.88), followed by *Ficus sycomorus* (1122.40). The least total sequestered carbon was in *Polyanthia longifolia* (43.04), followed by *Azadirachta*

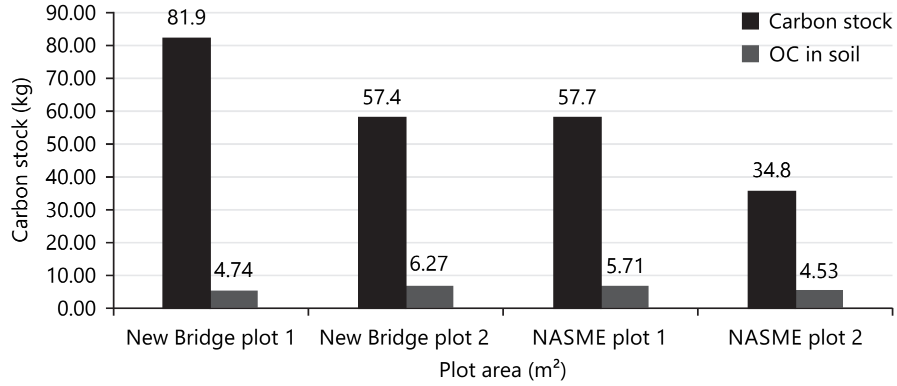

Fig. 10: Herbaceous carbon stock and soil organic carbon in New Bridge and NASME golf course

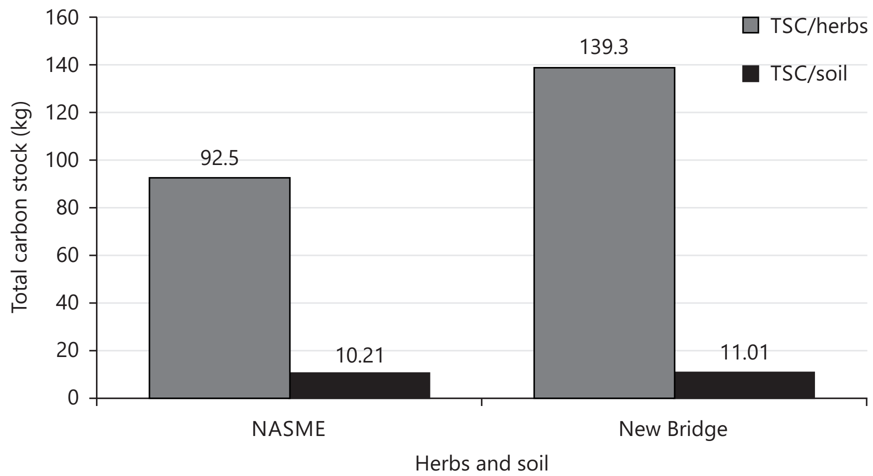

Fig. 11: Total carbon stock of herbs and soil in NASME and New Bridge golf course

indica (88.16). furthermore, the sequestered carbon equivalent (SCO_2E) was highest in *Parkia biglobosa* (7.66), followed by *Ficus sycomorus* (4.12), while *Polyanthia longifolia* and *Tectona grandis* had the least (0.16), followed by *Azadirachta indica* (0.32) (Table 5). Also, Fig. 8 shows how *Parkia biglobosa* had the highest SCO_2E (kg) (7655.17) and TSC/Tree (kg) (2085.88).

Total soil organic carbon stock and herbaceous carbon stock: In NASME, plot 1 had the highest soil organic carbon (5.71), then plot 2 (4.53; Fig. 10), while in New Bridge, plot 2 had the highest soil organic carbon (6.27; Fig. 10). Furthermore, in NASME, plot 1 had the highest herbaceous carbon stock (57.70), also in the new bridge plot 1 had the highest herbaceous carbon stock (81.90; Fig. 10). New Bridge had the highest soil organic carbon (11.01), then NASME (10.24), while in herbaceous carbon stock, New Bridge also had the highest (139.3) than NASME (92.5; Fig. 11).

Total sequestered carbon of trees, herbs, and soil: The NASME had the highest total sequestered carbon (700.7) than the total number of sequestered carbons in the new bridge (384.7) (Fig. 12).

DISCUSSION

The diversity of species studied in two selected golf courses in Makurdi demonstrated the tolerance potential of trees and herbs to withstand anthropogenic influence (disturbance, displacement of habitat, and pollution). There are factors associated with the abundance of some species in both sampled sites. The presence or absence of some species in the golf course are influenced by several factors. This may be due to disturbances from abiotic sources such as climate and pollution (chemical contaminants), other

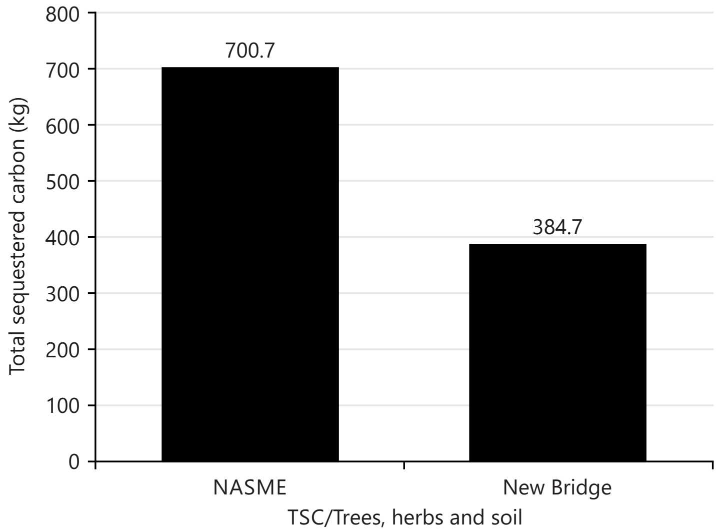

Fig. 12: Total sequestered carbon of NASME and New Bridge

factors include deforestation and introduction of exotic plants (such as grasses) and artificial vegetation to the site. Reported data in this work shows that *Parkia biglobosa* was the most distributed tree, a very important economic tree in Benue State. This aligns with the work by Howell *et al.*[31], who reported that species frequency and dominance values are indicative of its economic importance.

Sustainable management of golf courses, such as reduction in chemical inputs, creating native habitat areas, and efficient use of water resources, can lead to the rehabilitation of degraded soils and enhance carbon stock in plants. This work confirms previous work by Balogh and Walker[32], and Brown *et al.*[33] that golf courses are potential biodiversity havens when managed effectively. Golf courses' historical provides habitat for many species and a variety of phyto-remediating species, which occupy the area since they can absorb carbon, especially when natural habitats have been lost to development or urbanization.

Reports from investigations by Dobbs and Potter[34] have suggested that an estimated 42% success in carbon storage could be possible only through reduction in deforestation activities, while 3% from forest management strategies, and the remaining 27% from afforestation measures. In contrast, poor forest management combined with increased soil degradation can impact the quantity of carbon in reservoirs and consequently reduce the sequestration potential of plants thus results These findings attribute the level of carbon sequestered by plants in study location to the management practices engaged by golf course owners[35].

To mitigate the impact of climate change and reduce carbon storage, the golf landscape should therefore be sustainably managed through water conservation. This can be achieved by the introduction of smart irrigation methods (precision irrigation), selecting drought-resistant native species, and water cycling. Other strategies to mitigate climate change impact on golf courses include adoption of pest and waste management strategies, utilizing renewable sources of energy, introducing native plants into to landscape, workshops and training, as well as community engagements (Local Government and State Government).

The NASME golf course had the highest total carbon stock (700.7 kg) compared to the New Bridge golf course. One approach to maintaining and increasing carbon stock is through reforestation and afforestation projects (Colding, 2009). These projects involve planting native trees in areas that have been cleared of vegetation, which helps to sequester carbon and increase the carbon stock in the area. For example, a study conducted in Ethiopia demonstrated that reforestation efforts resulted in an increase in carbon stock by up to 44% in just in just five years[36].

Another approach that can be employed is through the utilization of sustainable land management practices, such as conservation agriculture, agroforestry, and sustainable forest management. These practices not only help to sequester carbon but also promote biodiversity, improve soil health, and increase resilience to climate change. A study conducted in Ethiopia reported an increase of 41 to 60% soil C stock and 83 to 87% above-ground C stock following the conversion of degraded grazing lands to enclosure.

CONCLUSION

Results from this investigation have revealed carbon sequestration potentials and carbon stock variance in two golf courses studied, which are crucial in the management and conservation of plant resources, especially in anthropogenically influenced ecosystems, to mitigate greenhouse effects. The analysis of total sequestered carbon and sequestered carbon dioxide equivalence from study sites showcased the impact of plant diversity and C4 grasses in the sequestration of carbon. The NASME golf course was the most diverse location and sequestered the highest quantity of carbon. This is attributed to the presence of *Poaceae* and *Cyperaceae* species. Also, the total carbon stock in herbs and organic carbon content in soil were recorded as highest in the New Bridge golf course, and can be attributed to the relative density and relative frequency of trees present. *Elaeis guineensis* and *Parkia biglobosa* were the most important trees in all the study sites. Based on this finding, the planting of trees for increased carbon sequestration and propagation of C4 grasses in lawns and gardens for the storage of carbon in both soils and tissues of plants is recommended. Therefore, regular measurement and monitoring of carbon stocks over time should be considered by conservationists and ecologists as it is an effective indicator of whether progress is made in the reduction of greenhouse gases in an ecosystem. Protecting the planet entails collaborative efforts by researchers and community stakeholders to accurately assess and manage carbon stock in the environment, as a means of mitigating the impacts of climate change, thereby creating a more sustainable future for all.

SIGNIFICANCE STATEMENT

This study demonstrates the variation in carbon stock at selected sampled sites based on the degree of disturbance. *Parkia biglobosa* recorded the highest SCO_2E (7655.17 kg), TSC/Tree (2085.88 kg), above-ground (5348.40 kg), and below-ground (3476.46 kg) biomass in both study locations. This investigation provides data on how much carbon is being stored in plants or soil and offers conservationists and ecologists informed strategies for monitoring carbon stocks in an ecosystem. Accurate assessments of carbon variance are an important instrument in the management and conservation of plant resources. The measurement and monitoring of carbon sequestration and carbon stocks over time is an effective indicator of whether progress is made in the reduction of greenhouse gases in an ecosystem.

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