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Assessment of Soil Properties in Proposed Botanical Garden Site at FCE Gidan Madi, Sokoto State

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Abstract

Soils of the Sudan Savanna are exposed to wide range of threats from human interference, weather fluctuations, precipitation deficit and are characterized by poor vegetation cover. The soils at Gidan Madi in Sokoto State, Nigeria are predominantly sandy (> 87% sand), slightly acidic (pH 6.13) and generally low in available phosphorus (0.99 mgkg-1), organic carbon (0.16%), organic matter (0.29%) and nitrogen (0.04 mg/g). The vegetation in the region hardly survives the longer dry seasons and the soil is seasonally exposed. The proposed garden site was deliberately stratified into dense woody, dense herbaceous, sparse woody, sparse herbaceous, more woody than herbaceous and more herbaceous than woody plots. The ANOVA experiment comprised of the six (6) plots replicated four times in a randomized complete block design (RCBD) with four blocks. Soil samples (0-20 cm depth) were collected and analyzed. The results show that dense woody and herbaceous plots had more silt content (20.52%) than the plots with sparse vegetation (9.25%). Clay increases (2.50%) & sand decreases (87.85%) in dense vegetation. Additionally, low bulk density (1.69gcm^3) & moisture content (1.25%), higher particle density (2.24 & 2.25 g/cm^3) were found in woody and herbaceous vegetation respectively. Soil pH was slightly acidic (5.90), slightly basic (6.13), and moderately basic (6.47) in soils under sparse vegetation cover, dense herbaceous cover and dense woody cover respectively. Organic carbon (0.29%) and organic matter (0.55%) were higher in herbaceous vegetation while nitrogen was higher (0.05gkg^{-1}) in the woody than in the herbaceous forms (0.04gkg^{-1}) and with higher P values in the dense cover (0.88 to 0.93gkg^{-1}) than in the sparse cover (0.56 to 0.76 mg/kg). Higher exchangeable bases: Ca^{2+} (0.62 cmolkg^{-1}), Mg^{2+} (0.71 cmolkg^{-1}) and K^{+} (1.09 cmolkg^{-1})

were obtained in the woody forms while higher Na^+ (0.82 to 0.85 $cmolkg^{-1}$) were recorded in the herbaceous forms. The CEC values are higher in mixed (woody & herbaceous) vegetation (3.45 and 3.55 $cmolkg^{-1}$). The soils at Gidan Madi thus demonstrate a significant potential to sustainably house the proposed botanical garden in the college premises.

Keywords: Botanical Garden, Soil Properties, Gidan Madi, Proposed Site, Woody Vegetation, Herbaceous Vegetation.

Introduction

Soils of the Semi arid Sudan Savanna Grassland are generally known to have low nutrient status and evapo-transpiration well in excess of annual precipitation (Ejaro and Lawal, 2010). The soils are predominantly sandy, having coarse texture, low moisture holding capacity and dry out quickly, making them highly susceptible to erosion by wind and water (Noma and Yakubu, 2012). The traditional agricultural practices predominant in the Savanna, initially encouraged long fallow periods to restore and maintain soil fertility which is majorly impracticable in the prevailing context due to rapid increase in human population and high rate of urbanization (Maniyunda and Malgwi, 2011). The reduction in size of farm holding per family or individual, increase the intensity of tillage practices on the farm lands aggravating soil erosion and nutrients depletion. Consequently, there is general decline in soil fertility and crop yield, leading to introduction of new improved cultivars, which are relatively expensive in addition to increased utilization of chemical fertilizers, with attendant negative effects on many life forms in the soil environment (FAO, 1999).

The fragile ecosystem in the Sudan Savanna region characteristic of Gidan Madi area, Sokoto State, exhibits fast degradation due to human pressure. These include trampling by humans and grazing animals, addition of contaminated organic manure and synthetic inorganic compounds by farmers such as fertilizers, herbicides, fungicides and insecticides among others (Yahaya et al., 2018). Loss of natural vegetation due soil cultivation and crop production processes, leading to desertification, soil erosion and declining soil productivity. The end result may include loss of plant genetic resource, depletion of natural vegetation and the inhabitant plant species (IUCN, 2020) Due to low ground water table in the relatively arid savanna area, the climate is characterized by short periods of rainfall. Consequently, the naturally growing tree species often struggle to survive during the long periods of dry season. As a result, only a relatively few drought resistant species can make it to the next rainy season. Consequently, species loss in the area becomes a yearly occurrence resulting in continuous loss of plant biodiversity (Osawaru et al., 2010).

Though the tropical region is endowed with diverse and abundant plant species, yet about 93% of plant species preserved in botanical gardens come from the temperate region.

Consequently, 76% of species estimated to have disappeared from extant collections are of tropical origin (Alabi *et al*., 2023). Botanical Gardens are established to conserve plant species *insitu* and *exsitu*. These are found distributed globally throughout at least 3,765 botanical institutions established worldwide in 180 different countries and are estimated to have preserved over 41% of known vulnerable species, and at least 30% of the diversity of all plant species. Biological systems can heal cities and its inhabitants through bioremediation, living architecture, and innovative water management with emphasis on an overview of urban toxicology, environmental issues, environmental justice, phytoremediation, bio-filtering, use of plant species and tree, grass, plant selection for pollution reduction (Alabi et al., 2023).

The study attempts to determine a suitable location for the establishment of a sustainable botanical garden for the college, which will be located within the college main campus at Gidan Madi Sokoto State for better accessibility, maximum utility and proper maintenance. The college garden area should be wide enough to accommodate all its components including provisions for its future expansion in the areas of teaching and research, conservation of plant biodiversity, aesthetic and recreation (Girmay, 2023). Particular concern of the study was to determine the suitability of soil at chosen site for growing of the different tree species targeted in the garden. Determination of physical and chemical properties of soil in the chosen site would guide informed decision making and ensure conservation of native and exotic plant biodiversity at habitat level, demonstration site for teaching of science, technology, and agriculture, as well as a unique ecotourism destination.

The college garden project intends to connect people to plants and the immediate environment by advancing botanical research through outdoor learning and recreational activities. The botanical garden project mandate includes inspiring environmental stewardship, advancing botanical research and providing a sustainable, aesthetically engaging outdoor learning and recreational environment.

Materials and Methods

The Study Area

The study area, Gidan Madi is located in Tangaza Local Government Area, Sokoto State, Nigeria. It is within Sudan Savanna/Sahel Savanna ecological region on latitudes 13º 17’ 44” N - 13º 17’ 52” N and longitudes 4º 58’ 09” E - 4º 58’ 28” E. in 2022, it was characterized by typical Savanna vegetation and extensive agricultural fields. The area fall within Sudan Savanna and comprises of open Tsetse fly-free grassland suitable for grain cultivation and animal husbandry. The vegetation in this region is adapted to harsh climate with a late-starting and early-ending rainy season (Ukoh *et al*., 2025). Average annual temperature is above 25º C annually. The warmest months of Gidan Madi are April, May and June with daily mean temperature range of 32º to 34º C. The area experiences more precipitation in July, August and September with an average monthly precipitation of 116 mm (4.6 inches). The peaks of dry season in the area occur during the months of January, March and November and the

highest level of ultraviolet (UV) radiation in the area can reach values of 12 – 14 in the months of July, August and September (CAMS, 2023).

The soil of the area is sandy to sandy loam in texture. It is ferruginous and light to brown in color. It is friable and easily cultivated with poor water holding capacity. Like most other soils of the dry Sudan savanna, the soil in Gidan Madi is young, lacking horizon development and therefore classified as *entisol* (Noma and Yakubu, 2012). Geology of the area primarily consists of Cretaceous and Tertiary sediments. The topsoil is largely composed of sand, sandstones and lateric sandy clay (CAMS, 2023).

Mostly herbs with scattered trees and shrubs characterize the natural vegetation of Gidan Madi, Sokoto State. The area falls under Sudan Savanna agroecological zone, northwestern Nigeria (SERC, 2015). High variation in vegetation cover is typically found around farmlands and nomadic routes due to activities like shifting cultivation and grazing (Atiku et al., 2013). Being naturally adapted to local climate and soil conditions, the indigenous wild trees often survive environmental stress and flourish better than the exotic ones, which constitute important biological resources in the global agro-biodiversity context (Awodoyin *et al*., 2015).

Soil Sampling

One quadrate (2m x 2m) was established at six (6) different sampling points within each quadrate, four (4) soil samples were collected at depth of 0 – 20 cm (top soil profile), accordingly and transported to the laboratory for analyses. Sample collection was done using 37.64 cm^3 steel core samplers and wet weight of the soil was determined in the field with 0.1 g precision before being transferred to pre-weighed sampling bags (Kemper, 2025).

Soil Particle Size Analysis

Hydrometer method (Sheldrick and Wang, 1993) was used for analyses of the soil samples to determine particle size distribution (sand, silt, and clay) and individual particles size proportions.

Soil Density Analysis

Soil density (particle and bulk) were determined by Core method (Blake and Hartge 1986; Lal and Shukla, 2004).

Soil Porosity

Total porosity (Ep) was determined from the results of particle and bulk densities (Lal and Shukla, 2004), thus:

$$E_p = 100\% - \left\{ \frac{\text{bulk density}}{\text{paricle density}} \times 100 \right\}$$

Soil pH

Soil pH was measured using pH meter with glass electrode in 0.01M $CaCl_2$ (Miller and Donahue, 1992).

Moisture Content Analysis
Gravimetric technique of Klute (1986) was used to determine percentage moisture in the soil samples across individual treatments.

Soil Organic Matter
Modified Walkley Black method (Jaiswal, 2004) was used for determination of organic carbon and organic matter contents in the soil.

Total Kjeldahl Nitrogen
The total kjeldahl nitrogen (TKN) method (Jaiswal, 2004) was used. The Soil was digested with appropriate digestion catalyst followed by Kjeldahl distillation techniques and back titration against ammonium hydroxide.

Available Phosphorus
The soil extract was measured using calorimeter by Dickman and Bray's method (Jaiswal, 2004) for the determination of Available Phosphorus.

Exchangeable Bases
Ammonium acetate extraction technique (Jaiswal, 2004) was utilized. Exchangeable K and Na were determined using an EEL flame photometer whereas exchangeable Ca and Mg were determined by Complexometric titration with EDTA (Pereira *et al*., 2011).

Cation Exchange Capacity (CEC)
The method of Wang *et al.* (2004) was used for the analysis.

Data Analysis
One way analysis of variance (ANOVA) using statistical analysis system (SAS) computer software package was utilized for analysis of the data generated from the experiments. Results were expressed as means ± standard error of mean (SEM) of each treatment. Significant differences between the treatment means were determined by Duncan's New Multiple Range (DNMR) Test and P values < 0.05 was regarded as significant (Sokal and Rohlf, 1995).

Experimental Treatments and Replications
The ANOVA model structure comprised of six treatments (plots): A – F replicated four times each in a completely randomized block design (CRBD) within four blocks and a total of 24 treatments as shown in figure 1.
A = Dense woody
B = Dense herbaceous
C = Sparse woody
D = Sparse herbaceous

E = 2:1 woody & herbaceous respectively
F = 1:2 woody & herbaceous respectively

[1] B	[4] E
[2] D	[5] C
[3] F	[6] **A**

[7] E	[10] D
[8] A	[11] C
[9] B	[12] F

[13] C	[16] E
[14] F	[17] A
[15] D	[18] B

[19] B	[22] F
[20] C	[23] D
[21] E	[24] A

BLOCK I BLOCK II BLOCK III BLOCK IV

Fig. 1: Experimental design (CRBD) pattern for the soil analyses at the proposed garden site

Results

Soil Physical Properties

Sand proportions were significantly high under D and F with 88.97% and 89.07% respectively and significantly low (86.43%). Four out of the six treatments had higher clay content. They include A (2.75%), B (3.08%), C (2.83%) and E (2.67%) with no significant ($P< 0.05$) difference between them. Low clay content was obtained in D (1.72) and E (1.97%). The soil textural class remains sandy texture. Moisture content is relatively higher in B (2.25%) and F (2.33%); moderate for D and E, each having 1.83% and low in A (1.25%) and C (1.33%).
Bulk density is significantly low in A (1.95 g/cm^3) which differ significantly ($P< 0.05$) from the C (1.82 g/cm^3), D (1.85 g/cm^3) and E (1.79 g/cm^3). Similarly, A and B, with 1.69 g/cm^3 does not differ significantly from either F with 1.72 g/cm^3. The treatment, F had the highest mean particle density of 2.25 g/cm^3 and shows no significant ($P< 0.05$) different from E (2.24 g/cm^3); D (2.16 g/cm^3); C (2.10 g/cm^3) and B (2.22 g/cm^3). The A with low particle density of 1.89 g/cm^3 is significantly ($P< 0.05$) different from F. The A having porosity of 20.33% is significantly ($P< 0.05$) different from the other five treatments: B (16.38%), C (17.60%), D (15.65%), E (17.43%) and F (15.08%).

Table 1: Physical Properties of Soil in Proposed Site for Botanical Garden at FCE Gidan Madi

Treatments	Parameter							
	Sand %	Silt (%)	Clay (%)	Moisture (%)	Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Textural class
A	86.43ab	20.52a	2.75a	1.25c	1.95a	1.89b	20.33a	Sand
B	88.23ab	9.50a	3.08a	2.25a	1.69d	2.22ab	16.38b	Sand
C	87.30ab	10.14a	2.83a	1.33c	1.82b	2.10ab	17.60b	Sand
D	88.97a	8.18a	1.72b	1.83b	1.85b	2.16ab	15.65b	Sand
E	87.10ab	8.88a	2.67a	1.83b	1.79bc	2.24ab	17.43b	Sand
F	89.07a	8.37a	1.97b	2.33a	1.72cd	2.25a	15.08b	Sand
SE±	0.52	0.39	0.16	0.12	0.03	0.05	0.72	
Significance	*	ns	*	*	*	*	*	

Soil Chemical Properties

The soil pH value of C (6.47) differs significantly ($P < 0.05$) from A (6.22), C (6.07), D (6.27) and E (5.90) but do not differ significantly ($P < 0.05$) from F (6.33). The F and D had the highest relative organic carbon contents of 0.29% and 0.27% respectively. They differ significantly (0.05) from the other four treatments. The treatment E with 0.24% differs significantly ($P < 0.05$) from the other five treatments. Both A and B had a relatively low organic carbon content of 0.09% each, they differ significantly ($P < 0.05$) from the other four treatments. The F and D had the highest organic matter contents of 0.55% and 0.47% respectively with no significant difference ($P < 0.05$) between the two. However, B (0.28%) came next to and differ significantly ($P < 0.05$) from the first two treatments. The E (0.23%) and C (0.22%) having moderate organic matter do not differ significantly ($P < 0.05$). The A had the least organic matter content of 0.17%.

Higher relatively N was obtained in A (0.06 gkg^{-1}), B (0.05 gkg^{-1}), C (0.05 gkg^{-1}) and E (0.05 gkg^{-1}) with lower values obtained in D and F (0.04 gkg^{-1} and 0.03 gkg^{-1} respectively. Available P is relatively high in A (0.93 $mgkg^{-1}$), B (0.92 $mgkg^{-1}$), E (0.93 $mgkg^{-1}$) and F (0.88 $mgkg^{-1}$), significantly low in D (0.76 $mgkg^{-1}$) and C (0.56 $mgkg^{-1}$). Calcium ($cmolKg^{-1}$) is highest in A (0.62), moderate in E (0.46), F (0.41) and C (0.35), low in B (0.26) and least in D (0.20). Magnesium is high in C (0.71 $cmolkg^{-1}$) and low in both A (0.28 $cmolkg^{-1}$); B (0.23 $cmolkg^{-1}$); D (0.17 $cmolkg^{-1}$), E (0.27 $cmolkg^{-1}$) and F (0.19 $cmolkg^{-1}$). Potassium content is relatively higher in F (1.09 $cmolkg^{-1}$), which is not significantly ($P < 0.05$) different from A (1.00 $cmolkg^{-1}$) and E (0.94 $cmolkg^{-1}$). But C having moderate potassium content of 0.90 $cmolkg^{-1}$ is significantly ($P < 0.05$) different from F. The B and D have low potassium contents of 0.63$cmolkg^{-1}$ and 0.64$cmolkg^{-1}$ respectively. High sodium content (0.85 $cmolkg^{-1}$) was obtained in D followed by B (0.82 $cmolkg^{-1}$) and F (0.77 $cmolkg^{-1}$) with no significant ($P < 0.05$) difference between the three. There are moderate sodium contents in E (0.73 $cmolkg^{-1}$) and C (0.71 $cmolkg^{-1}$). They are not significantly ($P < 0.05$) different from the C and E. High CEC values were obtained in F (3.55 cmolkg-1) and E (3.45 $cmolkg^{-1}$). Both C and A had moderate CEC values of 2.86 $cmolkg^{-1}$ and 2.84 $cmolkg^{-1}$ respectively while B and C had low CEC values of 2.76 $cmolkg^{-1}$ and 2.53 $cmolkg^{-1}$ respectively.

Table 2: Chemical properties of soil in proposed site for Botanical Garden at FCEGidan Madi

Site	Parameter									
	pH	Mean Org C %	Org M %	TN g/kg^{-1}	Av P mg/kg	Ca	Mg	K	Na	CEC
						$cmolKg^{-1}$				
A	6.22bc	0.09d	0.17d	0.06a	0.93a	0.62a	0.28b	1.00a	0.65c	2.84bc
B	6.07cd	0.15c	0.28b	0.05a	0.92a	0.26cd	0.23b	0.63c	0.82ab	2.76c
C	6.47a	0.09d	0.22c	0.05a	0.56c	0.35bc	0.71a	0.90b	0.71bc	2.86bc
D	6.27b	0.27a	0.47a	0.04b	0.76b	0.20d	0.17b	0.64c	0.85a	2.53c
E	5.90d	0.24b	0.23bc	0.05a	0.93a	0.46b	0.27b	0.94ab	0.73bc	3.45ab

Site	Parameter									
F	6.3	0.29a	0.55a	0.03b	0.88a	0.41b	0.19b	1.09a	0.77ab	3.55a
SE±	3ab	0.020	0.040	0.003	0.02	0.04	0.052	0.043	0.033	0.182
Sig.	0.110 *	*	*	*	*	*	*	*	*	*

Discussion

The reduced sand coupled with increased clay and silt in A, C and E indicated greater presence of vegetation cover on the soil, which has been reported to effectively control soil erosion by preserving the rich top soil (Aliero and Anka 2001). Significant clay content in soil was reported under high vegetation cover (Ogunwole *et al*., 2010). Like most soils of the derived savanna agro-ecological zone of Nigeria, the soil of the proposed garden is predominantly sandy, slightly acidic and well drained (Adegbite *et al*., 2019). The dense herbaceous plots appear to be instrumental in organic matter accumulation from plant litter. These have shown varied affect on the rate of water absorption, influence the soil porosity level and infiltration rate. Similar result in Ogunwole *et al.* (2010) showed a decrease in soil moisture content due to high population density of plants. In another related study, Adesoji *et al.* (2011) reported no significant influence on soil bulk density and volumetric moisture content in a sparsely grown wheat crop, but observed a reduction in the bulk density due to incorporation of Lablab and soy bean as well as increase in volumetric moisture content due to incorporation of mucuna and lablab.

The pH level varied significantly ($P < 0.05$) across the treatments from slightly acidic (pH 5.90) in E to near neutral (pH 6.47) in C, with dense vegetation cover generally having lower pH values than sparse cover. This result agrees with that of Abdullahi *et al.* (2011), who reported a slight decrease in soil pH at the vicinity of dense herbaceous plant cover. Furthermore, Cuesta *et al.* (2011) reported that ground cover cultivation under citrus tree canopy and inter-row spaces greatly influenced enzyme activity and hence the pH level in soil. The higher N content of A, B, E and C over D and F are attributable to shading effect of the vegetation cover, which reduce volatilization of soil nitrogen often caused by intense solar radiation in the area. The total N values in this study are slightly higher than those reported in Malami *et al.* (2011). The lower values of N & F (0.03 mg/kg) and D (0.04 mg/kg) are attributable to the scanty vegetation cover, which exposes the soil to volatilization, strong winds and run-off. Malami *et al.* (2011) attributed the low levels of nitrogen to the low levels of phosphorus, which was found to increase the fixation of nitrogen in soil.

The mean P value of 0.83 mg/kg^{-1} obtained in this study indicates low available P in the soil based on Esu (1991) soil nutrient ratings. The high relative P values obtained in A, E and B (0.92 to 0.93 mg/kg^{-1}) are attributed to high population density of plants and the low available P in C, D and F (0.56 to 0.88 mg/kg-1) are due to low population density of plants in the treatments. Exchangeable cations showed different values according to treatment. The higher values of K (1.00, 1.09 and 0.94 $cmolkg^{-1}$) in A, F and E respectively and the low K content (0.63$cmolkg^{-1}$ to 0.90$cmolkg^{-1}$) in herbaceous vegetation cover are related to litter

accumulation in the soil. This result also agrees with Malami *et al.* (2011). Values of K obtained in present study are very low due to poor litter accumulation on the soil.

The mean Na^{2+} of 0.76cmolkg^{-1} is generally lower than that of the control (0.84cmolkg^{-1}). By comparison with the standard in Landon (1991) that soils with exchangeable sodium level greater than 1.0 cmolkg^{-1} are considered potentially sodic, the soil of the study area is therefore non-sodic. Calcium values are generally higher under thick plant cover, probably due to higher contribution of litter to the soil. Higher Mg^{2+} content had been found in soil with dense herbaceous cover, which indicates possible influence of herbaceous plants cover on Mg^{2+} content of soils. Landon (1991) indicated that Mg levels of 0.5cmolkg^{-1} in soil are considered deficient in tropical environment. Therefore, except for C with, 0.7cmolkg^{-1}, the soils of other portions are deficient in Mg^{2+}. The results of the soil chemical properties in this study gave clear indication of low fertility status of the soil in relation to the standard Benchmark values in the Sudan Savanna Agroclimatic region of Nigeria as indicated

Cation exchange capacity values of soil in the proposed garden area (2.53 to 3.55 with a mean of 3.00 cmolkg-1) are generally low according to Esu (1991) rating of <6 low, 6-12 medium and >12 high. The low CEC is attributable to low clay and organic matter contents of soil in the study area, which according to Sharu *et al.* (2003) are too low to have any significant positive influence on the CEC. The relatively low available P coupled with low soil exchangeable bases principally, K^{+}, Ca^{2+} and Mg^{2+} as well as significantly varied CEC values across the treatments reported in the soils of Sokoto-Rima flood plains (Ukoh *et al*., 2025) are in many respects similar to those of the proposed botanical garden site at Gidan Madi, Sokoto State. The general fertility status of soils in the proposed botanical garden site is consequently low relative to the regional ratings of Esu (1991) and Landon (1991) and therefore may be improved through the selection and establishment of excellent plant cover and proper soil management practices.

Conclusion

The fields within FCE Gigan Madi Sokoto State have shown distinct Sudan savanna and Sahel savanna characteristic features. The stratified distinct portions have been surveyed for their potential to support growth of trees for botanical garden in the area. The dense herbaceous area typical of Sudan Savanna has shown improved soil pH, total nitrogen content and exchangeable bases chiefly, Ca, Mg. On the other hand, the Sahel Savanna area with sparse vegetation indicated low soil pH, increased organic matter, moisture contents and particle density. The areas showing dense vegetation cover would ultimately exhibit greater support for conservation of soil fertility due to their high biomass accumulation potential which when decomposed will release sufficient mineral nutrients for a sustainable college botanical garden project.

Recommendations

Based on the results of this study, some actionable recommendations are made as follows:

1. Conduct soil tests on the proposed garden site to determine amendments needed to replenish the nutrients requirements and address the inherent nutrient deficiency status of the soil. These should include analyses of soil pH, texture, fertility status, drainage capacity and compaction levels, which affect root growth and nutrients uptake of the soil.
2. Select and propagate tree species adapted to the persistent arid conditions of the region. Other desirable characteristics should include past growth rate, resistance to pests and diseases, production of few, easily decomposable & recycled litter, and should require less structural pruning to maintain safety and good appearance.
3. Ensure provision of efficient water sources for the year-round propagation, raising and maintenance of the tree species collections to enable uninterrupted and sustained operations in the botanical garden.

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