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Research Article

Study of Some Physicochemical Properties of Soil in the Tsanni Forest Region of Katsina State, Nigeria

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ABSTRACT

This study assessed the physical and chemical properties of soil in the Tsanni Forest, Katsina State, Nigeria. Five sampling sites (A, B, C, D, and E) were selected, with soil samples collected bi-weekly. Standard methods were used to evaluate organic matter, organic carbon, nitrogen, available phosphorus, potassium, particle size distribution, and soil color. Results indicated notable variations across sites. Site E had the highest nitrogen content (0.168%), while Site C had the lowest (0.105%). Site C also exhibited high organic carbon (1.296%) and organic matter (2.235%), whereas Site D had the lowest levels (0.438% and 0.756%, respectively). Site C recorded the highest available phosphorus (17.30 mg/kg), with Site D having the lowest (9.21 mg/kg). Potassium levels varied, with Site C having the highest (0.56 cmol/kg) and Site D the lowest (0.27 cmol/kg). These findings underscore the need for soil fertility maintenance strategies and careful monitoring of forest activities to prevent desert encroachment and maintain ecosystem health. Proactive measures and sustainable soil management practices are essential to preserve soil fertility and ensure long-term sustainability. Comparisons with other studies highlight the unique soil characteristics of the Tsanni Forest. Understanding these differences is crucial for informed decision-making, sustainable land management, and effective conservation strategies. Further research and monitoring are recommended to assess long-term changes in soil properties and their implications for vegetation dynamics in the region.

Keywords: Soil Properties, Tsanni Forest, Soil Fertility,

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INTRODUCTION

Soil, composed of weathered and eroded broken rock particles, undergoes chemical and environmental changes (Bridges, 1997; Hack, 2020). It comprises solid, gaseous, and aqueous states, incorporating mineral and organic constituents (Buol, Hole, & McCracken, 1989; SpRKS *et al.,* 2022). Crucial to biogeochemical cycles, soil bacteria and fungi facilitate the cycling of organic compounds (Molin & Molin, 1997; Basu *et al.,* 2021). Moisture levels in soil vary depending on soil type, climate, and humus content (Miles & Broner, 2011). The presence of water determines the viability of organisms in soil, as it facilitates nutrient transport and sustains cellular survival (Greg & Percy, 2005; Tecon and Or, 2017). Visually assessing soil moisture yields imprecise results. In contrast, determining soil moisture content involves drying a soil sample at 107°C for 24 hours and comparing the weight before and after drying (Fawole and Oso, 2001).

Soil microorganisms also profoundly impact above-ground ecosystems by contributing to plant nutrition, soil structure, texture, and fertility (George, Marchner, & Jakobsen, 1995; Evans *et al.,* 2017). The composition of plants and vegetation growing in the soil is crucial (Asadu *et al.,* 1997). The ability of soil to support plant growth relies on its physical and biological properties, which significantly influence crop production. Although many environmental ecologists have researched soil physicochemical parameters worldwide, limited information exists regarding the variations in these properties across different locations in the study area. This study aimed to address this gap by investigating and comparing the diverse physical and chemical properties of soil in the Tsanni Forest reserve of Katsina State. The objective is to enhance our understanding of soil analysis in Tsanni Forests, providing valuable insights for both its optimal utilization and conservation (Author *et al.,* 2023).

The Tsanni Forested Area in Katsina State, Nigeria, has been designated as a gazetted forest reserve since 1966. Additionally, the analysis focused on various elements, including total nitrogen, organic carbon, organic matter, potassium, and available phosphorus. The findings were compared among different sampling sites (A, B, C, D, and E) to assess the variations in soil properties.

MATERIALS AND METHODS

Study Area

The Tsanni Forested Area of Katsina State, Nigeria, lies on the 12°56'24" N latitude and 7°37'07" E longitude, it spans approximately 3.4 square miles and was officially designated as a gazetted forest reserve in 1966. Prior to its designation, it had served as a common grazing land. The soil in this forest is primarily characterized as light sandy soil, derived from sedimentary rocks. The soil in the western part of the forest, hasa higher clay content, resulting in a reddish-brown colour (Mortimore, 2005). The dominant plant species found in the forest include *Bauhinia reticulata, Combretum micranthum (Don), Guiera senegalensis (Gmel)., Anogeissus leiocarpa (DC.), Ziziphus jujube Mill., and Diospyros mespiliformis Hochst* (*Abdulaziz et al.,* 2015).

Sample Collection and Preparation

Soil samples were collected from five different sites, namely site A, B, C, D, and E. The sampling points were spaced at intervals of 100 meters. The soil samples were collected at a depth of 30 cm using a tabular sampling soil auger. For each depth and location, representative soil samples were obtained and recorded. This sampling was conducted monthly over a period of one year (Fernández-Ugalde *et al.,* 2020). These samples were then air-dried at room temperature for a period of two weeks, taking into consideration the initial moisture content. After drying, the samples were crushed to pass through a 2 mm mesh sieve. To determine the organic matter content, sub-samples of the soil from each location were taken and further ground to pass through a 100-mesh sieve. The remaining samples were subjected to analysis for both physical and chemical properties of the soil.

The collected soil samples were air-dried to remove any excess moisture. Subsequently, they were passed through a 2mm sieve mesh to obtain a homogeneous sample for analysis.

Sample Analyses

The soil samples collected for this study were subjected to various physicochemical analyses at the Umaru Musa Yaradua University Soil Laboratory, Department of Geography. Standard laboratory procedures were followed to ensure accurate and reliable results for the selected properties.

Organic Carbon Content Determination

The determination of Organic Carbon content was carried out using the Walkley-Black (1934) method. This method involves wet oxidation of the soil sample to release carbon, followed by titration to determine the organic carbon concentration.

Determination of Total Nitrogen

Total Nitrogen analysis was performed using the micro-Kjeldahl procedure. In this method, the nitrogen in the soil sample is converted to ammonia through digestion with sulfuric acid and potassium sulfate. The ammonia is then distilled and titrated to determine the nitrogen content.

Exchangeable Cations Determination

For the analysis of Exchangeable Cations, NH4OAc digestion was employed. This method involves extracting the cations from the soil sample using ammonium acetate solution. The extracted cations are then measured using appropriate analytical techniques (Nel *et al.,* 2023).

Determination of Phosphorous

Available Phosphorus content was determined using the Bray-1 (1945) method. This method utilizes an acidic extractant to extract the readily available phosphorus from the soil. The extracted phosphorus is then quantified using colorimetric or spectrophotometric techniques.

Particle Size DistributionDetermination

Particle Size Distribution was assessed using the hydrometer method proposed by Bouyoucos (1936). This method involves suspending the soil particles in water, allowing them to settle, and measuring the sedimentation rate to determine the particle size distribution.

Organic Matter Determination

Organic Matter content was determined following the Walkley-Black method, which involves wet oxidation of organic matter in the soil sample followed by titration to determine the organic matter content.

Determination of Potassium Content

The content of Available Potassium was determined using a flame photometer, with the analytical procedure based on the methods described by Chapman (1965) and Rowell (1994).

Soil Colour Determination

Soil Colour determination was performed by comparing the samples against the Munsell color chart, a standardized system for describing and classifying soil colours.

Table 1: Analytical Methods and Techniques Used for Soil Parameter Determination

SN	**Parameters**	**Method/Technique adopted**
1	Organic Matter	Walkley- black wet oxidation
2	Organic Carbon	Walkley- black
3	Total Nitrogen	Micro-Kjeldahl
4	Available Phosphorus	Colorimetry
5	Available Potassium	Flame photometry
6	Particle size Distribution	Hydrometer method as outlined by Juo
7	Determination of Soil Colour	Comparison using Munsell color chart

RESULTS AND DISCUSSIONS

The analysis of total nitrogen content in the soil samples revealed significant variations across the different sites studied. The results, as shown in Table 2, indicate notable differences in nitrogen content between the soil samples from each site. Specifically, Site C exhibited a low nitrogen content of 0.105%, while Site E displayed a higher nitrogen content of 0.168%, which falls within the low-medium range defined as 0.15% (Essiet, 1990). These findings are consistent with earlier reports by Mustapha et al. (2001) for soils in similar agroecological zones and Fadama locations in Nigeria, as noted by Singh (1991).

The observed low nitrogen content across the study sites can be attributed to the inherent nature and origin of the soils. The anaerobic conditions prevalent in these soils likely hinder nitrogen mineralization, causing nitrogen to remain in the ammonia stage. This, in turn, may result in nitrogen being lost as a gas to the atmosphere (Brady and Weil, 2008). Consequently, these conditions can significantly impact the availability of nitrogen in the soil, influencing the overall fertility and suitability for agricultural use.

Regarding organic carbon content, site D exhibited a low content of 0.438, while site C displayed a high content of 1.296 among the five analyzed samples (Table 2). According to Kodiya (1988), a soil with an organic carbon content of 0.00-0.75 is considered extremely low, 0.75-1.25 as medium low, 1.25-2.00 as very high, and 4.00-7.5 as extremely high. Based on these criteria, site A and D have extremely low organic carbon, site B and E fall within the medium-low range, and site C is classified as very high. The low organic carbon content in site D may be attributed to the low organic matter content in the soil which may lead to decreased soil fertility, reduced water retention capacity, and diminished microbial activity crucial for nutrient cycling and soil health. (Ramesh *et al.,* 2019).

The recorded organic matter (OM) values of 0.756 for site D, 2.235 for site C, and 1.960 for site E, falling within the low to medium range, highlight significant implications for the vegetation in the Tsanni forest region. These findings suggest varying levels of soil fertility and nutrient availability across the sites, which can directly impact plant growth and ecosystem dynamics.

Comparing these values with previous research, Fatumah, (2021) also observed similar organic matter values ranging from 0.75% to 2.85% across different land use types such as orchards, fallow lands, grazing lands, irrigated plots, and rain-fed plots. However, it's important to note that the values reported by Yakubu, (2012) for forests, fallow lands, and cocoa plantations in South-Western Nigeria were higher than those found in the Tsanni forest region.

This comparison underscores the unique soil characteristics of the Tsanni forest region and highlights potential differences in soil fertility and organic matter content compared to other regions in Nigeria. Understanding these differences is crucial for sustainable land management practices, conservation efforts, and the maintenance of ecosystem health in the Tsanni forest area. Further research and monitoring will be essential to assess any long-term changes in soil properties and their implications for vegetation dynamics in the region.

Potassium, a metallic element naturally found in various salts and clay minerals in soils (Strivastava, 2007), exhibited variations among the sites. Site C had a highest potassium content of 0.56, followed by site B with 0.48, site A; 0.39, site E 0.31 while site D having 0.27 as the one with the lowest potassium content. (Table 2). Generally, potassium is found to be low in forest soils. It is an essential nutrient element and the most abundant constituent in the soil (Lalitha and Dhakshinamoorthy, 2014).

In terms of available phosphorus (AVP), site D had values within the range of 9.21, while site C recorded the highest AVP content of 17.30, followed by site B with 13.79 (Table 2). The organic matter content of the soil affects the proportion of nitrogen and phosphorus, as the mineralization of organic matter significantly contributes to their concentrations (Adamu and Dawaki, 2008). The values obtained in this study indicate higher AVP concentrations compared to reported values for upland soils in the Savannah zone, which are generally considered very low (National Fertilizer Center, 1988).

Overall, the analysis of the soil's chemical properties highlights the significant variations in the studied elements across the different sites. Understanding these variations is crucial for optimizing soil fertility and enhancing agricultural productivity.

According to Essiet (2001), the fertility of any soil is determined by two components: clay and organic matter. However, in tropical soils, the clay fraction has undergone extensive weathering, resulting in minimal contributions to soil fertility. Its role is often negligible. The results of this study indicate that the soils examined are predominantly sandy, with sand content ranging from 84.8% to 88.8% (Table 3). The clay percentages vary from high to low (13.92% to 7.92%), while the silt percentages also range from high to low (5.28% to 1.28%) (Table 3). Comparatively, clay and silt content are low in the study area. This may be attributed to factors such as prolonged deforestation, desert encroachment, the movement of tropical continental air masses into the forest, or deposition from the neighbouring fringes of the Sahara Desert. These factors have had a noticeable impact on the forest, resulting in reduced clay and silt content.

The excavation of tree roots has been identified as a significant contributing factor to desert encroachment in the Tsanni Forest Region of Katsina State, Nigeria. Therefore, it is recommended that promoting sustainable soil management practices and raising awareness about the detrimental effects of such activities to mitigate further degradation of the soil and maintain ecosystem health. Drawing insights from field observations and research findings, this recommendation highlights the urgency of implementing proactive measures to preserve the integrity of the region's soil and combat desertification.

Table 2: The concentration of some chemical properties of Soils from five (5) Sampling sites of Tsanni Forest

SITES	N (%)	OC (%)	OM (%)	AVP (PPM)	K (Mc/100g)
A	0.126	0.678	1.169	11.28	0.39
B	0.154	1.037	1.788	13.79	0.48
C	0.105	1.296	2.235	17.30	0.56
D	0.112	0.438	0.756	9.21	0.27
E	0.168	1.137	1.960	11.89	0.31

Table 3: The concentration of some physical properties of Soils from five (5) Sampling sites of Tsanni forest

SITES	COLOUR	SAND (%)	CLAY	SILT (%)	TEXTURE
A	Reddish Brown	84.8	13.92%	1.28%	Loamy Sand
B	Reddish Brown	88.8%	9.92%	1.28%	Loamy Sand
C	Reddish Brown	88.8%	9.92%	1.28%	Loamy Sand
D	Light Brown	88.2%	7.92%	3.28%	Loamy Sand
E	Dark whitish	86.8%	7.92%	5.28%	Loamy sand

CONCLUSION

The chemical and physical properties of soil from different sites in the Tsanni forest show significant variability. These differences are crucial for understanding soil fertility and tailoring agricultural practices to enhance productivity. The findings highlight the importance of site-specific soil management strategies to optimize nutrient availability and improve crop yield in this region.

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