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COMPARATIVE ANALYSIS OF SOIL FERTILITY AND NUTRIENT DYNAMICS IN TWO SECONDARY FORESTS IN AWKA NORTH AND SOUTH LOCAL GOVERNMENT AREA, ANAMBRA STATE

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ABSTRACT: *This study examines the comparative analysis of soil fertility and nutrient dynamics in two secondary forests: Unizik Conservation Forest and Orebe Village Forest located in Awka North and South Local Government Areas of Anambra State, Nigeria. These forests are critical for biodiversity conservation and ecosystem restoration, particularly in the face of increasing deforestation and land-use changes. Through soil sampling and standard laboratory procedures, the research assesses soil properties to evaluate their potential for regeneration and long-term sustainability. Key soil parameters, including nitrogen, phosphorus, potassium, organic matter, and exchangeable acidity, were analyzed. Results reveal significant differences in nutrient availability and soil properties between the two forests. Amansea Forest exhibited higher nutrient levels and organic carbon, while Unizik Forest demonstrated better water-holding capacity and soil structure. These variations reflect differences in vegetation, soil management practices, and environmental conditions, highlighting the need for tailored conservation strategies to support forest regeneration and long-term sustainability. Future studies should focus on long-term monitoring of soil nutrient dynamics and the impact of climate change on soil fertility in secondary forests.*

KEYWORDS: Soil properties, soil nutrients, organic matter, forest, chemical analysis, minerals.

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INTRODUCTION

Soil fertility and nutrient dynamics play a crucial role in maintaining ecosystem productivity, influencing plant growth, species composition, and overall forest health. Secondary forests, which regenerate after disturbances such as logging and agricultural activities, often exhibit varying soil properties depending on factors such as land use history, soil type, and climatic conditions (Brady & Weil, 2008). Understanding soil fertility in these forests is essential for developing sustainable management strategies, particularly in tropical regions like Anambra State, Nigeria. This review examines soil fertility and nutrient dynamics in secondary forests, with a focus on key soil properties such as organic matter content, macronutrients (nitrogen, phosphorus and potassium), soil pH, and exchangeable acidity. It also explores the implications of these factors for forest ecosystem productivity and sustainable management in Awka North and South Local Government Areas.

Soil fertility in secondary forests is determined by a combination of physical, chemical, and biological properties that regulate nutrient availability and retention. Studies indicate that secondary forests often exhibit variable soil fertility due to differences in organic matter accumulation, microbial activity, and past land use practices (Wright, 2002; Lal, 2005). Organic matter is a critical component of soil fertility, influencing nutrient availability, water retention, and soil structure (Brady & Weil, 2008). Secondary forests in humid tropical regions tend to accumulate organic matter more slowly than primary forests, primarily due to the decomposition of litter and root biomass (Sanchez, 2019). Research suggests that secondary forests recovering from agricultural use may have lower organic carbon contents than undisturbed forests due to previous soil degradation (Lugo & Brown, 1993).

Nitrogen (N), phosphorus (P), and potassium (K) are key macronutrients essential for plant growth and ecosystem productivity. Studies have shown that nitrogen availability in secondary forests can be influenced by microbial activity, organic matter decomposition, and atmospheric deposition (Binkley & Fisher, 2012). Phosphorus availability is often limited in tropical soils due to strong fixation by iron and aluminum oxides, making it a critical factor in forest regeneration (Ganesh *et al.*, 2012). Potassium, though not as limiting as nitrogen and phosphorus, plays a vital role in plant metabolic processes and soil cation exchange capacity (Harper, 1977).

Soil pH influences nutrient availability and microbial activity, affecting species composition and productivity in secondary forests (Brady & Weil, 2008). Acidic soils, often characterized by high exchangeable aluminum (Al^{3+}) and hydrogen (H^{+}) concentrations, can limit nutrient uptake and reduce plant growth (Wright, 2002). In comparative studies, higher exchangeable acidity in certain forest soils has been linked to past land use and organic matter decomposition rates (Brady & Weil, 2008).

Several factors contribute to variations in soil fertility and nutrient dynamics in secondary forests, including climate, soil type, land use history, and vegetation composition. Tropical forests experience high rainfall, which can lead to nutrient leaching and soil acidification (Lal, 2005). Seasonal fluctuations in precipitation affect nutrient cycling and organic matter decomposition, influencing overall soil fertility (Binkley & Fisher, 2012). Previous land use practices, such as agriculture and logging, significantly impact soil properties in secondary forests (Sanchez, 2019). Studies have shown that land previously used for farming often exhibits lower organic matter and nutrient levels compared to undisturbed forests (Takim *et*

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al., 2013). Soil compaction from past land use can also reduce water infiltration and root penetration, further affecting forest regeneration (Brady & Weil, 2008). The dominant plant species in a forest influence soil fertility through litterfall and root exudates. Fast-growing pioneer species contribute to rapid biomass accumulation but may not provide long-term nutrient retention (Lugo & Brown, 1993). In contrast, mature secondary forests with diverse tree species often exhibit improved soil nutrient balance and organic matter content (Harper, 1977).

Understanding soil fertility and nutrient dynamics in secondary forests has important implications for forest conservation, ecosystem restoration, and sustainable management. Sustainable forest management practices should focus on maintaining soil organic matter, reducing nutrient depletion, and preventing soil erosion (Sanchez, 2019). Agroforestry systems and selective logging can help enhance soil fertility while supporting biodiversity conservation (Binkley & Fisher, 2012). Applying organic amendments, such as compost and biochar, can improve soil fertility in degraded secondary forests (Lal, 2005). Additionally, conservation practices, such as mulching and controlled burning, can enhance nutrient retention and promote forest recovery (Brady & Weil, 2008).

Regular soil monitoring is essential for assessing changes in soil fertility and implementing adaptive management strategies, to track soil nutrient dynamics and guide reforestation efforts (Ganesh *et al*., 2012). Hence, the aim of this study is to compare the soil fertility and nutrient dynamics in two secondary forests in Awka North and South Local Government Areas, Anambra State.

MATERIALS AND METHODS

Study Area

The study was carried out in Awka North and South Local Government Areas, Anambra State, Nigeria. It lies within the tropical rain and evergreen forest with a tropical climate that is humid all year round, although the humidity varies with the seasons. The rainy season spans from March to October and is bimodal with a two-week break of rainfall in August (August break). The mean annual rainfall in the southeast is 2000 m while the average annual temperature is between 25^0C and 28^0C with relative humidity of about 98% during the rainy season and between 50% and 60% during the dry season (ADP, 2010).

Two secondary forests were selected from different zones of the study area based on their high floristic composition:

1. Unizik Conservation Forest (Site 1)
2. Orebe Village Forest, Amansea (Site 2)

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Figure 1: Aerial Map Showing the Unizik Conservation Forest Awka South LGA
Source: (Iroka *et al.*, 2024).

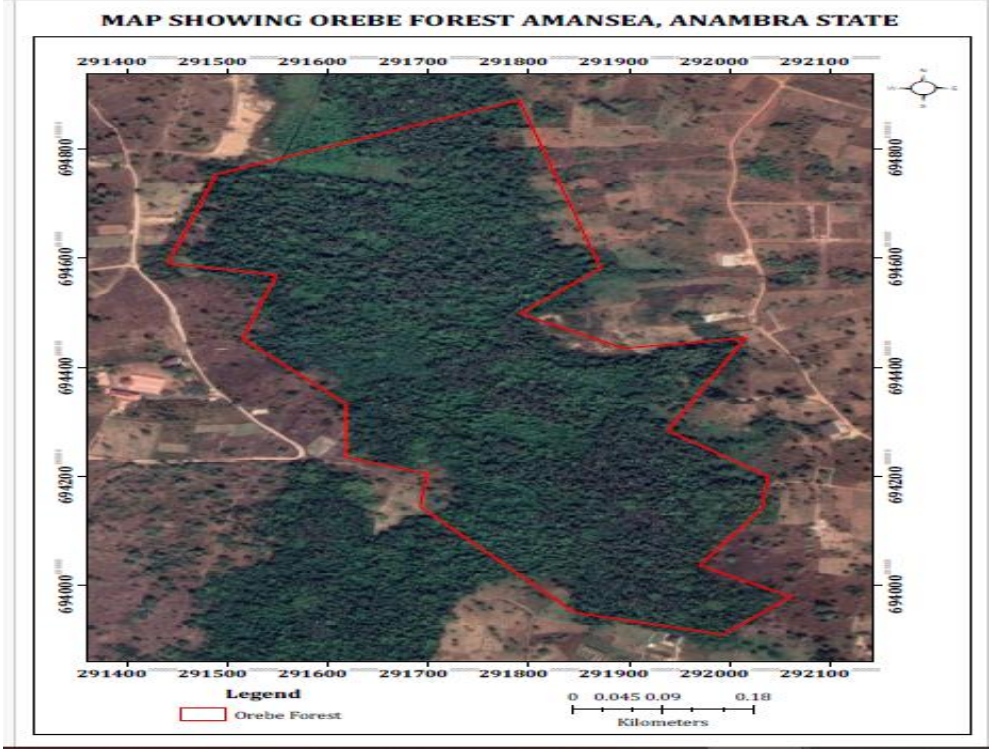

Figure 2: Aerial Map Showing the Orebe Forest, Amansea, Awka South LGA

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Soil Sampling Method

Each of the forest sites was divided into four parts. In each quarter, three randomly selected points were sampled using a soil auger with a diameter of 7.5 cm. Soil samples from different horizons (0–5 cm, 6–10 cm, and 11–15 cm) were collected at four points within each quarter of the plots. These samples were then mixed together to form a composite sample for each site. The composite sample for each soil layer was further divided into three equal parts, and one-third (1/3) of the sample was randomly selected for further soil analysis.

Analysis of Soil Physiochemical Properties

Air Drying of Soil Samples

Soil samples were collected and spread out on brown sheets of paper at room temperature for four weeks. Plant debris was removed with hand and one-third of the soil was sieved with a 2 mm sieve and used for soil physiochemical analysis.

Soil Textural and Chemical Analysis

Nitrogen Determination

The nitrogen content of the soil samples was determined using the microkjeldahl method of AOAC (1999). The samples were digested with concentrated sulphuric acid, using copper sulphate and sodium sulphate as catalysts to convert organic nitrogen to ammonium ions. Alkali was added and the liberated ammonia was distilled into an excess boric acid. The distillate was titrated with hydrochloric acid or sulphuric acid.

Procedure

Exactly 1 g of the sample was weighed and transferred into the Kjeldahl digestion flask followed by the addition of 3 g of a mixture of sodium sulphate and copper sulphate pentahydrate in the ratio 10:1 as catalyst. Four anti-bumping chips were added to prevent sticking of the mixture to the flask during digestion and also to enhance boiling. The Kjeldahl flask content was digested with 25 ml concentrated H_2SO_4. The flask was inclined and heated gently at first until frothing ceased, then heated strongly with shakings, at intervals, to wash down charred particles from sides of the flask. Heating was continued until the mixture become clear and free from brown or black colour. This was allowed to cool and the content of the flask made up to 100 ml using distilled water. Exactly 20 ml of this diluted digest was placed in the distillation flask. Also, 20 ml of 2% boric acid solution was measured into a conical flask, and few drops of screened methyl red indicator were added into the conical flask. The conical flask and its content were placed on the receiver, so that the end of the delivery tube dips just below the level of the acid. Few pieces of granulated zinc and anti-bumping granules were added to the distillation flask and about 40 ml of 40% NaOH solution was run into the flask to make the liquid in the flask alkaline. The content was boiled vigorously until the content of the flask bumped. The distillate was titrated with 0.1N HCl to a purple coloured end point (Vml).

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CALCULATION

$$\text{Nitrogen}(\%) = \frac{1.4\ x\ Titre\ Volume\ x\ total\ volume\ of\ digest}{1000\ x weight of Sample x Aliquot distilled} \text{ x } 100.$$

Methods for the Metal Analysis of Sample

Metal analysis was conducted using the Varian AA240 Atomic Absorption Spectrophotometer according to the method of APHA (1995) (American Public Health Association).

Working Principle: Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interference. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Wet Digestion Technique

The method of AOAC (1999) was adopted. Samples weighing approximately 1 g were transferred into a 100 ml digestion flask, and then 10 ml of 70% HNO_3 was added, followed by heating until any vigorous reaction subsided (30 minutes). After cooling, 8 ml of 70% perchloric acid ($HClO_4$) was added to each flask and the contents were gently heated on a hot plate until the solutions became colorless or nearly so, and white fumes of $HClO_4$ were evolved making sure contents did not dry. After cooling, approximately 30 ml of distilled water was added to each flask and boiled for another 10 minutes, cooled and then filtered at room temperature. The digests were then subjected to atomic absorption spectrophotometric analysis.

Preparation of Reference Solutions

A series of standard metal solutions in the optimum concentration range was prepared, and the reference solutions were prepared daily by diluting the single stock element solutions with water containing 1.5 ml concentrated nitric acid/litre. A calibration blank was prepared using all the reagents except for the metal stock solutions.

Calibration curve for each metal was prepared by plotting the absorbance of standards versus their concentrations.

Soil Chloride Determination

The method of AOAC (1999) was adopted. Exactly 5 g of soil sample was soaked in 50 ml of distilled water for 4 hours before filtration. Then, 50 ml of the filtrate was transferred in a 250 ml conical flask after which 4 drops of potassium dichromate indicator were added. This was titrated against 0.02M $AgNO_3$ to a red color (from a yellow color). The chloride content was calculated thus:

$$\text{Cl (mg/l)} = \frac{A \times M \times 70{,}900}{Volume of sample}$$ A = Volume of $AgNO_3$; M = Molarity of $AgNO_3$

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Soil Phosphate, Method by Ganesh *et al.* (2012)

Procedure

To suitable aliquots of stock standard solution and sample, 1 ml of 0.0055M ammonium molybdate and 0.4 ml of 0.0096M hydrazine sulphate were added and the solution was made up to 10 ml with double distilled water in a standard measuring flask. The standard measuring flasks were kept in a water bath for heating for 30 minutes. The temperature of the water bath was set to 60^{o}C. While heating, a blue colour developed due to the formation of ammonium phosphomolybdate complex. After heating for 30 minutes, the solution was cooled and its absorbance was measured at wavelength 830 nm. An experimental blank solution was used for carrying out correction for the baseline.

Soil Nitrate Determination (Vendrell & Zupancic, 1989)

Extraction: For the extraction, 10 g of soil samples were soaked in 20 ml of saturated $Ca(OH)_2$ with vigorous shaking for 15 minutes after which they were filtered.

Transnitration Using Salicylic Acid: In this method, 0.2 ml of each filtered calcium hydroxide extract was mixed with 0.8 ml of 5% salicylic acid in concentrated sulphuric acid. This was allowed to cool for 20 minutes before the addition of 19 ml of 1.7N NaOH. After cooling to room temperature, the absorbance was determined at 410 nm and concentration was determined against a reference nitrate standard.

Determination of Organic Carbon Content Colorimetrically

Principle

The determination of soil organic carbon is based on the Walkley & Black chromic acid wet oxidation method. Oxidizable organic carbon in the soil is oxidised by 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution in concentrated sulfuric acid. The heat of reaction raises the temperature which is sufficient to induce substantial oxidation.

Chemical reaction is as follows: $2\ Cr2O_7^{2-} + 3\ C^0 + 16\ H^+ \longrightarrow 4\ Cr^{3+} + 3\ CO_2 + 8\ H_2O$

The $Cr_2O_7^{2-}$ reduced during the reaction with soil is proportional to the oxidisable organic C present in the sample. The organic carbon can then be estimated by measuring the remaining unreduced dichromate by back-titrating with ferrous sulphate or ammonium ferrous sulphate using diphenylamine or o-phenanthroline-ferrous complex as an indicator.

$6\ Fe^{2+} + Cr2O_7^{2-} + 14\ H^+ \longrightarrow 2\ Cr^{3+} + 6\ Fe^{3+} + 7\ H_2O$

Alternately, the organic carbon can be calculated from the amount of chromic ion (Cr^{3+}) formed, using a colorimetric procedure measuring absorbance at 588 nm (Sims & Haby, 1971). An advantage of this procedure over the titrimetric method is that accurate standardisation of the $Cr_2O_7^{2-}$ solution is not required.

Procedure

Exactly 0.5 g of soil sample was weighed followed by the addition of 2 ml of 10% (0.34 M) $K_2Cr_2O_7$ solution, and mixed. This was followed by the addition of 5.0 ml of H_2SO_4, cooling and it was left to stand for 30 minutes before addition of 20 ml water to the tube. The entire

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mixture was left to stand overnight and the absorbance values of the calibration standards and samples were measured at 600 nm.

Soil pH

For the soil pH, 1 g of soil samples were mixed with 10 ml of distilled water whose pH had been measured (pH: 7). This was mixed and allowed to stand for two hours before determination of pH using a digital pH meter by immersing its electrode.

Particle Size Determination

This was carried out by adopting the method of Bouyoucos (1972). The analysis relies on the differences in particle size distribution between sand, silt and clay particles. Air dried soil samples were properly homogenized and 10 g was mixed with 100 ml of the dispersing solution (Sodium hexametaphosphate solution). This was transferred to a 250 ml measuring cylinder and allowed to settle for an hour. The settling rate was now measured using a soil hydrometer after which the percentage sand, silt and clay were now calculated.

Exchangeable Acidity (H and Al)

This was carried out by adopting the method of the Soil Science Society of America (2020). Soil samples were air dried and homogenized after which 5 g was mixed with 10 ml of 1 M KCl. This was allowed to stand for an hour after which it was filtered. This filtrate was shared into two for measurement of exchangeable acidity in terms of H and Al. For H, the pH values of the soil extract and KCl solutions were measured after which the exchangeable acidity was calculated thus:

Exchangeable acidity (meq/100g H) = $(Initial\ pH\ of\ KCl - pH\ of\ soil\ extract) \times 10$

For exchange acidity in terms of Al, the Al concentration was determined using an atomic absorption spectrophotometer and calculated thus:

Exchangeable Acidity (meq/100g Al) =

$$(Al\ concentration\ of\ extract) \times \left(\frac{1000}{atomic} weight\ of\ Al\right) \times 10$$

Bulk Density Determination

Fifteen grams (15 g) of the soil samples were weighed in a pre-weighed measuring cylinder and the volume was noted. The Bulk density was calculated thus:

Soil bulk density = $\frac{Soilmass}{Soilvolume}$

Soil Water Holding Capacity

Five grams (5 g) of soil samples were weighed and transferred into a pre-weighed centrifuge tube. To this, 5 ml of deionized water was added (1:1). This was mixed using a vortex mixer for 1 minute and allowed to stand for an hour. The mixture was then centrifuged at 3500 rpm for 30 minutes and the supernatant was carefully decanted. The weight of the centrifuge with the wet soil was then taken. The water holding capacity was calculated thus:

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Water Holding Capacity (%) = $\frac{Waterabsorbedbythesoil}{Soildryweight} \times 100$

where Water Absorbed = Weight of Wet Soil – Weight of Dry Soil.

Organic Matter by Ignition Determination (AOAC, 1999)

An empty crucible was fire-polished in a muffle furnace and allowed to cool in a desiccator containing calcium chloride for 20 minutes and then weighed (W_1). The samples (2 g each) were weighed into separate crucibles (W_2) and transferred into a muffle furnace and heated at 550^{o}C until the sample was completely ash; the crucible was removed and a drop of water was added to expose the unashed portion. The crucible was placed back in the muffle furnace and heated for more than 30 minutes. This was removed and allowed to cool in a desiccator, after which the crucible with the ash was weighed (W_3).

CALCULATION

% organic matter = $\frac{W2-W3}{W2-W1} \times 100$.

DATA ANALYSIS

The data collected were analyzed using one-way analysis of variance (ANOVA) to ascertain the significant difference within factors at a 5% level of probability.

RESULTS

Average Soil Parameters for the Two Forest Sites

A comparative analysis of average soil parameters from Unizik and Amansea secondary forests reveals distinct differences in nutrient availability and soil characteristics. Notably, the nitrogen content is higher in Amansea (6.34±0.71%) than in Unizik (3.41±0.72%), indicating greater nitrogen availability in the former. Similarly, phosphorus levels in Amansea (7.85±1.10 mg/g) significantly exceed those in Unizik (2.38±0.38 mg/g), suggesting enhanced soil fertility in Amansea. Potassium levels were comparable, with Unizik at 31.02±0.07 ppm and Amansea at 29.76±0.23 ppm. Nitrate concentration was also higher in Amansea (2.81±0.31 mg/g) than in Unizik (1.51±0.32 mg/g), indicating increased nitrogen mineralization in Amansea. Organic matter content was greater in Unizik (8.67±2.67%) compared to Amansea (6.00±0.23%), while organic carbon levels were higher in Amansea (22.44±0.73 µg/g versus Unizik's 14.59±1.11 µg/g). Additionally, Unizik displayed negligible exchangeable acidity (0.06±0.00 cmol/100g) compared to Amansea's 0.32±0.05 cmol/100g for H^+ ions and 3.90±0.91 cmol/100g for Al^{3+} ions, indicating more acidic conditions in Amansea. These findings highlight significant variations in soil fertility and composition between the two forest sites.

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Table 1: Average Soil Parameters for the Two Forest Sites

Parameters	Unizik Secondary Forest	Amansea Secondary Forest
Nitrogen (%)	3.41±0.72	6.34±0.71
Phosphorus (mg/g)	2.38±0.38	7.85±1.10
Potassium (ppm)	31.02±0.07	29.76±0.23
Nitrate (mg/g)	1.51±0.32	2.81±0.31
Organic matter (%)	8.67±2.67	6.00±0.29
Organic carbon (µg/g)	14.59±1.11	22.44±0.73
Exchangeable acidity (H^+) (cmol/100g)	0.06±0.00	0.32±0.05
Exchangeable acidity (Al^{3+}) (cmol/100 g)	1.48±0.03	3.90±0.91
pH	7.82±0.03	7.96±0.02
Soil chloride (mg/g of soil)	0.89±0.21	1.11±0.09
Bulk density (g/cm^3)	1.15±0.00	1.25±0.00
Water holding capacity (WHC) (%)	48.93±5.57	37.53±2.07
Particle size (%)		
Sand (%)	61.00±2.08	56.67±2.33
Silt (%)	26.67±1.67	25.67±0.67
Clay (%)	13.33±0.88	12.67±0.88

Both Unizik and Amansea secondary forests demonstrate near-neutral pH levels, with Unizik at 7.82±0.03 and Amansea slightly higher at 7.96±0.02, indicating good conditions for plant growth. Soil chloride content was greater in Amansea (1.11±0.09) than in Unizik (0.89±0.21), suggesting variations in water sources or mineral composition. The bulk density of both forests is similar, with Unizik at 1.25±0.00 and Amansea at 1.25±0.09, reflecting comparable soil compaction. Unizik also shows a superior water-holding capacity of 48.93±5.57% compared to Amansea's 37.53±2.07%, likely due to higher clay content. In terms of particle size, Unizik has a higher sand percentage (61.00±2.08) than Amansea (56.67±2.33), enhancing drainage. Both forests show similar silt content, while Unizik possesses more clay (13.33±0.88) than Amansea (12.67±0.88), further contributing to its water retention ability. Overall, while Amansea displays higher nutrient levels and organic carbon, its elevated exchangeable acidity may hinder root penetration. Conversely, Unizik, with its higher potassium and water-holding capacity, likely offers improved drainage, albeit with lower fertility. These differences may be attributed to variations in vegetation, soil management, or environmental conditions between the two forests.

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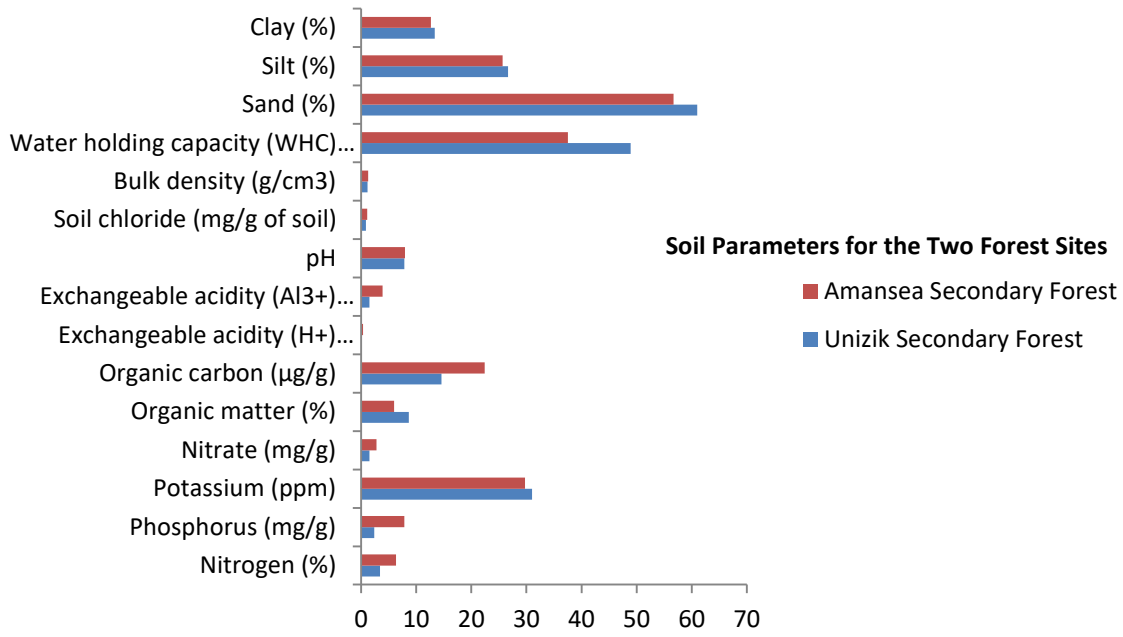

Figure 3: Soil Parameters for the Two Forest Sites

DISCUSSION

The soil properties of a forest significantly influence its vegetation structure, species composition, and overall ecosystem health. Table 1 compared various soil parameters between the Unizik and Amansea Secondary Forests. Key parameters include nitrogen, phosphorus, potassium, nitrate, organic matter, organic carbon, exchangeable acidity, pH, soil chloride, bulk density, water holding capacity (WHC), and particle size distribution (sand, silt and clay).

Higher nitrogen (6.34%) and phosphorus (7.85 mg/g) levels in the Amansea forest suggest greater soil fertility compared to the Unizik forest (3.41% nitrogen and 2.38 mg/g phosphorus). Enhanced fertility can support a more diverse and robust plant community. In both forests, species like *Ageratum conyzoides* and *Chromolaena odorata* are common, thriving in nutrient-rich conditions. Daws *et al*. (2005) and Brady and Weil (2008) highlighted the importance of nutrient availability for plant growth and seed bank composition.

Organic matter (8.67%) and organic carbon (14.59 µg/g) levels are higher in the Unizik forest, indicating better soil structure and microbial activity, which are vital for decomposition and nutrient cycling. The Amansea forest shows higher organic carbon (22.44 µg/g), suggesting significant biomass input and carbon sequestration potential. The result also suggests that Unizik secondary forest may have richer litter deposition or slower decomposition rates, while Amansea secondary forest has more carbon storage potential (Lal, 2005). Harper (1977) and Six *et al.* (2020) discussed the role of organic matter and carbon in maintaining soil fertility and supporting diverse plant communities.

Higher exchangeable acidity (H^+ 0.32 cmol/100g, Al^{3+} 3.90 cmol/100g) in Amansea indicates more acidic conditions compared to Unizik (H^+ 0.06 cmol/100g, Al^{3+} 1.48 cmol/100g). Acidic

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soils can limit nutrient availability and affect species composition. Both forests maintain a neutral pH (around 7.82 to 7.96), which is favorable for most plant species, as supported by Wright (2002) and Brady and Weil (2008) who explained how soil pH influences species diversity and distribution in tropical forests.

Lower bulk density in Unizik (1.15 g/cm³) suggests better soil porosity and root penetration compared to Amansea (1.25 g/cm³). Higher water holding capacity (48.93%) in Unizik indicates better moisture retention, supporting plant growth during dry periods. This finding correlates with the observations made by Reynolds *et al.* (2015), Smith and Smith (2012) and Adhikari and Hartemink (2016) where they emphasized the importance of soil physical properties in supporting plant growth and maintaining ecosystem stability. Similarly, particle size distribution in both forests (sand, silt and clay) indicates comparable soil textures, influencing water retention, drainage, and root growth (Saxton & Rawls, 2016); this similarity contributes to the comparable species composition observed in the above-ground vegetation and seed banks.

CONCLUSION

The study highlights significant differences in soil parameters between Unizik and Amansea secondary forests. Amansea secondary forest exhibits higher nutrient levels, organic carbon, and exchangeable acidity, making it potentially more fertile but with slightly more acidic conditions. Unizik secondary forest, on the other hand, has higher potassium content, organic matter, and water holding capacity, as well as sand content, likely offering better drainage but comparatively lower fertility. Addressing soil acidity in the Amansea forest by incorporating lime or other soil amendments will neutralize pH levels and improve nutrient availability. Also, by enhancing soil organic matter content in both forests through the addition of compost and organic residues, the soil structure and water retention will be improved.

DECLARATION OF AI USAGE

Author(s) hereby declare that generative AI technologies, such as Large Language Models, have been used during the writing and editing of this manuscript. The details of AI usage are as follows:

1. **Name and Version:** ChatGPT-4, Open AI.
2. **Model and Source:** Open AI's Large Language Model (GPT-4).
3. **Usage Details:**
    - Assisted in refining the language and clarity of the manuscript.
    - Suggested improvements in structuring methodology and discussion sections.
    - Provided recommendations for incorporating relevant comparative studies and recent literature.

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