Innovations

Assessment of Fertility and Degradation Status of Soils in Federal University Oye-Ekiti, Nigeria

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Abstract: *Soil fertility and degradation are critical in maintaining agricultural productivity and environmental health. This study presents an assessment of the fertility and degradation status of soils across different land use types; oil palm, cassava, cashew, maize and fallow land, within the Federal University Oye-Ekiti (Ikole-Ekiti Campus). Representative soil samples were collected and analyzed for key soil physicochemical properties such as pH, organic matter (OM), nutrient levels, and soil texture in order to access the fertility and degradation status of the soil. Results indicate significant variations in soil fertility and degradation status among the different land use categories. Land use types exhibited varying degrees of soil limiting factors andnutrient depletion, highlighting potential challenges for sustainable crop production. The soil fertility results showed that all the land use types have modifiers d (moisture regime), k (Potassium deficiency), e (Effective cation exchange capacity), and m (Organic matter) as limiting factors with the exception of Oil palm for modifier e and Cassava, Cashew and Fallow for modifier m. While soil degradation assessment revealed that all the land uses are non - slightly degraded in terms of bulk density, total nitrogen, available phosphorus and exchangeable sodium percentage. This research sheds light on the critical interplay between land use, soil fertility, and degradation status within the Federal University Oye-Ikole Campus. The findings have implications for sustainable land management strategies and agricultural practices. Land users may alter management strategies to improve soil health, boost agricultural output, and reduce environmental consequences by recognizing the varying soil conditions under various land uses.*

Keywords: *Evaluation, Management, Productivity, Soil, Sustainability.*

1.0Introduction

Soil, a dynamic natural resource, sustains life on Earth. According to Gomeiro (2016), soil fertility and degradation status are pivotal for agriculture, ecosystems, and food security. Gomeiro also noted that soil fertility, providing nutrients for plant growth, and soil degradation, reducing quality and productivity, interact in complex ways.Thirkell *et al*. (2017) stated that soil fertility is a critical component of agricultural productivity and plays a pivotal role in ensuring food security and sustainable farming practices worldwide. It is the soil's ability to provide essential nutrients and create a suitable environment for plant growth. Studies by Henneron *et al*. (2020) show that soil organic matter (SOM) is a critical component of soil fertility. The SOM consists of decomposed plant and animal residues as well as microorganisms, and it plays a fundamental role in maintaining soil structure, water retention, and nutrient availability. Researchers like Huang *et al*. (2020) have emphasized the significance of managing SOM through practices like cover cropping and reduced tillage to improve soil fertility while also sequestering carbon in the soil, contributing to climate change mitigation.The use of organic amendments, such as compost and manure, has been widely studied as an effective means of enhancing soil fertility. Research conducted by Singh *et al*. (2020) highlighted the potential of organic amendments to improve soil fertility, increase crop yields, and reduce the reliance on synthetic fertilizers, which can have adverse environmental impacts.Crop rotation and diversification are agricultural practices that have also been extensively studied for their positive effects on soil fertility (Shah *et al*., 2021). In line with the research by Kumar *et al*. (2020) which proposed that these practices, as indicated by Shah *et al.*(2021)break pest and disease cycles, improve nutrient cycling, and enhance SOM. Studies by Shah *et al*. (2021) investigated the impact of crop rotation on soil fertility, concluding that it can significantly increase soil organic carbon and improve soil structure, thus promoting sustainable agricultural systems.According to Jang *et al*. (2021), soil degradation, conversely, worsens with declining fertility. Jang *et al*. (2021) noted in their research that nutrient-poor, organic matter-lacking soil struggles against erosion, compaction, and degradation, and then suggested that the loss of soil quality reinforces degradation.Soil degradation jeopardizes agriculture, food security, and the environment. It leads to reduced soil fertility, ecosystem services, and land usability. Soil erosion, a primary cause, results from factors like deforestation and poor land management. Govers *et al*. (2006) highlight its impact, leading to nutrient-rich topsoil loss. Effective erosion control measures, like contour farming, mitigate soil erosion and its effects (Chalise *et al*., 2019).Soil compaction, another form of degradation, compresses soil particles, reducing pore spaces and hindering water infiltration and root growth. Shaheb *et al*. (2021) emphasize soil aeration and tillage's role in restoring structure.Chemical degradation arises from excessive chemical fertilizers and pesticides, causing soil acidification and contamination. Shukla *et al*. (2019) discuss the impact of soil acidification on nutrient availability, advocating balanced nutrient management and sustainable pesticide use.Salinization, which accumulates salts in the soil, according to Etikala *et al*. (2021), renders it unsuitable for most crops. Essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) are crucial for soil fertility. Degradation leads to the loss of these nutrients through erosion, leaching, and compaction. For instance, erosion removes nutrient-rich topsoil, reducing fertility (Rashmi *et al*., 2022). According to Le *et al*. (2022), soil degradation can result in soil acidification, negatively impacting fertility. The excessive acidic fertilizers and industrial emissions decrease soil pH, limiting nutrient availability and hindering plant growth.Research conducted by Mosier *et al*. (2021) indicated that degraded lands stem from intensive management, inadequate soil preservation, and climate change. The harm caused by intensive annual crop production to the soil ecosystem,disrupts the physical and chemical properties of the soil. Hence, regenerative agriculture emphasizes soil health restoration (Schreefel *et al*., 2020). This study aims to assess the fertility and degradation status of soils in land use of Federal University Oye-Ikole Campus.

2.0 Materials and Methods

2.1 Experimental Site

The research was conducted at the Federal University, Oye Ekiti (Ikole campus). Geographically, Ikole- Ekiti is located within the latitude 7.79° N and longitude 5.51° E with an elevation of 569.98 m. The climate is of south-western Nigeria lowland tropical rainforest characterized with distinct wet and dry seasons an annual rainfall range of 1,200 mm to 1,600 mm. The dry season usually come up between November and April while the wet season prevails between May and October. Over the course of the year, the temperature varies from 17 to 32 C and is rarely below 13° C or above 35° C.

2.2 Sampling and Measurement

The following land use types; oil palm plantation, cashew plantation, arable crops (cassava and maize) and fallow land were selected for the study. A representative portion of each land used was demarcated (50 by 100 m). It was divided into four and mini-pits were dug in each. Soil samples were collected from mini pits in the representative portions of each land use type at 0-30 cm. the slope angle in each land used was recorded with clinometers and the soil moisture regime of the area was recorded.

2.3 Laboratory Analysis

Samples collected were air-dried and then gently crushed by agate mortar and pestle, air-dried and sieved through a 2 mm mesh prior to soil chemical analysis. The following parameters on soil physical and chemical properties were determined: Particle size distribution was determined by Gee and Bauder (1986) method. The Bulk density was determined by Grossman and Reinsch (2002) method, organic carbon was determined using Walkley and Black method as described by Nelson and Sommers (1982) and was converted to OM using a coefficient of 1.724. Total Nitrogen (N) was determined using kjeldahl method of nitrogen determination Bremmer (1966). Available Phosphorus (P) was determined by Bray's method (Kuo, 1996).

Percentbase saturation was calculated using the formula:

$$Percent\ base\ saturation, \%\ BS = \frac{Total\ exchangeable\ bases, TEB}{Effective\ cation\ exchange\ capacity, ECEC} \times \frac{100}{1}$$

Exchangeable sodium percentage (ESP) was also calculated as the proportion of the ECEC occupied by sodium (Na) cations as follows:

$$Exchangeable\ sodium\ percentage, ESP = \frac{Exchangeable\ Na}{Effective\ cation\ exchange\ capacity, ECEC} \times \frac{100}{1}$$

2.4 Land Degradation Assessment

The level of degradation of the soil *were* assessed using the standard indicator and criteria for degradation assessment (Table 1) by FAO (1979), Snakin *et al*. (1996) and Senjobi *et al*. (2013). Analytical data from each sample was placed in a degradation class by matching the soil characteristics with the land degradation indicator. The estimates of the degree of degradation were based on the physical, chemical and biological parameters

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3.0results and Discussion

3.1 Soil properties

The results of the soil physico-chemical properties are presented in Table 2. Particle size analysis shows that sand has the highest range of values (736.20-848.70 g/kg). This indicates that the soils of the location are sandy.The texture is sandy loam in oil palm and cashew land use and loamy sand in other land use. The sandy nature can be attributed to the nature of the parent rock and similar result has been reported on soil formed on the basement complex (Babalola and Fasina, 2006; Fasina *et al*. 2007; Babalola *et al*., 2013). There is a low variation between the land use for sand with coefficient of variation of 5.47% and moderate variability of clay and silt (23.13 and 28.90% respectively). The bulk density ranged from 1.46-1.48 g/cm^3. These values are moderately suitable for good plant growth. According to Veihmeyer and Hendrickson (1948), bulk density between 1.70 and 1.80 g/cm^3 for sandy soils and between 1.45 and 1.65 g/cm^3 for clay soils will inhibit root growth. The Base Saturation is in the range of 9.20-37.21%. The oil palm and cassava land use have higher percentage base saturation than all the other land use. There was high variation among all the land use with coefficient of variation of 56.82%. Base saturation for soils to be greater than 80%. A soil with base saturation less than 40% is an indication that the soil will be less productive and likelihood of leaching is very high in all the land use. The total nitrogen ranged from 1.7-2.4 g/kg. There is moderate variation between the land uses with coefficient of variation of 21.00%. The highest value was recorded in the oil palm land use, while the lowest was at cashew field. This is understandable in that the oil palm field has been established for over 20 years and could have been contribution from parent litters along with minimal removal of plant residues and soil disturbance. This view was held by Babalola *et al*. (2021). Furthermore, the variation in Nitrogen could have been influenced by fertilizer use especially in maize and cassava. Schmidt *et al*. (2000) declared that the rate of total nitrogen in soils depends mainly on soil biological activity and fertilizer type. Nitrogen rates are in line with 0.15-0.20% set as critical levels in Nigeria. The available phosphorus ranged from 11.33-52.78 mg/kg. The oil palm land use has high available phosphorus than the other land use. The highest value was obtained at the oil palm land use. There was high variation among all the land use type with coefficient of variation of 78.84%. The very high variation could have been occasioned by cultivation and crop removal. The nature of the parent material is a principal determinant of the amount available phosphorus in the soil, according to Maniyunda*et al*. (2013). The exchangeable potassium ranged from 0.04-0.09 cmol/kg. The Exchangeable potassium is higher in oil palm land use (0.09 cmol/kg) and lower in fallow land (0.04 cmol/kg) than all the other land use type. Diversity of crop cultivation practices on the land use could have occasioned the high variation recorded (coefficient of variation of 45.25%). Generally, potassium level is low in all the soils of the land use studied. The low potassium can be attributed to the nature of the soil, low base saturation of the soil, as well as intensive crop cultivation that took place in the fallow land before it was left to fallow. The Exchangeable Sodium Percentage is in the range of 4.21-8.65%. The values are less than 15% benchmark for sodic soils therefore, the soils in all the land use are not sodic. There was medium variation among all the land use type with coefficient of variation of 34.19%. Organic matter ranged from 2.03-4/55%. The organic matter is rated higher for the oil palm land use (4.55%), followed by the fallow land (2.59%) due to the accumulation of plant debris than other land use. The situation in the fallow land is evident that the fertility of the soil is being gradually restored. There was high variation among all the land use with CV of 41.02%. This is because the organic matter deposition, accumulation and decomposition of the land use types differs. Principally, levels of organic matter in soils have been attributed to photo-cycling, land use and clay among other factors (Babalola *et al*., 2021).

3.2 Fertility Capability Classification (FCC)

The FCC evaluation results for the soils studied were presented in Table 3. At the surface (topsoil), Oil palm and Cassava were loamy textured (L) indicating moderate to well-drained soils, while Maize, Cashew and Fallow were classified as sandy textured (S). This indicates that the topsoil is sandy making it susceptible to leaching of nutrients. At the substrata (subsoil), all the land use types were classified as L, except fallow (S). This indicates a soil with good infiltration and water holding capacity, while the sandy soil at the subsoil in the fallow land use type suggest a soil low organic matter content. The modifiers d implied that the soils have an Ustic moisture regime. According to Sanchez *et al*. (2003), this favors soil dynamics such as slowing down of nitrogen mineralization and leaching as well as the death of many soil microorganisms. However, it may limit round the year production of crops, supplementary water is supplied through irrigation. All the soils were rated with k modifiers, indicating low nutrient reserve(K deficiency). This could be due to the high leaching potential of the land use types. All the land use types with the exception of oil palm are rated with modifier e. This shows that the soils have low buffering capacity. This could be as a result of prevalent clayey granulated soils with low activity clay minerals and the coarse nature of the soils. All the land use types had depleted soil organic matter except oil palm and maize. The aggregate FCC of the soils show that oil palm was classified as $LLd^{+}k^{+}e^{-}$, maize was classified as $SL^{+}k^{+}e^{+}$, cassava was classified as $LLd^{+}k^{+}e^{+}m^{-}$, cassava was classified as $SLd^{+}k^{+}e^{+}m^{-}$, while fallow was classified as $SSd^{+}k^{+}e^{+}m^{-}$.

3.3 Land Degradation Assessment

The land/soil requirement for grouping lands into different degradation classes are given in Table 1. The matching of the soil indicators/criteria are given in Table 4. The bulk density rated Class 1 for all land use, indicating that the soils ranged from non - slightly degraded for the soil property with productivity rate of 75-100%. This suggests that there will not be resistance to root penetration and growth, there will be adequate aeration, nutrient uptake and water movement. Land rating rated all the land use below Class 1. Fallow is highly degraded (Class 3 with productivity range of 25-50%, while the land use is very highly degraded soil (Class 4) with productivity range of 0-25%. The low base saturation is typical of ultisols which the soils of the area belong to. Also, the sandy nature of the soils and parent material played a role. Similar findings by Maniyunda *et al*. (2013) reported that parent material significantly influences base saturation. Total nitrogen was rated in degradation Class 1 for all the land use, indicating that soils are non - slightly degraded for the soil property with productivity rate of 75-100%. Available phosphorus was rated in Class 1 for all the land use, indicating that the soils are non - slightly degraded for the soil property with productivity rate of 75-100%. The degradation rating for potassium was Class 4 (very highly degraded) for all the land use type with productivity rating of 0-25%. This indicates that there will be need to supplement the potassium needs of crops in the area with fertilizer for optimum crop yield. The exchangeable potassium was rated in Class 4 in all the land use. The ESP was rated in Class 1 for all the land use, indicating that the soils are non - slightly degraded for the soil property with productivity rate of 75-100%. Therefore, the soils will not experience serious soil degradation problem such as crusting and reduction in infiltration due to clay dispersion. The degradation rating shows that the oil palm and fallow land use are non - slightly degraded soils (Class 1) with productivity range of 75-100%, while the maize, cassava, and cashew land use are moderately degraded (Class 2) with productivity range of 50-75%. The lower rating recorded, especially in maize and cassava could be as a result of continuous cultivation and crop removal. The aggregate degradation rating shows that all the land use types were rated into Class 4 (very highly degraded) due to one or more limiting soil properties.

Conclusion

The soil fertility and degradation status of various land use types were assessed. There were limitations to soil fertility, while degradation also occurred in the study area with respect to bulk density, base saturation, total nitrogen, available phosphorus, organic matter, and exchangeable bases. It is concluded that soil properties vary across land use types, and practices in land use strongly affect soil properties. Therefore, sustainable management practices that will promote soil properties and reduce soil limitations should be adopted.

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Table 1. Indicators and criteria of physical and chemical degradation of soil

Indicator		*Degree of degradation (%)			
		1	2	3	4
Physical	Initial level				
Soil bulk density (g cm^{-3})	1.25 – 1.4	< 1.5	1.5 – 2.5	2.5 – 5	> 5
Permeability (cm hr^{-1})	5 – 10	< 1.25	1.25 – 5	5 – 10	> 20
Chemical					
Content of nitrogen element (multiple decrease), N (%)	–	> 0.13	0.10 – 0.13	0.08 – 0.10	< 0.08
Content of phosphorus element (mg kg^{-1})	–	> 8	7 – 8	6 – 7	< 6
Content of potassium element (cmol kg^{-1})	–	> 0.16	0.14 – 0. 16	0.12 – 0. 14	< 0.12
Content of exchangeable sodium percentage (ESP) (Increase by 1% of CEC)	–	< 10	10 – 25	25 – 50	> 50
Base saturation (decrease of saturation in more than 50%)	–	< 2.5	2.5 – 5.0	5 – 10	> 10
Excess salt (Salinization – increase in conductivity, mmho $cm^{-1}yr^{-1}$)	–	< 2	2 – 3	3 – 5	> 5
Content of organic matter in soil (%)	–	> 2.5	2 – 2.5	1.0 – 2	< 1.0

Modified from: FAO (1979), Snakin *et al*. (1996), and Senjobi *et al*. (2013).

1 = Non to slightly degraded soil where productivity ranges from 75 – 100%

2 =Moderately degraded soil where productivity ranges from 50 – 75%

3 =Highly degraded soil where productivity ranges from 25 – 50%

4 =Very high degraded soil where productivity ranges from 0 – 25%

Table 2.Selected soil properties of the study areas

Soil unit	BD	Sand	Silt	Clay	Textural class	Total N	Av. P	Exch. K	OM	ESP	BS
	($g\ cm^{-3}$)	($g\ kg^{-1}$)				($g\ kg^{-1}$)	($mg\ kg^{-1}$)	($cmol\ kg^{-1}$)	(%)		
Oil palm	1.48	736.20	133.10	130.70	SL	2.40	52.78	0.09	4.55	6.87	37.21
Maize	1.46	848.70	63.10	88.20	LS	1.80	17.95	0.06	2.22	4.21	12.18
Cassava	1.47	821.20	80.60	98.20	LS	1.80	16.32	0.08	2.03	8.65	26.05
Cashew	1.48	796.20	83.10	120.70	SL	1.70	18.57	0.08	2.10	7.10	19.10
Fallow	1.46	791.20	110.60	98.20	LS	1.90	11.33	0.04	2.59	5.64	9.20
CV	1.05	5.48	28.90	23.13	–	21.00	78.84	45.25	41.02	34.19	56.82

BD = Bulk density, Av. P = Available phosphorus, Exch. K = Exchangeable potassium, OM = Organic matter, ESP = Exchangeable sodium percentage, BS = Base saturation, SL = Sandy loam, LS = Loamy sand, and CV = Coefficient of variation.

Table 3. Fertility capability classification of studied soil

Land use	Type	Substrata types	Modifiers				Aggregates
	(Topsoil)	(Subsoil)	d	k	e	m	
Oil palm	L	L	+	+	-+		$LLd^+k^+e^-m^+$
Maize	S	L	+	+	+	+	$SLd^+k^+e^+m^+$
Cassava	L	L	+	+	+	-	$LLd^+k^+e^+m^-$
Cashew	S	L	+	+	+	-	$SLd^+k^+e^+m^-$
Fallow	S	S	+	+	+	-	$SSd^+k^+e^+m^-$

L = Loamy texture, S = Sandy texture, d = Ustic moisture regime, k = low nutrient capital reserves (K deficiencies), e = low ECEC < 10 cmol kg^1 soil by sum of EB + EA (Exchangeable Bases + Acidity),and m =Organic matter content.

Table 4.Soil degradation assessment of the study areas

Soil unit	BD	Total N	Av. P	Exch. K	OM	ESP	BS	Aggregate
	(g cm^{-3})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})	(%)			degradation
Oil palm	1	1	1	4	1	1	4	4
Maize	1	1	1	4	2	1	4	4
Cassava	1	1	1	4	2	1	4	4
Cashew	1	1	1	4	2	1	4	4
Fallow	1	1	1	4	1	1	3	4

BD = Bulk density, Av. P = Available phosphorus, Exch. K = Exchangeable potassium, OM = Organic matter, ESP = Exchangeable sodium percentage, and BS = Base saturation.

1 = Non to slightly degraded soil where productivity ranges from 75 – 100%,
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