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Assessment of Soil Physical and Geotechnical Properties Under Different Land Use Types in Ifite-Ogwari, Anambra State, Southeastern Nigeria

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ABSTRACT

Objective: This study investigated the effects of different land-use types on selected physical and geotechnical properties of soils in the Faculty of Agriculture, Ifite-Ogwari, Anambra State, southeastern Nigeria. The aim was to assess how land-use practices influence soil quality for agricultural production and civil engineering applications.

Materials and Methods: Six representative soil profile pits were excavated under three land-use types: Mechanized Cleared Arable Land (MCAL), Ongoing Construction Sites (OGCS) and Fallow Land (FL). Soil samples were collected from the genetic horizons and analyzed using standard laboratory procedures. The measured properties included particle size distribution, Bulk Density (BD), Total Porosity (TP), Moisture Content (MC), saturated hydraulic conductivity (Ksat), Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and Linear Shrinkage (LS). Descriptive statistics and coefficients of variation were used to evaluate variations among soil profiles and land-use types.

Results: Sand, clay and bulk density values ranged from 22.40 to 66.40%, 17.60 to 55.60% and 1.12-1.67 g cm^{-3}, respectively. Total porosity and saturated hydraulic conductivity varied from 37-58% and 0.002-0.137 cm h^{-1}, respectively. Disturbed land-use types, particularly OGCS and MCAL, exhibited higher bulk density, lower total porosity, lower hydraulic conductivity and increased plasticity and shrinkage characteristics compared with fallow land. The plasticity index ranged from 0.42-8.01%, indicating slight to moderate plasticity, while linear shrinkage ranged from 7.14-19.79%, reflecting slight to high shrinkage potential. Higher values of liquid limit, plasticity index and linear shrinkage were observed in clay-enriched horizons, indicating the influence of clay accumulation and compaction on soil consistency and engineering behavior.

Conclusion: Land-use intensity significantly altered the physical structure and geotechnical properties of the soils. Disturbed land uses increased compaction and reduced favorable soil physical conditions, thereby affecting both agricultural productivity and engineering performance. The adoption of minimal tillage, vegetative stabilization and controlled traffic practices is recommended to improve soil sustainability and maintain favorable physical and geotechnical conditions.

INTRODUCTION

Soil physical and geotechnical properties are important indicators of soil quality, structural stability, environmental sustainability and engineering suitability. These properties influence several essential soil functions, including water infiltration, aeration, root growth, load-bearing capacity and deformation under varying moisture conditions[1]. However, increasing anthropogenic activities such as mechanized agriculture, urbanization, construction and mining, driven by rapid technological development in the tropics, have intensified soil degradation. Soil compaction, structural disruption and the loss of natural pore systems are among the major consequences of these activities and contribute significantly to land degradation.

Land-use change is a major factor influencing variations in soil physical and geotechnical properties, particularly in the highly weathered soils of southeastern Nigeria[2]. Geotechnical parameters such as Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and Linear Shrinkage (LS) are commonly used to assess soil consistency, shrink-swell potential, compressibility and engineering stability. These properties are strongly influenced by soil texture, clay mineralogy, moisture content and the degree of disturbance and compaction. Soils with high clay content and greater compaction generally exhibit higher plasticity and shrinkage potential, which can increase the risks of cracking, differential settlement, erosion and structural instability under alternating wet and dry conditions[3].

Similarly, physical properties such as bulk density, total porosity and saturated hydraulic conductivity are widely used as indicators of soil compaction, water movement and overall soil functionality for agricultural and engineering purposes[4]. In southeastern Nigeria, the increasing intensity of cultivation, mechanical land clearing and construction activities has raised concerns about declining land quality and soil stability. Despite the importance of these issues, studies that simultaneously evaluate both the physical and geotechnical properties of soils under different land-use types in the humid tropics remain limited.

Therefore, this study evaluated the physical and geotechnical properties of soils under mechanized cleared arable land, an ongoing construction site and fallow land within the Faculty of Agriculture, Ifite-Ogwari, Anambra State, Nigeria. The objective was to determine the extent of variation in soil structural integrity, hydraulic behavior and geotechnical performance under different land-use intensities. The findings will provide baseline information for sustainable agricultural management and engineering applications in the area.

MATERIALS AND METHODS

Study area: The study was conducted at the Teaching and Research Farm of the Faculty of Agriculture Annex, Ifite-Ogwari, Ayamelum Local Government Area, Anambra State, southeastern Nigeria. The area is located at latitude 06°60 14"N and longitude 06°95 02"E, with an elevation of approximately 42 m above sea level. It lies within the humid tropical rainforest zone and is characterized by an annual rainfall of 1700 to 2000 mm, mean temperatures ranging from 29-31°C and relative humidity between 61 and 81%[5]. These climatic conditions promote intense weathering and rapid soil formation. The natural vegetation consists of a secondary forest-savanna mosaic, which has been modified by human activities. The soils are mainly derived from Coastal Plain Sands and shale parent materials, resulting in considerable variation in soil texture and structural characteristics. Major land-use activities in the area include mechanized cultivation, construction and fallow management, all of which influence soil physical and geotechnical properties[6].

Land-use types and field sampling: Three contrasting land-use types were selected for the study: Mechanically Cleared Arable Land (MCAL), Ongoing Building Construction Sites (OGCS) and Fallow Land (FL), which served as the reference land-use type. A targeted soil survey approach was used for site selection. Six representative soil profile pits were excavated across the selected land-use types to a depth of approximately 150 cm or until a restrictive layer was encountered. Soil profile morphology was described in the field according to standard soil profile description procedures[7]. Disturbed soil samples were collected from each identified genetic horizon for laboratory analyses, while undisturbed core samples were obtained for bulk density determination.

Laboratory Analysis

Determination of soil physical properties: Particle size distribution was determined using the hydrometer method[8], while bulk density was measured using the core method[9]. Total porosity was calculated by assuming a particle density of 2.65 g cm^{-3} using the following equation:

$$\text{Total porosity (\%)} = \frac{\text{1-BD}}{\text{PD}} \times 100$$

Where
BD : Bulk density
PD : Particle density (2.65 g cm^{-3})

Gravimetric moisture content was determined by oven-drying soil samples at 105°C and calculated as follows:

$$\text{GMC (\%)} = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where,
W_1 : Weight of the empty container
W_2 : Weight of the wet soil plus container
W_3 : Weight of the oven-dried soil plus container[10]

Saturated hydraulic conductivity (Ksat) was determined using the constant-head permeability method[11]. The Silt-clay Ratio (SCR) was calculated as the ratio of silt content to clay content and was used as an indicator of soil weathering intensity.

Determination of geotechnical properties: Selected geotechnical properties, including Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and linear shrinkage (LS), were determined using standard laboratory procedures. Liquid limit was measured using the Casagrande apparatus, whereas plastic limit was determined by rolling moist soil into 3 mm diameter threads until crumbling occurred[12]. Plasticity index was calculated as the difference between liquid limit and plastic limit. Linear shrinkage was determined using the shrinkage bar method by measuring the reduction in sample length after oven drying.

Soil consistency and engineering characteristics were evaluated using Atterberg limit criteria. Plasticity index values were used to classify soils from non-plastic to highly plastic, while linear shrinkage values were used to assess shrinkage potential ranging from low to very high[13,14].

Statistical analysis: Data obtained from the laboratory analyses were subjected to descriptive and multivariate statistical analyses using the R statistical environment[15]. Mean, standard deviation and coefficient of variation (CV) were calculated to assess the variability of soil physical and geotechnical properties across land-use types and soil horizons. Variability classes were interpreted according to Wilding[16] as low (0-15%), moderate (16-35%) and high (>35%).

Correlation and regression analyses were performed to examine relationships among the measured variables. Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used to identify patterns of soil variability and grouping among land-use types. Graphical presentations, including bar charts, boxplots, violin plots, regression plots, radar charts, dendrograms and PCA biplots, were generated using R software.

RESULTS AND DISCUSSION

Variability of soil physical properties across land-use types: The physical properties of soils under Mechanically Cleared Arable Land (MCAL), Ongoing Construction Sites (OGCS) and fallow land (FL) varied considerably among land-use types (Table 1). These variations were influenced by soil-forming processes, land-use practices, compaction and vegetation cover. Land-use intensity played a major role in determining soil structural characteristics, water dynamics and ecological functions within the study area.

The soils were predominantly classified as Sandy Clay Loam (SCL), Clay Loam (CL) and clay, with sand contents ranging from 22.40 to 66.40%, silt from 2.00 to 24.00% and clay from 17.60 to 55.60% (Table 1). In most soil profiles, clay content increased with depth, particularly within the Bt horizons, indicating active clay illuviation and the downward movement of fine particles from upper to lower horizons[17]. This pattern is characteristic of highly weathered tropical soils developed under humid climatic conditions, where eluviation and illuviation are dominant pedogenic processes. The higher clay content observed in subsurface horizons suggests advanced profile development and enhanced structural differentiation.

The MCAL profiles contained relatively high clay contents, with average values of 43.10 and 40.93% in Profiles 1 and 2, respectively. Continuous cultivation and machinery traffic may have accelerated aggregate breakdown and promoted the downward movement of fine particles. Long-term agricultural activities can weaken soil structure, increasing its susceptibility to raindrop impact and mechanical pressure, thereby enhancing clay translocation within the profile.

In contrast, the OGCS profiles exhibited greater textural heterogeneity. Excavation, soil displacement, backfilling and compaction during construction activities likely disrupted the natural horizon sequence and resulted in irregular particle distribution. Such disturbances commonly reduce horizon continuity and increase textural variability. The FL profiles showed a more balanced textural distribution and better-developed horizons than both MCAL and OGCS profiles. This condition is likely associated with reduced disturbance and improved biological activity under natural vegetation cover.

The silt-clay ratio (SCR) ranged from 0.34 to 0.91 across the land-use systems. Lower SCR values in subsurface horizons indicate advanced weathering and prolonged pedogenic development, whereas relatively higher values in surface horizons may reflect selective erosion, accumulation of finer materials, or partial rejuvenation of surface soils[18]. The relatively uniform SCR values observed in some OGCS profiles may be attributed to the mechanical mixing of soil materials during construction activities. Since SCR is widely used as an indicator of weathering intensity, the low values recorded in clay-rich horizons confirm the highly weathered nature of the soils.

Soil moisture content ranged from 2.62 to 6.35% and generally increased with increasing clay content. Fine-textured soils retain more water because of their greater surface area, higher adsorption capacity and abundance of micropores. Consequently, clay-rich horizons stored more moisture than sandy horizons. The FL profiles maintained relatively stable moisture levels due to continuous vegetation cover, improved structural stability and reduced evaporative losses. Vegetation cover also promotes water infiltration and protects the soil surface from direct solar radiation.

Bulk Density (BD) values ranged from 1.12-1.67 g/cm^3, while Total Porosity (TP) ranged from 37 to 58% across the land-use types (Table 1). Higher BD values were observed under MCAL and OGCS, reflecting substantial soil compaction caused by repeated machinery traffic, engineering operations and construction activities. Surface sealing and structural degradation also contributed to the

Table 1: Physical properties of the soil

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	SCR	TC	MC (%)	BD (g/cm^3)	TP (%)	Ksat (cm/hr)
MCAL (profile 1)										
A	0-10	52.40	14.00	33.60	0.42	SCL	6.14	1.63	38	0.014
AB	10-40	46.40	16.00	37.60	0.43	CL	3.75	1.34	49	0.025
Bt1	40 -85	34.40	2.0	45.60	0.44	Clay	5.20	1.24	53	0.012
Bt2	85-150	22.40	22.00	55.60	0.40	Clay	4.10	1.24	53	0.024
	Mean	38.9	13.6	43.10	0.42		4.80	1.36	48.25	0.046
	CV	31.05	60.12	19.18	7.83		19.27	12.58	12.61	109.22
	Ranking	MV	MV	MV	LV		MV	HV	LV	MV
MCAL (profile 2)										
A	0-40	52.40	16.00	31.60	0.51	SCL	2.62	1.42	46	0.126
AB	40-80	44.40	14.00	41.60	0.34	Clay	2.78	1.36	49	0.019
Bt1	80-150	28.40	22.00	49.60	0.44	Clay	3.62	1.34	48	0.012
	Mean	41.73	17.33	40.93	0.43		3.01	1.37	47.67	0.052
	CV	23.79	19.55	17.59	16.65		15.02	2.48	2.21	99.94
	Ranking	MV	MV	MV	MV		MV	LV	LV	HV
OGCS (profile 3)										
A	0-30	66.40	16.00	17.60	0.91	SL	5.74	1.33	50	0.04
AB	30-50	36.40	22.00	41.60	0.53	Clay	3.52	1.45	45	0.127
Bt1	50-70	42.40	18.00	39.60	0.45	CL	5.80	1.30	50	0.035
Bt2	70-150	42.40	20.00	37.60	0.53	CL	5.97	1.27	50	0.042
	Mean	46.90	19.0	34.10	0.61		5.26	1.34	48.75	0.061
	CV	11.36	2.24	10.49	1.18		0.07	2.30	0.04	62.30
	Ranking	LV	LV	LV	MV		LV	LV	LV	LV
OGCS (profile 4)										
A	0-38	64.40	10.00	25.60	0.39	SCL	5.84	1.64	38	0.014
AB	38-67	34.40	22.00	43.60	0.50	Clay	5.53	1.51	43	0.002
Bt1	67-150	42.40	16.00	41.60	0.38	Clay	5.23	1.48	44	0.032
	Mean	47.07	16	36.93	0.42		5.53	1.54	41.67	0.160
	CV	26.87	30.62	22.46	11.89		4.38	4.48	5.86	76.88
	Ranking	MV	MV	MV	LV	-	LV	LV	LV	HV
FL (profile 5)										
A	0-32	52.40	22.00	25.60	0.86	SCL	5.24	1.46	45	0.015
AB	32-80	42.40	24.00	33.60	0.71	CL	5.07	1.38	48	0.015
Bt1	80-150	42.40	14.00	41.60	0.34	Clay	6.35	1.56	41	0.014
	Mean	45.60	20.00	33.60	0.64		5.55	1.47	44.67	0.015
	CV	10.86	21.67	19.45	36.58		8.63	5.61	6.71	58.61
	Ranking	LV	MV	MV	HV		LV	LV	LV	HV
FL (profile 6)										
A	0-20	56.40	16.00	27.40	0.58	SCL	5.88	1.67	37	0.137
AB	20-50	32.40	18.00	49.40	0.36	Clay	5.64	1.39	48	0.076
Bt1	50-92	42.40	24.00	33.60	0.71	CL	4.92	1.42	46	0.037
Bt2	92-150	42.40	24.00	33.60	0.71	CL	2.73	1.12	58	0.020
	Mean	43.40	20.50	36.00	0.59		4.54	1.40	47.25	0.070
	CV	19.65	17.41	21.92	29.77		24.31	11.63	16.39	64.89
	Ranking	MV	MV	MV	MV		MV	LV	MV	HV

SCR: Silt clay ratio, TC: Textural class, MC: Moisture content, BD: Bulk density TP: Total porosity, SHC: Saturated hydraulic conductivity, SCL: Silty clay loam, CL: clay loam, SL: Silty loam, LV: low variation 0- 15, MV: moderate variation, 16 -35, HV: high variation >35. MCAL: Mechanical clear arable land, OGCS: Ongoing building construction sites and FL: Fallow land

observed increases in bulk density. Figure 1 clearly illustrates the higher BD values recorded in construction sites compared with the other land-use types. The BD value of 1.64 g cm^{-3} recorded in the surface horizon of OGCS Profile 4 indicates severe structural compression resulting from construction-related loading and machinery movement. Increased compaction reduced pore space, particularly macropores and disrupted pore continuity. The inverse relationship between BD and TP shown in Fig. 2 demonstrates that increasing soil compaction reduces total pore space and restricts the movement of air and water within the soil. Similar findings have been reported for intensively cultivated and urbanized tropical soils, where machinery operations and construction activities cause aggregate breakdown and pore collapse[19]. The relatively lower BD values observed in some subsurface horizons may be attributed to reduced traffic pressure, improved aggregation and partial recovery of soil structure.

High bulk density has important implications for both agriculture and engineering. In agricultural systems, excessive compaction restricts root growth, reduces nutrient uptake, limits soil aeration and decreases microbial activity. These effects can reduce crop productivity and increase vulnerability to drought due to restricted root development

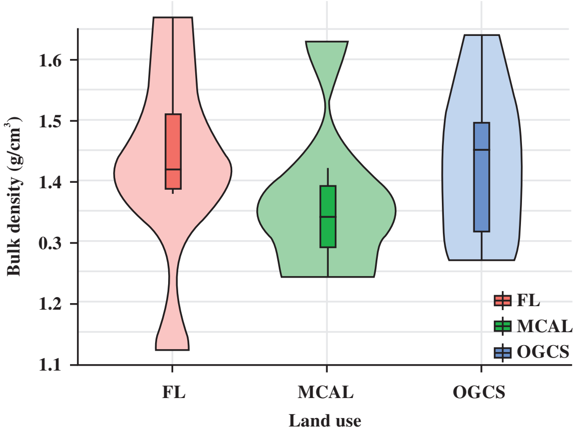

Fig.1: Variation in bulk density of soils under different land-use types at Ifite-Ogwari

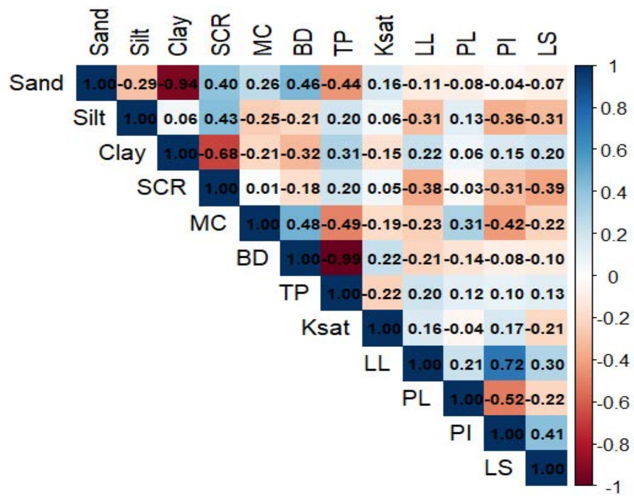

Fig. 2: Correlation matrix showing relationships across land-use types

and lower water availability. Reduced infiltration associated with compacted soils also increases surface runoff and the risk of erosion during heavy rainfall events.

From an engineering perspective, moderate soil compaction may improve load-bearing capacity. However, excessive compaction can increase susceptibility to shrink-swell behavior, surface cracking, drainage problems and structural instability under fluctuating moisture conditions. Figure 3 presents an integrated assessment of physical and geotechnical properties across the land-use systems and shows that disturbed land uses, particularly MCAL and OGCS, were characterized by higher bulk density, lower total porosity and lower saturated hydraulic conductivity than the fallow land. These findings indicate that increasing human disturbance progressively degrades soil structure and hydraulic functioning.

Saturated hydraulic conductivity (Ksat) showed considerable variability among the soil profiles, ranging from 0.002 to 0.137 cm h^{-1}. Higher Ksat values were generally associated with sandy and less-compacted surface horizons, whereas clay-rich and compacted horizons exhibited much lower conductivity values. The lowest Ksat value (0.002 cm h^{-1}), recorded in OGCS Profile 4, indicates severe restriction of water movement due to compaction and reduced pore connectivity. Low Ksat values reflect poor pore continuity and limited transmission of gravitational water through the soil profile, further confirming the negative effects of intensive land-use practices on soil hydraulic properties.

Relationship between bulk density and hydraulic conductivity: A strong inverse relationship between bulk density and saturated hydraulic conductivity (Ksat) is shown in Fig. 4a. This indicates that soil compaction significantly reduces infiltration rates and disrupts pore continuity. Reduced hydraulic conductivity has important implications for agriculture and environmental management. Slow infiltration limits groundwater recharge, increases surface runoff and enhances erosion risk, while also causing temporary waterlogging in cultivated fields. In agricultural systems, reduced water movement restricts nutrient transport to the root zone, thereby limiting crop water availability during critical growth periods.

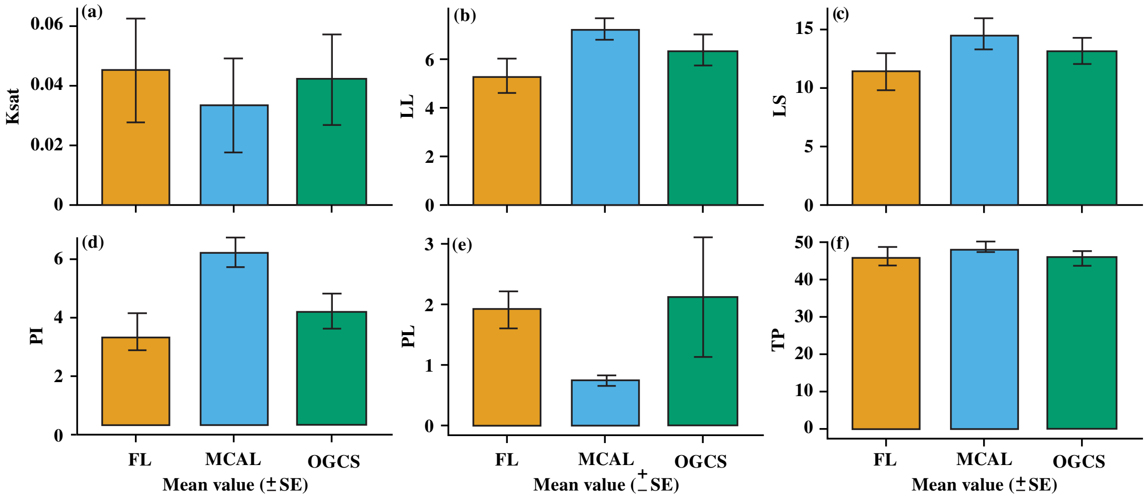

Fig. 3: Comparative distribution of selected physical and geotechnical properties across land-use types

In engineered soils, poor infiltration can lead to increased pore-water pressure, differential settlement and reduced bearing capacity. In contrast, fallow land exhibited better hydraulic performance, suggesting the beneficial role of vegetation cover and soil biota in improving soil structure. Improved infiltration and permeability in fallow soils are likely due to organic matter accumulation, root penetration and biological activity such as macrofaunal burrowing.

Variability of geotechnical properties across land-use types: Soil geotechnical properties varied significantly across land-use types and soil horizons (Table 2). These variations are mainly associated with clay translocation, compaction, moisture conditions and structural disturbance. The observed ranges for Liquid Limit (LL), Plastic Limit (PL), plasticity index (PI) and Linear Shrinkage (LS) were 2.26-10.38 mm, 0.23-7.43 mm, 0.42-8.01% and 7.14-19.79%, respectively. These values indicate that the soils range from non-plastic to moderately plastic, with low to high shrink-swell potential.

Higher values recorded in MCAL Profile 1 (mean 7.36 mm) represent conditions influenced by mechanical cultivation, whereas the lowest values in FL Profile 5 (mean 3.47 mm) reflect relatively undisturbed soil conditions. The higher values in MCAL are associated with increased clay activity and greater water adsorption due to the exposure of fine particles caused by repeated wetting and drying cycles under tillage. High liquid limit values are typical of clay-rich soils because of their large surface area and strong affinity for water molecules.

Figure 4b shows that MCAL soils exhibit higher variability and generally higher values of LL, PI and LS compared with FL soils. The greater variability in MCAL and OGCS soils is likely due to soil heterogeneity caused by aggregate breakdown, horizon mixing, structural disturbance and compaction. Construction activities in OGCS and agricultural tillage in MCAL expose clay-rich subsoil materials and modify their structure, leading to increased plasticity. Continuous tillage further promotes clay movement, enhances aggregate breakdown and increases shrink-swell behavior.

Based on standard classification, most soils showed low to moderate plasticity in terms of PI. However, the highest PI value (8.01%) was recorded in the AB horizon of MCAL Profile 1, indicating moderate plasticity and a higher tendency for deformation under wet conditions. High plasticity in disturbed soils reflects the dominance of clay accumulation and compaction in controlling soil consistency behavior[20]. Such soils deform easily when wet but become hard and rigid upon drying, creating difficulties for tillage operations, seed germination, plant establishment and engineering works.

In contrast, FL Profile 5 showed low PI values, indicating more stable soil consistency and lower shrink-swell potential. Under fallow conditions, vegetation cover and organic matter accumulation improve soil structure and stabilize consistency behavior. Organic matter enhances particle bonding and buffers moisture fluctuations, thereby reducing plastic deformation and shrinkage.

Linear shrinkage values ranged from low to high shrinkage classes. The highest LS value (19.79%) was observed in OGCS Profile 4, indicating high shrink-swell potential and a strong tendency for cracking and volumetric instability under changing moisture conditions. Such behavior can compromise the stability of engineering structures in construction-affected soils. The relationships among clay content, liquid limit, PI and LS (Fig. 4a, b and 2) confirm that clay is the dominant control factor governing soil consistency and engineering behavior.

Table 2: Geotechnical properties of soils

Horizon	Depth (cm)	LL (mm)	PL (mm)	PI (%)	LS (%)
MCAL (profile 1)					
A	0-10	5.10	0.97	4.13	8.0
AB	10-40	8.74	0.73	8.01	16.43
Bt1	40-85	8.26	0.93	7.33	15.57
Bt2	85-150	7.34	0.68	6.66	18.14
	Mean	7.36	0.83	6.53	14.54
	CV	17.73	19.84	21.63	25.57
	Ranking	MV	MV	MV	MV
MCAL (profile 2)					
A	0-40	5.88	0.82	5.06	14.50
AB	40-80	7.72	0.60	7.12	18.93
Bt1	80-150	6.84	0.58	6.26	9.57
	Mean	6.81	0.67	6.15	14.33
	CV	10.79	22.19	13.20	26.47
	Ranking	MV	MV	MV	LV
OBCS (profile 3)					
A	0-30	4.51	0.23	4.28	11.29
AB	30-50	6.26	0.56	5.70	12.64
Bt1	50-70	10.38	7.43	2.95	14.00
Bt2	70-150	4.82	2.32	2.50	9.43
	Mean	6.74	2.64	3.86	11.84
	CV	35.82	113.58	27.29	15.74
	Ranking	MV	LV	MV	MV
OBCS (profile 4)					
A	0-38	7.97	0.60	7.37	19.79
AB	38-67	5.30	1.0	4.30	11.64
Bt1	67-150	4.74	2.77	1.97	12.64
	Mean	6.0	1.46	4.55	14.69
	CV	19.23	61.91	54.18	26.01
	Ranking	MV	HV	HV	MV
FL (profile 5)					
A	0-32	3.84	2.96	0.88	7.14
AB	32-80	4.32	0.73	3.59	18.93
Bt1	80-150	2.26	1.84	0.42	14.70
	Mean	3.47	1.84	1.63	13.59
	CV	25.99	47.72	85.99	35.95
	Ranking	MV	HV	HV	HV
FL (profile 6)					
A	0-20	8.23	1.24	6.99	8.29
AB	20-50	6.81	2.67	4.14	10.29
Bt1	50-92	4.47	2.21	2.26	11.00
Bt2	92-150	6.25	1.87	4.38	9.43
	Mean	6.44	2.25	4.69	9.75
	CV	21.67	30.36	41.88	9.57
	Ranking	MV	MV	HV	LV

LL: Liquid Limit, PL: Plastic limit, PI: Plasticity index, LS: Linear shrinkage, PI: 0 -Non plastic, P1-7: slightly plastic, PI-7-17: Medium plastic, PI- 17 or more-Highly plastic. LS: 5-10 %: low shrinkage, 10-15 %: moderate shrinkage, 15-20%: high shrinkage, 20% or more: very high shrinkage[20]. MCAL: Mechanical clear arable land, OGCS: Ongoing building construction sites and FL: Fallow land

Soils with higher clay content exhibit greater water retention and plasticity due to their large specific surface area and adsorption capacity. As moisture increases, clay particles swell and become plastic, while drying leads to shrinkage and cracking. Figure 2 further shows positive relationships between clay content and PI (r = 0.15), indicating that higher clay content is associated with increased plasticity and shrink-swell potential. In contrast, bulk density and Ksat show a negative relationship (r = -0.22), confirming that compaction reduces permeability by destroying macropores and reducing pore connectivity. Soils with high PI and LS values are more prone to tillage difficulties, cracking, restricted root penetration, seasonal deformation and instability of engineering structures under fluctuating moisture conditions. These effects can reduce agricultural productivity and increase engineering risks.

Multivariate analysis of soil properties: Multivariate analysis showed that land-use intensity significantly influenced both physical and geotechnical soil properties. The principal component analysis (PCA) biplot (Fig. 5) clearly separated soils according to land-use type. Soils from MCAL and OGCS were strongly associated with bulk

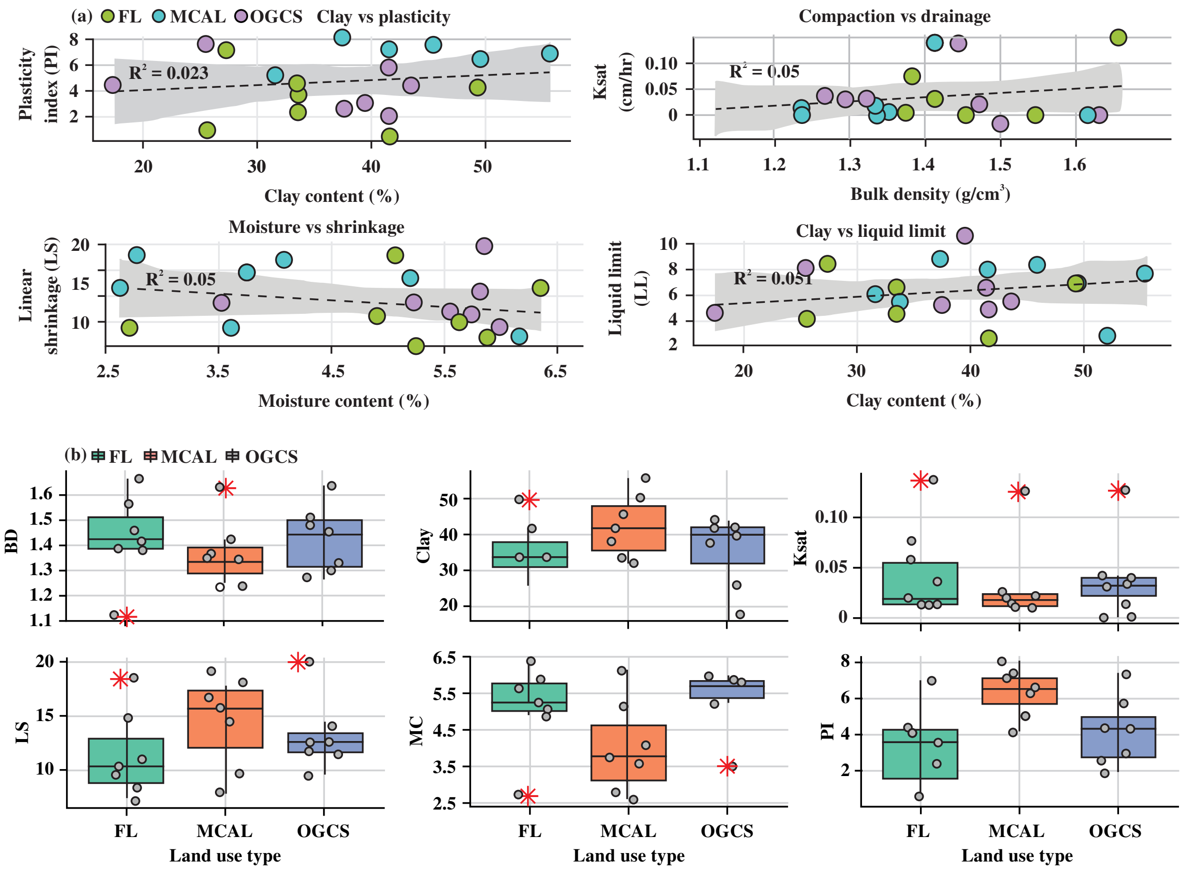

Fig. 4(a,b): (a) Regression Relationships Between Selected Physical and Geotechnical Properties of Soils at Ifite-Ogwari and (b) Distribution Patterns of geotechnical properties of soils under MCAL, OGCS and FL Uses

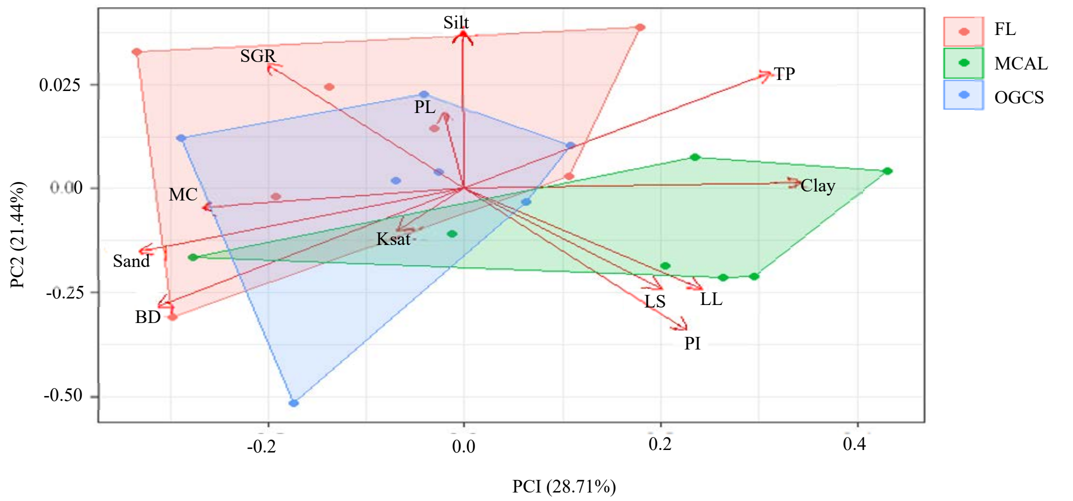

Fig. 5: Principal component analysis (PCA) biplot under different land-uses

density, plasticity index and shrinkage variables, indicating higher compaction and physical degradation². In contrast, fallow soils were closely associated with total porosity and hydraulic conductivity, reflecting improved pore structure and better water transmission properties. This suggests that vegetation recovery enhances soil structure and restores hydrological function.

The radar chart (Fig. 6) further illustrates the integrated effects of land use on soil properties. Disturbed soils (MCAL and OGCS) showed higher bulk density, PI and LS, whereas fallow soils exhibited higher porosity and hydraulic conductivity. These results confirm that increasing human disturbance leads to progressive deterioration of soil structural stability and hydraulic efficiency.

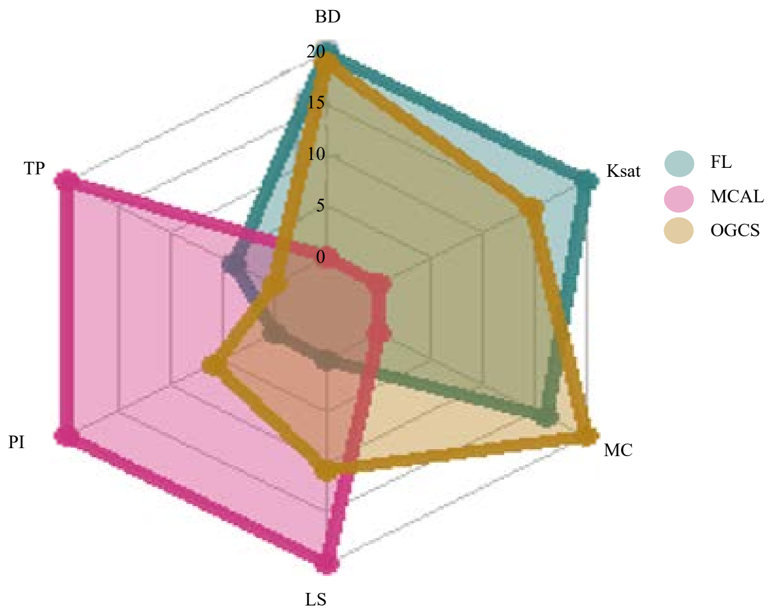

Fig.6: Radar chart illustrating integrated soil physical and geotechnical quality across land-use types

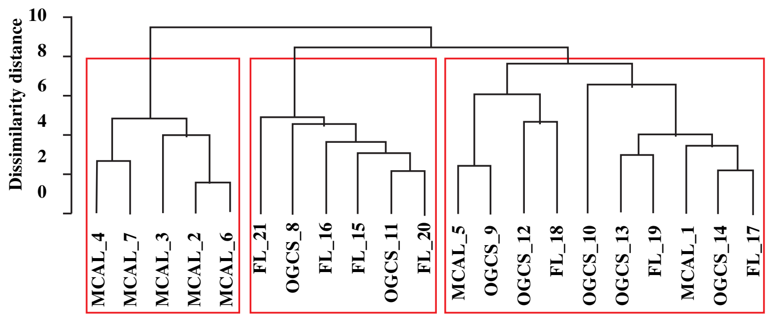

Fig.7: Hierarchical cluster dendrogram of soil physical and geotechnical properties under different land-use systems

Cluster analysis (Fig. 7) grouped MCAL and OGCS soils into a single cluster due to their similar characteristics of compaction, high plasticity and shrinkage behavior. Fallow soils formed a separate cluster, reflecting better structural stability and improved water movement characteristics. Overall, the results demonstrate that land-use intensity strongly controls both physical and geotechnical soil quality, with fallow conditions supporting more favorable soil functions.

CONCLUSION AND RECOMMENDATIONS

The results of this study demonstrate the significant influence of land-use type on the physical and geotechnical properties of soils in the Faculty of Agriculture, Ifite-Ogwari. Soils affected by mechanized agriculture and construction activities showed higher bulk density, lower total porosity and reduced saturated hydraulic conductivity. These soils also exhibited higher plasticity and shrinkage values, indicating lower structural stability and greater susceptibility to mechanical deformation. In contrast, soils under fallow land conditions were less disturbed and therefore maintained better soil structure, improved porosity and higher hydraulic conductivity. Overall, the findings show that soil texture, compaction level and land-use intensity strongly control soil behavior and performance for both agricultural and engineering applications. Based on these results, sustainable land management practices are recommended. These include minimizing soil disturbance through controlled traffic and reduced tillage, maintaining soil structure and promoting vegetation cover. Such practices will help reduce soil degradation and improve long-term soil quality, stability and productivity for agricultural and engineering use.

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