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Effect of Land Use Types on Soil Properties in Benin City, Nigeria

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ABSTRACT: This study examined the impact of land use types on soil characteristics in Benin City, Nigeria. In both the rainy and dry seasons, soil samples were taken from a farmland at the University of Benin in Nigeria at depths of 0–15 and 15–30 cm, respectively. The physicochemical parameters investigated include pH, EC, carbon content, nitrogen, organic matter, phosphorus, aluminum, and Cation Exchange Capacity (CEC), as well as Ca, Mg, K, and Na. When comparing seasonal differences in pH, phosphorus, aluminum, and CEC levels, significant differences were revealed at $\rho < 0.05$, $d = 0.0001$ for pH, $\rho < 0.05$, $d = 0.0001$ for phosphorus, $\rho < 0.05$, $d = 0.0002$ for aluminum, and $\rho < 0.05$, $d = 0.019$ for CEC, respectively. Conversely, the seasonal differences in EC, carbon content, nitrogen, and organic matter were not significant at $\rho < 0.05$, $d = 0.46$ for EC, $\rho < 0.05$, $d = 0.30$ for carbon content, $\rho < 0.05$, $d = 0.46$ for nitrogen, and $\rho < 0.05$, $d = 0.31$ for organic matter, respectively. The investigated soil physico-chemical properties did not vary significantly according to land use types at ρ and d values. This study showed that, in general, soil characteristics were highly influenced by different land uses and hence emphasizes the need to monitor urban land use activities.

KEYWORDS: Carbon content; significant difference; environmental; urban, soil properties

1. Introduction

Human activity is the defining characteristic of urban areas, and soil quality degradation is frequently correlated with human health and food safety degradation [1, 2]. Accelerated urbanization can, therefore, result in the highly intensified use of lands in those areas on the periphery of cities, having a significant impact on the soil's properties [3, 4]. Changes in land use are regarded as significant contributors to, and a root cause of, environmental changes worldwide [5]. The interaction of the bio-physical and human dimensions in space and time is what causes these changes. The different soil types, topography, climatic factors, and types of land use all have an impact on how quickly soil quality degrades. According to research by [5], improper land use exacerbates the deterioration of the physico-chemical and biological characteristics of the soil. Changes in land use and management practices frequently alter most soil morphological, physical, chemical, and biological properties to the extent that this is reflected in agricultural productivity [6].

Human activity in the environment has the potential to significantly change soils, and these changes set these soils apart from those found in other systems and within the environment. Numerous investigations have evaluated the distinctive physical, biological, and chemical characteristics of soils [6]. Particularly, soil bulk density, soil microbial biomass and activity, and the quantity and quality of soil organic matter have all been investigated and found to be impacted by human activities. Due to the decrease in productivity and changes to the ecological functions of the soil, this degradation implies a change in soil quality [3]. According to [5], land use types have a significant impact on the clay, sand, and silt fractions. Sand and silt decrease with soil depth while clay increases. The soil's pH, total N, organic carbon, available P, exchangeable Ca, exchangeable Al, sum of bases, Effective Cation Exchange Capacity (ECEC), and Al saturation were all significantly influenced by the type and systems of land use. Although Al toxicity was present in the subsoils and increased with soil depth, issues with acidity affected the topsoil. It is well known that when native forest and native rangeland are converted to cultivated agricultural land, the soil properties deteriorate [7]. According to the authors, the main effects include a rise in bulk density, the breakdown of organic matter, and a reduction in Cation Exchange Capacity (CEC), all of which have a negative impact on soil fertility. Further, altering soil characteristics and decreasing yield can be caused by changes in land use, protracted cultivation, deforestation, excessive grazing, and mineral fertilization [8].

In Nigeria [9], where pressures from industrialization and urbanization frequently result in the loss of prime agricultural land and tree cover, land use changes often take place at the edges of dense urban areas. These frequently have a negative impact on the hydrological balance of the region, increasing the risk of floods and landslides as well as air and water pollution, among other things. Other local effects include land pollution, coastal erosion, marine and aquatic pollution of nearby water bodies, extinction of indigenous species, soil erosion, sedimentation, contamination of soil and groundwater, and salinization. Due to the swift increase in the human population, Benin City has seen a sharp rise in soil pollution and the spread of many land use activities. The attendant environmental consequences of most of these unregulated land uses include erosion, flooding, and pollution of water bodies. To ensure proper management of soil resources, there is a need to understand how the soil responds to use and management over time. Information regarding the effects of unauthorized land use on the quality of the soil in Benin City is unfortunately scarce. This study, therefore, becomes imperative as it intends to reveal the impact of land use type on soil properties within Benin City metropolis with the hopes also that the findings will be a base for land use planning by the appropriate authority. The goal of the current study was to ascertain how three different land use types in Benin City, Edo State, affected a few different soil properties.

2. Research methodology

2.1.Study area.

Benin City is in the Mid-Western region of Nigeria and serves as the capital of Edo State. It is situated within Latitudes 6°0’N and 6°26’N, and Longitudes 5°35’E and 5°4’E (Figure 1). Over the past decade, Benin City has undergone significant growth in both population and the structural complexity of its activities. The current population stands at 1,125,058. This population growth is attributed to increased employment opportunities resulting from the establishment of more government departments and the expansion of retail trade. Located in south-south Nigeria, Benin City is situated on a lowland plain that gradually ascends to the Esan Plateau in the north, characterized by very fertile soil suitable for agriculture. The city is underlain by the Benin Formations, sedimentary formations dating back to the Miocene and Pleistocene era. These formations, covering the entire Niger Delta, consist of consolidated sand and sandy clays. The topography is largely uniform, with a surface area gently undulating from about 505 meters in the southeast to about 215 meters in the north, resulting in a mean elevation of about 83 meters above sea level. Benin City experiences a tropical rainforest climate, with annual rainfall ranging from 1900 to 2050 mm and a mean temperature of 26.2°C.

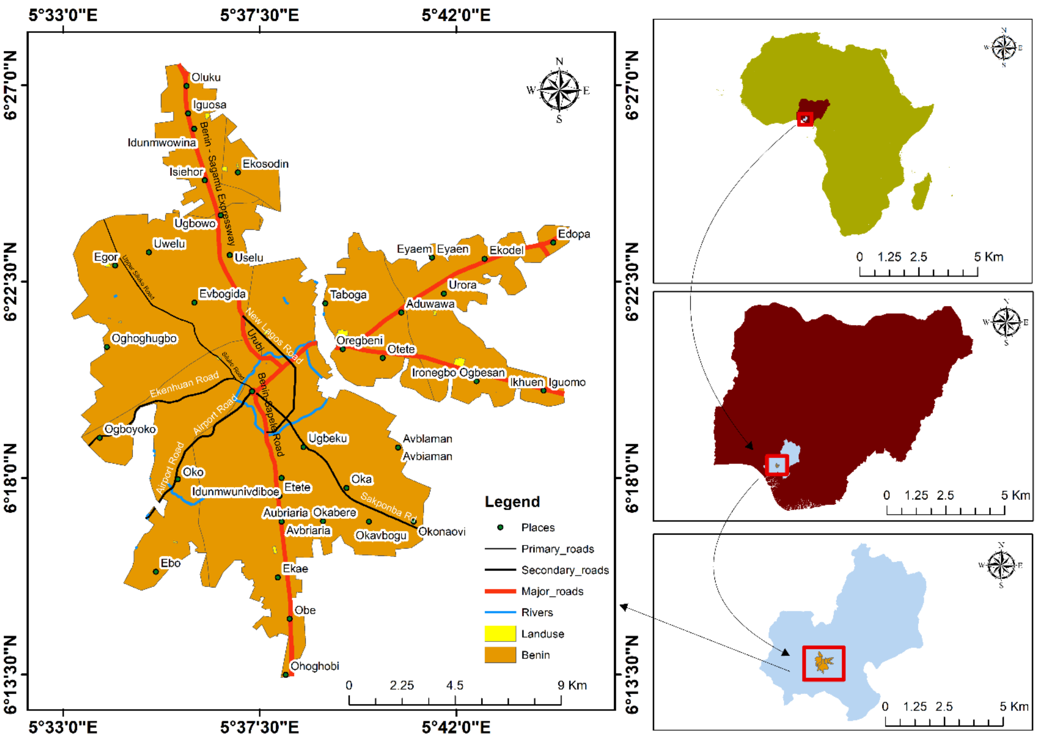

Figure 1. Map of Africa showing the location of Nigeria, Edo State and Benin City.

2.2. Data collection.

Five random soil samples were collected from various locations: a farmland at the Agricultural Science Department, The University of Benin; a mechanic workshop at Uwelu; a dumpsite located at Doctor Quarters behind the University of Benin Teaching Hospital (UBTH); and a residential area located at Ekosodin. The samples were collected using a hand trowel at a depth not exceeding 30 cm. The device was thoroughly cleaned with water after every sample collection before being used for any other collection. Samples were collected monthly for three (3) months (September - November) during the 2011 rainy season, and during the dry season, samples were collected from December to February 2012. The residential area, Ekosodin, is a community of indigenous people and students at the University of Benin. Various land use practices take place in the area, ranging from construction to farming. The farmland is utilized by students of the Faculty of Agriculture at the University of Benin for the cultivation of crops such as cassava and corn. Soil samples were also collected from a waste dump site behind the UBTH, containing both clinical and domestic waste. Additionally, soil samples were collected from a mechanical workshop in a community called Uwelu, known as a spare parts market, consisting mainly of spare parts shops and a few residential buildings. The soils in this area occasionally have petroleum products spilled.

2.3.Soil sampling, preparation, and analyses.

At each sampling site, the land was segmented into four portions, each containing at least two transects. Soils were collected randomly using a soil auger at depths of 0–15 and 15–30 cm, respectively. Two cores were combined into one composite sample in each segment, resulting in five composite samples from each segment. In total, 10 samples, representing 5 topsoils (0–15 cm) and 5 subsoils (15–30 cm), were collected and transported to the laboratory in polyethylene bags. The soils were sieved through a 2 mm mesh stainless sieve in the laboratory after being air-dried for 72 hours at room temperature (22–25°C). 2-mm samples that had been air-dried were stored in polyethylene bags for later analysis. The Nigerian Institute for Oil Palm Research (NIFOR), located in Benin City, conducted the analysis using the 2-mm fractions to determine various soil properties. The pH of the soil was calculated in a 1:2.5 soil-water solution using a pH meter. Exchangeable Ca, Mg, K, and Na were measured using a flame photometer, while Electrical Conductivity (EC) was determined following the methods advised by [8]. Chromic acid oxidation was employed to determine the amount of organic carbon (OC), and a specific M0 to C factor was used to calculate the amount of organic matter (M0), subsequently used to calculate exchangeable acidity. The amount of soil nitrogen was calculated using the Kjeldahl Digestion Method [8, 9], and the amount of readily available phosphorus was determined using the Olsen Method [7, 10].

2.4.Statistical analysis.

A range of parametric statistics was applied to the data obtained from the laboratory analysis. The degree of variation among soil variables and the effects of various land use types on those characteristics were assessed using one-way ANOVA. The Statistical Package for Social Sciences (SPSS) was utilized to determine correlations between the various parameters. The comparison of sample distributions was conducted using the Student t-test with a significance level of 0.05.

3. Results and Discussion

3.1. Seasonal variation results of the pH.

Results of spatial and temporal variations of the studied soil characteristics are illustrated in Figures 2. In Figure 2, it was observed that the mean value of pH level of soils from residential areas had the highest pH reading (4.62 in Dry Season and 7.29 for Rainy Season), followed by soils from the mechanical workshop (4.05 in Dry Season and 6.42 for Rainy Season). Farm soil recorded the lowest reading (3.42 in Dry Season and 5.62 for Rainy Season). In addition, pH levels of soils were higher at 15–30 cm in all the sampling points and seasons when compared to values at 0–15cm. Significant differences between the rainy and dry seasons' pH levels were found at 0.05, d = 0.0001. The soil pH ranges from 0-14, with 7 being neutral. Acidity is indicated by a pH value of less than 7, whereas alkalinity is indicated by a pH value greater than 7. The soil in this area has generally acidic pH levels (the value ranged from 3–5), except for a soil sample from the mechanical workshop. It is crucial to understand that a change of just a few pH units can have a significant impact on the chemical environment and delicate biological processes because the pH scale is expressed in logarithmic units. In the tropical region, soil with a pH of 5 is 10 or 100 times more acidic than soil with a pH of 6 or 7. The geology of the area affects, rainfall pattern leaching, organic matter decay, nitrification of ammonium, and external sources including waste generation such as organic and inorganic waste can all be considered contributing factors to the study area's generally more acidic soil pH levels. Plant growth, chemical, biological, and physical characteristics of the soil are all influenced by its pH. Understanding how acidic soils affect plant growth in terms of both soil pH and harmful elements is crucial for successful revegetation because acidic soils have indirect effects on plant growth, such as the dissolution of harmful elements. For instance, Al, which makes up about 7% of the mass of the Earth, is easily released in water with small pH changes, which prevents plant growth, including root growth. Al, which is typically present in soils as $Al(OH)_3$, dissolves in water as Al^{3+} when the pH is acidic (<4.5) and is released as $Al(OH)_4$ when the pH is alkaline. Al^{3+} readily reacts with phosphoric acid, resulting in the formation of insoluble aluminum phosphate in soils, which depletes plants of phosphorus. The growth of plants is also hampered by other harmful elements like Fe and Mn [11].

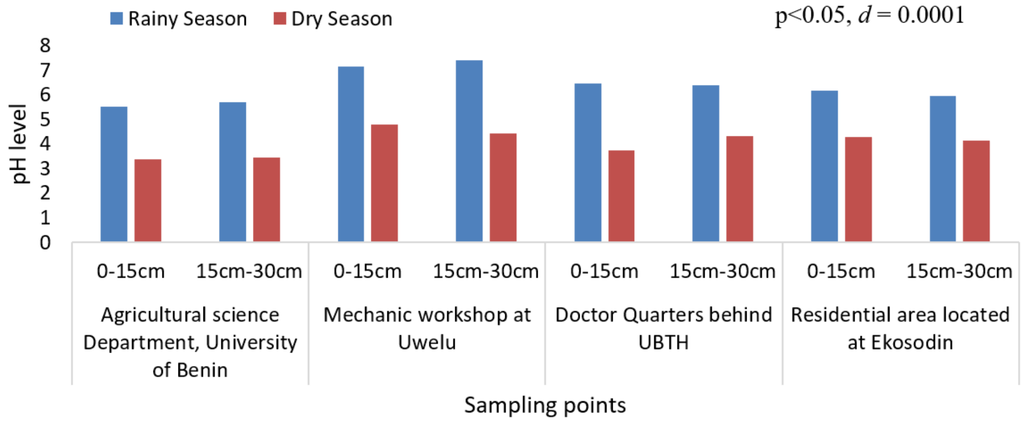

Figure 2. Seasonal variation in soil pH.

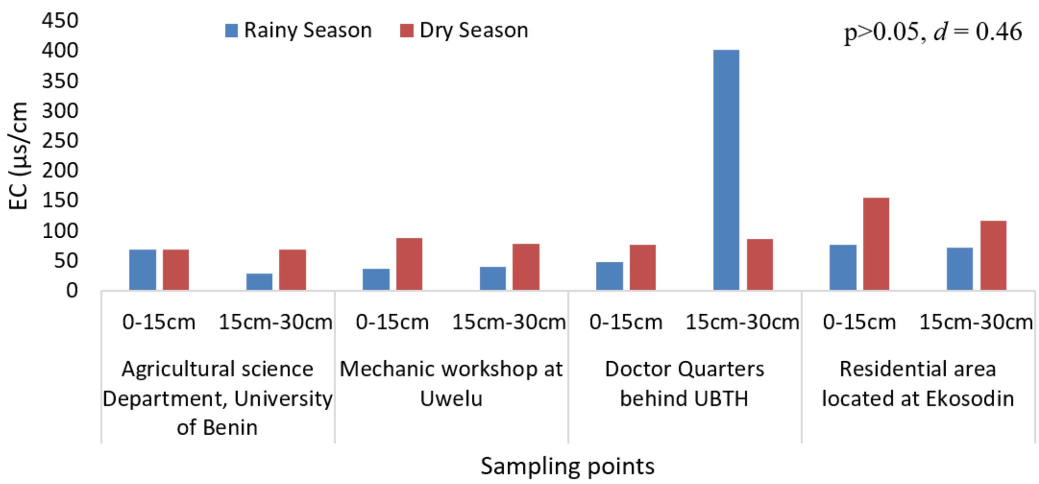

Figure 3. Seasonal variation in Electrical Conductivity (EC).

3.2. Seasonal variation results of the electrical conductivity.

Figure 3 displays the mean electrical conductivity of soils from the four study sites. Soils from the mechanical workshop had the highest reading at the 15–30 cm depth during the rainy season (401.56 µS/cm), while the dumpsite had the highest dry season reading at the 0-15 cm depth (115.92 µS/cm). Low electrical conductivity (EC) values were generally common in the dry season. Statistical differences in seasonal levels of EC were not significant at ρ > 0.05, d = 0.46, although high values of EC were observed in the mechanical workshop soils. This could possibly be attributed to the release of oil and grease, which distorts the soil properties due to reactions with various hydrocarbon compounds in the oil product compared to the other types of land use. Soil EC, also known as salinity or ion concentration, is the electrical conductivity of a solution over a unit distance, indicating the number of soluble salts present in the matrix. The quantity of soluble salt ions in the solution directly impacts the EC value. Irrigation water and fertilizer solutions are the main sources of soluble salt ions. However, excessive fertilizer use can cause the soil to become more salinized [12, 13]. The EC of normal soil should be less than 4 mS/cm [14]. EC levels for the study area were generally high, and this may be attributed to both soil type and agricultural activities in the area. Studies have shown that factors such as temperature, salinity, moisture content, irrigation [15], and soil types [16] impact a soil solution's EC in addition to fertilizer applications. Due to their texture, which can hold a lot of water and result in a high moisture level, clay-rich soils have higher electrical conductivity (EC) values [16]. Reverse osmosis pressure, which replaces the water in the root system and causes the root tip to turn brown or dry, may occur if the soluble salt content (EC value) of the substrate is too high [17]. Root rot brought on by the cotton rot fungus is more likely to occur at very high EC values. If the EC value is too low, it is an indication that some nutrients are not getting enough [18]

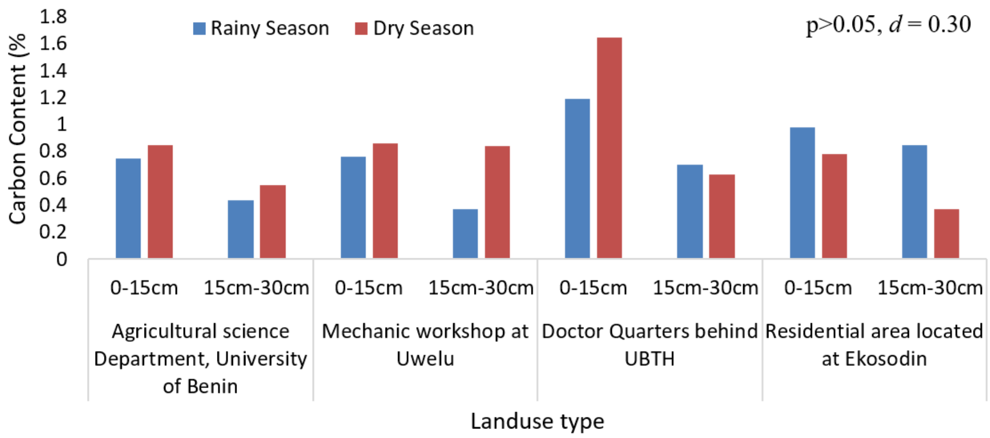

Figure 4. Seasonal variation in organic carbon content.

3.3. Seasonal variation in percentage organic carbon content in the soil.

Figure 4 illustrates the mean percentage of organic carbon in soils from all four sites. Soils from the mechanical workshop had the highest reading at the 0–15 cm depth during the dry season (1.6512%). The percentage of carbon in the residential area was the lowest during the rainy season at the 15–30 cm depth (0.3712%). At the UBTH dump site, carbon content was highest during the rainy season, irrespective of soil depth. At the University of Benin farm, during the dry season, the soil at a depth of 0–15 cm had the highest carbon content. At > 0.05, d = 0.30, statistical differences in seasonal levels of organic carbon content were not significant. Due to years of nutrient mining, the soil organic carbon content in the study area was typically low, as is common in most soils in sub-Saharan Africa's semi-arid tropics [19]. The topsoil usually has the highest concentration of soil organic carbon, ranging from 0.5% to 3.0%. Desert regions are the only places where soils have less than 0.5% organic carbon. Organic soils (histosols) are defined as soils with more organic carbon than 12–18% [20]. The observed levels of soil organic carbon content in the study area are generally low, and this can be attributed to the clay content, precipitation, shallow topsoil, and urbanization activities in the area. [21] have shown that soil structure variability is influenced by the SOC to clay ratio, and this ratio should not be less than 10% for acceptable soil structure variability. Clay content is important due to its effects on SOC protection, such as adsorption on mineral surfaces and within soil aggregates. Soils tend to have a steady-state SOC content when land management techniques are used, as well as organic matter inputs. Decreasing SOC has implications for flood and erosion controls, as well as climate change mitigation. Soil quality is hence largely dependent on topsoil SOC content [22].

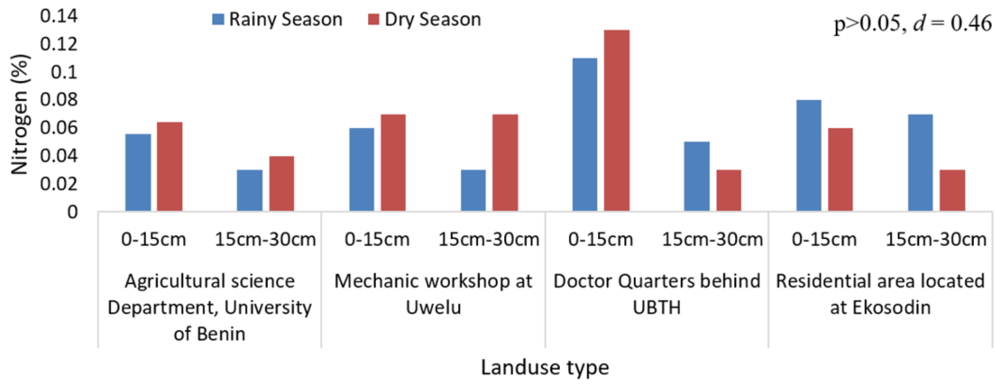

Figure 5. Seasonal variation in soil nitrogen.

3.4. Seasonal variation in nitrogenous content in the soil.

One of the most crucial macronutrients is nitrogen, and factors such as soil pH, moisture content, temperature, land use, and substrate affect how readily available it is. It is a part of proteins, pigments, genetic material, amino acids, and other important organic molecules [23–25]. Many crops experience a significant reduction in plant photosynthesis when soil N levels are low. About 75% of the nitrogen in leaves is found in the chloroplasts, with most of it in the photosynthetic apparatus, there is a strong correlation between leaf nitrogen content and plant photosynthetic capacity. The percentage Nitrogen of soils from all the four sites is represented in Figure 5. Soils from the mechanical workshop had the highest reading at the 0 – 15 cm depth for both the dry and rainy seasons (0.13 and 0.11%, respectively). Percentage nitrogen was lowest at the UBTH dumpsite for the dry season at the 15–30cm depth (0.027%) and the rainy season had the lowest percent Nitrogen reading at the residential area of Ekosodin (0.027%).

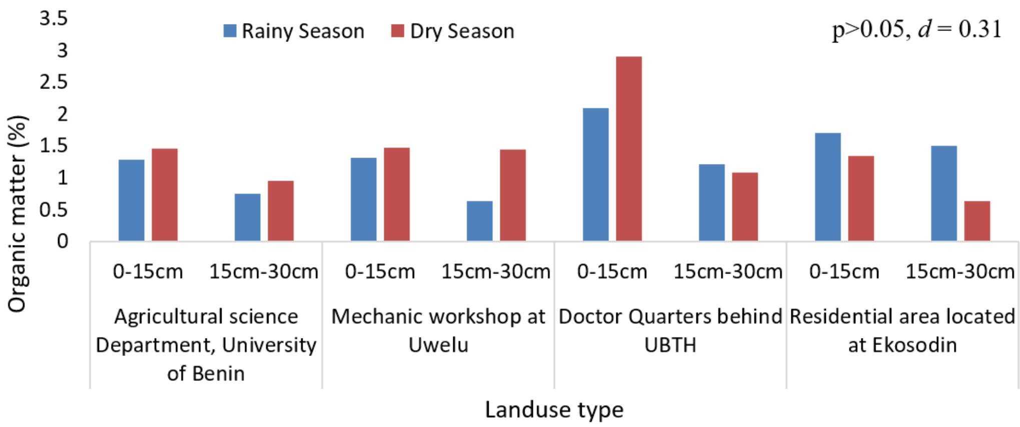

Figure 6. Seasonal variation in soil organic matter.

Residential soils at Ekosodin had a steep topography and this made water erosion a common occurrence and this could have been the main reason as to why there was low soil nitrogen content in the rainy season. Seasonal differences in soil nitrogen levels between the rainy and dry seasons did not show significant differences at $\rho > 0.05$, d = 0.46. The soil nitrogen levels are generally low and range from 1 to 5 %. On average, plant tissues exposed above ground contain around 3-4% nitrogen. Erosion and runoff may probably have led to the low soil nitrogen levels in the study area. Similar studies conducted elsewhere discovered a connection between a lack of nitrogen and surface leaching, soil water content, microbial biomass, and soil fertility status [26, 27].

3.5. Seasonal variation in soil organic matter.

The portion of the soil that is made up of plant or animal tissue that is decomposing is known as soil organic matter. SOM is a key metric for assessing soil quality in the field. SOM plays a crucial role in supplying the soil with resources, such as water or nitrogen, has been primarily blamed for improved crop yield [28]. Most agricultural soils are productive when the organic matter content is between 3 and 6% [29]. The soil organic matter at the mechanical workshop was the highest at the 0–15 cm depth for both dry and rainy seasons (2.86 and 2.06%, respectively) (Figure 6). At the UBTH dumpsite SOM was highest during the rainy season at both the 0–15 and 15–30 cm depths. At the residential area of Ekosodin SOM was highest during the dry season as compared with the rainy season levels. Nevertheless, statistical differences in seasonal levels of SOM were not significant at $\rho > 0.05$, d = 0.31. Organic matter is added to soil via vegetative residue decay. It is quite clear that vegetation cover is absent at the mechanical workshop, and this therefore means that little or no organic matter is added to the soil over time. Apart of soil samples from the University of Benin Teaching hospital, where SOM for the dry season was 2.9%, SOM for the entire study area was low; this can be attributed to urban and agricultural land use activities that lead to enhanced organic carbon oxidation.

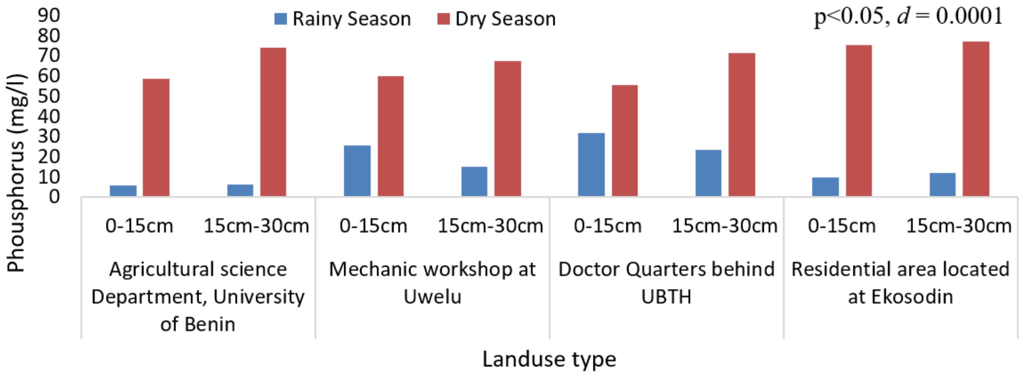

Figure 7. Seasonal variation in available soil phosphorus.

Soil organic matter (SOM) attributes used to describe the various SOM functions include soil organic carbon (SOC) and soil organic nitrogen (SON). Native vegetation, climate, soil types, management techniques, previous land use patterns, and the timing of land conversion all affect SOM dynamics [30]. Changes in land use have an impact on the microbial communities that make up soil ecosystems and how readily available C and N are in the soil. Land use change, particularly in sandy soils, may have an impact on soil moisture and temperature, which ultimately reduces the accumulation of SOC and SON. Numerous studies have demonstrated that changes in land use, including those to crop types, vegetation cover, and agricultural practices, have a significant impact on the accumulation of SOM. According to Ethiopian research, cropland, grazing land, and eucalyptus plantations all had lower SOM stocks than forest soil (0–20 cm) [29, 30]. Additionally, researchers in New Zealand discovered that soil from forests contained more total nitrogen (2.90 g/kg) than soil from pine tree plantations (2.70 g/kg). In the Northeast of Thailand, [31] discovered that forest soils had significantly higher SOM contents than agricultural soils at a depth of 0–15 cm. [32] discovered that upland crop soil had a lower SOM than forest soil. Several studies indicated that SOM accumulation in forest topsoil was influenced by leaf litter decomposition [33]. Another Brazilian study on how land use affects SOM compared soil from a coconut orchard treated with leguminous cover crops, chemical-organic fertilizer application, and mulching to soil from a forest. The coconut soil had higher SOM content in the 0-30 cm depth than the native forest soil [34]. [35] discovered that SOM was higher in the upper soil layer (10–30 cm) from coconut fields than in the lower soil layer (0–10 cm).

3.6. Seasonal variation in phosphorous content.

Phosphorus (P) content was generally higher during the dry season as compared to the rainy season (Figure 7). However, P values were observed to be highest at the UBTH dump site at both 0–15 and 15–30 cm. The lowest values of phosphorus were recorded at the University of Benin Farm. Seasonal differences in phosphorus levels between the rainy and dry seasons revealed significant differences at $\rho < 0.05$, d = 0.0001. Most of the phosphorus in soils is found to be orthophosphate, with total phosphorus concentrations typically ranging from 500 to 800 mg/kg dry soil. In the current study, Phosphorus levels at all the sampled sites were very low; this can be linked to the low SOM and acidic nature of the soils. A sizeable portion of this P is linked to organic matter, number of free oxides of iron and aluminum, soil pH, placement of fertilizer, clay content and soil mineralogy [36]. For example, aluminum and iron oxides and hydroxides in the soil material as well as clay silicates are known to undergo sorption reactions with phosphates. Aluminum and iron oxides are the primary phosphate adsorbents in sandy soils, according to [37]. In acidic soils, P can be primarily absorbed by Al/Fe oxides and hydroxides, such as gibbsite, haematite, and goethite. These properties have been found to be closely correlated. P can first be adsorbed by forming different complexes on the surface of clay minerals and Fe/Al oxides. While the protonated bidentate inner sphere complex predominates in acidic soil conditions, the non-protonated and protonated bidentate surface complexes may coexist at pH 4–9. Large specific surface areas of clay minerals and Fe/Al oxides provide many adsorption sites. As a result, increasing ionic strength can improve soil P adsorption [36]. The most popular sources of organic phosphorus for crops are compost, sewage sludge, and animal manure. The release of P is slow and erratic, and the phosphorus content of organic sources varies. Phosphorus aids in the development of roots in young plants and is crucial for breathing and energy supply.

It plays crucial roles in the metabolism of nitrogen compounds, carbohydrate transportation, carbohydrate metabolism, and fat metabolism in addition to being an essential component of macromolecules like proteins, nucleic acids, the plasma membrane, vitamins, and Adenosine TriPhosphate (ATP). It also has a significant impact on stress resistance, plant dependence on vesicular-arbuscular mycohrrhizal fungal for P uptake, and crop quality and yield. It also plays a significant role in signal transduction and photosynthesis in plants. Due to the loss of P nutrients brought on by high temperatures and heavy rainfall as well as the fixation of P by sesquioxide in the soil, P deficiency has emerged as one of the primary factors limiting crop growth in tropical and subtropical regions [38]. According to [39], their findings revealed that P deficiency significantly reduced the Dry Weight (DW) of lettuce and tomato roots and shoots as well as the number of leaves on Chinese milk vetch, alfalfa, lettuce, tomato, and marigold plants. In rice, sunflower, and maize, a P deficiency significantly decreased the net photosynthesis rate and energy capture efficiency of the PSII reaction center [40]. Additionally, sugar beet, soybean, tobacco, oats, sheep grass, barley, tea, and Zizania latifolia were all found to have lower photosynthesis rates due to phosphorus (P) deficiency [38, 41, 42]. P deficiency affected crop production and grain yield [40, 43]. Short-term P deprivation decreased tomato seedlings' total chlorophyll (Chl), as well as their carotenoid and P concentrations [44].

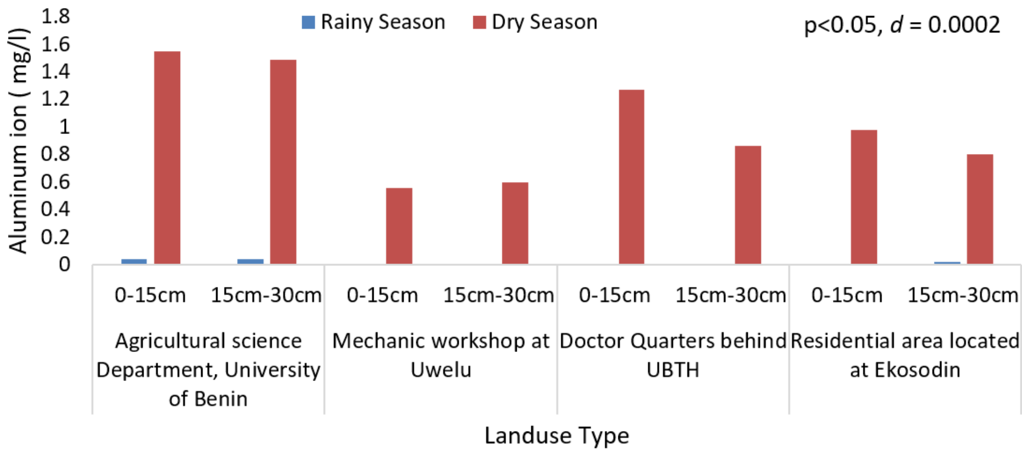

Figure 8. Seasonal Variation in Aluminum ion (Al^{3+}).

3.7. Seasonal variation in aluminum ions.

In Figure 8, there are significant variations in seasonal and spatial patterns of aluminum ions in the four sampled sites. However, it was observed that dry season concentrations were higher at all the sites. At some of the sampled sites, such as the residential, mechanic and UBTH dump sites, aluminum ions were not detected. Statistical differences in seasonal levels of aluminum ions were significant at $\rho < 0.05$, d = 0.0002. Aluminosilicate minerals contain significant amounts of Al ions, but only a very small amount is soluble and capable of affecting plant growth and development [43]. Aluminum concentrations in soils typically range from 1 to 30% (10,000 to 300,000 mg Al/kg). Although aluminum (Al) is not regarded as a necessary nutrient for plants, it can occasionally have positive effects such as accelerating plant growth. However, plants grown in acidic soils all over the world may be constrained in their ability to grow due to aluminum toxicity. Agriculture production is most likely to be restricted by aluminum toxicity in acidic soils (with a pH of 5.5 or lower). The pH of the soil and the chemical environment of the soil solution affect the total Al concentration in the soil as well as the types of Al species [45]. Aluminum-hydroxy cations and $Al(H_2O)_6^{3+}$ (Al^{3+}) are released from aluminosilicate clays and aluminum hydroxide minerals when the pH falls below 5.5 [46]. These cations then exchange with other cations. $Al_3 > Al^{3+} > Al(OH)^{2+} > Al(OH)^{2+} > Al(OH)^{4-}$ [47] is the order in which different Al species have a toxic effect on plant growth. This is the case with the study area especially during the dry season when pH levels are less than 5.0. Since 40–50% of the world's total potential arable land has acidic soils, aluminum (Al) toxicity poses a significant barrier to plant growth and physiology there [48].

There are acid soils (pH 5.5 or lower) all over the world, making up about 30% of the planet's land area. Soil acidification is an organic process that primarily affects tropical and subtropical areas. The rate of soil acidification is being accelerated by several anthropogenic and/or natural inputs [49]. Acidic precipitation (H^+ ions in precipitation), input of acidifying gases or particles (e.g., SO_2 and NO_3), contribution of nitric and hydrochloric acids from the atmosphere, application of elemental sulfur (S), ammonium-based fertilizer (NH^{4+}), nutrient uptake by leguminous crops, and mineralization of organic matter are some of the major causes of soil acidification on agricultural land [50]. Root apices are crucial in the response to Al toxicity because Al can be taken up as Al^{3+} by an active process [46]. Previous study [51] noted that although significant amounts of Al ions efficiently enter the root symplas, they may later affect the cytosolic side of the membrane's growth. Inhibition of root growth in plants is one of the main effects and one of the most obvious symptoms of Al toxicity [52]. Excess Al promotes the growth of swollen root apices and inhibits root cell division and elongation as well as the formation of root hair. Al ion toxicity levels prevent plants from absorbing water and nutrients [49]. According to several studies, toxic Al^{3+} ions affect the levels of nutrients like N, K, Ca, Mg, and P as well as the rate of photosynthetic rate (PN), stomatal conductance (gs), and leaf transpiration (E) in plants. Al has also been linked to other phytotoxic effects in various cellular organelles, including the inhibition of mitochondrial respiration and the disruption of free cytosolic Ca^{2+} callose deposition at plasmodesmata.

3.8. Seasonal variation in cation exchange capacity.

In Figure 9, Cation Exchange Capacity at the four sampled sites showed general increase during the dry season, except at Ekosodin at the 0–15 cm depth and mechanical workshop at 0–15 cm depth, reaching a peak at the University of Benin farm at 0-15 cm depth. Significant seasonal changes in the CEC of the study area's soils at 0.05, d = 0.019. The cation Exchange Capacity is influenced by the pH level, and according to [52], a higher concentration of H^+ (lower pH) neutralizes the negative charge on colloids, resulting in a lower CEC. [28] also found that the organic carbon content has a significant impact on CEC.

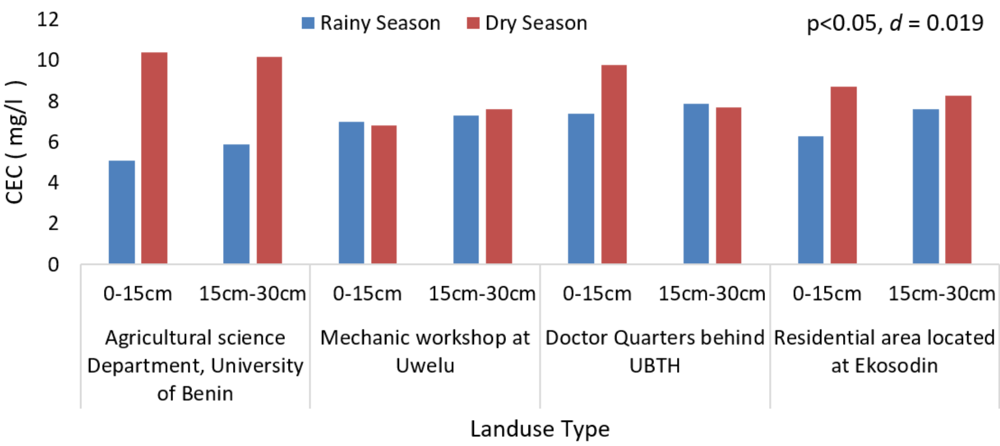

Figure 9. Seasonal variations in Cation Exchange Capacity (CEC).

To understand the relationships that exist among soil characteristics, the Pearson product moment statistics was used, and results presented in Table 1. From the table, positive relationship was observed between pH and C, OM, P and CEC. This means that any increase in pH of soil was matched with corresponding increase in values of C, OM P and CEC. Negative relation on the other hand was observed between pH and EC, Mg, Al^{3+}, which suggest that any increase in pH was matched with corresponding decrease in EC, mg, Al^{3+}.

Positive relationship was recorded between EC, N, Na and ECEC while the relationship was negative between EC, C and OM. The only parameters that correlated well with C are OM and CEC. N corrected very well with P, Ca, mg while negative with OM, K and Al^{3+}. OM and ECEC corrected positive with correction coefficient of 0.79. P corrected positively with Ca, Na, the relationship was however negative with H^+ and Al^{3+}. Ca only corrected positively with Na, while there was no positive relationship between mg and other soil variables. There was a strong relationship between Na and K as well as between H^+, CEC and Al^{3+}. Farming in the study area had both positive and negative effects in the study area, this is because of the different practices and techniques adopted. Biodiversity, soil pH, Nutrient depletion, soil organic maters were all affected by farming. Some of the waste disposal sites where proper management structures were not in place soil notable effects seen includes soil pollution, nutrient imbalance, and propensity for leachate contamination of groundwater leading to groundwater poisoning. Mechanic workshops at the locations had poor waste materials handling/management techniques especially disposal of spent oil and condemned vehicular parts. Soil pH and microbial imbalance, habitat disruption and hazardous materials were highest at these locations.

Table 1. Inter-correlation between soil physico-chemical variables.

	pH	EC	C	N	OM	P	Ca	Mg	Na	K	Al_3+
pH	1										
EC	-0.16	1									
C	0.85	-0.63	1								
N	0.26	0.853	-0.18	1							
OM	0.89	-0.56	0.99	-0.089	1						
P	0.56	0.72	0.056	0.87	0.13	1					
Ca	0.82	0.40	0.41	0.67	0.47	0.92	1				
mg	-0.017	0.36	-0.073	0.62	-0.01	0.18	0.05	1			
Na	0.18	0.59	-0.26	0.38	-0.24	0.70	0.60	-0.47	1		
K	0.19	0.17	-0.066	-0.060	-0.08	0.38	0.41	-0.82	0.89	1	
Al3+	-0.95	0.063	-0.73	-0.25	-0.76	-0.64	-0.88	0.24	-0.44	-0.47	1

4. Conclusion and recommendations

The soil system (soil ecosystem) supports and performs several environmental services and functions. However, the use to which soil resources are put is currently under threat from anthropogenic practices. The main factor deteriorating soil quality is human activity. Soil quality is impacted by both large and small industrial operations, agriculture, mine waste discharges, and intentional and unintentional pollution incidents. This study looked at the effects of various land use types on a few selected soil characteristics. The findings demonstrated that the studied land use types significantly influenced the general soil characteristics. The soil from the mechanical workshop and the neighborhood of Ekosodin suffered the most damage. Planning for land use and soil conservation must address the observed impacts. However, farming practices like cover cropping, crop rotation, organic matter incorporation, reduced tillage, and precision agricultural techniques can help reduce environmental risks. Proper waste disposal management, including recycling, composting, and responsible disposal of hazardous materials, is essential. Regulation and enforcement, as well as sustainable waste management, should be prioritized. Responsible practices, including hazardous waste management, implementing eco-friendly practices, and routine monitoring, should be adopted to prevent further negative impacts.

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Competing Interest

There are no competing interest in this work.

References

[1] Hu, K.L.; Li, H.; Li, B.G.; Huang, Y.F. (2007). Spatial patterns of soil heavy mental in urban-rural transition zone of Beiging. *Geoderma*, *141*, 302–310. https://doi.org/10.1016/S1002-0160(06)60104-5.

[2] Hu, X.F.; Wu, H.X.; Hu, X.; Fang, S.Q.; Wu, C.J. (2004). Impact of urbanization on Shanghai's soil environmental quality. *Pedosphere, 14,* 151–158.

[3] Pan, X.Z.; Zhao, Q.G. (2007). Measurement of urbanization process and the paddy soil loss in Yixing City, China between 1949 and 2000. *Catena, 69,* 65–73. https://doi.org/10.1016/j.catena.2006.04.016.

[4] Cao, W.Z.; Zhu, H.J.; Chen, S.L. (2007): Impacts of urbanization on topsoil nutrient balances–a case study at a provincial scale from Fujian, China. *Catena, 69,* 36–43. https://doi.org/10.1016/j.catena.2006.04.014.

[5] Agoume, V.; Birang, A.M. (2009). Impact of Land Use Systems on some Physical and Chemical Soil Properties of an Oxisol in the Humid Forest Zone of Southern Cameroon. *Tropicultura, 27,* 15–20.

[6] Heluf, G.; Wakene, N. (2006). Impact of land use and management practice on chemical properties of some soils of Bako area, Western Ethiopia. *Ethiopian Journal of Natural Resources 8*. 177–197.

[7] Mulugeta, L.; Karltun, E.; Olsson, M. (2005). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, Ecosystems and Environment, 105,* 373–386. https://doi.org/10.1016/j.agee.2004.01.046.

[8] Conant, R.T.; Six, J.; Paustian, K. (2003). Land use effects on soil carbon fractions in the Southeastern United States: Management incentive versus extensive grazing. *Biology and Fertility of Soils, 38*, 386–392. http://doi.org/10.1007/s00374-003-0652-z.

[9] Awoniran, D.R.; Adewole, M.B.; Salami, A.T. (2011). Wetland Conversion and Fragmentation Pattern with its Impacts on Soil in the Lower Ogun River Basin. *Ife Research Publication in Geography, 10,* 125–133.

[10] Mathieu, C.; Pieltain, F. (2003): Chemical Analysis of Soils: Selected Methods in French Agence de Coop´eration Culturelle et Technique, Paris, France.

[11] Matsumoto, S.; Shimada, H.; Sasaoka, T.; Miyajima, I.; Kusuma, G.J.; Gautama, R.S. (2017). Effects of Acid Soils on Plant Growth and Successful Revegetation in the Case of Mine Site. In Soil pH for Nutrient Availability and Crop Performance; Oshunsaya, S., Ed.; IntechOpen. https://doi.org/10.5772/intechopen.70928.

[12] Mirzakhaninafchi, H.; Mishra, I.M.; Mirzakhani, A.N. (2017). Study on Soil Nitrogen and Electrical Conductivity Relationship for Site-Specific Nitrogen Application. 2017 Spokane, Washington, pp. 56–61. http://doi.org/10.13031/aim.201700892.

[13] Che Othaman1, N.N.; Md Isa1, M.N.; Ismail I.R.C.; Ahmad, M.I.; Hui, C.K. (2020). Factors That Affect Soil Electrical Conductivity (EC) Based System for Smart Farming Application. *AIP Conference Proceedings, 2203*, 020055. https://doi.org/10.1063/1.5142147.

[14] Abegunrin, T.P.I.; Awe, G.O.; Idowu, D.O.; Onigbogi, O.O.; Onofua, O.E (2013). Effect of kitchen wastewater irrigation on soil properties and growth of cucumber (*Cucumis sativus*) *Journal of Soil Science and Environmental Management*, *4*, 139–145, https://doi.org/10.5897/JSSEM2013.0412.
[15] Visconti, F.; de Paz, J.M. (2016). Electrical Conductivity Measurements in Agriculture: The Assessment of Soil Salinity. Oxford Publishers: Oxford, UK, pp. 94–101.
[16] Hawkins, E.; Fulton, J.; Port, K. (2017): Using Soil Electrical Conductivity (EC) to Delineate Field Variation, Oxford Publishers, 22, 1–7.
[17] Signore, A.; Serio, F.; Santamaria, P. (2016). A targeted management of the nutrient solution in a soilless tomato crop according to plant needs. *Frontier in Plant Science*, *7*, 391–397. https://doi.org/10.3389/fpls.2016.00391.
[18] Ding, X.; Jiang, Y.; Zhao, H.; Guo, D.; He, L.; Liu, F.; Zhou, Q.; Nandwani, D.; Hui, D.; Yu, J. (2018): Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. Chinensis) in a hydroponic system. *PloS one*, *13,* 8–12. https://doi.org/10.1371/journal.pone.0202090.
[19] Abdulkadir, A.; Mohammed, I.; Daudu, C.K. (2021). Organic Carbon in Tropical Soils: Current Trends and Potential for Carbon Sequestration in Nigerian Cropping Systems. In Handbook of Climate Change Management; Luetz, J.M., Ayal, D., Eds.; Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-030-57281-5_307.
[20] Panagos, P.; Ballabio, C.; Yigini, Y.; Dunbar, M.B. (2013). Estimating the soil organic carbon content for European NUTS2 regions based on LUCAS data collection. *Science of the Total Environment*, *442*, 235–246. https://doi.org/10.1016/j.scitotenv.2012.10.017.
[21] Courtney, M.; Christopher, B.C. (2022). Wetland Soils: Physical and Chemical Properties and Biogeochemical Processes. In Encyclopedia of Inland Waters, 2nd Ed.; Mehner, T., Tockner, K.; Elsevier. 157–168, https://doi.org/10.1016/B978-0-12-819166-8.00049-9.
[22] Bünemann, E.K.; Bongiorno, G.; Bai, Z.; Creamer, R.E.; De Deyn, G.; de Goede, R. (2018). Soil quality - a critical review. *Soil Biology and Biochemistry*, *120*, 105–125. https://doi.org/10.1016/j.soilbio.2018.01.030.
[23] Chen, L.H.; Dong, T.F.; Duan, B.L. (2014): Sex-specific carbon and nitrogen partitioning under N deposition in *Populus cathayana*. *Trees*, *28*, 793–806. https://doi.org/10.1007/s00468-014-0992-3.
[24] Ji, D. H.; Mao, Q. Z.; Watanabe, Y.; Kitao, M.; Kitaoka, S. (2015). Effect of nitrogen loading on the growth and photosynthetic responses of Japanese larch seedlings grown under different light regimes. *Journal of Agricultural Meteorology, 71*, 232–238. https://doi.org/10.2480/agrmet.D-14-00027.
[25] Liu, N.; Wang, J.; Guo Q.; Wu, S.; Rao, X.; Cai, X.; Lin, X. (2018). Alterations in leaf nitrogen metabolism indicated the structural changes of subtropical forest by canopy addition of nitrogen. *Ecotoxiclogy and Environmental Safety*, *160,* 134–143. https://doi.org/10.1016/j.ecoenv.2018.05.037.
[26] Carswell, A.M.; Hill, P.W.; Jones, D.L. (2018): Impact of microbial activity on the leaching of soluble N forms in soil. *Biology and Fertility of Soils, 54,* 21–25. https://doi.org/10.1007/s00374-017-1250-9.
[27] Cheng, Y.; Li, P.; Xu, G.; Wang, X.; Li, Z.; Cheng, S.; Huang, M. (2021) Effects of dynamic factors of erosion on soil nitrogen and phosphorus loss under freeze-thaw conditions. *Geoderma, 390*, 114–972, https://doi.org/10.1016/j.geoderma.2021.114972.
[28] Lal, R. (2020). Soil organic matter content and crop yield. *Journal of Soil and Water Conservation, 75*, 27–32. https://doi.org/10.2489/jswc.75.2.27A.
[29] Assefa, D.; Rewald, B.; Sandén, H. (2017). Deforestation and land use strongly effect soil organic carbon and nitrogen stock in Northwest Ethiopia. *Catena 153,* 89–99. https://doi.org/10.1016/j.catena.2017.02.003.

[30] Kassa, H.; Dondeyne, S.; Poesen, J.; Frankl, A.; Nyssen, J. (2017). Impact of deforestation on soil fertility, soil carbon and nitrogen stocks: the case of the Gacheb catchment in the White Nile Basin, Ethiopia. *Agriculture, Ecosystems & Environment*, *247*, 273–282. https://doi.org/10.1016/j.agee.2017.06.034.
[31] Kunlanit, B.; Butnan, S.; Vityakon, P. (2019). Land-use changes influencing C sequestration and quality in topsoil and subsoil. *Agronomy*, 9, 520–616. https://doi.org/10.3390/agronomy9090520.
[32] Wang, T.; Kang, F.; Cheng, X.; Han, H.; Ji, W. (2016). Soil organic carbon and total nitrogen stocks under different land uses in a hilly ecological restoration area of North China. *Soil and Tillage Research*, *163*, 176–184. https://doi.org/10.1016/j.still.2016.05.015.
[33] Kundu, M.C.; Das, T.; Biswas, P.K. (2017). Effect of different land uses on soil organic carbon in new alluvial belt of West Bengal. *International Journal of Bioresource, Environment and Agricultural Sciences*, *3*, 517–520.
[34] Guimarães, D.V.; Gonzaga, M.I.S.; da Silva, T.O.; Da Silva, T.L.; Da Silva, N., Dias; Matias, M.I.S. (2013). Soil organic matter pools and carbon fractions in soil under different land uses. *Soil and Tillage Research*, *126*, 177–182. https://doi.org/10.1016/j.still.2012.07.010.
[35] Bojórquez-Quintal, E.; Escalante-Magaña, C.; Echevarría-Machado, I.; Martínez-Estévez, M. (2017). Aluminum, a friend, or foe of higher plants in acid soils. *Frontier Plant Science*, *8*, 17–67. doi: https://doi.org/10.3389/fpls.2017.01767.
[36] Asomaning, S.K. (2020). Processes and Factors Affecting Phosphorus Sorption in Soils. In Sorption; Kyzas, G., Lazaridis, N. Eds.; Intech Open. https://doi.org/10.5772/intechopen.90719.
[37] Borggaard, O.K.; Szilas, C.; Gimsing, A.L.; Rasmussen, L.H. (2004): Estimation of soil phosphate adsorption capacity by means of a pedotransfer function. *Geoderma. 118*, 55–61. https://doi.org/10.1016/S0016-7061(03)00183-6.
[38] Long, L.; Ma, X.; Ye, L. (2019). Root plasticity and Pi recycling within plants contribute to low-P tolerance in Tibetan wild barley. *BMC Plant Biology*, *19*, 244–340, https://doi.org/10.1186/s12870-019-1949-x.
[39] Yoneyama, K.; Xie, X.; Kim, H.I. (2012). How do nitrogen and phosphorus deficiencies affect strigolactone production and exudation? *Planta*, *235*, 1197–1207. https://doi.org/10.1007/s00425-011-1568-8.
[40] Zhang, W.; Chen, X. X.; Liu, Y. M.; Liu, D. Y.; Du, Y. F.; Chen, X. P.; Zou, C. Q. (2018). The role of phosphorus supply in maximizing the leaf area, photosynthetic rate, coordinated to grain yield of summer maize. *Field Crops Research*, *219*, 113–119. https://doi.org/10.1016/j.fcr.2018.01.031.
[41] Yan, N.; Zhang, Y.L.; Xue, H.M.; Zhang, X.H.; Wang, Z.D.; Shi, L.Y.; Guo, D.P. ((2015). Changes in plant growth and photosynthetic performance of Zizania latifolia exposed to different phosphorus concentrations under hydroponic condition. *Photosynthetica*, *53*, 630–635. http://doi.org/10.1007/s11099-015-0149-7.
[42] Li, L.; Yang, H.; Peng, L.; Ren, W.; Gong, J.; Liu, P.; Wu, X.; Huang, F. (2019). Comparative Study Reveals Insights of Sheepgrass (*Leymus chinensis*) Coping with Phosphate-Deprived Stress Condition. *Frontier in Plant Science*, *10*, 111–170. https://doi.org/10.3389/fpls.2019.00170.
[43] Veronica, N.; Subrahmanyam, D.; Vishnu Kiran, T.; Yugandhar, P.; Bhadana, V.P.; Padma, V. (2017). Influence of low phosphorus concentration on leaf photosynthetic characteristics and antioxidant response of rice genotypes. *Photosynthetica*, *55*, 285–293. http://doi.org/10.1007/s10535-016-0640-4.
[44] Muneer, S.; Jeong, B.R. (2015). Proteomic analysis provides new insights in phosphorus homeostasis subjected to Pi (inorganic phosphate) starvation in tomato plants (*Solanum lycopersicum* L.). *PLoS One*, *10*, e0134103. https://doi.org/10.1371/journal.pone.0134103.
[45] Kisnieriene, V.; Lapeikaite, I. (2015). When chemistry meets biology: the case of aluminum- a review. *Chemija*, *26*,148–158.

[46] Grevenstuk, T.; Romano, A. (2013). Aluminium speciation and internal detoxification mechanisms in plants: Where do we stand? *Metallomics*, *5*, 1584–1594. https://doi.org/10.1039/c3mt00232b.

[47] Singh, S.; Tripathi, D.K.; Singh, S.; Sharma, S.; Dubey, N.K.; Chauhan, D.K.; Vaculík, M. (2017). Toxicity of aluminum on various levels of plant cells and organism: A review. *Environmental and Experimental Botany*,137, 177–193. https://doi.org/10.1016/j.envexpbot.2017.01.005.

[48] Kochian, L.V.; Piñeros, M.A.; Liu, J.; Magalhaes, J.V. (2015). Plant adaptation to aid soils: The molecular basis for crop aluminum resistance. *Annual Review in Plant Biology*, *66*, 571–598. https://doi.org/10.1146/annurev-arplant-043014-114822.

[49] Bojórquez-Quintal, E.; Escalante-Magaña, C.; Echevarría-Machado, I.; Martínez-Estévez, M. (2017). Aluminum, a friend or foe of higher plants in acid soils. *Frontier in Plant Science*, *8*, 1767. https://doi.org/10.3389/fpls.2017.01767.

[50] Dashuan, T.; Shuli, N. (2015): A global analysis of soil acidification caused by nitrogen addition. *Environmental Reseach Letter*, *10*, 20–49, https://doi.org/10.1088/1748-9326/10/2/024019.

[51] Ovie1, S.; Obande, A. O.; Ataga, E. (2013). Effects of Land Uses on the Properties of Soils formed on Makurdi Sandstones in North Central, Nigeria. Mindex Publishers: Benin, Nigeria, pp. 3–9.

[52] Frankowski, M. (2016): Aluminum uptake and migration from the soil compartment into *Betula pendula* for two different environments: A polluted and environmentally protected area of Poland. *Environmental Science and Pollution Research Internation*, *23*, 1398–1407. https://doi.org/10.1007/s11356-015-5367-9.