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Analysis of Soil pH and Organic Matter in Central and Southern Zones of Plateau State

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Abstract:- This study assessed soil pH and organic matter in central and southern zones of Plateau state. Stratified random sampling method was adopted for collecting the soil samples, and a total of 736 samples covering the total area were collected. The physico-chemical characteristics of the soil samples were analyzed at the laboratory of the Centre for Dry Land Agriculture (CDA) located within Bayero University Kano (BUK) in Nigeria. The soil pH and organic matter values for the collected soil samples were determined by Potentiometric 1:2 pH-m and Walkely and Black methods respectively. The values of the parameters were entered in attribute table and linked with the ArcGIS 10.8 to develop a relational database. The investigation involved employing the Inverse Distance Weighting (IDW) interpolation method to create a spatial representation of soil pH and organic matter distribution. The study maps revealed that a significant percentage (87.7%) of the study area fall within 5.5 and 6.5 pH levels while organic matter which is heterogeneously distributed has 51.1% of the total area showing a very low and moderate variability of OM which indicated that the trend of the spatial distribution of the soil pH and organic matter are not common. The investigation also involved conducting Pearson's product moment correlation analysis between soil pH and organic matter across multiple soil sample locations, utilizing SPSS version 25, a statistical software package. The result obtained for the correlation co-efficient γ is –0.071 and the p-value is 0.055 using 0.01 level of significance showed that; the association or relationship between soil pH and organic matter is weak, since 0.071 is less than 0.3, they have a negative relationship, which means that they move in an opposite direction, and that an increase in soil organic matter leads to a decrease in soil pH and vice versa; the association between the two variables (soil pH and organic matter) is insignificant, since the p-value 0.055 is greater than the level of significance + 0.01. The study recommends that farmers should be discouraged

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from the slash and burn practice which does not allow for the decomposition of organic material to enhance the organic matter content of the soil.

Keywords:- *Soil pH; Organic Matter; Correlation; Spatial Analysis.*

I. INTRODUCTION

Soil is the topmost layer of the earth crust. It is very important to man for habitation, food production and other uses. A good knowledge of the soil, serves as a parameter for determining its current and potential and the uses. The soil has so many properties, which are either physical or chemical. Soil pH, which is the potential hydrogen or degree of alkalinity or acidity of the soil influences the solubility, nutrients availability, and performance of pesticide (including herbicide) and the decomposition of organic matter (McCauley et al, 2009). Soil pH also affects significantly a number of other soil properties. However, extremes in acidity or alkalinity usually change the nutrients available in the soil and result in the imbalances of elements in plants (Zhao et al, 2011). Several investigations have been conducted to explore how soil pH influences the absorption of nutrients by plants, as documented by (Farringetal in 2019, Neina in 2019, and Ghimire et al. in 2017).

The organic matter of the soil is defined as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances (Brady and Weil, 1999). The intricate composition of soil organic matter (SOM) typically exerts an impact on various soil characteristics and the process of nutrient cycling (Loveland and Webb, 2003). In soils, most organic matter originates from plant tissue, with residues containing 60-90 percent moisture. The dry matter of the residue consists of carbon, oxygen, hydrogen and small amounts of sulphur, nitrogen, phosphorus, potassium, calcium and magnesium (FAO,2023). With the derivation of organic matter from decayed and decomposed living matter, it contains all the essential plants nutrients. The presence of more organic matter serves as a reserve for plant nutrients

The research findings have shown that pH levels have a direct influence on the rate of microbial decomposition, as demonstrated in controlled laboratory investigations (Andersson and Nilsson, 2001). Moreover, a recent study conducted in China has established a correlation between soil organic carbon (SOC) augmentation in agricultural fields and the process of acidification (Zhang et al., 2020).

Soil pH and organic matter as essential physical properties of the soil which relates to nutrients availability in the soil and affects plants nutrients uptake. Against this backdrop, this research paper aims to investigate how soil pH and the presence of organic matter impact agricultural productivity in various regions of Plateau

II. STUDY AREA

The central and southern zone of plateau state comprises of eleven (11) local government areas namely; Bokkos, Kanam, Kanke, Langtang South, Langtang North, Mangu, Mikang, Quan'pan, Shendam and Wase. The study area has a total land area of twenty thousand four hundred and eleven kilometer square (20,411km^2), and total population of one million, nine hundred and eight thousand, one hundred and seventy nine (1,908,179) by the 2006 census (Wikipedia). The geographical location of the central and southern plateau ranges from 8^{o}21'50.885'' to 9^{o}46'24.955''N and 8^{o}38'23.358'' to 10^{o}38'28.662''E.

The climate is marked by rainy and dry seasons with a temperature range of 17^o C to 38^o C and annual rainfall of about 1,500mm (NIMET, 2018). The average annual rainfall is above 1324mm. Annual average humidity rises above 80%. The humidity is highest around July and August at above 85% and then usually drops to about 60% in January. The area has a hot and humid climate and has two distinct seasons (April to October) and much colder during the harmattan (December to February) (Adesikuteb et al, 2020).

However, the elevated region within the specified zone, characterized by its greater altitude, results in a climate that closely resembles a temperate one, boasting an average temperature range of 17 to 22 degrees Celsius. The annual precipitation averages range from 131.75 centimeters (52 inches) in the southern sector to 146 centimeters (57 inches) on the plateau. The peak of rainfall occurs during the wet season, primarily in the months of July and August (Plateau, 2021).

The geological composition of the Jos Plateau primarily consists of the Precambrian Basement complex, which comprises migmatite, gneiss, and quartzite. This complex underlies approximately half of the entire region and has, in certain areas, experienced intrusion by various rock types ranging from Precambrian to late Paleozoic Pan-African granite (referred to as Older Granite), diorite, and charnockite. Additionally, the Jurassic anorogenic alkali Younger Granites have intruded into these Basement Complex rocks. Accompanying the Younger Granites are volcanic rocks like basalts and rhyolites, which either overlay or cut across this geological formation, including both the Basement rocks and the Younger Granites (Mallo & Wazoh, 2017, as cited in Macleod et al., 1971). The migmatite gneiss which forms the lower plains, underlies the entire area, while the granite gneiss rhyolite and the biotite granite, forms the higher grounds, reaching heights of about 600 to 800 meters above sea level (Dibal et al, 2008).

Soils in the central and southern zone of plateau state are not homogenous in nature. Soil characteristics exhibit variations in both space and time, as documented by (Sokouti and Mahdian in 2011). These variations are indicative of systematic alterations influenced by geological features and associated landforms, as discussed by (Burke in 2002), as well as the composition of soil parent materials, as studied by (Koojman et al. in 2005), and the impact of soil management

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practices, such as land use, as explored by (Amusan et al. in 2006). In line with this, (Markus et al., 2008) observed that soils originating from basaltic rock formations in tropical and sub-tropical climates predominantly contain kaolonites and sesquioxides as their primary clay constituents. These soils are categorized under different soil taxonomy groups, including Oxisols, Ultisols, and Alfisols. The major soil types of the southern zone of plateau state belong to broad category of tropical ferruginous soils which attain greater depths in the area. There are also sizeable pockets of clay soils and sandy-loam soils in this zone (Investing guide, 2020).

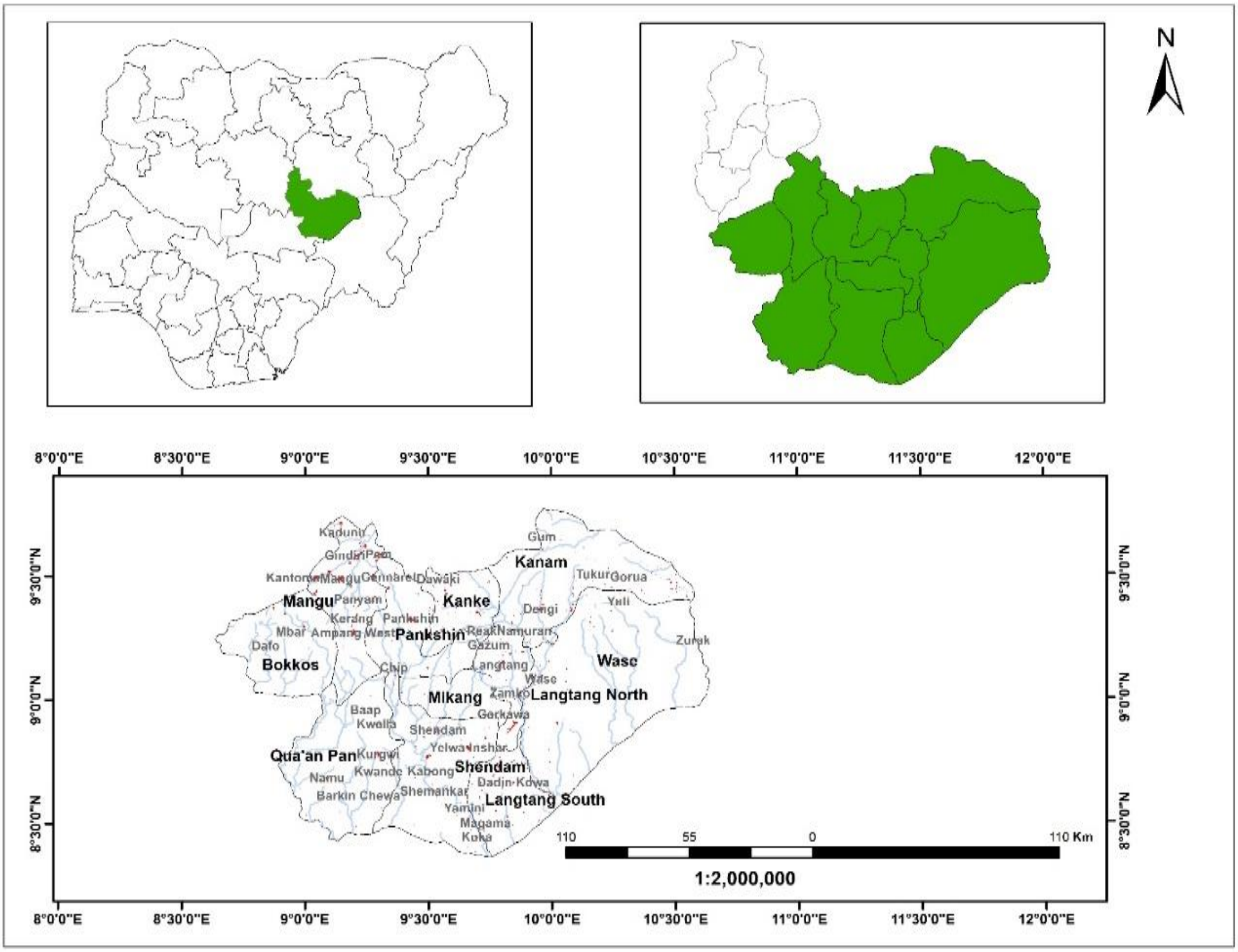

Fig 1 Map of the Study Area

III. MATERIALS AND METHODS

The materials used are GPS, geological maps, desktop, ArcGIS 10.8 software, polythene bag, plastic bucket, masking tape, marker and auger. The research work is segmented into field work and data collection, and laboratory analysis of soil samples for pH and organic matter. The field work was conducted for a period of 4 weeks which spanned from 3rd April 2022 to 4th May, 2022; The soil samples were collected from selected farm locations using soil sampling auger at depths of 0–30cm. The samples collected were mixed thoroughly inside a plastic rubber to have one soil composite. The stratified random sampling method was adopted for the soil sampling based on the variation of the soils in the study region. A total of 738 soil samples were collected using auger, hand trowel. GPS points of the soil samples were obtained using a handheld GARMIN GPSMAP 78s receiver. The soil samples were analyzed for their physicochemical properties. Also, spatial analysis (IDW) method was employed to ascertain the variation of the soil properties (pH, texture). The laboratory analysis of the soil samples was conducted at Centre for Dry Land Agriculture, Bayero University, Kano, Nigeria. Total soil organic carbon (total C) was measured using a modified Walkley & Black chromic acid wet chemical oxidation and spectrophotometric method (Heanes, 1984). Total nitrogen (total N) was determined using a micro-Kjeldahl digestion method (Dane & Topp, 2020). Soil pH in water (S/W ratio of 1:1) was measured using a glass electrode pH meter and the particle size distribution following the hydrometer method (Bremner & Mulvaney, 1983). Available phosphorus (avail. P), exchangeable cations (K, Ca, Mg and Na) and micronutrients (Zn, Fe, Cu, Mn, and B) were analyzed based on the Mehlich-3 extraction procedure preceding inductively coupled plasma optical emission spectroscopy (MP-AES, 4200, Agilent Inc., Waltham, MA, USA). Exchangeable acidity (H + Al) was determined by extracting the soil with 1N KCl and titration of the supernatant with 0.5M NaOH (Robinson, 1994). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable cations (K, Ca, Mg and Na) and exchangeable acidity (H + Al).

The data were organized and prepared in an excel worksheet and subsequently saved in the "CSV" format. To facilitate further spatial analysis, the data was imported into the ArcGIS 10.8 software for conversion into a shapefile format. This transformation allowed for more comprehensive and in-depth spatial analysis to be performed on the data. The main technique employed for spatial analysis was the Inverse Distance Weighted (IDW) interpolation extension in the Spatial Analyst tool of ArcGIS. This interpolation method is valuable for estimating values at unmeasured locations based on a set of known data points.

To build a relational database, the soil parameter values were imputed into the attribute table of the ArcGIS 10.8 software and linked accordingly. This database facilitated a comprehensive analysis of the spatial distribution of the physicochemical properties under investigation. The Inverse Distance Weighting interpolation method was particularly employed to delineate the spatial variation of the soil parameters across the study area. This approach allowed us to generate thematic maps representing the distribution of the chosen soil parameters. The point data obtained from the field were interpolated using the IDW technique. The different soil parameters tested as well as methods adopted are as shown below.

Table 1 Parameters and Methods Adopted for the Laboratory Analysis

S/N	Parameters	Methods
1	Soil pH	Potentiometric 1:2 (Jackson, 1973) pH-meter
2	Organic Matter	Walkely and Black, (Walkely and Black, 1934)
1	Soil pH was determined in distilled water at 1:2.5 soil: water-solution ratio using the Beckman zeromatic pH meter	
2	Organic Matter (OM) was determined by the modified Walkley and Black method (Nelson and Sommers, 1982).	

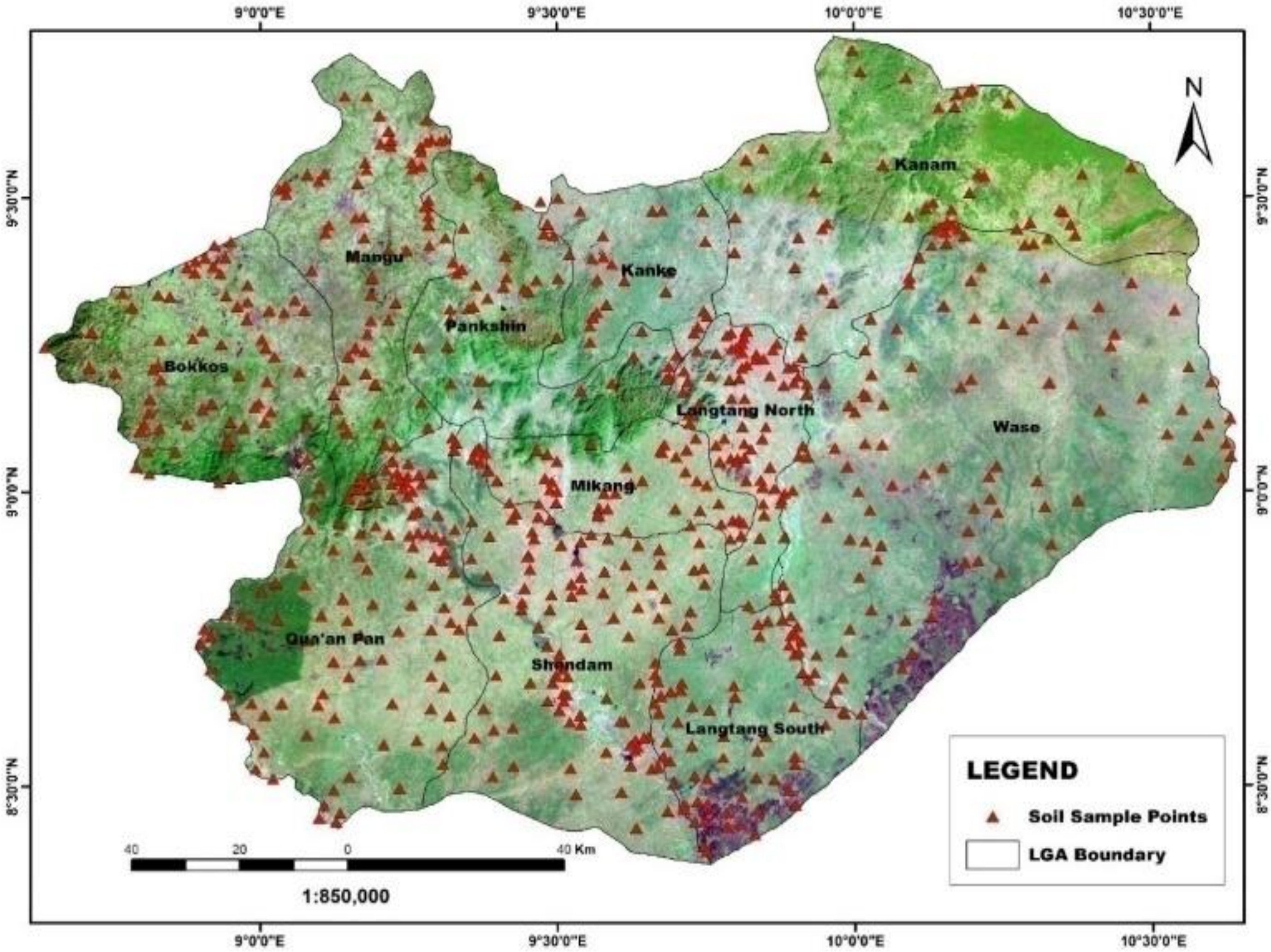

Fig 2 Soil Sample Distribution Points in the Study Area

IV. RESULTS AND DISCUSSION

Pearson's product moment correlation analysis was carried out for soil pH and organic matter for the various soil sample points using SPSS (Statistical Packages for Social Sciences) version 25. This analysis was carried out to ascertain the magnitude and nature of relationship between the parameters at significant level of 0.01.

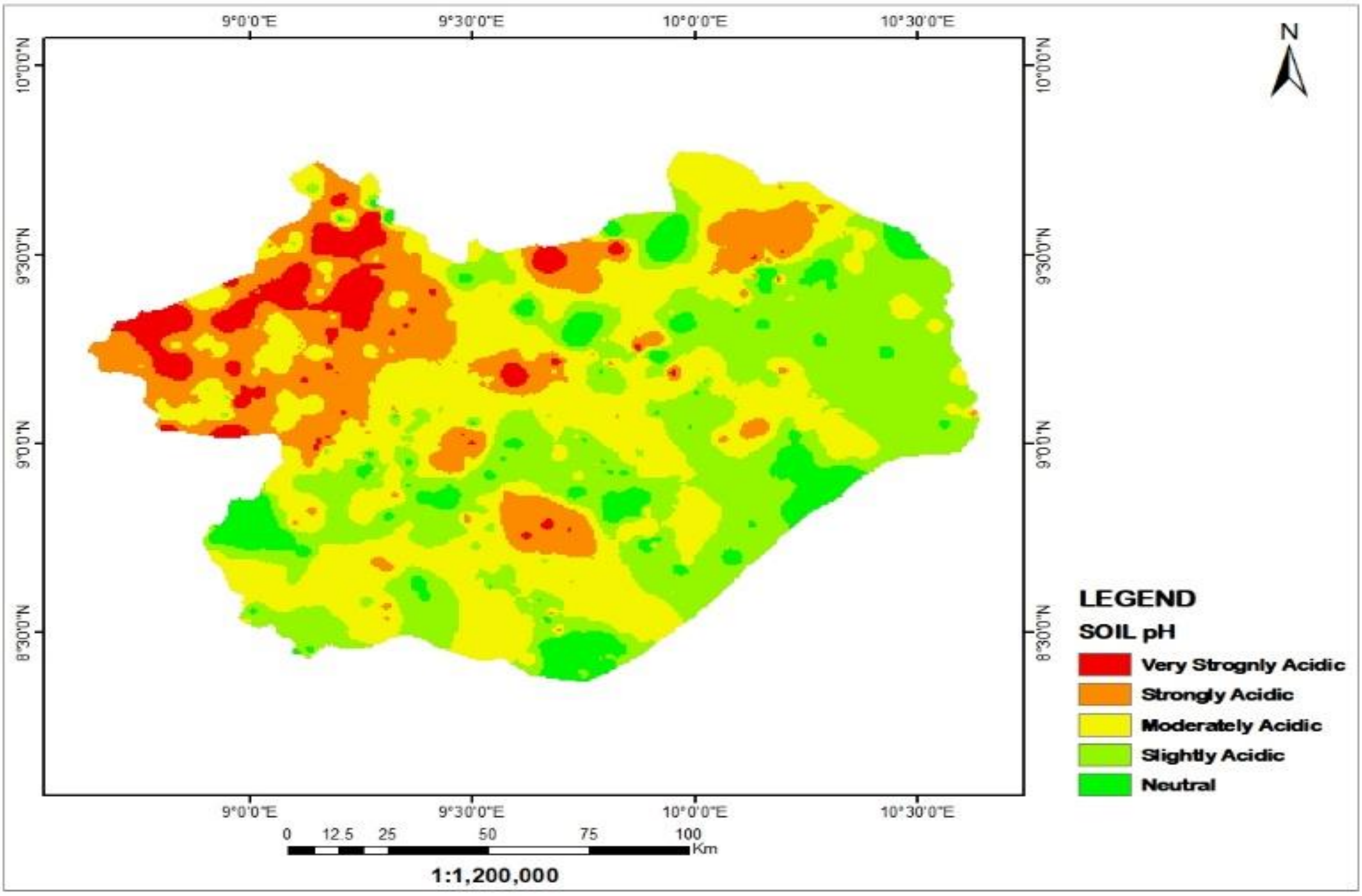

Fig 3 Soil pH Map

Table 3 Area (Km^2) Coverage and Percentage of Each Category of Soil Ph

S/N	pH	Percentage (%)	Area (km^2)
1	< 5.0 Very Strongly Acidic	4.8	1006.9
2	5.1–5.5 Strongly Acidic	16.8	3556.7
3	5.6-6.0 Moderately Acidic	35.9	7612.2
4	6.1-6.5 Slightly Acidic	35.0	7409.9
5	6.1-6.5 Slightly Acidic	7.5	1585.3

The soil pH value of the study was ranged in categories between < 5.0 to 7.3 as shown in the table above (Table 3). From the map, the pH classified range showed the percentages covered as 4.8%, 16.8%, 35.9%, 35.0% and 7.5% to reflect very strongly acidic, strongly acidic, moderately acidic, slightly acidic and neutral respectively(Fig. 6). It is deducted from the spatial distribution map that 35.9% of the soils were moderately acidic while 35% were slightly acidic in reaction. More of the soils collected from the North western area of the map, covering communities in Bokkos and Mangu were acidic in reaction (very strongly acidic to strongly acidic). The spatial distribution of the soil pH also showed that moderately Acidic (5.6-6.0) and slightly acidic (6.1-6.5) soils were observed in 7612.2 km^2 (35.9%) and 7409.9 km^2 (35.0.0%), and covered more area from the middle to the Southern part of the map. The communities located in this axis are mostly parts of Kanke, Langtang North and Kanam.

Data from the pH map revealed that a significant percentage (87.7%) of the study area fall within 5.5 and 6.5 pH levels, the implication of this is that much of the land is generally suitable for crop cultivation. However, the pH variability may have been affected more by the geology of the terrain rather than the organic matter. Although there are studies that showed that organic matter affects the variability of soil pH due to acidification (Zhou, et al 2019, and Sharma, 2022).

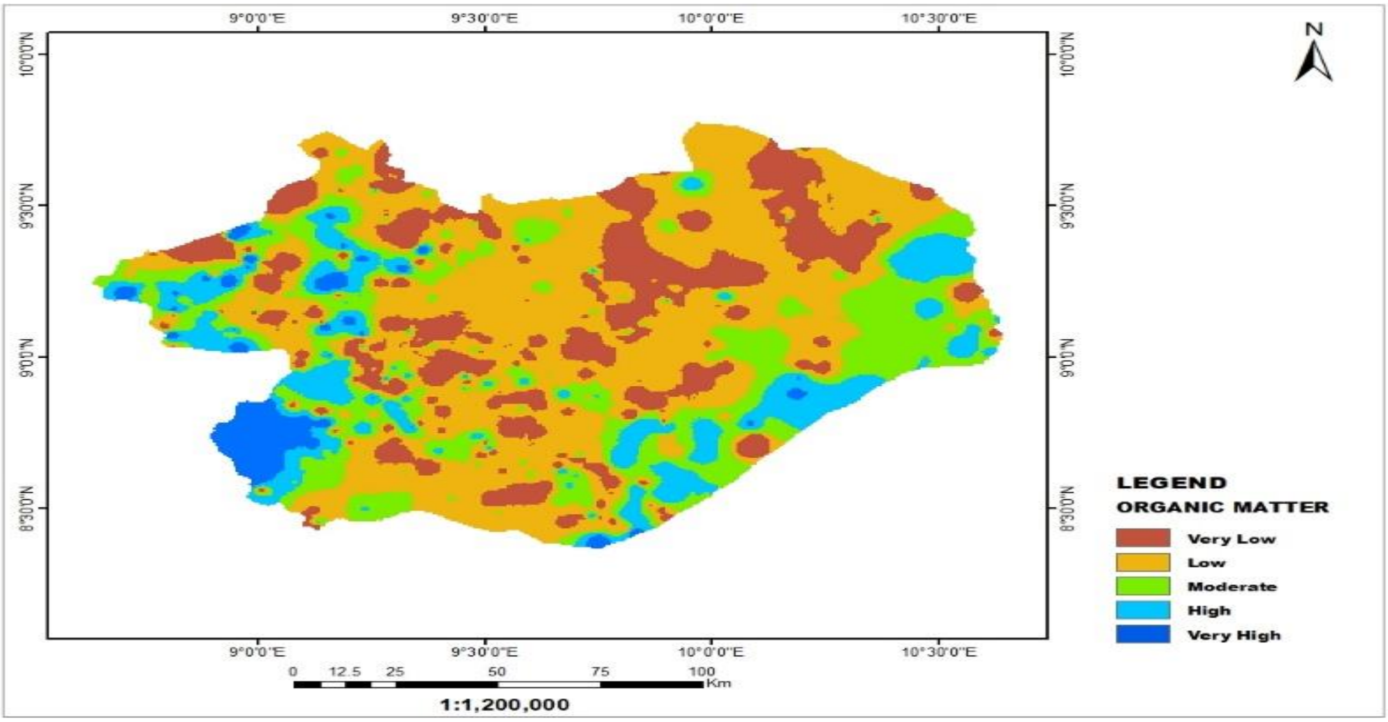

Fig 4 Soil Organic Matter

Table 4 Area (Km^2) on the Level of Organic Matter in the Soil

Level	Area(km^2)	Percentage (%)
Very low	4412.6	20.8
Low	9218.0	43.9
Moderate	4304.8	20.3
High	2464.2	11.6
Very high	721.3	3.4

A. Soil Organic Matter

The IDW map of organic matter (OM) showed an obvious trend of spatial distribution. The study area showed a heterogeneous spatial pattern of soil organic matter content, with low levels of OM accounting for one third (43.9%) of the total area (Figure 4). The map showed high and very high level of OM content in an area of 2,464.2 km^2 and 721.3 km^2 representing 11.6% and 3.4% respectively (Table 4). An area of 4,304.8 and 4,412.6 km^2 representing 20.3% and 20.8% of the area showed a very low and moderate variability of OM.

The organic matter (OM) content of soils in the study area was generally low. This might be due to the slash and burn mode of farming practices which does not allow for decay and decomposition of organic materials. Similarly, the mineral from the parent material of the soil may have contributed significantly to the available organic matter as distributed in the map

From the maps, the pH and organic matter variability does not show a common trend. Areas with very high organic matter seem to not at a proportional level have high to very high acidity level.

B. Correlations of pH and Organic Matter.

In the correlation analysis of the soil pH and soil organic matter of the study area, the result obtained for the correlation co-efficient γ is –0.071 and the p-value is 0.055 using 0.01 level of significance as obtained showed that;

- The association or relationship between soil pH and organic matter is weak, since 0.071 is less than 0.3
- They have a negative relationship, which means that they move in an opposite direction, that is an increase in soil organic matter leads to a decrease in soil pH and vice versa
- The association between the two variables (soil pH and organic matter) is insignificant, since the p-value 0.055 is greater than the level of significance + 0.01.

Generally, while the distribution of pH gives a suitable range for crop cultivation, the distribution of the organic matter did not give absolute providence for alteration of the pH values of the various soil samples in the study area.

V. CONCLUSION AND RECOMMENDATION

The study on the analysis of soil pH and soil organic matter in the central and southern zones of plateau state showed that a large percentage (87.7%) of the area has a pH value ranging from 5.5 to 6.5, hence indicating high suitability level for crop production.

Similarly, the distribution organic matter in the study area is generally low compared to the pH level. The correlation analysis of the parameters showed that there is a weak relationship between the organic matter and the pH, and they therefore have a negative relationship with their association said to be insignificant.

The study recommends that in the practice of agriculture, farmers should be discouraged from the slash and burn practice. This is with a view to allowing for the slashed organic matter to decay and decompose so that the organic matter content of the soils will be enriched.

Organic matter has literally been stated to have a lot of impact and positively so on the various parameters of the soil and not excluding soil pH.

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