World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Soil pH Variability in Mangu, Bokkos and Pankshin Local Government Areas of Plateau State

Halilu Shaba [1], Omomoh Emmanuel [2], Nannim Sunday [3], Gujahar Rengje Danlami Rogers [4,*], Moses Omirinde Omitunde [5] and Gwamzhi Emmanuel Ponsah [6]

[1] *Director General, National Space Research and Development Agency (NASRDA), Airport Road, P.M.B 437, Abuja, Nigeria.*
[2] *The Coordinator, Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*
[3] *The Assistant Coordinator, Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*
[4] *Geology and Water Resources, Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*
[5] *Agric and Land Resources, Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*
[6] *Geointelligence, Zonal Advanced Space Technology Applications Laboratory (ZASTAL), P.M.B 47, Pajat, Langtang North, Plateau State, Nigeria.*

World Journal of Advanced Research and Reviews, 2023, 19(03), 1508–1517

Publication history: Received on 14 August 2023; revised on 25 September 2023; accepted on 27 September, 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.19.3.1967

Abstract

This paper investigates soil pH variability in three local government areas (LGAs) in Plateau State, Nigeria: Bokkos, Mangu, and Pankshin. Soil pH is a crucial factor influencing soil biogeochemical properties, which in turn affect crop yield, soil nutrient levels, and microbial activity. The study utilized Stratified Random Sampling to collect soil samples, and employed IDW (Inverse Distance Weighted) interpolation for analysis.

The results revealed a pH range of 4.5 to 7.07, categorized into five classes: very strongly acidic (4.5 - 5.05), strongly acidic (5.05 - 5.35), moderately acidic (5.35 - 5.58), slightly acidic (5.58 - 5.83), and neutral (5.83 - 7.07). Slightly acidic and moderately acidic soils were predominant across the entire study area, covering 1643.96 Km^2 and 1444.41 Km^2 respectively.

Noteworthy variations in pH were observed between the LGAs, with Bokkos and Mangu exhibiting more acidic soils, while Pankshin had soils tending towards neutrality. These variations were attributed to the local topography and geology. The pH variations also play a significant role in determining suitable crops for cultivation. Bokkos and Mangu are conducive for extensive farming of maize and Irish potatoes, while Pankshin is better suited for millet and sorghum cultivation.

Given the global implications of events like the Russia-Ukrainian war on food supply, the study recommends that relevant government agencies identify areas with similar soil characteristics and invest in extensive cultivation of crops well-suited to those soils. This could contribute significantly to enhancing food security on a global scale

Keywords: Soil pH; Ecosystem services; Soil fertility; Topography; Land use change

* Corresponding author: Gujahar Rengje Danlami Rogers

Copyright © 2023 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution Liscense 4.0.

1. Introduction

Soil is the basis for the growth of terrestrial plants and animals. It is closely related to the material cycle and ecosystem service supply[1]. The ecosystem services provided by soil are crucial for achieving the United Nations' sustainable development goals (SDGs), such as food security guarantee, ecosystem health maintenance, climate change mitigation, and biodiversity conservation [2]. However, in recent decades, soil degradation has intensified because of the changing environment and human activities[3]. Therefore, studies of the environmental capabilities for food production are essential in ensuring food security for the increasing population worldwide. One of the important factors in food production is soil fertility and its measurable parameters. A gradual decline of soil fertility induced by some management practices, especially in intensively cropped areas, is a major cause of decreased yields and food production per capita. Soil properties, in association with environmental factors such as topography, climate and parent materials, plays a significant role in sustainable food production. Among these soil parameters, soil pH has an influential role. Soil pH is one of the most essential and important physicochemical properties for the chemistry and fertility of soils. The pH of the soil has great influence on soil biogeochemical properties[4]. pH is the negative logarithm of the hydrogen ion concentration (more exactly, the activity) or algebraically pH = −log10 [H+] or pH= log101/[H+] [5]. Soil pH is the measure of the hydrogen ion (H+) concentration in the soil. In other words, it is the degree of acidity or alkalinity of the soil. Studies have shown that soil pH can influence crop yield, soil nutrient, and soil microbial activities to a large extent [6]. Abnormal changes in soil acidity and alkalinity are a major form of soil degradation characterized by the acceleration of nutrient leaching, reduction in nutrient availability, activation of heavy metals, and suppression of microbial activity [6-9].

[10] in his study; factors affecting variation of soil pH in different horizons in hilly regions, reported that climate and topography has influence on soil pH variation. Temperature, mostly affect rock weathering and precipitation affect flow of materials. The authors also noted that soil chemical reactions are affected by climate, the soil from different climates have different soil pH ranges. In arid climate, the soil pH is highly alkaline while soil of humid climate is acidic with low pH values. Changes in climatic conditions influences rainfall leading to increase precipitation which accelerates leaching, causing basic cations to be leached from topsoil and making the topsoil more acidic. These leached cations include; Mg2+, K+ and Na+. Topography also affects soil pH by affecting the rate of water flow and material transport. Elevation and climate influence local temperature and precipitation that is, low temperature and abundant rainfall occurs at higher altitudes.

[11] reported a relationship between soil pH and soil organic matter in both the top and bottom soil profile respectively. The soil organic matter in the top soil were found to be below the desired values while the soil organic carbon showed a spatial variability in both top and sub-surface layers. Soil pH ranges from acidic to almost neutral in top soil but tends to increase with an increase in depth of soil. Soil carbon and nitrogen correlate negatively with soil pH meaning low pH (acidic soils) favors accumulation of organic matter[12]. Furthermore, bush burning and the irrigation systems employed are found to contribute to pH variability [11].

Variability in soil pH is also influenced by several other factors such as soil physicochemical properties, atmospheric deposition, fertilizer application, and land use change (LUC) [13]. LUC refers to changes in surface cover and soil use, which can alter the influence of natural conditions (such as topographical and meteorological factors) and human activities (such as human disturbance and nitrogen application) on soil properties and environment [14]. Such alterations may affect soil pH status and variability patterns, leading to challenges for soil management [15].

2. Study area

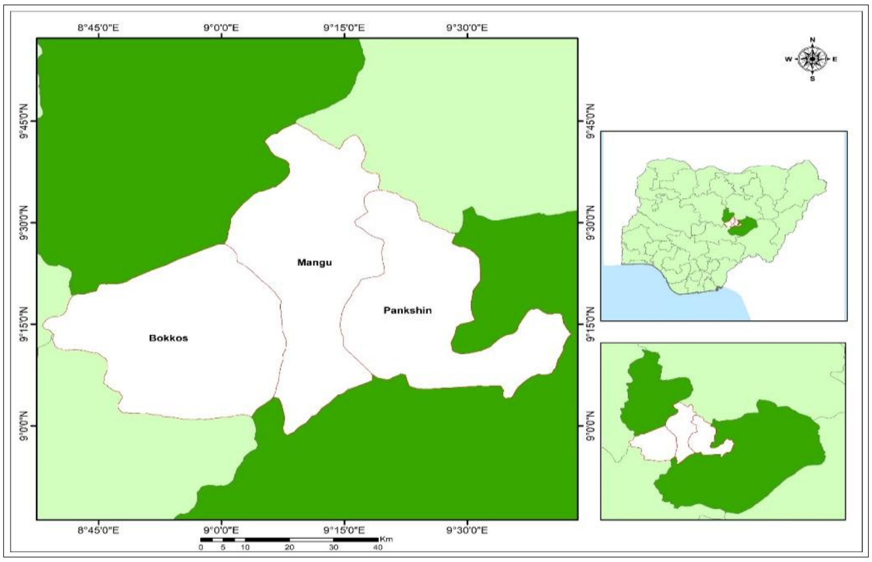

Figure 1 Map Showing Study Area

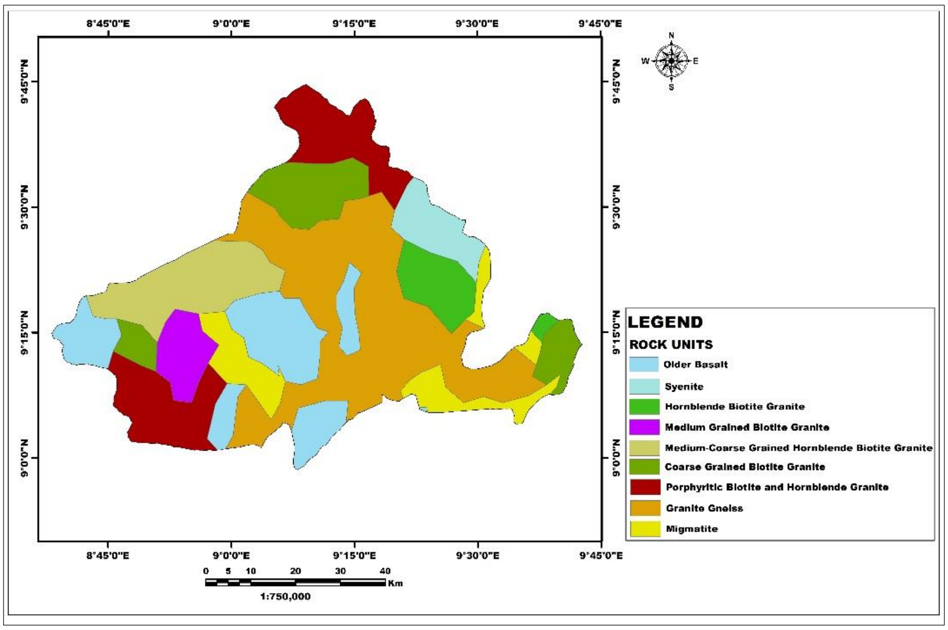

Figure 2 Geology of the Study Area

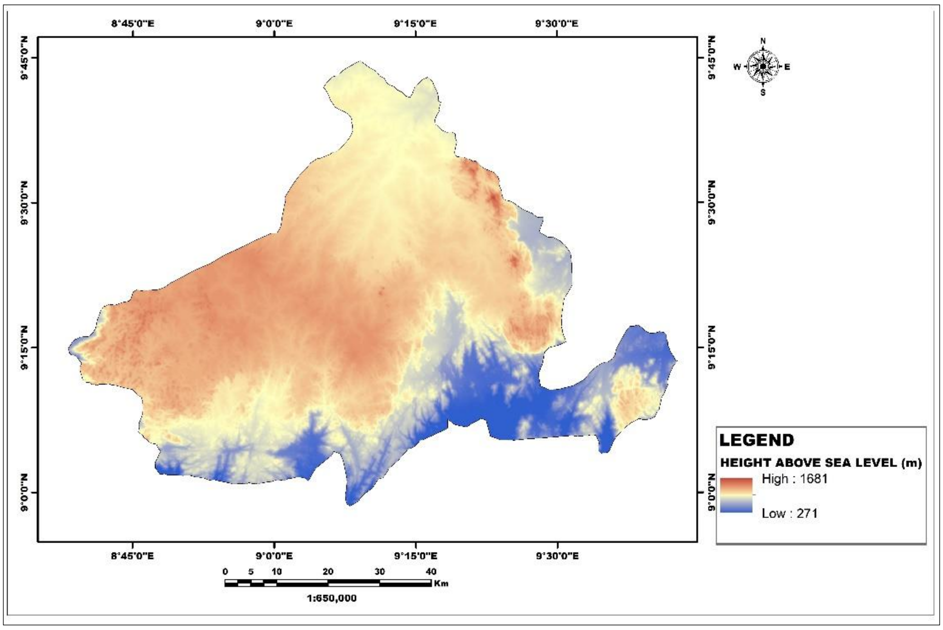

Figure 3 Elevation Map

The study area lies within 8°38'9.294" E, 8°58'37.175" N and 9°42'43.283" E, 9°44'41.14" N with an elevation ranging from 271m to 1681m above sea level. The study covers an area of 4762.12 Km^2 and contains 3 local government areas (Bokkos, Mangu and Pankshin) located in the western half of central Plateau state. The climate is of the Guinea savanna type characterized by dry season from November to March and average temperatures of 18°C – 22°C. The rainy season starts from April to October, with an annual rainfall of approximately 1270mm – 1524mm. Generally, rainfall in the Guinea savannah is convectional, but the Jos Plateau (which includes the study area alongside Jos North, South and East, Riyom, Barkin Ladi and Bassa) enjoys both the convectional and orographic rainfall types [16]. The topography is generally undulating with significant quantity of rock outcrops. The land mass is entirely fertile and soil are not easily eroded by rain [17]. The soil type is mainly sandy loam, clay loam and loamy in nature. The major crops grown are maize, millet, Irish potatoes, sweet potatos, soya beans, guinea corn, red beans, acha. The people are predominantly farmers, most of cultivated lands are characterized by continues farming and cropping. The land is also grazed by animals and considered to be communal grazing land where everyone can graze their cattle without restrictions [17]. Although the actual vegetation of the study area used to be dense savannah woodland, human activities have resulted in extensive and severe degradation so much as to leave only remnants of woodlands, which are even restricted to the steep and less accessible margins of Plateau. Most of the regions with rock exposures have woodlands with riparian forests along streams emanating from the high lands, while those with flat terrains usually have a lot of grassland intercalated with shrublands and scattered trees [18]. The geology of the area is dominated by granite gneiss, syenite, hornblende granite, biotite granite and other leucocratic (acidic) rocks.

3. Material and methods

Materials required for this research included soil samples, Global Positioning System (GPS) fixes, Geology Map (Nigerian Geological Survey Agency) and Shuttle Radar Terrain Mission (SRTM). The field work was conducted for a period of 4 weeks which spanned from 3rd April 2021 to 4th May, 2021; GPS points of the soil samples were obtained using a handheld GARMIN GPSMAP 78s receiver. 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 container to have one soil composite. The stratified random sampling method was used for the soil sampling based on the variability of the soils in the study region. Several soil samples were obtained from different farmlands in the three LGAs of interest; Bokkos, Mangu and Pankshin in the central zone of Plateau state.

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 [19]. Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable cations (K, Ca, Mg and Na) and exchangeable acidity (H + Al).

The field data obtained from the study area were organized and prepared for spatial analysis. Initially, the collected field data's coordinates were carefully arranged within an excel worksheet and subsequently saved in the ".csv" format. This facilitated further spatial analysis in the ArcGIS 10.8 where the data was imported into the software interphase 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 physico-chemical properties under investigation. The Inverse Distance Weighting (IDW) interpolation was the specific method 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. Subsequently, comparison was made between the various parameters and other factors (geology, elevation, rainfall) that affect soil pH. Finally, further comparison is made between each of the local government areas within the study area.

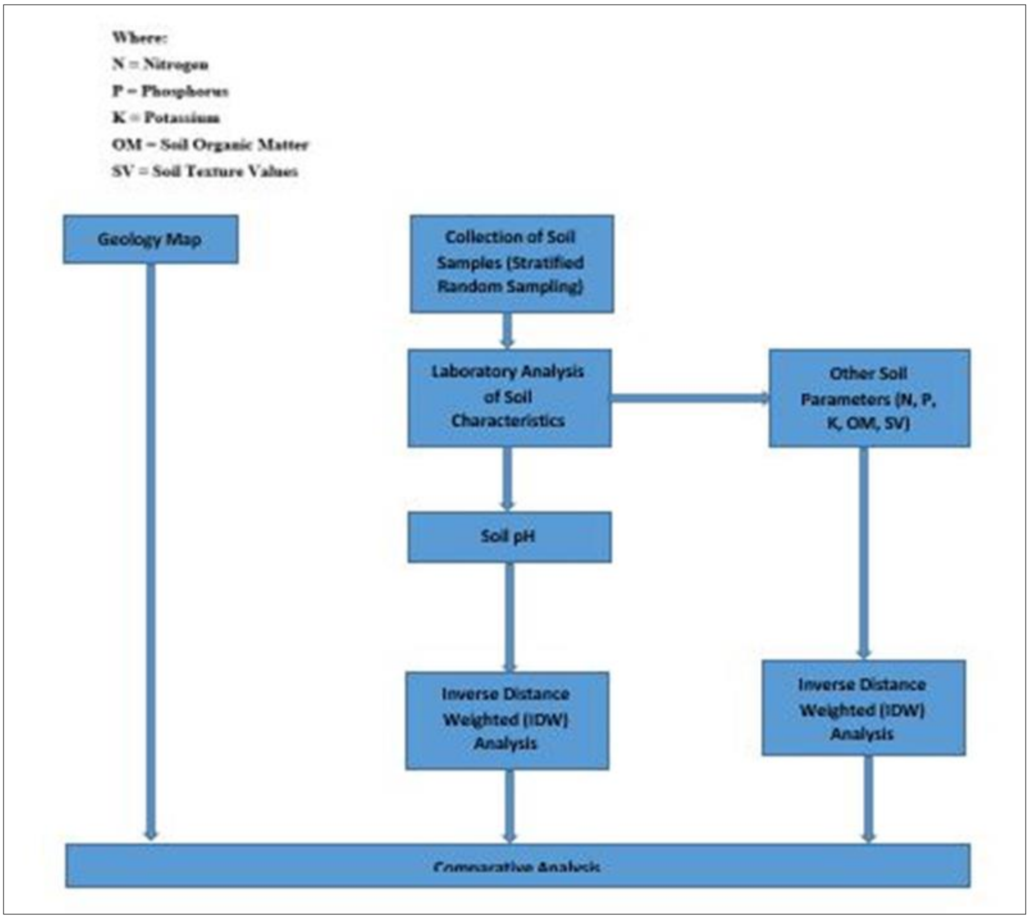

Figure 4 Work Flow Chart

4. Results and discussion

The results revealed variations in the soil pH across the area between 4.5 and 7.07 which were then sliced into five (5) classes using Jenk's Natural Breaks (table 1). The classes are very strongly acidic (4.5 – 5.05), strongly acidic (5.05 – 5.35), moderately acidic (5.35 – 5.58), slightly acidic (5.58 – 5.83) and neutral (5.83 – 7.07). Across the study area, slightly acidic soils cover the most area (1643.96 Km2) followed by moderately acidic with 1444.41 Km2 (table 2). Neutral soils cover the least area at 382.43 Km2 with very strongly acidic soils covering an area of 426.52 Km2 and strongly acidic soils being the median value with 835.79 Km2 of area covered (figures 5 and 6).

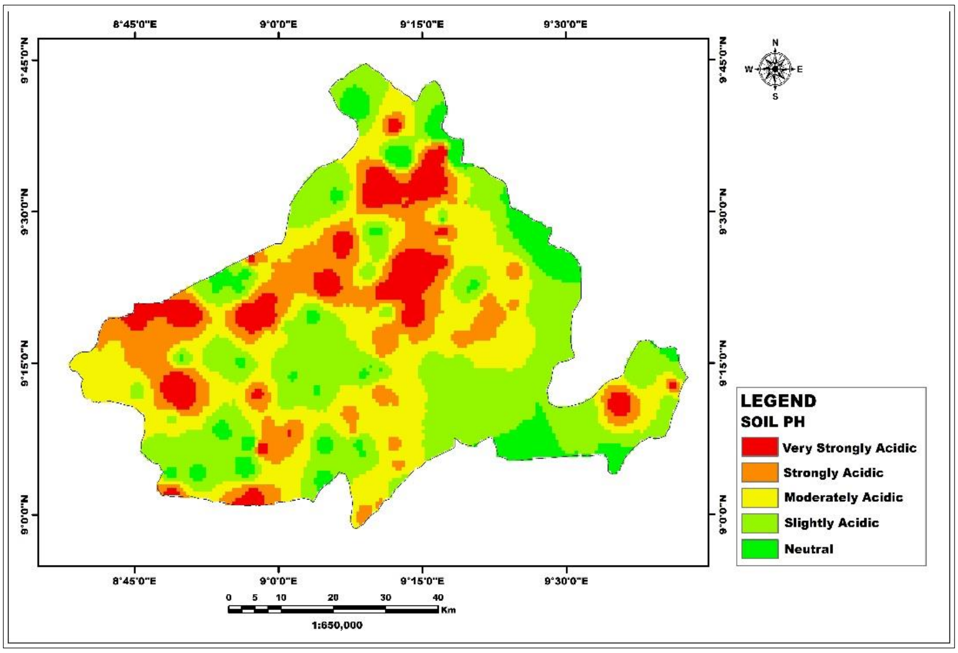

Figure 5 Soil pH Map

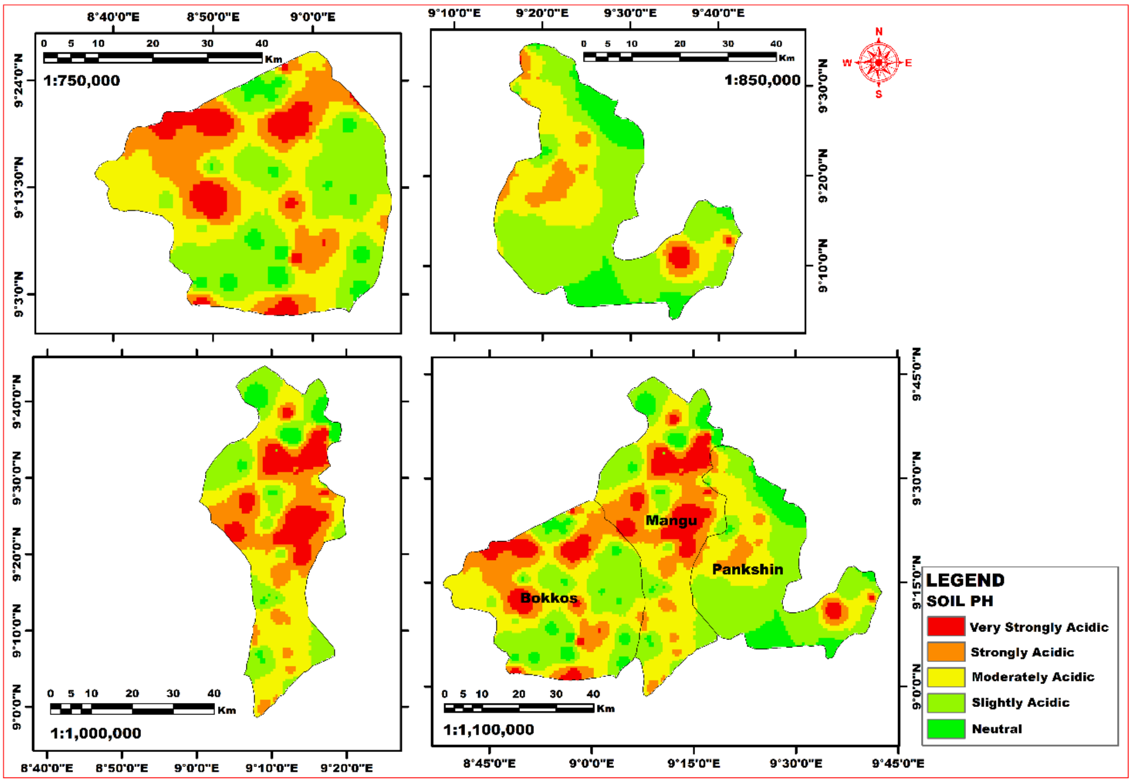

Figure 6 Soil pH Map

Table 1 Soil pH Classes and Range

SOIL pH CLASSES	pH RANGE
Very Strongly Acidic	4.5 - 5.05
Strongly Acidic	5.05 -5.35
Moderately Acidic	5.35 - 5.58
Slightly Acidic	5.58 - 5.83
Neutral	5.83 - 7.07

Table 2 Statistics of the Study Area

SOIL pH CLASSES	BOKKOS	MANGU	PANKSHIN	TOTAL AREA (Km2)
Very Strongly Acidic	159.65	248.27	18.59	426.52
Strongly Acidic	362.92	360.95	111.92	835.79
Moderately Acidic	530.93	523.92	389.56	1444.41
Slightly Acidic	567.55	373.78	702.63	1643.96
Neutral	91.41	90.81	200.21	382.43
Total	1712.47	1597.75	1422.90	4733.12

Table 3 Statistics of pH in Pankshin

SOIL pH CLASSES	AREA (Km2)	AREA (%)
Very Strongly Acidic	18.59	1.31
Strongly Acidic	111.92	7.87
Moderately Acidic	389.56	27.38
Slightly Acidic	702.63	49.38
Neutral	200.21	14.07
Total	1422.9	100.00

Results across Pankshin show that slightly acidic soils predominate with 702.63 Km^2 of area covered (table 3). This accounts for almost 50% of the total area of the local government. Moderately acidic soils follow with 389.56 Km^2 (27.38%) and neutral soils with 200.21 Km^2 (14.07%). At the lower range of the spectrum are very strongly acidic (18. 59 Km^2, 1.31%) and strongly acidic (111.92 Km^2, 7.87%). The predominance of less acidic and neutral soils (accounting for a total of 90.83% of area) can be attributed to the relatively low terrain with most of the land close to 271m above sea level. This results in cations leached from the higher elevation of neighboring areas being deposited within this receptive area and thereby reducing the overall acidity of soils in the area. The presence of Older Basalts in the northern reaches of the local government may have some influence on the less acidic nature of soils in the area with its predominantly alkaline component minerals weathering to produce less acidic soils and also release cations into the neighboring lowlands.

Table 4 Statistics of pH in Mangu

SOIL pH CLASSES	AREA (Km2)	AREA (%)
Very Strongly Acidic	248.27	15.54
Strongly Acidic	360.95	22.59
Moderately Acidic	523.92	32.79
Slightly Acidic	373.78	23.39
Neutral	90.81	5.68
Total	1597.75	100.00

In Mangu (table 4), the soils have a more equitable distribution but with a more acidic character (compared to Pankshin). Moderately acidic soils cover 523.92 Km2 (32.79%). This is followed by slightly acidic and strongly acidic soils at 373.78 Km2 (23.39%) and 360.95 Km2 (22.59%) respectively. Very strongly acidic soils occupy 248.27 Km2 (15.54%) while neutral soils are least with 90.81 Km2 (5.68%) area covered. It can be observed that areas with very strongly acidic and strongly acidic soils coincide with areas of high altitude in Mangu. This is due to the leaching away of alkaline cations from these elevated positions leaving progressively acidic soils and other residue. The acidic nature of the underlying rocks across most of the local government would also have contributed to the nature of soils in the area, bearing in mind that the geology is predominantly granite gneiss and hornblende biotite granite.

Table 5 Statistics of pH in Bokkos

SOIL pH CLASSES	AREA (Km2)	AREA (%)
Very Strongly Acidic	159.65	9.32
Strongly Acidic	362.92	21.19
Moderately Acidic	530.93	31.00
Slightly Acidic	567.55	33.14
Neutral	91.41	5.34
Total	1712.47	100.00

Soils in Bokkos have similar characteristics to those in Mangu based on their pH values. Slightly acidic soils cover 567.55 Km^2 of land which is 33.14% of the total area of the local government. This is closely followed by moderately acidic at 530.93 Km^2 (31%). Strongly acidic soils cover 362.92 Km^2 (21.19%), very strongly acidic 159.65 Km^2 (9.32%) and neutral soils 91.41 Km^2 (5.34%). Soils in Bokkos show some correlation between level of acidity and elevation though it is a more complex relationship due to variations in elevation as well as parent material interactions. Some elevated areas are very strongly to strongly acidic while others are moderately acidic. Areas of slightly acidic and neutral soils also coincide with relatively lower altitudes. The presence of older basalts also influences a noticeable area of slightly acidic and neutral soils along the eastern boundary of the local government (figure 2 and 6).

5. Conclusion

The research has established that there are similarities between soils in Mangu and Bokkos while the soils in Pankshin have a different pH character. The similarities between the soils in Mangu and Bokkos may be deduced to also play a role in the similar predominant crops cultivated in both areas. Irish potatoes and Maize are the main crops produced in both local governments. Pankshin, on the other hand, produces sorghum and millet as their main crops. The difference in soil pH ranges can therefore be noticed to promote the cultivation of different types of crops. Nonetheless, other physical and environmental factors also have some effects on the choice of crops to plant.

Recommendation

Considering the affinity of Irish potatoes and Maize for acidic soils (baring all other physico-chemical considerations) it would be advisable areas with such soils are identified for extensive cultivation of these crops. This would help boost the Irish potato value chain program of the government. It also would help boost the production of grains bearing in mind the present issues with worldwide grain supplies die to the Russo-Ukrainian war.

Compliance with ethical standards

Acknowledgments

We would like to express our sincere gratitude to everyone who contributed to the successful completion of this research paper, "Soil pH Variability in Mangu, Bokkos, and Pankshin Local Government Areas of Plateau State."

First and foremost, we extend our appreciation to the National Space Research and Development Agency (NASRDA) for providing the necessary resources and support for this study.

We are deeply thankful to our colleagues at the Zonal Advanced Space Technology Applications Laboratory (ZASTAL) for their collaboration, valuable insights, and technical assistance throughout the research process.

Finally, we appreciate the Plateau State Government and the local communities in Bokkos, Mangu, and Pankshin Local Government Areas for granting us access to their lands and providing valuable information during our data collection.

This research would not have been possible without the collective efforts and support of these individuals and institutions. We are grateful for their contributions to the advancement of knowledge in the field of soil science and agriculture.

Disclosure of conflict of interest

The authors of the paper "Soil pH Variability in Mangu, Bokkos, and Pankshin Local Government Areas of Plateau State" declare that they have no financial or non-financial conflicts of interest that could have influenced the research, analysis, or interpretation of the findings presented in this paper.

Author Contributions

- Dr. Halilu Shaba contributed to the conceptualization of the study, data collection, and interpretation of results.
- Dr. Omomoh Emmanuel contributed to data analysis and manuscript writing.
- Dr. Nannim Sunday provided expertise in geospatial analysis and contributed to the interpretation of geospatial data.
- Dr. Gujahar Rengje Danlami Rogers contributed to the analysis of soil samples and laboratory work.
- Mr. Moses Omirinde Omitunde assisted in the fieldwork and data collection.
- Mr. Gwamzhi Emmanuel Ponsah contributed to the spatial analysis and mapping of soil pH.

Funding

The research presented in this paper was conducted with internal resources, and there was no external funding involved. Therefore, there are no financial conflicts of interest related to this study.

Ethical Considerations

The research adhered to ethical guidelines and regulations relevant to scientific research, including obtaining necessary permissions for soil sampling and analysis.

Contact Information

For any inquiries related to this paper or the research presented herein, please contact the corresponding author Mr. Gwamzhi Emmanuel Ponsah, at eponsah@gmail.com.
This disclosure of conflict of interest statement is provided to ensure transparency and maintain the integrity of the research presented in the paper. The authors affirm that there are no undisclosed conflicts of interest that could potentially affect the objectivity or credibility of the study's findings.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

Statement of informed consent

Informed consent was obtained from all the Chairmen of the LGAs wherein the study was tailored

References

[1] Berks BC, Richardson DJ, Robinson C, Reilly A, Aplin RT, Ferguson SJ. Purification and characterization of the periplasmic nitrate reductase from Thiosphaera pantotropha. European journal of biochemistry. 1994;220(1):117-24.

[2] Gwanshak JY, Danbauchi ES. Geospatial Surface Area Mapping of Bokkos Local Government Area (LGA) of Plateau State of Nigeria. International Journal of Research in Social Science and Humanities (IJRSS) ISSN: 2582-6220, DOI: 1047505/IJRSS. 2021;2(2):1-6.

[3] Ikelegbe OO. Forest Exploitation and the Challenges of Conservation in Nigeria.

[4] Wuyep S, Daloeng H, Isha A, Arin H. Application of Remote Sensing and GIS to Detect Land Use and Land Cover Changes in Jos East, Plateau State, Nigeria. Bok Jour of Scie Rep. 2020;1:1-8.

[5] Adhikari K, Hartemink AE. Linking soils to ecosystem services—A global review. Geoderma. 2016;262:101-11.

[6] Lal R, Bouma J, Brevik E, Dawson L, Field DJ, Glaser B, et al. Soils and sustainable development goals of the United Nations: An International Union of Soil Sciences perspective. Geoderma Regional. 2021;25:e00398.

[7] Amundson R, Berhe AA, Hopmans JW, Olson C, Sztein AE, Sparks DL. Soil and human security in the 21st century. Science. 2015;348(6235):1261071.

[8] Neina D. The role of soil pH in plant nutrition and soil remediation. Applied and environmental soil science. 2019;2019:1-9.

[9] Lewis MJ, Bamforth CW, Lewis MJ, Bamforth CW. Water and Energy. Essays in Brewing Science. 2007:143-60.

[10] Zeng F, Ali S, Zhang H, Ouyang Y, Qiu B, Wu F, et al. The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants. Environmental pollution. 2011;159(1):84-91.

[11] Pietri JA, Brookes P. Relationships between soil pH and microbial properties in a UK arable soil. Soil Biology and Biochemistry. 2008;40(7):1856-61.

[12] Daliakopoulos I, Tsanis I, Koutroulis A, Kourgialas N, Varouchakis A, Karatzas G, et al. The threat of soil salinity: A European scale review. Science of the total environment. 2016;573:727-39.

[13] Wan W, Hao X, Xing Y, Liu S, Zhang X, Li X, et al. Spatial differences in soil microbial diversity caused by pH-driven organic phosphorus mineralization. Land Degradation & Development. 2021;32(2):766-76.

[14] Zhang Y-Y, Wu W, Liu H. Factors affecting variations of soil pH in different horizons in hilly regions. Plos one. 2019;14(6):e0218563.

[15] Dinka MO, Dawit M. Spatial variability and dynamics of soil pH, soil organic carbon and matter content: The case of the Wonji Shoa sugarcane plantation. Journal of Water and Land Development. 2019(42).

[16] Zou C, Zhu R, Chen Z-Q, Ogg JG, Wu S, Dong D, et al. Organic-matter-rich shales of China. Earth-Science Reviews. 2019;189:51-78.

[17] Guo L, Luo M, Zhangyang C, Zeng C, Wang S, Zhang H. Spatial modelling of soil organic carbon stocks with combined principal component analysis and geographically weighted regression. The Journal of Agricultural Science. 2018;156(6):774-84.

[18] Khaledian Y, Kiani F, Ebrahimi S, Brevik EC, Aitkenhead-Peterson J. Assessment and monitoring of soil degradation during land use change using multivariate analysis. Land Degradation & Development. 2017;28(1):128-41.

[19] Alvarez R, Gimenez A, Pagnanini F, Recondo V, Gangi D, Caffaro M, et al. Soil acidity in the Argentine Pampas: Effects of land use and management. Soil and Tillage Research. 2020;196:104434