

Geospatial Techniques for Spatial Variability of Soil Physicochemical Properties and Their Impact on Irish Potato Production on the Jos Plateau: A Case Study of Jos South and Riyom Local Government Areas

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ABSTRACT

Irish potato (*Solanum tuberosum* L.) is a globally significant tuber crop, ranking fourth in global food production after rice, wheat, and maize (Ezekiel et al., 2023; Barta et al., 2022). Varieties such as Nicola, Marabel, and Caruso are commonly cultivated in Nigeria as well as in Egypt, Italy, Turkey, Germany, Pakistan, and China (Youssef and Hassan, 2022). The crop was first introduced to the Jos Plateau in Plateau State, central Nigeria, in the early nineteenth century (Taiy et al., 2017; Tadesse et al., 2018). However, its productivity remains constrained by multiple factors, including pest and disease pressure, inadequate supply of quality seed material, poor post-harvest storage infrastructure, a progressive decline in soil fertility associated with intensive cropping practices, limited access to improved varieties, and high labour costs. This study was undertaken to generate spatial data on soil quality variability and its implications for sustainable Irish potato production in Jos South and Riyom Local Government Areas. The study area spans latitudes 9°01'50.2"N to 9°44'6.5"N and longitudes 8°41'27"E to 9°19'56"E, at an elevation of approximately 800 m above sea level. The study area is underlain by crystalline basement rocks comprising migmatite, granite-gneiss, and Pan-African (Older) granites. A total of 240 composite soil samples were collected from Irish potato farms at a sampling depth of 0–30 cm and analysed for key physicochemical properties. Spatial distribution maps were generated using Inverse Distance Weighting (IDW) interpolation within ArcGIS 10.8. Results indicate that macro- and micro-nutrients are adequate to support Irish potato cultivation in areas with moderate to high concentrations of nitrogen (N), phosphorus (P), potassium (K), and organic matter, combined with slightly to moderately acidic soil pH. The application of geospatial technologies equips farmers with the means to implement site-specific nutrient management strategies, optimize resource allocation, and enhance the productivity and sustainability of Irish potato cultivation across the study area.

Keywords: Irish potato, spatial variability, soil physicochemical properties, geospatial techniques, IDW interpolation, Jos Plateau, precision agriculture, soil fertility

INTRODUCTION

Irish potato (*Solanum tuberosum* L.) is a tuber crop that has long served as a staple food for many people worldwide, ranking fourth in global production behind rice, wheat, and maize (Ezekiel et al., 2023; Barta et al., 2022). In Nigeria, popular potato cultivars include Nicola, Marabel, and Caruso, all of which are also cultivated in Egypt, Italy, Turkey, Germany, Pakistan, and China (Youssef and Hassan, 2022).

Tubers are rich in edible starch and serve as food for both people and livestock, as well as a raw material for the production of starch, beverages, flour, and fermented food products. Irish potato is an annual herbaceous crop and the world's largest non-cereal food crop, ranking fourth in terms of total area harvested and volume produced globally (FAOSTAT, 2016). Its production is primarily concentrated in lower temperate zones. Irish potato is particularly sensitive to temperature and rainfall; it performs best under a cool growing season with moderate,

evenly distributed rainfall of 800 to 1,200 mm per year and no prolonged dry spells. The crop can be grown under both rain-fed and irrigated conditions, although waterlogged soils are unsuitable. Temperatures exceeding 27°C are unfavourable for the formation of economically sized tubers.

Global production data from FAOSTAT (2022) indicate that approximately 375 million tonnes of potatoes were produced worldwide in 2022, with China (95.5 million tonnes) and India (56 million tonnes) as the leading producers. Other major producers include Russia (18.9 million tonnes), Ukraine (20.9 million tonnes), the United States (17.8 million tonnes), Germany (10.6 million tonnes), France (8 million tonnes), the Netherlands (6.9 million tonnes), Canada (6.2 million tonnes), Egypt (6.1 million tonnes), South Africa (2.5 million tonnes), and Australia (1.1 million tonnes). The total global harvested area in 2022 stood at approximately 17.79 million hectares.

In Africa, Irish potato output was projected to reach 25 million metric tonnes, with a yield of 13,215.4 kg/ha and per capita consumption of 18.76 kg/year (FAOSTAT, 2019). Egypt is the continent's leading producer at approximately 6.16 million metric tonnes, followed by South Africa (2.53 million metric tonnes) and Morocco (1.77 million metric tonnes). Nigeria ranks as the fourth largest Irish potato producer in Sub-Saharan Africa and seventh in Africa, with an annual output of approximately 1.22 million metric tonnes and a yield of 37,201 hg/ha (FAOSTAT, 2022).

Irish potato was first cultivated on the Jos Plateau, Plateau State, in the early nineteenth century (Taiy et al., 2017; Tadesse et al., 2018). It is among the most productive tuber crops in Nigeria in terms of tuber yield and days to maturity. Its short growth cycle (80–90 days) enables multiple planting seasons per year, providing farmers with a consistent income stream. The Potato Research Centre in Kuru-Vom, Plateau State, plays a central role in improving Irish potato output through seed multiplication, farmer training, varietal breeding, and the development of improved cultural practices (Zemba et al., 2013).

Despite its potential, crop productivity remains constrained by pests and diseases, inadequate quality seed supply, poor storage, declining soil fertility under intensive management, limited varietal options, and high labour costs. Nigeria's average potato yield of approximately 3.1 tonnes per hectare is among the lowest globally. This study was therefore carried out to investigate the spatial variability of soil physicochemical properties and their impact on Irish potato production in Jos South and Riyom Local Government Areas (LGAs) of Plateau State, North Central Nigeria.

The specific objectives of the study were to: (i) characterize the available soil physicochemical properties and their spatial distribution in Irish potato farming areas on the Jos Plateau; (ii) identify the predisposing factors influencing the spatial pattern of these properties; (iii) assess the impact of soil physicochemical variability on Irish potato production; and (iv) recommend low-cost soil management strategies to improve potato yields.

The Study Area

The study area is located within the central zone of Plateau State, Nigeria, and encompasses two Local Government Areas (LGAs): Jos South and Riyom, both of which are important Irish potato-producing areas (Figure 1). The study region spans latitudes 9°01'50.2"N to 9°44'6.5"N and longitudes 8°41'27"E to 9°19'56"E, at an elevation of approximately 800 m above sea level. Jos South and Riyom have approximate land areas of 499.58 km² and 765.09 km², respectively. Both LGAs share similar climatic conditions with the broader Jos Plateau region, characterized by an average maximum temperature of 34°C and a minimum of 27°C (Figure 3). Peak temperatures are recorded between March and May, while the coolest temperatures occur during December and January (the Harmattan period). The rainfall season extends from April to October, followed by a dry, cold Harmattan season from November to February. This near-temperate climatic regime is well suited to Irish potato cultivation, which requires an optimum temperature of approximately 27°C for tuber formation (Okonkwo et al., 2009). The spatial distribution of rainfall and relative humidity in the study area is illustrated in Figures 2 and 4. Both LGAs meet the climatic requirements for Irish potato cultivation in both the rainy and dry seasons, making it one of the most important root crops on the Jos Plateau. Other crops grown in the area include maize, sweet potato, Acha (Fonio), finger yam, cucumber, carrots, millet, and guinea corn. Vegetation in the area falls within the Northern Guinea Savannah zone.

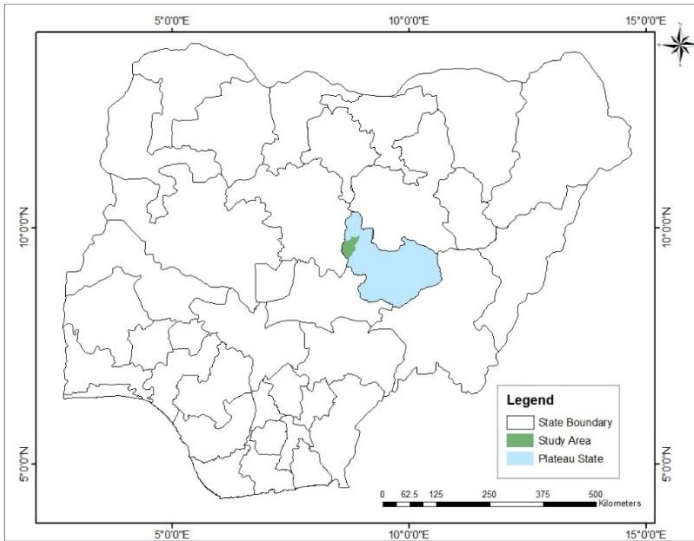


Figure 1: Map of Nigeria showing Plateau State and the study area

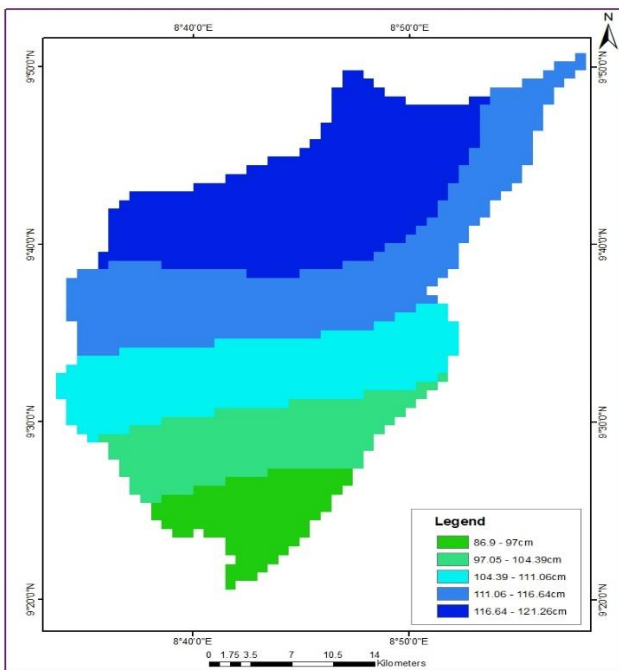


Figure 2: Rainfall Distribution in the Area

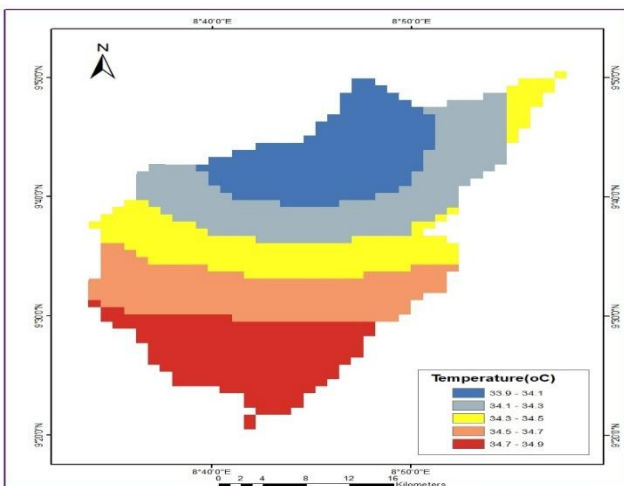


Figure 3: Temperature Variation in the Area

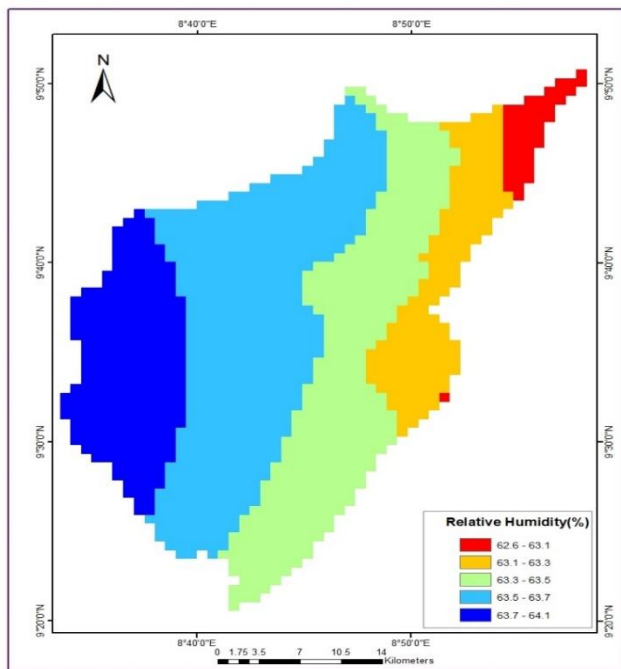


Figure 4: Percentage Variation of Relative Humidity in the area

Elevation

The study area's elevation ranges from approximately 523 m to 1,500 m above sea level, with the highest elevations occurring in the central plateau region (Figure 5). The general topography is relatively flat, interrupted by prominent younger granite intrusions. The Riyom Rock, located approximately 25 km southwest of Jos on the Jos–Akwanga Road at an elevation of approximately 1,350 m above sea level, is one of Nigeria's most distinctive geological formations, a stack of massive boulders that has become a notable landscape and cultural landmark. The Ganawuri younger granite ring complex rises to approximately 1,380 m and hosts a variety of granitic rock units. Weathering of these rock units has released macro- and micro-nutrients into the surrounding soils, contributing to their fertility.

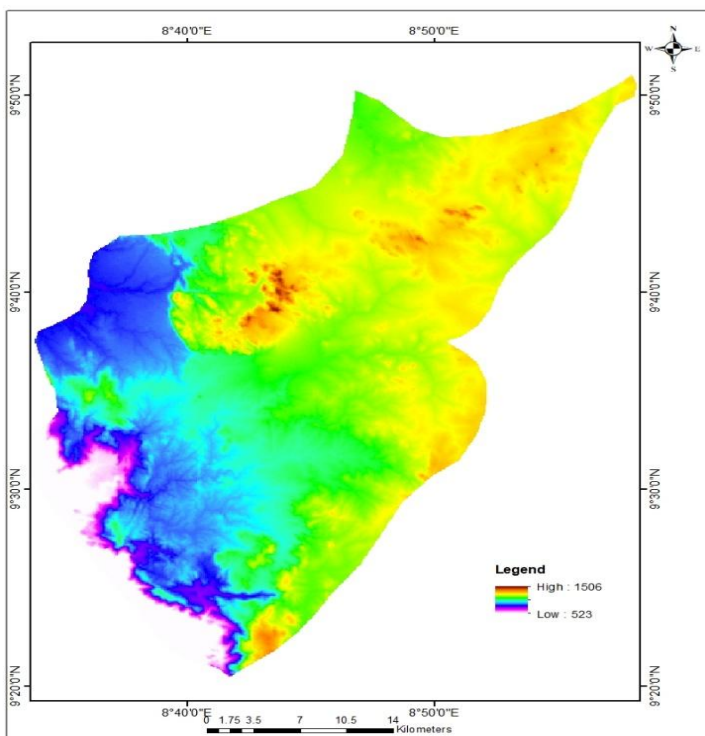


Figure 5: Elevation of the Study Area

Geology of the Study Area

The geology of Plateau State lies within the Precambrian Basement Complex of North Central Nigeria, comprising predominantly migmatite–gneiss assemblages believed to have been emplaced over 600 million years ago. The study area is characterized by crystalline basement rocks including migmatite, granite-gneiss, and Pan-African (Older) granites. In addition, younger granitic intrusions occur as elongated and massive bodies distributed across Jos South and Riyom. The Ganawuri complex exposes two principal rock units, the Crystalline Basement and the Younger Granite, each reflecting distinct intrusive cycles. The Crystalline Basement consists primarily of granite-gneiss, diorite, basalt, and pegmatite, progressing in younging direction from granite-gneiss through to pegmatite. The sole representative of the Younger Granite in the area is Biotite Granite (Ibeneme et al., 2013).

The dominant rock-forming minerals are quartz, feldspars, and biotite. On weathering, these yield sandy clay loam and loamy soils with variable clay content. K-feldspar weathering releases potassium and contributes to clay mineral formation. Basaltic rocks occur as boulders primarily around Vom in Jos South and at Tahos, Rim, Jol, Bachit, and Ganawuri in Riyom. Soils derived from basaltic parent materials and volcanic ash are notably more productive for food crops, including Irish potatoes and maize, compared with their granitic counterparts (Olowolafe, 2002). These reddish basaltic soils are highly fertile for agricultural activities in the region. Mine ponds resulting from colonial-era tin and columbite surface mining are also present and are used as water reservoirs for irrigation agriculture, particularly for Irish potatoes, tomatoes, cabbage, and green beans.

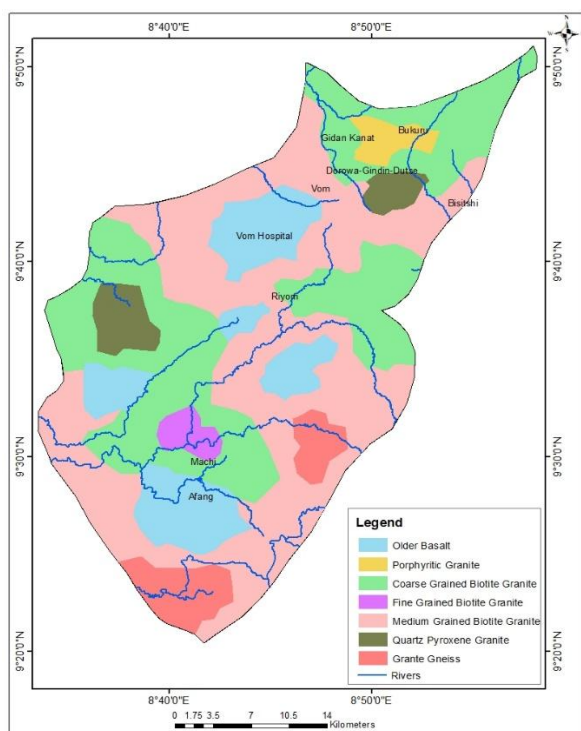


Figure 6: Geology of the Study Area

Materials and Methods

Materials

Remotely sensed data acquired for this study included NigeriaSat-X imagery, ASTER Digital Elevation Model (DEM) at 30 m spatial resolution, and Sentinel-2 imagery at 10 m resolution. Climatic data, including rainfall, temperature, and relative humidity, were obtained from the National Space Research and Development Agency (NASRDA) and from online repositories. Additional field materials included a handheld GPS receiver, a soil auger, plastic buckets, polythene bags, a hand trowel, a permanent marker, masking tape, a hardcover notebook, and pen.

Soil Sampling Design and Data Collection

Soil samples were collected from Irish potato farms distributed across the study area, which encompasses a total area of approximately 3,329.41 km². At each sampling location, four sub-samples were collected from randomly selected farm plots using a soil auger at a standardized depth of 0–30 cm. The four sub-samples from each location were thoroughly mixed to produce a single composite sample, thereby reducing local micro-scale variability. The geographic coordinates of each sampling point were recorded in situ using a handheld GPSmap 78CSx receiver. A total of 240 composite samples (Figure 7) were collected from diverse farming communities within Jos South and Riyom LGAs. Each sample was stored in a clean, labelled polythene bag with a unique identifier for subsequent laboratory analysis.

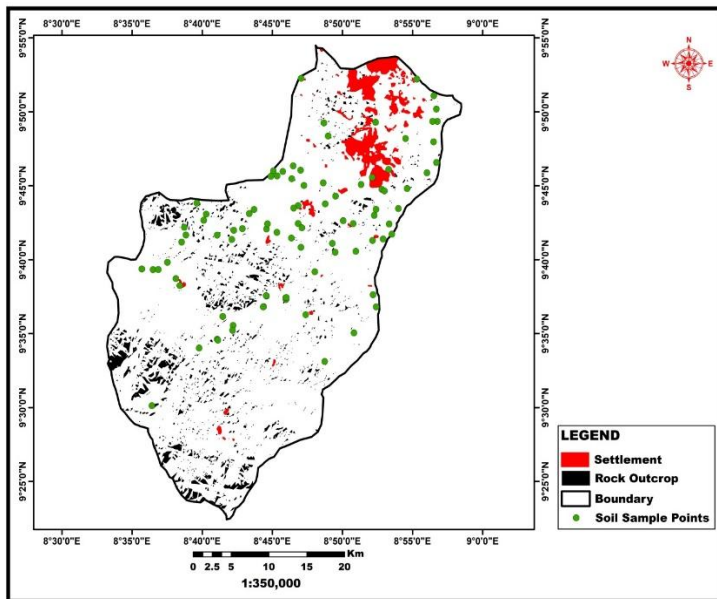


Figure 7: Soil sample distribution points in the study area

The soil samples were transported to the CDA Laboratory, Bayero University Kano (BUK), for physicochemical analysis. The parameters analysed and the corresponding laboratory methods are presented in Table 1.

Table 1: Soil parameters and laboratory methods adopted for analysis

S/N	Parameter	Unit	Method/Reference
1	Soil Texture	—	Hydrometer method (Bouyoucos, 1927)
2	Soil pH	—	Potentiometric, 1:2 soil: water ratio, pH meter (Jackson, 1973)
3	Organic Matter	%	Walkley–Black wet oxidation (Walkley and Black, 1934)
4	Total Nitrogen (N)	%	Micro-Kjeldahl digestion (Bremner and Mulvaney, 1982)
5	Available Phosphorus (P ₂ O ₅)	mg/kg	Olsen's method (Olsen et al., 1954)
6	Available Potassium (K ₂ O)	mg/kg	Ammonium acetate extraction (Jackson, 1967)
7	Iron (Fe)	mg/kg	Atomic absorption spectrometry

Soil Texture Classification

Soil texture reflects the relative proportions of sand, silt, and clay particles and influences water-holding capacity, aeration, workability, and drainage. The United States Department of Agriculture (USDA) Soil Textural Triangle was employed to classify soil texture based on measured particle-size distribution. Visual representation of possible texture combinations (Figure 8) was used to assign textural class names to the soil samples.

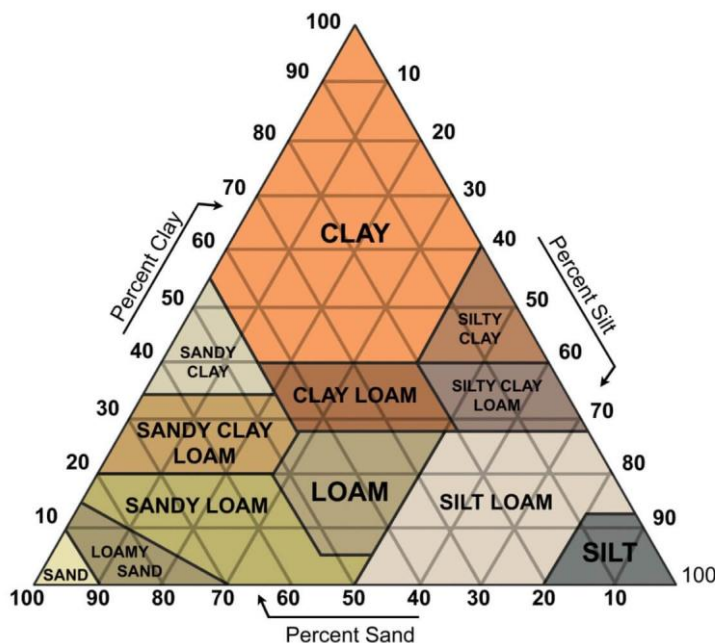


Figure 8: The USDA Soil Texture Triangle Chart. (After USDA, 2017)

Spatial Analysis and Interpolation

Analysed soil data were imported into ArcGIS 10.8, where GPS-referenced sampling coordinates were linked to laboratory-determined soil property values in a relational geodatabase. Spatial distribution maps for each physicochemical parameter were generated using Inverse Distance Weighting (IDW) interpolation. IDW was selected for its computational simplicity, non-negativity of interpolated values, and suitability for datasets where spatial autocorrelation decreases with increasing distance between sampling points, characteristics that are well established for soil nutrient data in agricultural landscapes (Mandal and Sharma, 2009; Mishra et al., 2013). The IDW method assumes that sampled values closer to the prediction location have greater influence than those farther away. Soil properties were classified into five concentration classes: very low, low, moderate, high, and very high. Soil pH was further classified as: very strongly acidic, strongly acidic, moderately acidic, slightly acidic, and neutral.

Statistical Analysis

Area statistics were computed for each soil parameter class within the GIS environment. Additional fields were created in the attribute tables, and class areas were calculated in square kilometres by multiplying the spatial resolution of the resampled imagery (10 m × 10 m) by the pixel count, then dividing by 1,000,000. The tabulated area data were exported to Microsoft Excel for calculation of total and percentage area coverage by class.

Study Limitations

This study has several limitations that should be acknowledged. First, the spatial analysis was based on point-data interpolation, which inherently carries interpolation uncertainty between sampling locations, particularly in areas of steep environmental gradients. Second, the study did not include temporal replication of soil sampling; seasonal fluctuations in soil nutrient levels may therefore not be fully captured. Third, while IDW is an accepted

spatial interpolation method, geostatistical alternatives such as ordinary kriging could provide additional information on spatial autocorrelation structure and prediction uncertainty, and future studies are encouraged to compare these approaches. Fourth, soil microbiological properties, which are closely linked to nutrient cycling, were not assessed in this study.

RESULTS

Overview of Soil Physicochemical Mapping

Geospatial soil mapping provides critical insight into spatial patterns of soil quality, enabling the identification of zones for targeted agricultural inputs. The following subsections present the spatial distribution of key soil physicochemical properties, texture, pH, organic matter, total nitrogen, available phosphorus, and available potassium, derived from IDW interpolation of the 240 composite samples.

Soil Texture

The study area is predominantly sandy clay loam, covering 876.80 km² (69.33% of the total area). Sandy loam, sandy clay, and loam textures account for 176.83 km² (13.98%), 135.02 km² (10.68%), and 76.01 km² (6.01%), respectively (Figure 9 and Table 2). Sandy clay loam and loamy textures are generally well-suited for the cultivation of a wide range of crops, including Irish potatoes, cassava, yam, and cocoyam.

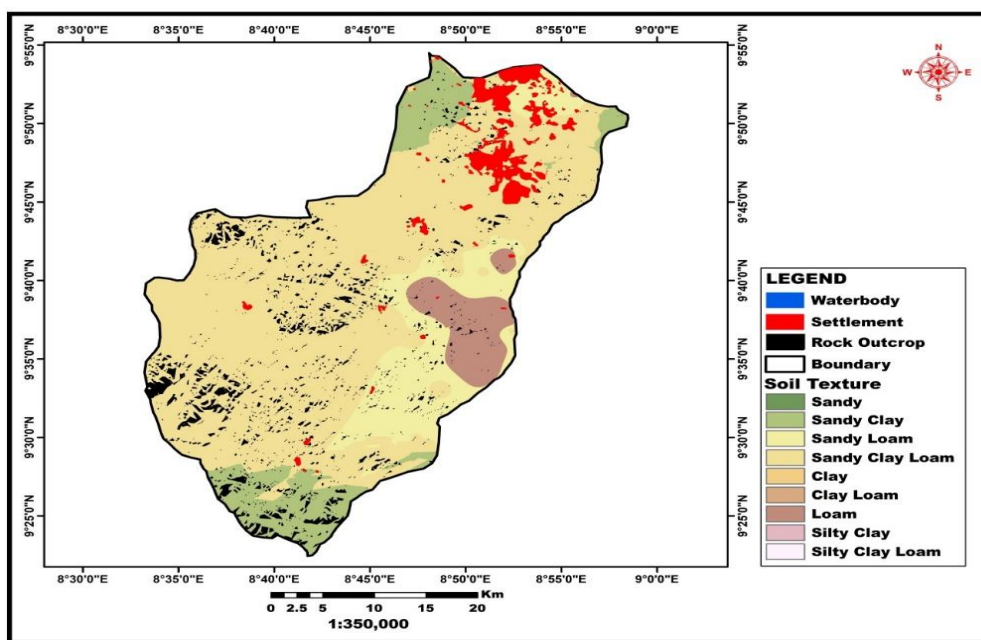


Figure 9: Soil Texture

Table 2: Soil texture area statistics

Textural Class	Area (km ²)	Area (%)
Loam	76.01	6.01
Sandy Clay	135.02	10.68
Sandy Clay Loam	876.80	69.33
Sandy Loam	176.83	13.98
Total	1,264.66	100.00

Soil pH

Soil pH across the study area ranges from approximately 5.28 to 5.97. The pH distribution was classified into five categories (Table 3). The majority of soils fall within the moderately acidic to neutral range (pH 5.64–5.97), collectively covering 81.91% of the study area: moderately acidic soils (403.82 km², 31.93%), slightly acidic soils (368.48 km², 29.14%), and neutral soils (263.56 km², 20.84%). Strongly acidic soils (pH 5.55–5.64) cover 172.27 km² (13.62%), while very strongly acidic soils (pH < 5.55) are limited to 56.52 km² (4.47%) of the area (Figure 10 and Table 3).

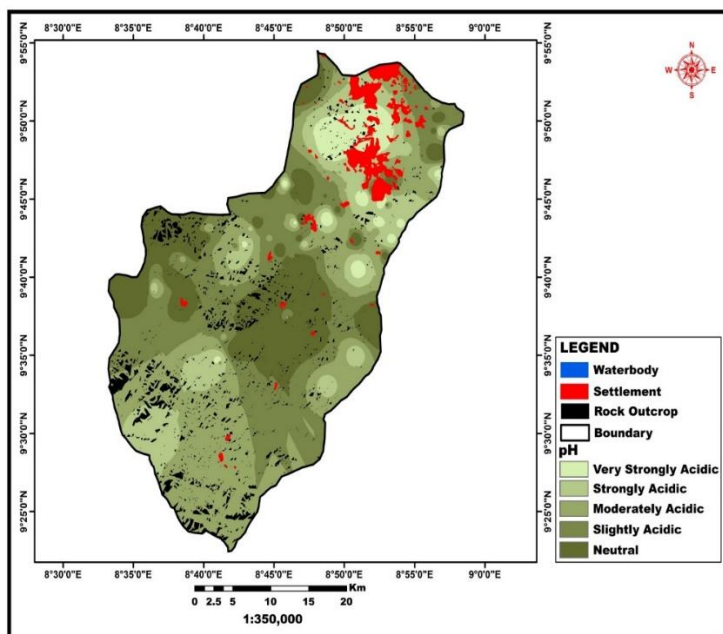


Figure 10: Spatial distributions of soil pH

Table 3: Soil pH classification ranges for Jos South and Riyom

pH Class	Lower pH Value	Upper pH Value	Area (km ²)	Area (%)
Very Strongly Acidic	5.28	5.55	56.52	4.47
Strongly Acidic	5.55	5.64	172.27	13.62
Moderately Acidic	5.64	5.70	403.82	31.93
Slightly Acidic	5.70	5.76	368.48	29.14
Neutral	5.76	5.97	263.56	20.84
Total	—	—	1,264.66	100.00

Organic Matter

Organic matter distribution across the study area is presented in Figure 11 and Table 4. Soils with high and moderate organic matter contents dominate, with high organic matter (391.46 km², 30.95%) and moderate organic matter (331.67 km², 26.23%) together accounting for over 57% of the area. Very low organic matter covers 202.82 km² (16.04%), low organic matter covers 200.49 km² (15.85%), and very high organic matter is present across 138.23 km² (10.93%).

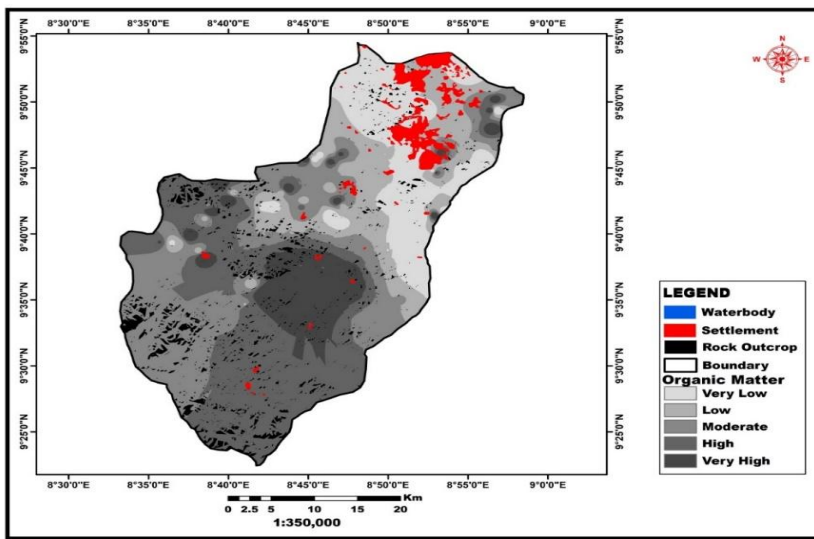


Figure 11: Spatial Distribution of Organic Matter

Table 4: Organic matter area statistics

Class	Area (km ²)	Area (%)
Very Low	202.82	16.04
Low	200.49	15.85
Moderate	331.67	26.23
High	391.46	30.95
Very High	138.23	10.93
Total	1,264.66	100.00

Total Nitrogen

The distribution of total nitrogen is relatively heterogeneous, with concentrations spread across all five classes. Soils with very low nitrogen levels cover the largest proportion of the study area at 432.37 km² (34.19%), followed by low (262.64 km², 20.77%), moderate (253.55 km², 20.05%), very high (160.64 km², 12.70%), and high (155.46 km², 12.29%) categories (Figure 12 and Table 5).

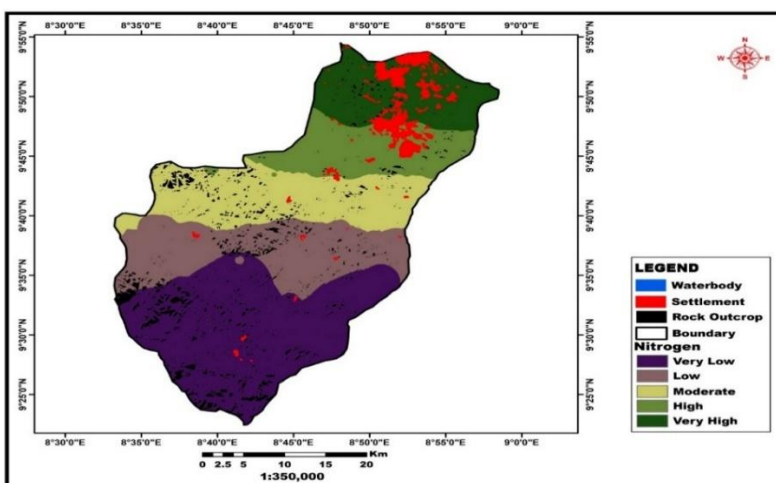


Figure 12: Spatial distributions of Total Nitrogen

Table 5: Total nitrogen area statistics

Class	Area (km ²)	Area (%)
Very Low	432.37	34.19
Low	262.64	20.77
Moderate	253.55	20.05
High	155.46	12.29
Very High	160.64	12.70
Total	1,264.66	100.00

Available Phosphorus

Available phosphorus concentrations in the study area are predominantly low to very low. Very low concentrations cover 472.88 km² (37.39%), and low concentrations cover 473.94 km² (37.48%), together accounting for approximately 75% of the total area. Moderate phosphorus levels are found in 188.56 km² (14.91%) of the area, while high and very high concentrations are restricted to 104.50 km² (8.26%) and 24.79 km² (1.96%), respectively (Figure 13 and Table 6).

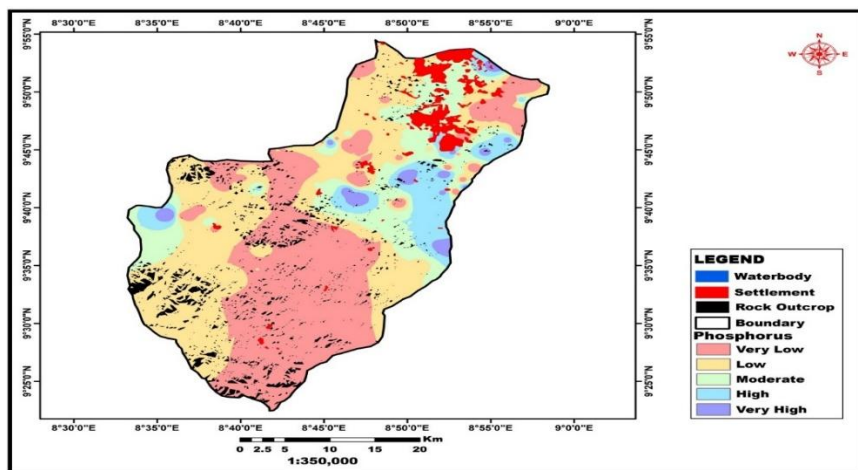


Figure 13: Spatial distributions of Available Phosphorus

Table 6: Available phosphorus area statistics

Class	Area (km ²)	Area (%)
Very Low	472.88	37.39
Low	473.94	37.48
Moderate	188.56	14.91
High	104.50	8.26
Very High	24.79	1.96
Total	1,264.66	100.00

Available Potassium

Potassium concentrations peak at the moderate class, which covers 435.74 km² (34.46%) of the study area. Low and high concentration classes each account for more than 20% of the area (287.47 km², 22.73% and 277.29 km², 21.93%, respectively). Very low and very high concentrations cover 140.75 km² (11.13%) and 123.41 km² (9.76%), respectively (Figure 14 and Table 7).

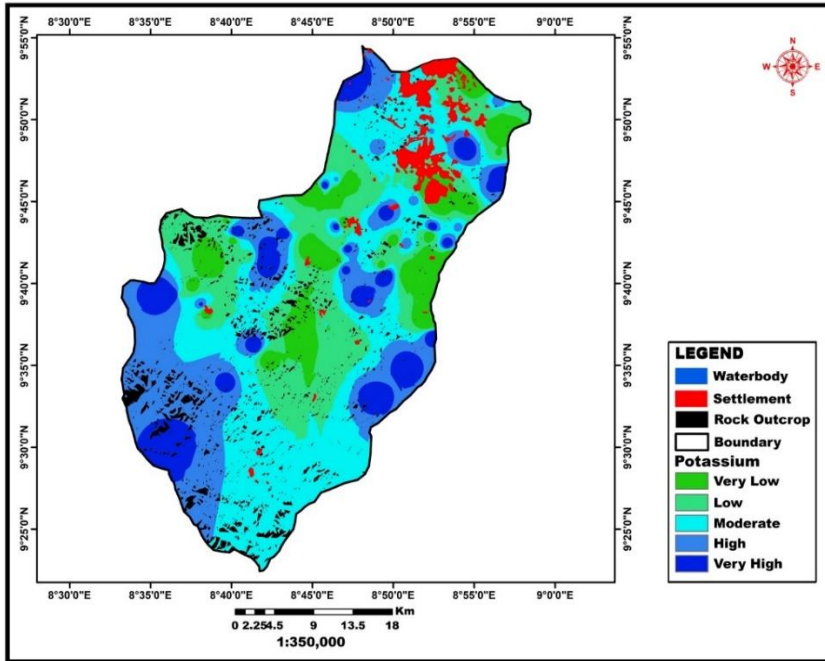


Figure 14: Spatial Distributions of Potassium

Table 7: Available potassium area statistics

Class	Area (km ²)	Area (%)
Very Low	140.75	11.13
Low	287.47	22.73
Moderate	435.74	34.46
High	277.29	21.93
Very High	123.41	9.76
Total	1,264.66	100.00

DISCUSSION

Soil Texture

The study area encompasses four textural classes, with sandy clay loam predominating (Figure 9). Sandy clay loam and loam textures are well-suited for Irish potato cultivation; indeed, the textural preference of Irish potato within the study area aligns with these soil types. Notably, purely sandy soils are absent from the study area, which may indicate that excessively well-drained soils are insufficient to support adequate potato growth. The prevalence of clay-bearing textures in the study area is attributable to the in-situ breakdown of feldspars and other clay-forming minerals within the granitic and volcanic parent rocks, a process that generates significant clay fractions in the resulting soils.

Fine-grained extrusive and volcanic rocks, particularly associated with the Ganawuri ring complex, Vom basaltic volcanics in Jos South, and volcanics at Rim, Jol, and Tahos in Riyom, enrich the silt content of local soils, contributing to higher potato yields per hectare. These soils, derived from volcanic ejecta and pyroclasts rich in nutrient minerals, are highly productive for agriculture. The proximity of these soils to active volcanic and magmatic intrusion sites means they remain relatively juvenile and mineral-rich, having not yet undergone extensive weathering and nutrient depletion. Additionally, tin and columbite mining activities in the Middle Belt region have exposed subsurface micronutrients through excavation, further enhancing the fertility of affected soils. The mine ponds left by these activities provide water for dry-season irrigation, enabling near-year-round Irish potato cultivation.

Soil pH

Soil pH exerts a fundamental influence on crop performance through its effects on nutrient availability, microbial activity, and root development. Plants generally perform best at pH levels above 5.5, with pH 6.5 commonly regarded as optimal for nutrient availability (Quigley et al., 2018). Below this optimum, the solubility of aluminium (Al), manganese (Mn), and iron (Fe) increases, potentially reaching phytotoxic levels and inhibiting root elongation. Irish potatoes specifically perform best within a pH range of 6.0–6.5, which supports maximum nutrient availability and healthy root growth.

Results from this study indicate that soil pH across the study area ranges from 5.28 to 5.97, and moderately acidic to neutral soils predominate, covering over 80% of the total area. Very strongly acidic soils occur predominantly in Jos South, particularly in areas such as Gyel and Bukuru, where leaching from leucocratic granites and granodiorites releases acidic cations. In comparison, very strongly acidic soils account for only 0.07% of the Riyom land area but 11.21% of Jos South. The acidic character of the soils is consistent with their setting on an elevated plateau underlain by acidic parent rocks and subjected to high annual rainfall, which promotes leaching of basic cations. These conditions are similarly observed in other nearby LGAs such as Mangu, Bokkos, Barkin Ladi, and peri-urban areas of Jos North. Strongly acidic soils require liming interventions to raise pH and improve phosphorus, calcium, and magnesium availability, while reducing the risk of aluminium and manganese toxicity. Regular pH monitoring is recommended to prevent further acidification. Overall, however, the pH range observed across the study area falls broadly within acceptable limits for Irish potato cultivation, suggesting that with appropriate management, soil pH does not represent a major barrier to production for the majority of the study area.

Organic Matter

Organic matter (OM) plays a critical role in Irish potato production by improving soil structure, water-holding capacity, nutrient availability, and microbial activity (Grob et al., 2023). The spatial distribution of OM in the study area reveals that low to very low OM soils (31.89% combined) are concentrated in Jos South, where they occupy 37.23% (185.98 km²) and 34.47% (172.20 km²) at the very low and low classes, respectively. Potatoes grown in such soils are likely to exhibit stunted growth, weak root systems, reduced tuber size, and lower yields due to limited nutrient availability and poor water retention. These soils are also more susceptible to erosion and compaction. The low OM content in these areas is attributed to sparse vegetation cover, high rates of organic matter decomposition under warm conditions, surface erosion, and anthropogenic disturbance including construction and unsustainable farming practices.

Conversely, soils with high and very high OM content are located principally in central parts of the study area, including around Tahos and the Ganawuri environs, spreading southward and westward. High and very high OM soils (30.95% and 10.93%, respectively) provide excellent conditions for potato production: they support strong nutrient cycling, improved moisture retention, and a more active microbial environment conducive to robust plant growth and high tuber yield. Importantly, the spatial patterns of OM distribution closely mirror those of soil pH, suggesting a strong co-variation between these two properties. Soil management interventions targeting one parameter, such as liming to raise pH or organic mulching to improve OM, are therefore likely to benefit both. More than 66% of soils in the study area have moderate to very high OM content and can support productive potato cultivation with minimal intervention.

Total Nitrogen

Nitrogen (N) is essential for vegetative growth, tuber development, and overall yield in Irish potato production. A clear south-to-north gradient of increasing nitrogen content is evident across the study area, a trend that holds when the two LGAs are examined separately. This pattern may reflect the proximity of the northern areas to Jos City, which facilitates access to NPK fertilizers, as well as nitrogen inputs from urban and peri-urban waste streams rich in ammoniacal compounds. Consistent with findings from the literature, soils with high nitrogen availability support vigorous early vegetative growth, strong leaf and stem development, and ultimately enhanced tuber formation (Grob et al., 2023). However, excessive nitrogen can promote excessive foliage development at the expense of tuber yield, delay tuber maturity, and increase susceptibility to late blight. Nitrogen management in high-availability zones must therefore be carefully calibrated.

Approximately 55% of the study area (combining very low and low classes, Table 5) has inadequate nitrogen availability to support healthy potato growth without fertilizer supplementation. This deficiency is especially acute in Riyom, where very low and low nitrogen soils account for approximately 86% of the LGA's land area. Low nitrogen availability in these zones is likely driven by high rainfall intensities, which promote surface runoff and leaching of nitrates. Conversely, soils with moderate to very high nitrogen availability (approximately 45% of the area) are capable of supporting healthy potato growth, though careful management remains important in high-nitrogen zones to prevent nutritional imbalance.

Available Phosphorus

Phosphorus (P) is vital for root development, energy transfer, and overall plant vigour, with direct implications for tuber quality and yield in Irish potato. The spatial data reveal that over 74% of the study area has very low to low available phosphorus concentrations (37.39% and 37.48%, respectively). These deficiencies are likely to result in stunted root growth, delayed tuber maturity, and significantly reduced yields unless corrected through targeted phosphorus fertilization. Areas with moderate phosphorus (14.91%) can sustain reasonable potato growth, though some supplementation remains beneficial.

Areas with high (8.26%) and very high (1.96%) phosphorus concentrations are confined primarily to Zawan and Anguldi in Jos South, and portions of western Riyom, together representing just over 10% of the total area. These zones are likely to support strong plant health, adequate root development, and above-average yields, with minimal additional phosphorus inputs required. However, it is important to note that very high phosphorus concentrations can interfere with the uptake of zinc and iron, potentially inducing secondary micronutrient deficiencies. This underscores the importance of balanced fertilization and regular soil testing. Consistent with findings from other studies (Medhe et al., 2012), phosphorus availability in the study area is closely linked to soil pH, organic matter content, and parent material, all of which vary spatially across the study area.

Available Potassium

Potassium (K) is critical for tuber development, osmoregulation, disease resistance, and overall plant health in Irish potato. Potato crops have relatively high potassium requirements. The spatial distribution of soil potassium across the study area shows considerable variability, with very low to low concentrations covering approximately 33.86% of the area, concentrated particularly in Zawan, Bukuru, and Mararaba Jama'a. These areas are likely to experience suboptimal tuber development and increased susceptibility to environmental stress and disease unless potassium is supplemented.

Approximately 65% of the study area has moderate to very high potassium concentrations, including large portions of Riyom and central areas of Jos South (Table 7 and Figure 14). These soils are favourable for Irish potato production, supporting stronger plants, better tuber formation, and higher yields, with minimal or no additional potassium inputs required. The occurrence of moderate to high potassium levels in volcanic terrain around the Ganawuri ring complex, Rim, Jol, Tahos, and Vom is consistent with the elevated K-feldspar content of granitic rocks in these areas, which releases potassium during weathering (Lar et al., 2020). The periodic application of NPK fertilizers by farmers in these localities may further contribute to potassium accumulation in the topsoil.

CONCLUSION

This study has demonstrated the utility of geospatial techniques in characterizing the spatial variability of soil physicochemical properties and their implications for Irish potato production in Jos South and Riyom LGAs, Plateau State. The IDW-interpolated soil maps reveal that macro- and micro-nutrients in the study area are adequate to support Irish potato cultivation in zones with moderate to high concentrations of nitrogen, phosphorus, potassium, and organic matter, combined with slightly to moderately acidic soil pH. Soils derived from basaltic parent materials, particularly in and around Vom, Ganawuri, Rim, Jol, and Tahos, are most fertile and represent the most productive zones for sustainable potato cultivation. These areas have the potential to serve as focal hubs for potato value chain development, including the transformation of tubers into high-value processed products that can increase farmer incomes, generate rural employment, reduce post-harvest losses, and contribute to national food and economic security. The results of this study provide a scientific basis for site-specific nutrient management decisions and underscore the need for continued soil fertility monitoring across the Jos Plateau.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. A digital soil management map should be developed from the geospatial data generated in this study. Such a tool would serve as a practical decision-support resource for farmers, agronomists, and land use planners by providing detailed, location-specific information on soil properties, guiding the type, quantity, and spatial targeting of farming inputs to optimize productivity while minimizing environmental impact.
2. The success of geospatial precision agriculture technologies depends on coordinated collaboration among researchers, agricultural extension officers, policymakers, and farmers. Investment in farmer training and capacity building is essential to translate spatial soil data into practical on-farm management improvements.
3. For zones identified as having very strongly acidic soils, targeted liming programs should be implemented to raise soil pH and improve nutrient availability, particularly for phosphorus, calcium, and magnesium. Regular soil pH monitoring is recommended to track acidification trends and evaluate the effectiveness of interventions.
4. Water stored in mine ponds across Jos South and Riyom should be systematically harnessed to support dry-season irrigation, thereby extending the Irish potato growing season and improving food security in the region.
5. Future studies should explore the use of geostatistical methods such as ordinary kriging alongside IDW to compare interpolation performance and quantify spatial prediction uncertainty. Temporal soil sampling across seasons would also provide valuable insight into nutrient dynamics under prevailing farming systems.

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