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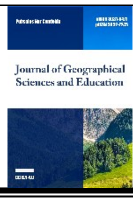

[Research Article]

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A Survey of Maize Cultivars and Soil Textural Suitability Across Agro-Ecological Units of The River Watari Basin, Kano State, Nigeria

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Abstract

The urgency of optimizing maize (Zea mays L.) productivity in semi-arid regions like the River Watari basin depends heavily on aligning soil physical characteristics with appropriate cultivar selection to ensure regional food security. This study evaluates soil texture and maize cultivar suitability within irrigated agro-ecologies by analyzing 54 soil samples for physicochemical properties, including soil pH, nitrogen, phosphorus, and potassium, exchangeable bases, and organic carbon. The research identified that the area is predominantly characterized by loamy and sandy loam soils, which are moderately suitable for maize production. Seven major cultivars, including hybrid and open-pollinated varieties, were identified. Results reveal clear relationships between soil texture and distribution: hybrid varieties are concentrated in well-drained sandy loam, while early maturing cultivars are common in clay-rich soils with higher moisture retention. These findings emphasize that soil texture critically determines cultivar performance and farmer selection strategies. Integrating soil suitability evaluation into extension services is essential for yield stability and sustainable irrigation planning in northern Nigeria.

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Abstrak

Pentingnya mengoptimalkan produktivitas jagung (Zea mays L.) di daerah semi-kering seperti cekungan Sungai Watari sangat bergantung pada penyelarasan karakteristik fisik tanah dengan pemilihan varietas yang tepat untuk memastikan ketahanan pangan regional. Studi ini mengevaluasi tekstur tanah dan kesesuaian varietas jagung dalam ekologi pertanian irigasi dengan menganalisis 54 sampel tanah untuk sifat fisikokimia, termasuk pH tanah, nitrogen, fosfor, potasium, basa yang dapat dipertukarkan, dan karbon organik. Penelitian ini mengidentifikasi bahwa daerah tersebut sebagian besar dicirikan oleh tanah lempung dan lempung berpasir, yang cukup sesuai untuk produksi jagung. Tujuh varietas utama, termasuk varietas hibrida dan penyerbukan terbuka, diidentifikasi. Hubungan yang jelas terdapat antara tekstur tanah dan distribusinya; varietas hibrida terkonsentrasi di tanah lempung berpasir yang berdrainase baik, sedangkan varietas yang cepat matang umum ditemukan di tanah kaya lempung dengan retensi kelembapan lebih tinggi. Temuan ini menekankan bahwa tekstur tanah sangat menentukan kinerja varietas dan strategi pemilihan petani. Mengintegrasikan evaluasi kesesuaian tanah ke dalam layanan penyuluhan sangat penting untuk stabilitas hasil panen dan perencanaan irigasi berkelanjutan di Nigeria bagian utara.

INTRODUCTION

Maize is one of the most important cereal crops in Nigeria, both in terms of the number of farming households engaged in its cultivation and its contribution to national food security and rural incomes. Originally introduced to the region as a subsistence crop (Iken & Amusa, 2004; Ammani, 2015), maize has evolved into a commercially significant commodity used for human consumption, livestock feed, and agro-industrial processing. Its high carbohydrate content, versatility, and market demand make it a preferred crop across diverse agro-ecological zones of the country, particularly within the savanna belt. In northern Nigeria, maize production has increasingly shifted toward irrigated systems along river basins, floodplains, and dam command areas (Adnan et al., 2017a).

This transition is largely driven by population growth, urban food demand, declining reliability of the rainy season, and farmers' adaptive responses to climate variability (Adnan et al., 2017b). The River Watari irrigation corridor represents one of the most intensively cultivated dry-season agricultural zones. It is one of the most productive dams in the region, utilised for a variety of purposes, particularly dry-season irrigation, providing livelihoods to thousands in the rural populace (Tanko & Momale, 2014). Consequently, maize has emerged as the dominant crop in the area because it is the most widely cultivated (Zhang et al., 2020).

Despite its agronomic and economic importance, maize productivity in irrigated environments remains constrained by inappropriate land use practices, declining soil fertility, and limited scientific guidance on cultivar–land matching. Farmers often rely on experiential knowledge when selecting maize varieties, with limited reference to systematic land suitability evaluation, which provides a framework for matching land characteristics with crop requirements for sustainable land use. In this context, the Food and Agriculture Organization (FAO) classifies land according to its suitability for crops based on drainage, soil texture, nutrient status, and slope (FAO, 2022).

Soil texture plays an important role in determining aeration, water retention, and root development, which affect crop development (Mawia et al., 2025). Given the proliferation of improved maize cultivars ranging from extra-early to late-maturing, hybrid, and open-pollinated types, there is a pressing need to assess how these cultivars interact with soil spatial variability. Although several studies, such as Abagyeh et al. (2016), Durodola & Mourad (2020), and Tofa et al. (2020) have focused primarily on yield performance, agronomic practices, or irrigation management, limited attention has been given to the relationship between soil textural variability and the suitability of specific maize cultivars within irrigated river-basin environments.

Maize production in Kano State exhibits a marked contrast between rain-fed and irrigated systems. In contrast, rain-fed yields are often lower due to high moisture and nutrient requirements, irrigated maize has become one of the most productive and economically attractive crops. Along the River Watari, a substantial proportion of irrigated land is devoted to maize, reflecting strong market demand for fresh, boiled, and roasted maize during the dry months. However, the increasing availability of diverse maize cultivars differing in maturity period, water demand, and stress tolerance poses a challenge for farmers.

The absence of detailed land-suitability information has resulted in suboptimal cultivar placement, inefficient water use, and variable yields across the basin. Poor drainage or low nutrient levels trigger stunted growth, prompting farmers to compensate by increasing irrigation and fertilizer use, thereby raising production costs and potentially leading to long-term soil degradation. This study addresses this gap by systematically assessing soil texture and documenting the suitability of dominant maize cultivars within the River Watari irrigation ecology.

The research aims to identify and map dominant soil textural classes through laboratory analysis and examine how major maize cultivars relate to these specific soil conditions. The findings will contribute to a better understanding of soil-crop interactions, assist farmers in selecting strategies to improve productivity, and provide an empirically grounded basis for sustainable maize intensification in semi-arid northern Nigeria. This approach supports regional food security by integrating soil suitability into agricultural planning and extension services. Furthermore, this study establishes a technical framework for site-specific nutrient management, ensuring that agricultural inputs are tailored to the inherent water-holding and drainage capacities of the identified soil textures

LITERATURE REVIEW

Land suitability evaluation provides a scientific basis for matching land characteristics with crop requirements to achieve optimal and sustainable agricultural production (Suntoro et al., 2023). The framework developed by the FAO of the United Nations classifies land into suitability categories based on key indicators such as soil properties, climate, and water availability (FAO, 1976). Within this framework, soil texture is a critical factor influencing water retention, infiltration, aeration, and nutrient dynamics. These factors directly affect crop growth and productivity, particularly in irrigated systems in semi-arid environments (Aune & Lal, 1997). In northern Nigeria, where irrigation increasingly supplements unreliable rainfall, soil texture and maize cultivar characteristics interact in complex ways to influence land suitability.

Sandy loam and loamy soils generally provide favourable conditions for maize cultivation due to their balanced drainage and moisture retention, which support optimal root development and nutrient uptake. In contrast, clay-rich soils, although capable of retaining moisture, often present challenges such as poor drainage, compaction, and temporary waterlogging. These conditions can restrict root growth and reduce oxygen availability under irrigated conditions (Çakir et al., 2017). Such soil constraints interact directly with maize's physiological requirements, including its sensitivity to excess moisture and its demand for well-aerated soils during critical growth stages. As a result, soil physical properties remain a primary determinant of agricultural performance in river-basin ecologies.

Farmers tend to adopt early maturing or stress-tolerant cultivars in less suitable soils, while reserving high-yielding hybrid varieties for more favourable soil conditions (Badu-Apraku & Fakorede, 2017). This adaptive strategy, however, can lead to spatial mismatches where cultivars are not optimally aligned with soil characteristics. Such misalignment often results in reduced yields, inefficient water use, and increased production risk for the farming households. Despite the widespread application of the FAO land evaluation framework, existing studies in Nigeria have largely focused on general crop suitability or yield performance (FAO, 1976; Mustapha & Loks, 2008). These studies often fail to adequately link soil textural variability to the adaptation and distribution of specific maize cultivars.

Limited attention has been paid to how spatial differences in soil texture influence cultivar selection and performance in irrigated river-basin environments, such as the River Watari basin in Kano State. This gap highlights a key land suitability challenge: variability in soil properties, combined with limited access to site-specific agronomic information, constrains effective land-crop matching. Addressing this challenge requires integrating soil physical properties with crop-specific requirements within structured land evaluation approaches (FAO, 1976). Such integration is essential for improving cultivar-soil matching and enhancing resource-use efficiency. Ultimately, these efforts are crucial for promoting sustainable irrigated maize production in semi-arid regions.

METHOD

Study Area

The study area is in the northwestern part of Kano, situated between latitudes 12°6'54.54''N and 12°9'1.78''N and longitudes 08°11'50.62''E and 08°16'28.05''E (Adamu, 2014). Specifically, the research was conducted in the downstream area of the River Watari within the Bagwai Local Government Area (LGA). This region, located in the northern part of Kano State, covers an area of 405 km^2. According to the 2022 census, the area had a population of ± 265.700 (City Population, 2022).

The climate of the study area is classified as the Tropical Wet and Dry type, coded as Aw according to Köppen's classification. While climatic changes are believed to have occurred in the past, the current characteristics remain typical of the West African Savannah. Temperatures in the region are generally high year-round (Abdulhamed et al., 2011). These thermal conditions influence the evaporation rates and water requirements for crops within the irrigation corridor.

Rainfall patterns vary between the southern and northern extremes of Kano due to latitude and continental influences. The average annual rainfall for the region is approximately

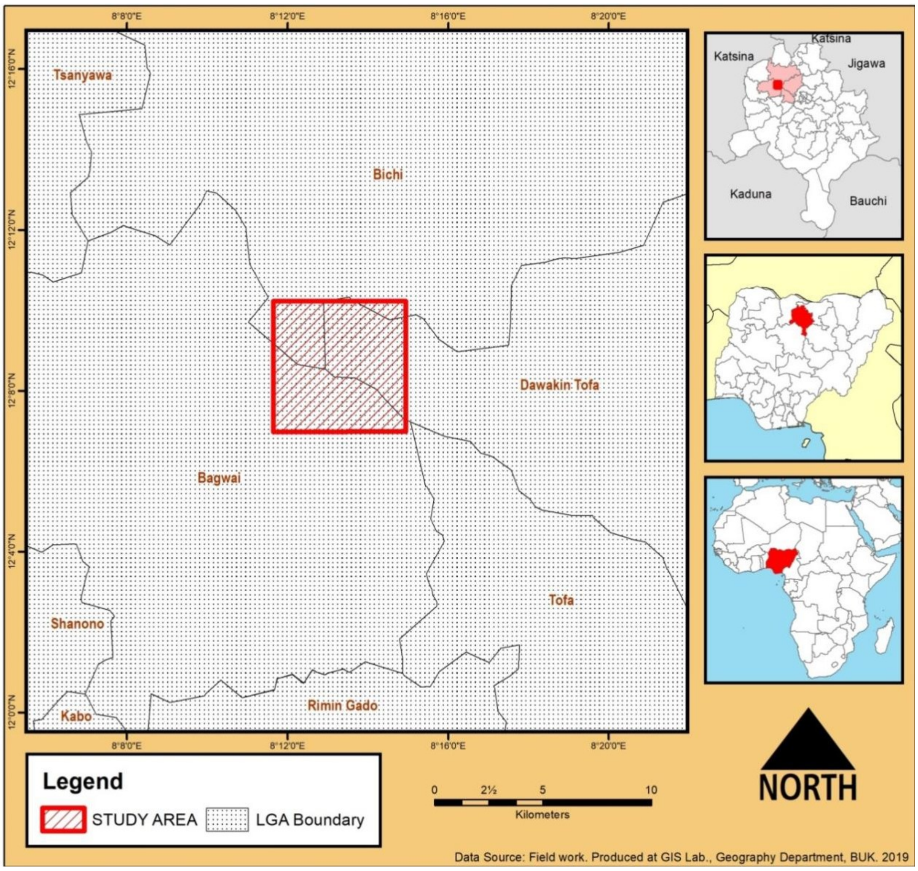

Figure 1. Study area

884 mm, generally increasing from north to south. In the extreme north, including the Bagwai and Dambatta LGAs, the annual rainfall is often below 800 mm, particularly near the desert fringe. This northern section is known as Zone 1, typically experiencing between 110 to 130 rainy days per year (Tanko & Momale, 2014).

The soils of the Kano region are derived from two primary geological formations: the Basement Complex and the Chad Formation. Soils developed on the rocks of the Basement Complex are generally mature, relatively well-structured, and possess sufficient depth for staple crop cultivation. Conversely, soils on the Chad Formation, often derived from Aeolian materials, are poorly structured and excessively drained. Most soils in the region are predominantly sandy, particularly within the surface horizon (0–30 cm), and are generally free of stones.

Historically, the farming system in the area was mainly rain-fed, which often resulted in insufficient food production due to limited rainfall. However, the introduction of the irrigation scheme has significantly enhanced agricultural activities, enabling more stable livelihoods. This development enables farmers to grow various crops twice a year, including maize, rice, tomatoes, pepper, onion, and okra. Consequently, the area has transitioned from subsistence farming to a more intensive, productive agricultural system.

Source and Type of Data

Both primary and secondary data sources are used in this study to ensure a comprehensive evaluation of the research area. Primary data were collected directly from farmers in the irrigation corridor through structured interviews. These interviews generated essential information regarding local land classification, the specific types of cultivars currently in use, and the varieties preferred by the farmers. This first-hand information provides a ground-level perspective on agricultural practices and farmer decision-making strategies.

In addition to survey data, primary information was obtained through laboratory analysis of soil physicochemical properties. The parameters analyzed include soil pH, nitrogen (N), available phosphorus (P), and potassium (K). Furthermore, the analysis included exchangeable bases and organic carbon content to determine the area's baseline fertility. These technical data points serve as the empirical foundation for assessing soil suitability for various maize cultivars.

Secondary data were collected and synthesized from a wide range of relevant materials to provide contextual support for the study. These sources include academic books, peer-reviewed journals, conference proceedings, and unpublished theses. Additionally, information on climate, soils, and water resources was extracted from Google Earth maps and other official documents. This synthesis of secondary information ensures that field observations are well-integrated with existing geographical and environmental knowledge of the region.

Soil Sampling and Analysis

A grid-based sampling framework was adopted for this study, utilizing a 500m × 500m grid overlaid on a geo-referenced base map derived from high-resolution satellite imagery (Figure 2). This systematic approach ensured comprehensive spatial coverage across the irrigated agro-ecologies of the River Watari basin. A total of fifty-four (54) soil samples were collected at specific locations corresponding to the grid intersections and central points. This method allowed for a representative characterization of the soil variability across the entire study area.

The soil collection process utilized composite sampling at a consistent depth of 0–15 cm, which corresponds to the active root zone of maize. By focusing on this depth, the study ensures that the analyzed physicochemical properties directly reflect the environment encountered by the crop's roots. Each of the fifty-four samples was carefully labeled and stored for subsequent laboratory evaluation. This depth-specific sampling is critical for accurate land suitability assessment in irrigated systems.

Following field collection, the samples were air-dried to prepare them for detailed physicochemical evaluation. The laboratory analysis focused on determining textural composition and other key properties using standard laboratory procedures. These parameters included soil pH, N, available P, K, exchangeable bases, and organic carbon. The resulting data provides the empirical basis for matching soil characteristics with specific maize cultivar requirements.

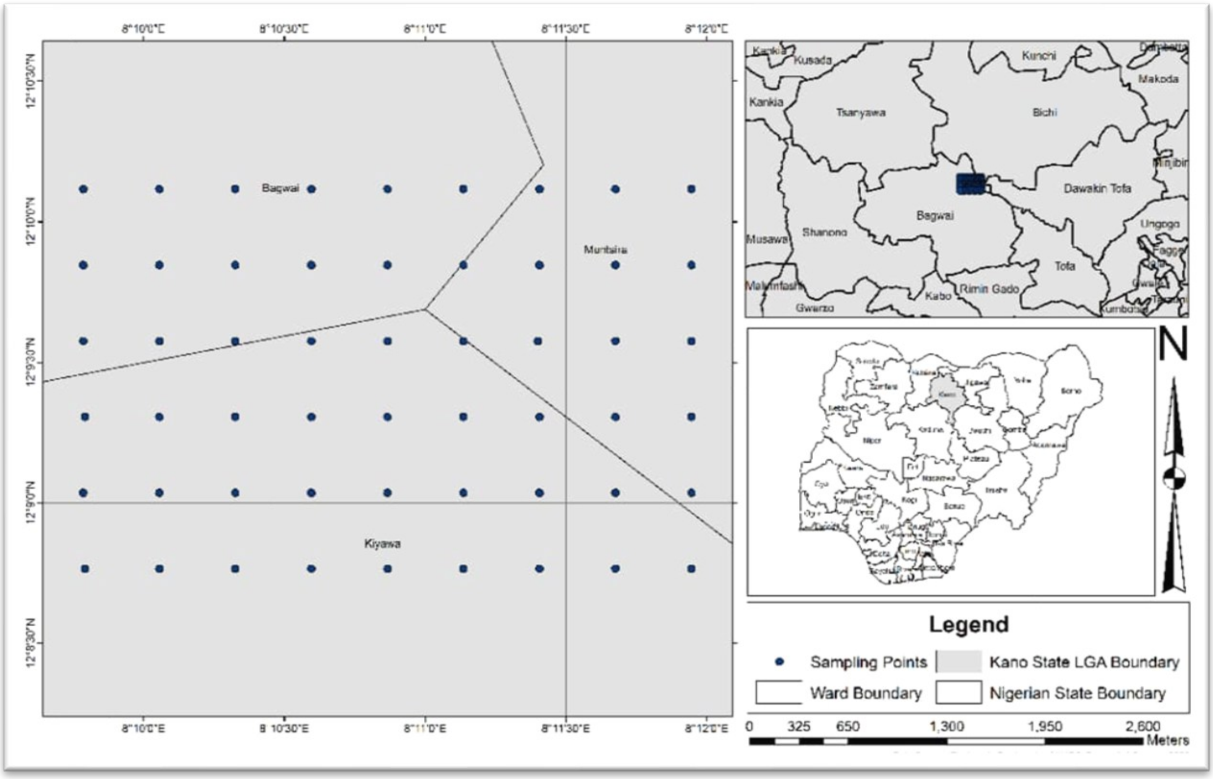

Figure 2. Study Area Showing Points Composite Sampling Method

Laboratory Analysys

The soil samples collected from the field were meticulously prepared by air-drying and sieving to ensure consistency across all tests. Following this preparation, they were taken to the laboratory for the analysis of key soil fertility indicators using standard laboratory procedures. This phase of the research is critical for identifying the nutrient status and physical characteristics of the River Watari irrigation corridor. The resulting data provides empirical evidence needed to evaluate land suitability for different maize cultivars.

The chemical properties analyzed during this process included essential macronutrients such as N, available P, and K. Additionally, the analysis covered Organic Carbon (OC), soil pH, and the full suite of exchangeable bases, including Sodium (Na), Calcium (Ca), Magnesium (Mg), and Potassium (K+). These chemical indicators are vital for understanding the nutrient availability and chemical balance of the soil. Such data is indispensable for determining how well specific maize varieties can perform in these specific environments.

The physical properties of the soil were also examined to complement the chemical data and provide a holistic view of the land. This analysis included determining particle size distribution and soil colour, and identifying specific textural classes. Understanding the soil's physical makeup is essential, as it dictates water retention, aeration, and root penetration for the crop. By integrating both chemical and physical properties, the study establishes a comprehensive profile of the soil's productive capacity in the basin.

Identification of Soil Mapping Units

Soil mapping units were delineated by integrating observable field characteristics such as texture, colour, and moisture regime with quantitative laboratory results. This spatial analysis was conducted using ArcGIS version 10.2.0, which facilitated the precise mapping of soil variability across the River Watari basin. The mapping method involved interpolating point data from the 54 sampling locations to create continuous surfaces of soil properties. This GIS-based approach ensures that the spatial distribution of soil types is accurately represented for land management purposes.

Soil textural classes were formally determined using the United States Department of Agriculture (USDA) textural triangle, which categorizes soils based on their relative proportions of sand, silt, and clay. These classes were then evaluated for maize suitability following the established FAO land evaluation framework (FAO, 1976). This framework provides a systematic approach to matching soil physical and chemical properties with the specific agronomic requirements of maize. By applying these standardized criteria, the study ensures that the suitability classifications are scientifically robust and comparable to other regional studies.

The land suitability for maize was categorized into four distinct classes based on the degree of limitation observed: S1 (Highly Suitable), S2 (Moderately Suitable), S3 (Marginally Suitable), and N (Not Suitable). Class S1 represents land with no significant limitations, while S2 and S3 denote land with minor to severe limitations that may require specific management interventions. Class N indicates land that possesses limitations so severe that they preclude successful maize cultivation under current conditions. This classification system allows for a clear spatial identification of areas where specific maize cultivars will perform optimally.

Farmer Survey and Cultivar Identification

Structured interviews were conducted with maize farmers to systematically document the varieties cultivated within the River Watari irrigation corridor. These interviews were essential for gathering data on local nomenclature, maturity periods, and the perceived agronomic performance of different cultivars. By engaging directly with the farming community, the study generated a detailed inventory of both hybrid and open-pollinated varieties (OPVs) used in the area. Additionally, observational methods were used during field visits to validate respondents' varietal identifications. This dual approach ensured that the qualitative data from farmers were accurately aligned with the physical characteristics of the crops observed in the field.

Method of Mapping Suitability

A multi-criteria evaluation model was employed to determine the spatial suitability of the study area for maize cultivation. This model integrated all laboratory-measured soil parameters with the specific environmental requirements for maize crops identified in the literature review. To create continuous spatial data, the Natural Neighbor Interpolation technique was used to map each soil property across the basin. Each resulting parameter map was then reclassified into four distinct categories according to the FAO suitability order (FAO, 1976). This systematic reclassification enabled a standardized comparison of soil physical and chemical variables.

The reclassified maps for each soil parameter were subsequently combined using the Geographic Weighted. This process assigned relative importance to different soil factors to produce a comprehensive final suitability map. The resulting output provides a clear spatial representation of the suitability classes, ranging from highly suitable to not suitable, across the River Watari irrigation corridor. Finally, the weighted map was exported for detailed presentation and discussion within the research findings. This GIS-based modeling approach ensures that the relationship between soil texture and maize performance is accurately visualized for agricultural planning.

RESULT AND DISCUSSION

Soil Textural Classes

The textural classes of the soil within the River Watari irrigation corridor were evaluated based on the relative proportions of sand, silt, and clay particles. This determination followed the USDA textural triangle to ensure standardized classification for agricultural suitability. The resulting data are presented in Table 1 below.

Table 1. Textural Classes around River Watari

Soil Classes	Suitability Rating	Suitability
Loamy soil	S2	Moderate
Sandy loam	S2	Moderate
Sandy clayed loam	S1	High
Silt clay loam	S2	Moderate
Clay loam	S3	Marginal
Clay	S3	Marginal

Source: Field Survey, 2025.

Six distinct soil textural classes were identified within the River Watari basin: loam, sandy loam, sandy clay loam, silty clay loam, clay loam, and clay (Table 1). Among these, sandy loam soils dominate the study area, covering approximately three-quarters of the total extent. According to the evaluation, these sandy loam soils are classified as moderately suitable (S2) for maize production. This classification indicates that the soil provides an optimal balance between moisture retention and drainage, which is vital for maize growth under irrigation systems.

These findings align with the FAO land suitability framework, which identifies soil texture as a critical determinant of crop performance. Similar results have been reported in the semi-arid regions of northern Nigeria, where sandy loam soils are known to support stable maize yields due to their physical properties (Maniyunda & Malgwi, 2011; Shehu et al., 2018; FAO, 2022). While sandy loams are the most prevalent, sandy clay loam soils, though spatially limited, exhibit high suitability. This is due to their superior balance of moisture retention and nutrient availability compared to coarser textures (Malgwi et al., 2000; Lawal et al., 2014).

In contrast, clay and clay loam soils in the basin are categorized as marginally suitable (S3) for maize cultivation. This lower suitability is primarily due to drainage constraints and the inherent risk of waterlogging under intensive irrigation. Such physical limitations can impede root aeration and overall plant development during critical growth stages. Maniyunda & Malgwi (2011) also found that lowland soils, or those with high clay content, often downgrade to Marginally Suitable (S3) or Not Suitable (N) due to drainage limitations that cause anoxic conditions in corn roots. Adesemuyi (2014) also stated that land units that occupy depressions (low-lying) with fine-textured soils (clay) are not suitable for corn due to poor drainage and the risk of waterlogging during irrigation or periods of intensive rainfall. The spatial distribution of textural classes across the irrigation corridor is shown in Figure 3.

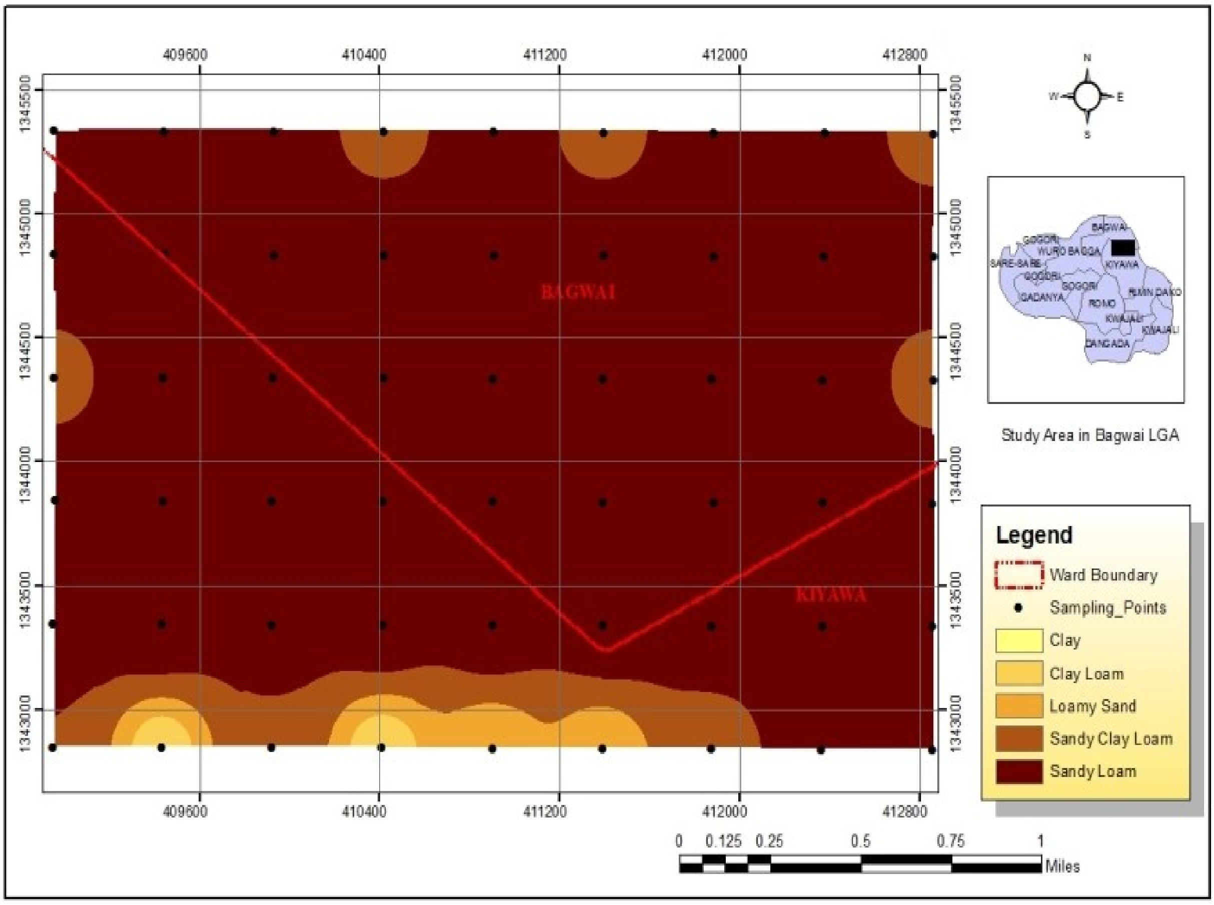

Figure 3. Textural Classes around River Watari

Maize Cultivars and Their Soil Conditions

The field survey identified seven major maize cultivars actively growing within the River Watari irrigation corridor: ACR 97, Extra-early varieties, Oba 98, Oba Super-1, Sammaz 17, Sammaz 18, and 95TZEE. Among these, hybrid varieties such as Oba 98 and Oba Super-1 are the most widely adopted by local farmers. Tahiru et al. (2015) showed that hybrid varieties have higher nutrient-use efficiency, which helps explain why farmers prefer them in intensive systems. This preference is also consistent with recent findings by Badu-Apraku et al. (2021), who identified that early and extra-early maturing tropical maize cultivars are specifically developed to offer robust resistance against foliar diseases like Northern Corn Leaf Blight, which has become a significant threat to maize productivity in the lowland agro-ecologies of West and Central Africa. Furthermore, the adoption of these improved varieties is significantly driven by socio-economic factors such as farm size and access to extension services (Kadafur et al., 2020). This high adoption rate reflects a strong preference for cultivars with high yield potential, early maturity, and robust disease resistance, which are critical for maximizing productivity under intensive irrigation. These hybrids are typically positioned on the most suitable land units to leverage their genetic potential for high output.

In contrast, OPVs like Sammaz 17 and ACR 97 continue to play a vital role in the local agricultural system, particularly in specific soil contexts. While they may have lower peak yields than hybrids, OPVs are valued for their broad adaptability to varying soil fertility levels, lower requirements for external inputs, and the ability for farmers to recycle seeds for subsequent seasons. The results of research by Kamara et al. (2003) showed that although hybrids were superior under optimal conditions, OPVs showed good yield stability in environments with low inputs or varying soil fertility. This preference for seed autonomy and low-input requirements aligns with the findings of Adegbola et al. (2011), who observed that small-holder farmers in West Africa often prioritize technologies and varieties that offer economic flexibility and mitigate long-term

Table 2. Maize Cultivars around River Watari

Cultivar	Local Name	Variety Type	Maturity Period (Days)	Dominant Soil Type
ACR 97	*Hakorin jaki*	Open-pollinated (white)	~100 (medium)	Loamy soil
Extra-early	*Isra Ali Mai aure*	Hybrid (red/white)	80–90 (early)	Clay soil
Oba 98	*Yar Obansu*	Hybrid (white)	~75 (early)	Sandy loam
Oba Super-1	*Yar obansu or premier*	Hybrid (white/yellow)	110–120 (late)	Sandy loam
Sammaz 17	-	Open-pollinated (white)	~100 (medium)	Loamy soil
Sammaz 18	*Isra ali/ gajera*	Open-pollinated (white)	90–100 (medium)	Silty clay loam
95TZEE	*Yar eka*	Hybrid (white/yellow)	65–70 (extra-early)	Loamy soil

Source: Field Survey, 2025.

production risks. The distribution of these cultivars is closely linked to soil characteristics; for instance, certain varieties are favored in areas with higher clay content due to their relative tolerance to moisture stress. Detailed information regarding each cultivar and its corresponding soil type is presented in Table 2.

The distribution of cultivars across various soil types reveals a distinct relationship between soil physical properties and crop selection. Sandy loam and loamy soil were found to support the widest range of cultivars, particularly high-yielding hybrids such as Oba 98 and Oba Super-1 (Maniyunda & Malgwi, 2011; Tahiru et al., 2015). These soil types provide favorable conditions for maize growth, offering a critical balance between adequate drainage and moisture retention, which is essential for success under irrigation. These findings align with the FAO land suitability framework (FAO, 1976), which identifies soil texture as a primary determinant of crop performance and management requirements.

In contrast, extra-early cultivars like 95TZEE and other early-maturing varieties are strategically linked to clay-rich soils. This trend is likely explained by the high water-retention capacity and poor drainage inherent in clay soils, which often lead to transient waterlogging. To mitigate this, farmers typically select short-duration cultivars that can complete their growth cycle before unfavorable soil moisture conditions negatively impact production. This serves as a vital adaptive method to reduce production risks in Alfisols of the Savanna zone, where soil quality and physical properties significantly dictate maize yield (Badu-Apraku et al., 2011; Odunze et al., 2017). Such environmental escape strategies are essential for maintaining yield stability in the tropical savannas of Nigeria, where moisture and nitrogen availability are often inconsistent.

Furthermore, loamy soils appear to support both hybrid and OPVs, suggesting their broad aptitude and adaptability for maize agriculture. This observation is consistent with research conducted in the semi-arid regions of northern Nigeria, where the balanced physical characteristics of loamy soils are frequently linked to sustained maize performance (Yusuf & Yusuf, 2008). Ultimately, matching maize cultivar selection with specific soil textural features is crucial for maximizing productivity, increasing water-use efficiency, and strengthening the long-term sustainability of irrigated systems in the River Watari basin. Tofa et al. (2022) demonstrated that optimizing the interaction between nitrogen and phosphorus is essential for enhancing grain yield and nutrient-use efficiency in the inherently low-fertility soils of the Nigerian savanna. Such integrated approaches are vital for increasing water-use efficiency and strengthening the long-term sustainability of irrigated systems in the River Watari basin.

Relationships between Soil and Cultivars

Significant correlations were observed between soil textural classes and the selection of maize cultivars within the study area. Sandy loam and loamy soil were found to support the widest diversity of cultivars, particularly high-performing hybrid varieties such as Oba 98 and Oba Super-1. This spatial distribution suggests that these soil textures provide the optimal physical environment required for intensified maize development under irrigation. Specifically, the balanced proportions of sand, silt, and clay in these soils ensure adequate aeration, effective drainage, and sufficient water retention (Lal, 1979), collectively minimizing physiological stress during critical growth stages.

The preference for hybrid varieties on these soil types also reflects a management strategy aimed at maximizing yield potential where edaphic constraints are minimal. In these favorable soil settings, the genetic advantages of hybrids, such as uniform maturity and high nutrient-use efficiency, can be fully expressed. These observations are consistent with the FAO (1976) land suitability framework and the agroecological assessments of Ojanuga (2006), which identify loamy textures as the most versatile for cereal production due to their superior tilth and favorable moisture-holding characteristics.

Beyond physical suitability, the successful integration of high-performing hybrids in loamy and sandy loam soils is closely linked to nutrient-use efficiency and fertilizer response. In the Nigerian savanna, maize productivity is inherently limited by low soil nitrogen and phosphorus levels, necessitating a synergistic management approach. As demonstrated by Tofa et al. (2022), the interaction between nitrogen and phosphorus significantly enhances grain yield and nutrient uptake, particularly in well-aerated soils where root development is not restricted. In the River Watari basin, the concentration of hybrid cultivars in loamy areas likely reflects a strategic decision by farmers to apply intensive fertilization where the soil's physical structure can best support nutrient recovery. Conversely, the lower adoption of nutrient-demanding hybrids in heavier clay soils may be a rational response to the risk of nutrient loss through denitrification and leaching during transient waterlogging periods, further emphasizing the importance of matching genotype with both the physical and chemical environments of the soil (Eissa & Negim., 2019; Tofa et al., 2022).

Implications, Limitations, and Policy Recommendations

The findings of this study have significant implications for agricultural development and land management within irrigated systems. First, the observed mismatch between certain cultivars and soil types highlights a critical need for enhanced extension services to guide farmers in selecting maize varieties best suited to their specific soil conditions. By improving soil–crop alignment, farmers can significantly boost productivity and mitigate the risk of yield losses. Furthermore, integrating soil suitability assessments into irrigation planning is essential for optimizing water-use efficiency. This is particularly vital in semi-arid regions like Kano, where limited water resources must be managed strategically to ensure that crops are cultivated in soils that provide optimal moisture retention and drainage.

This matching strategy between genotypes and their respective environments serves as a cornerstone for resource-use efficiency at the field level. The successful adoption of high-performing hybrids in loamy soils indicates an adaptive awareness to maximize genetic potential in favorable environments. However, this study recognizes the limitations inherent in the dynamic nature of soil chemical variables. While the relationship between texture and cultivar selection is evident, seasonal fluctuations in Nitrogen and Phosphorus availability, as well as denitrification rates in transiently waterlogged clay soils, were not measured in situ over a long-term period. Additionally, the role of socio-economic factors, such as access to capital, requires further exploration to determine whether cultivar choice is driven purely by biophysical constraints or by limited purchasing power.

For future research, it is recommended to integrate crop growth models with geospatial data to precisely map cultivar suitability across Nigeria's irrigation schemes. Such integration would allow for more accurate yield predictions by accounting for weather anomalies and localized soil variability. Research focus should also be directed toward developing varieties that are not only drought-tolerant but also tolerant of waterlogging to optimize productivity in clay-rich soils.

From a policy perspective, institutions such as the Kano State Agricultural and Rural Development Authority should formulate strategies informed by agro-edaphic zoning. Rather than uniform seed distribution, hybrid seed assistance and fertilizer subsidies should be tailored to the soil texture maps of specific irrigation blocks. As demonstrated by Tofa et al. (2022), optimizing the interaction between nitrogen and phosphorus is essential in these low-fertility savannas; thus, policies must ensure that targeted input distribution aligns with the soil's physical and chemical environment to enhance nutrient recovery.

Overall, optimizing the River Watari irrigation system requires a synergy between soil science, plant breeding, and inclusive public policy. By strengthening the improved seed supply chain and ensuring the targeted distribution of agricultural inputs, the sustainability of food production in Northern Nigeria can be significantly enhanced. This soil-based adaptation model offers a replicable framework for other savanna regions in West Africa to bolster regional food security amidst increasingly dynamic environmental challenges.

CONCLUSION

This study evaluated the spatial distribution of maize cultivars in relation to soil texture within the River Watari irrigation basin of Kano State. The results indicate that the region is predominantly composed of loamy and sandy loam soils, which are categorized as moderately suitable for maize cultivation, with localized areas exhibiting higher suitability.

The findings further reveal a diverse landscape of maize cultivars, including both hybrid and OPVs, with distinct correlations observed between soil texture and cultivar selection. Specifically, hybrid cultivars are primarily concentrated in sandy loam and loamy soils, whereas early-maturing varieties are more prevalent in clay-rich areas.

These results confirm that soil texture is a critical determinant of maize distribution and productivity in irrigated environments. By demonstrating that soil characteristics and cultivar traits jointly dictate land suitability and agricultural performance, this study provides a comprehensive answer to the research questions. It offers a framework for optimized crop management in the River Watari basin.

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