West African Journal of Life Sciences. Available online at
http://www.wajls.com ISSN (Print):2992-5150. eISSN:3122-0916
Volume 2; Issue 2: pages 23-33

Full Length Research

Effects of Different Land Use Types on Maize (*Zea mays* L.) Productivity: A Comparative Study of Soils from Farm, Dumpsite, Roadside, Field, and Built-up Areas

Oseremen, M. N[1]*., Ogie-Odia, E. A[2]., Eseigbe, D. A[3]., Ehilen, O. E[4]. and Ahmed, A. S[5].

[1,2,3,4,5]Department of Plant Science and Biotechnology, Ambrose Alli University, Ekpoma, Edo State, Nigeria

***Corresponding Author's Email**: marychoiceoseremen@aauekpoma.edu.ng Tel: + 234 703 530 0541

ABSTRACT

Land use plays a critical role in determining soil quality and crop productivity. This study investigated the effects of different land use types on the growth performance of maize (*Zea mays* L.) using soils collected from farm, dumpsite, roadside, field, and built-up areas. Maize seeds were planted in pots containing the soils, and data were collected on germination percentage, plant height, leaf area, and chlorophyll content for a period of 32 days. The results revealed significant variations in maize performance across the land use types. Germination percentage was highest in soils from built-up (86%) and field areas (82%), while the lowest was observed in dumpsite soils (54%). In contrast, vegetative growth and chlorophyll content were superior in maize grown in dumpsite soils, which recorded the tallest plants (42.6 cm) and largest leaf area (95.4 cm^2). Farm soils performed least across most parameters, while roadside soils supported moderate growth but showed signs of stress, possibly due to compaction and contamination. This study concludes that land use history significantly influences the capacity of soils to support maize growth. Although soils from non-agricultural environments such as dumpsites enhanced vegetative growth, their low germination performance and potential contamination risks highlight the need for caution. Sustainable land management practices remain essential to improving soil quality and ensuring crop productivity.

Received July 10, 2025

Received in Revised form, Nov. 29, 2025

Accepted Nov. 30, 2025

Available Online Dec. 30, 2025

W. Afr. J. Life Sci. 2 (2):23-33

Keywords: Maize Productivity, Land Use Practices, Soil Types, Chlorophyll Content, Germination rate, Plant Growth Parameters, Sustainable Agriculture.

INTRODUCTION

Maize (*Zea mays* L.), a member of the grass family Poaceae, is one of the most important cereal crops globally and a key staple in sub-Saharan Africa (Santpoort, 2020). Introduced to West Africa by the Portuguese in the 10th century, maize has evolved into a socio-economically significant crop in Nigeria, where it ranks third among cereals in terms of cultivated area and production volume (Osundare, 2017). Beyond its importance as a food crop, maize serves as a critical input in the production of poultry feeds—accounting for about 80% of feed ingredients—and supplies raw materials for various agro-industries, including those producing starch, syrup, and oil (FAO, 2008; Oluwatayo et al., 2008). Despite its versatility and demand, maize productivity in Nigeria remains low, primarily due to poor input use, weak seed systems, and environmental challenges (IITA, 2009).

A major underlying factor affecting maize productivity is the way land is used and managed. Land use entails the modification and utilization of land resources for various human activities, especially agriculture (Mwavu & Witkowski, 2009). In Nigeria, smallholder farmers are the primary producers of maize, often relying on rudimentary land management practices, which contributes significantly to declining soil fertility and reduced yields (Ajibefun, 2002; Oluwatayo et al., 2008). Poor land management, characterized by over-cultivation, deforestation, and limited fallow periods, has resulted in land degradation, a condition defined as the long-term decline in the productive capacity of the land (Heyi & Mberegwa, 2012; Orchard et al., 2016). Land degradation in Nigeria is largely driven by anthropogenic activities, compounded by socio-economic pressures such as urbanization, population growth, and insecure land tenure systems (Babalola & Olayemi, 2013). The consequences include erosion, nutrient depletion, and loss of vegetative cover, all of which significantly impair agricultural productivity, particularly for crops like maize (Kiage, 2013). Moreover, changing rainfall patterns linked to global climate change further complicate the relationship between land use and crop productivity (IITA, 2009). To combat these challenges, sustainable land management practices (SLMPs) have been promoted. These practices such as contour farming, crop rotation, mulching, and conservation tillage aim to optimize land productivity while preserving its ecological functions (Awoyinka et al., 2009; Henttonen et al., 2017). According to Raveloaritiana and Wanger (2024), appropriate land-use diversification, when properly implemented, can substantially enhance both economic returns and environmental sustainability in agriculture.

Given the central role of maize in Nigeria's food and economic systems, and the increasing stress on land resources, understanding the effect of land use on maize productivity is both timely and essential. This study, therefore, seeks to investigate how different land use practices impact the productivity of maize focusing on various soil types, with a view to promoting sustainable agricultural development and informing land policy interventions.

MATERIALS AND METHODS

Plant materials

Maize (*Zea mays)* seeds were purchased from

Anglican market in Alli square Ekpoma, Edo State. The seeds were brought to the Herbarium of the Department of Plant Science and Biotechnology, Faculty of Life Science, Ambrose Alli University, Ekpoma in a polythene bag and authenticated to be the desired species. The maize seeds were planted at a depth of 5 cm in soil-filled bags for the experiment. Soil samples were collected in Ekpoma, Edo state from farms, dumpsites, roadsides, fields, and built-up areas for the study.

Experimental Design and Cultivation

The experiment was arranged in a Completely Randomized Design (CRD) comprising five soil types; farm, dumpsite, roadside, field, and built-up area soils were used as treatments, each replicated three times. Pots were randomly assigned to treatments using a lottery method to ensure equal probability of allocation and to minimize experimental bias. The CRD was selected due to the homogeneity of the experimental environment, allowing treatment effects to be attributed solely to soil type. Soils were packed inside 15 polythene bags for the treatments in triplicates, 4 maize seeds were planted per bag and watered to field capacity every morning throughout the experimental period.

Data Collection

Measurement and data were collected on plant height, leaf length, leaf width, leaf area, stem diameter, leaf number, root depth, leaf colour, and chlorophyll content. These data were collected twice in a week except for root depth and chlorophyll test which were collected at the end of the experiment.

Plant Height

This was measured using a 150 cm measuring tape, placed from the base of the stem to the tip of the newest leaf. Mean values were calculated from replicates.

Leaf Length

Leaf length was measured with a 150 cm measuring tape, placed from the petiole base to the apex of the healthiest, longest, and broadest leaf per plant. Averages were taken across replicates.

Leaf Width

Measurement of leaf width was done horizontally at the widest portion of the same selected leaf using a 150 cm measuring tape. Average values were recorded.

Leaf Area

The leaf area was estimated non-destructively using the formula by Mokhtarpour *et al*. (2010):

Leaf Area = 0.75 × (L×W).

where L = leaf length, and W = leaf width.

Stem Diameter

Measured at the midpoint of the stem using the 150 cm measuring tape. Mean values were recorded.

Leaf Number

The total number of leaves per plant was counted, and averages were taken for each treatment.

Emergence rate / Germination percentage

The number of germinated seedlings was counted for each treatment (12 seeds planted per treatment). Germination percentage was calculated accordingly. Final germination percentage (GP) was calculated as:

GP = (Number of germinated seeds / Total seeds sown) × 100.

Root Depth

Plants were carefully uprooted, roots washed free of soil, and depth measured from the stem base to the tip of the longest root using a 150 cm measuring tape.

Leaf Colour

Visually assessed as part of growth performance evaluation.

Chlorophyll Content

Chlorophyll content was determined using a solvent extraction method with 80% acetone. Fresh leaf samples (1 g) were cut into small pieces and ground into a fine pulp with a mortar and pestle, using 20 ml of 80% acetone. The homogenate was centrifuged at 5000 rpm for 5 minutes, and the supernatant was collected. This process was repeated four times until the residue was nearly colourless. The combined extracts were made up to 100 ml with 80% acetone. Absorbance readings were taken at 645 nm and 663 nm using a spectrophotometer, with 80% acetone as blank. Chlorophyll concentrations were calculated in accordance with Porra et al. (2022).

Chlorophyll-a per gram of tissue = $[12.7 (A_{663}) – 2.69 (A_{645})] \times V \div (1000 \times W)$

- Chlorophyll-b per gram of tissue = $[22.9 (A_{645}) – 4.68 (A_{663})] \times V \div (1000 \times W)$
- Chlorophyll per gram of tissue = $[20.2 (A_{645}) + 8.02 (A_{663})] \times V \div (1000 \times W)$

Where: A = absorbance at specified wavelength; V = final extract volume (100 ml); W = fresh weight of leaf sample (1 g).

STATISTICAL ANALYSIS

Microsoft Excel and IBM SPSS Statistics (version 29) were used to analyze data obtained. Relevant charts and tables were used to present the findings of the study. Also, data were subjected to one-way analysis of variance (ANOVA) and mean separation was performed with Tukey's HSD and Duncan's multiple range test at a 5% significance level.

RESULTS

Germination percentage varied considerably across the different soil type (Table 1). Built-up area soil yielded the highest germination percentage (92%), followed by field soil (83%) and farm soil (75%). Roadside soil showed a moderate germination rate of 67%. Notably, dumpsite soil, despite supporting the most robust subsequent growth, had the lowest germination percentage at 50%.

Table 1: **Germination Percentage of Maize seeds across the five Soil Treatments.**

Soil Type	Total Seeds Planted	Seeds Germinated	Germination Percentage
Built-up area soil	12	11	92%
Field soil	12	10	83%
Farm soil	12	9	75%
Roadside soil	12	8	67%
Dumpsite soil	12	6	50%

Growth Parameter of Maize

Growth parameters of maize cultivated in different soil types are presented in Table 2, while the final mean values of selected parameters are summarized in Figure 1. Overall, maize plants grown in dumpsite soil consistently exhibited superior growth compared to other soil types across all weeks. By the third week, plants in dumpsite soil reached the tallest height (58.2 cm), widest leaves (6.0 cm), largest leaf area (264.6 cm²), and greatest stem diameter (4.5 cm). In contrast, plants in farm soil recorded the lowest values in most parameters, including plant height (26.5 cm), leaf area (30.6 cm²), and stem diameter (1.6 cm). Roadside soil supported intermediate growth performance, while built-up area soil and field soil displayed moderate values for most parameters. Root depth measurements also indicated clear variation, with dumpsite soil (37.0 cm) supporting the deepest root system, followed by roadside (23.8 cm), field (22.7 cm), built-up area (16.0 cm), and farm soil (9.7 cm).

Chlorophyll Content of Maize Plant

The chlorophyll content of maize plants varied significantly across the different soil types. Chlorophyll *a*, Chlorophyll *b*, and total chlorophyll followed a similar trend, with the highest concentrations observed in plants grown in dumpsite soil**,** followed closely by roadside soil (Figure 3). In contrast, the lowest chlorophyll levels were consistently recorded in plants from farm soil and built-up area soil**.**

Specifically, chlorophyll *a* ranged from 0.45 mg/g in farm soil to 1.38 mg/g in dumpsite soil, while chlorophyll *b* ranged from 0.65 mg/g in farm soil to 2.10 mg/g in dumpsite soil. Similarly, total chlorophyll peaked in dumpsite soil (2.40 mg/g) and was least in farm soil (0.75 mg/g). Analysis of variance revealed highly significant differences in chlorophyll a and total chlorophyll content among the different soil types.

Table 2: Weekly Growth Parameters of Maize Cultivated in Different Soil Types

Duration in Week	Parameters	Farm soil	Dumpsite soil	Road side soil	Field soil	Built-up area soil
Week 1 (1st Readings)	Plant height(cm)	16	26	35.5	23.7	17
	Leaf length(cm)	24.3	29	34.5	30.7	29
	Leaf width(cm)	1.2	1.4	1.3	1.3	1.2
	Leaf area(cm^2)	22	30.5	33.7	30	26
	Stem diameter(cm)	1.1	1.6	1.3	1.2	1
	Leaf number	3	4	3	4	4
Week 1 (2nd Readings)	Plant height(cm)	16.3	29	27	26.7	24
	Leaf length(cm)	23.7	34	32	28.2	26.5
	Leaf width(cm)	1.7	2.5	2	1.9	1.8
	Leaf area(cm^2)	30	63.8	48	40	35.8
	Stem diameter(cm)	1.3	2	1.5	1.3	1.2
	Leaf number	3	5	4	4	4
Week 2 (1st Readings)	Plant height(cm)	24.3	30.3	29.5	23	26.7
	Leaf length(cm)	22	39	29	25.3	28.3
	Leaf width(cm)	2	3.6	2.6	2.4	2.2
	Leaf area(cm^2)	33	105.3	56.6	45.5	46.7
	Stem diameter(cm)	1.5	2.5	1.8	1.5	1.5
	Leaf number	5	7	6	5	5
Week 2 (2nd Readings)	Plant height(cm)	24.7	44.7	31.5	24.7	22.9
	Leaf length(cm)	16.3	46.3	32	24	27.7
	Leaf width(cm)	1.8	4.6	2.9	2.5	2.3
	Leaf area(cm^2)	22	259.8	69.8	45	48
	Stem diameter(cm)	1.4	3.5	2	1.8	1.7
	Leaf number	4	8	6	4	4
Week 3 (1st Readings)	Plant height(cm)	20.3	56.3	43	29.3	30
	Leaf length(cm)	24.7	54.7	35	30.7	25
	Leaf width(cm)	2.1	5.4	3	2.4	2.2
	Leaf area(cm^2)	39	221.6	78.8	55.3	41.3
	Stem diameter(cm)	1.5	4.1	2.5	1.7	1.6
	Leaf number	4	8	6	4	4
Week 3 (2nd readings)	Plant height(cm)	26.5	58.2	47.3	19.8	26.3
	Leaf length(cm)	20.4	58.8	41	27.4	27.6
	Leaf width(cm)	2	6	3.2	2.4	2.2
	Leaf area(cm^2)	30.6	264.6	98.4	49.4	60.7
	Stem diameter(cm)	1.6	4.5	2.2	1.7	1.6
	Leaf number	**4**	**8**	**5**	**5**	4

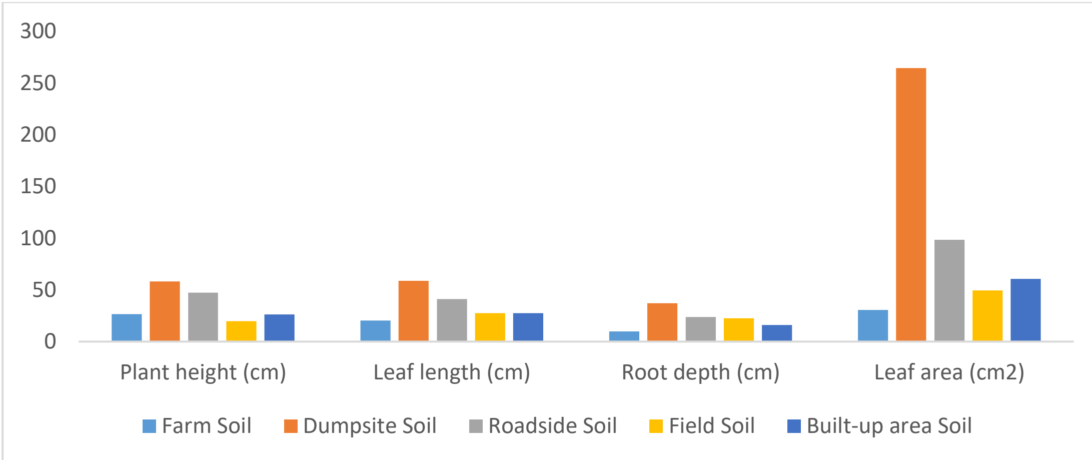

Figure 1: Final Measurements of Plant Height, Leaf Length, Root Depth and Leaf Area

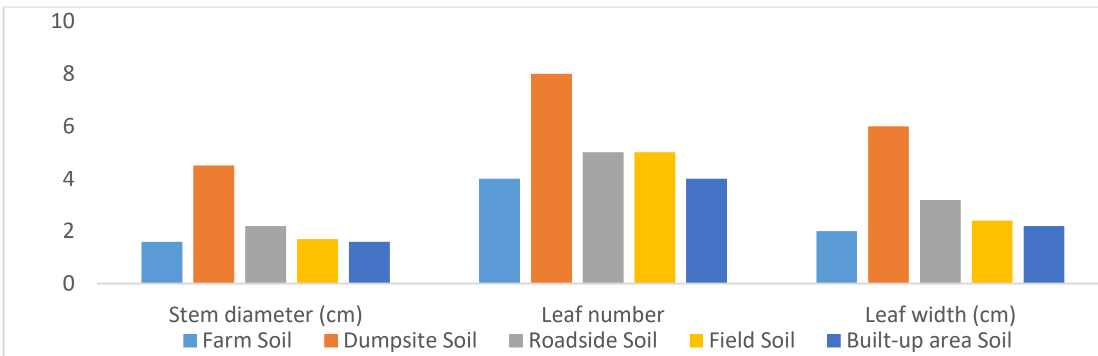

Figure 2: Final Measurements of Stem Diameter, Leaf Number and Leaf Width

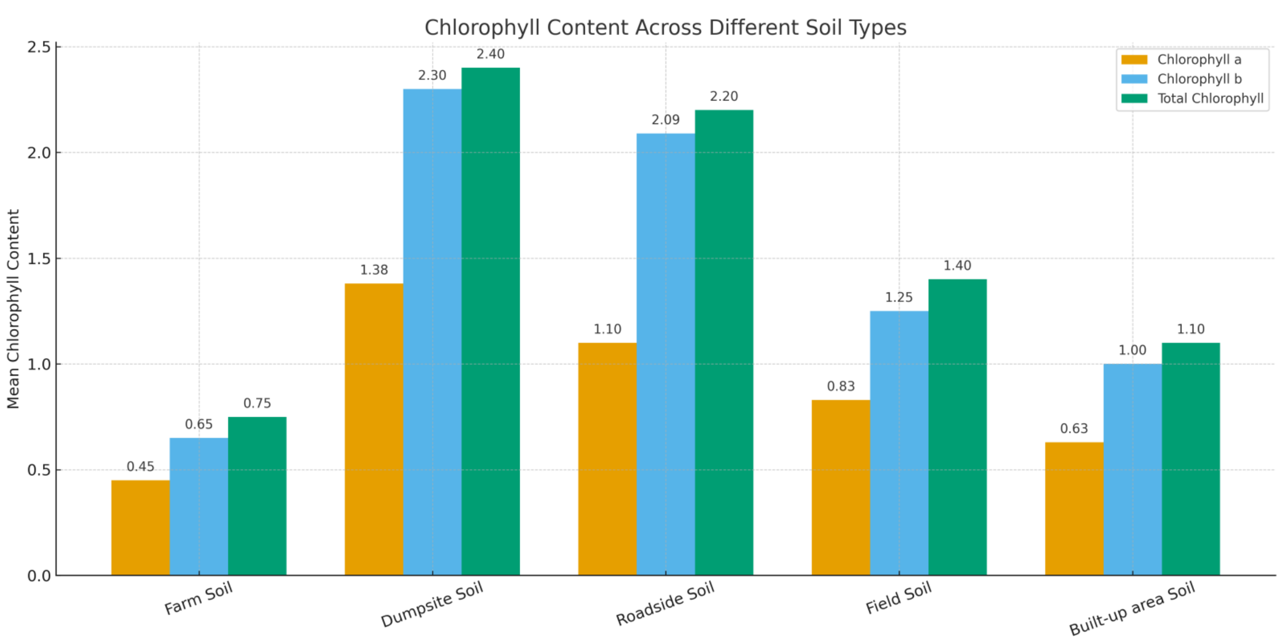

Figure 3: Chlorophyll Content of Maize in different Soil Type.

DISCUSSION

This study investigated the effects of land use on maize productivity by evaluating maize growth in five different soil types: farm soil, dumpsite soil, roadside soil, field soil, and built-up area soil, each replicated in triplicate over a 32-day period. Parameters measured included plant height, leaf length, leaf width, leaf area, stem diameter, leaf count, root depth, chlorophyll content, and germination percentage.

By the fourth day after sowing, maize planted in dumpsite and farm soils showed the earliest emergence, while seeds in roadside soil emerged last. Results from Table 2 and Figures 1 and 2 indicate that dumpsite soil produced the highest vegetative growth across nearly all parameters such as plant height, leaf dimensions, stem diameter, leaf count, and root depth, compared to the other soil types. The plants grown in dumpsite soil also exhibited deeper green pigmentation, indicating higher chlorophyll content.

The chlorophyll content of maize plants varied significantly across the different soil types. Chlorophyll a, chlorophyll b, and total chlorophyll followed a similar trend, with the highest concentrations observed in plants grown in dumpsite soil, followed closely by roadside soil. In contrast, the lowest chlorophyll levels were consistently recorded in plants from farm soil and built-up area soil. The higher chlorophyll concentrations in dumpsite and roadside soils may reflect the relatively higher organic matter and nutrient availability in these soils, likely due to anthropogenic inputs such as waste deposition and roadside runoffs. Conversely, the reduced chlorophyll contents in farm and built-up area soils could be attributed to nutrient depletion from continuous cultivation and soil compaction or contamination in urbanized areas. Overall, these results suggest that soil type strongly influences chlorophyll biosynthesis in maize, with nutrient-enriched soils such as dumpsite and roadside soils supporting enhanced pigment accumulation, which may translate into improved photosynthetic capacity (Li et al., 2025).

The findings of this study agree with those of Adamu et al. (2024), who reported that maize yield and plant height were significantly enhanced in sandy, clay, and loamy soils when appropriately amended with organic manure. This demonstrates that well-drained soils rich in organic matter greatly support maize growth. Dumpsite soils often contain decomposed organic wastes, which can enrich the soil and enhance crop performance. Similar conclusions were drawn by Jaja and Agwor (2023), who found that maize grown in dumpsite soil in Port Harcourt, Nigeria exhibited superior growth, likely due to elevated nutrient levels. Despite its superior growth performance, dumpsite soil recorded the lowest germination percentage (50 percent), possibly due to excessive moisture retention, poor aeration, or the presence of heavy metals and allelopathic substances that may inhibit seed germination. In contrast, soil from the built-up area recorded the highest germination rate (92 percent), followed by field soil (83 percent) and farm soil (75 percent). Roadside soil had a moderate germination rate (67 percent), although variability was observed due to non-germination in one of the replicates.

The low emergence in dumpsite soil may be attributed to poor soil structure and compaction, which can limit oxygen availability to the seeds. This is in line with the observations of Shaheb et al. (2021). Heavy metals or chemical residues common in dumpsite environments may further suppress germination, even if they later enhance vegetative growth in surviving plants. This agrees with the research findings of Orimisan et al. (2024).

The results demonstrate that although dumpsite soil significantly enhances maize vegetative growth and chlorophyll content, its poor germination rate presents a limitation. Conversely, built-up area soil, although producing moderate growth, exhibited excellent germination performance. These findings suggest that alternative land uses, particularly nutrient-rich but structurally balanced soils, could be explored to improve maize productivity. Further investigation is recommended to assess long-term effects, soil toxicity levels, and the sustainability of using non-traditional soils such as dumpsites for maize cultivation.

CONCLUSION

This study establishes that land use history creates a fundamental trade-off in maize productivity between establishment and yield potential. Soils from dumpsites produced the most vigorous growth and highest chlorophyll content but exhibited severe germination constraints. Conversely, built-up area soils showed excellent germination but poor subsequent development. Roadside soils presented an optimal balance with moderate germination and strong growth performance. Conventional agricultural soil was consistently outperformed by these alternatives, challenging assumptions about optimal growing media. The superior growth in dumpsite soils indicates significant nutrient availability from organic matter decomposition, while the germination inhibition suggests concomitant phytotoxicity. These findings highlight both the resource value of urban organic waste and the critical need for processing to eliminate contaminants. Key implications for advancing maize productivity include: development of phytotoxin-free composts from urban waste to enhance farm soil fertility, investigation of the balanced properties of roadside soils to improve soil management practices, and research into specific growth-promoting compounds and germination inhibitors in these soils. These findings reveal the potential of leveraging land-use-specific soil properties to develop innovative amendments that boost yields while addressing urban waste challenges. This integrated approach represents a promising pathway toward sustainable agriculture and food security.

Building upon the findings that dumpsite soils promote superior vegetative growth despite exhibiting germination constraints, future research should prioritize sustainable amendment development and long-term food safety. Investigating the feasibility of processing urban waste into phytotoxin-free composts is essential to mitigate the observed germination inhibition while simultaneously providing nutrient-rich amendments to enhance the fertility of conventional farm soils. Concurrently, given the potential for contaminant transfer, follow-up studies must rigorously assess the uptake and bioaccumulation of heavy metals and other potential contaminants in maize grains grown in dumpsite and roadside areas to establish the food safety profile and inform responsible land-use policies for utilizing these marginal land-use areas for food crop production.

AUTHORS' CONTRIBUTIONS

1. Oseremen, M. N. (OMN) conceived and designed the study, and developed the methodology.
2. Ogie-Odia, E. A. (OEA) performed the validation, visualization of result and contributed to the original draft preparation.
3. Ehilen, O. E (EOE) contributed to the critical review, visualization of results and editing.
4. Eseigbe, D. A. (EDA) contributed to the critical review and editing.
5. Ahmed, A. S. (AAS) contributed to the original draft preparation and project administration.

All authors read and approved the final manuscript.

REFERENCES

Adamu, I., John, O. U., Yusuf, H. I., Irinews, A. A., & Musa, R. (2024). Statistical analysis of soil type and organic manure quantity on maize growth and yield: A case study from the Department of Crop Science, Federal University of Technology. *International Journal of Research and Innovation in Applied Sciences*, IX(XI), 24–37. https://doi.org/10.51584/IJRIAS.2024.911003

Ajibefun, I. A. (2002, July). *Analysis of policy issues in technical efficiency of small scale farmers using the stochastic frontier production function: With application to Nigerian farmers* [Paper presentation]. International Farm Management Association Congress, Wageningen, Netherlands.

Awoyinka, Y. A., Akinwumi, J. A., Okoruwa, V. O., & Oni, O. A. (2009). Effects of livelihood strategies and sustainable land management practices on food crop production efficiency in South-West Nigeria. *Agricultural Journal*, *4*(3), 135–143.

Babalola, D. A., & Olayemi, J. K. (2013, September). *Determinants of farmers' preference for sustainable land management practices for maize and cassava production in Ogun State, Nigeria* [Paper presentation]. Fourth International Conference of the African Association of Agricultural Economists, Hammamet, Tunisia.

Food and Agriculture Organization. (2008). *FAO global information and early warning system on food and agriculture, world food programme (GIEWS): Special report on markets, prices and food situation for Benin, Niger and Nigeria*. FAO.

Henttonen, H. M., Nöjd, P., & Mäkinen, H. (2017). Environment-induced growth changes in the Finnish forests during 1971–2010: An analysis based on national forest inventory. *For. Ecol. Manag.*, *386*, 22–36. https://doi.org/10.1016/j.foreco.2016.11.045

Heyi, D. D., & Mberegwa, I. (2012). Determinants of farmers' land management practices: The case of Tole District South West Shewa Zone, Oromia National Regional State, Ethiopia. *Journal of Sustainable Development in Africa*, *14*(1), 76–96.

International Institute of Tropical Agriculture (IITA) (2009). *IITA annual report* (ISSN 0331-4340). Ibadan, Nigeria.

Jaja, E. T., & Agwor, M. O. (2023). Effects of dumpsite soils on maize yield in Port Harcourt, Rivers State. *International Journal of Agriculture and Research*, *6*(11), 79–89.

Kiage, L. M. (2013). Perspectives on the assumed causes of land degradation in the rangelands of Sub-Saharan Africa. *Progress in Physical Geography*, *37*(5), 664–684. https://doi.org/10.1177/0309133313492543

Li, X., Zhu, B., Li, S., Liu, L., Song, K., & Liu, J. (2025). A comprehensive review of crop chlorophyll mapping using remote sensing approaches: Achievements, limitations, and future perspectives. *Sensors*, *25*(8), 2345.

https://doi.org/10.3390/s25082345

Mokhtarpour, H., Teh, C. B. S., Saleh, G., Selamat, A. B., Asadi, M. E., & Kamkar, B. (2010). Non-destructive estimation of maize leaf area, fresh weight, and dry weight using leaf length and leaf width. *Communications in Biometry and Crop Science*, *5*(1), 19–26.

Mwavu, E. N., & Witkowski, E. T. F. (2009). Population structure and regeneration of multiple-use tree species in a semi-deciduous African tropical rainforest: Implications for primate conservation. *Forest Ecology and Management*, *258*(5), 840–849. https://doi.org/10.1016/j.foreco.2009.03.019

Oluwatayo, I. B., Sekumade, A. B., & Adesoji, S. A. (2008). Resource use efficiency of maize farming households in rural Nigeria: Evidence from Ekiti State. *World Journal of Agricultural Sciences*, *4*(1), 91–99.

Orchard, S. E., Stringer, L. C., & Manyatsi, A. M. (2016). Farmer perceptions and responses to soil degradation in Swaziland. *Land Degradation & Development*, *28*(1), 46–56. https://doi.org/10.1002/ldr.2587

Orimisan, A. E., Olarewaju, A. J., Babaniyi, B. R., & Olumuyiwa, A. O. (2024). Heavy metal content in dumpsite soils and vegetables: A case study of Ondo Town, Nigeria. *Environmental Toxicology and Chemistry*, *43*(2), 123–134.

Osundare, F. O. (2017). Technical efficiency differentials of maize production technologies in Southwestern Nigeria. *Journal of Biology, Agriculture and Healthcare*, *7*(6), 14–20.

Porra, R. J., Thompson, W. A., & Kriedemann, P. E. (2022). Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophylls a and b extracted with four different solvents: Verification of the concentration of chlorophyll standards by atomic absorption spectroscopy. *Biochimica et Biophysica Acta (BBA) – Bioenergetics*, *1863*(5), 148556. https://doi.org/10.1016/j.bbabio.2022.148556

Raveloaritiana, E., & Wanger, T. C. (2024). *Decades matter: Agricultural diversification increases financial profitability, biodiversity, and ecosystem services over time* [Preprint]. *arXiv*. https://arxiv.org/abs/2403.05599

Santpoort, R. (2020). The drivers of maize area expansion in Sub-Saharan Africa: How policies to boost maize production overlook the interests of smallholder farmers. *Land*, *9*(3),1–13. https://doi.org/10.3390/land9030068

Shaheb, M. R., Venkatesh, R., & Shearer, S. A. (2021). A review on the effect of soil compaction and its management for sustainable crop production. *Journal of Biosystems Engineering*, *46*(4), 417–439. https://doi.org/10.1007/s42853-021-00117-7