LAND SUITABILITY PREDICTION FOR MAIZE PRODUCTION IN SOUTHWEST NIGERIA USING GEOGRAPHICAL INFORMATION SYSTEM AND MOST-LIMITING SOIL NATIVE FERTILITY FACTORS

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ABSTRACT

Maize yield per hectare in Southwest Nigeria has been found to be one of the lowest compared to other regions of the world. Digital land suitability assessment was carried out using indices of most-limiting soil native fertility and geographical information systems. We explored the combined use of continuous soil attributes modeling, and ordinal logistic regression through a two-stage mapping process to accomplish the land suitability assessment for maize production. Stepwise forward regression analysis of environmental covariates was conducted to reduce the number of predictors to only those having significant effects at 95% confidence interval. Most area from northern to southern part of the study area had organic carbon content less than 1%. Larger portion of the study area northern part had soil native total nitrogen below 0. 1 g/kg. Most portion of the study area had extractable phosphorus between 23 and 28 mg/kg while the northern part had extractable potassium between 0.29 and 0.33 g/kg. Only some area around southern part of the study area had pH less than or equal 5.5 while other parts had values above 5.5. According to FAO land suitability classification systems, 69.078% of the landmass is moderately suitable, 29.865% is unsuitable and only 1.056% is suitable for maize production. We recommend that policy should be enacted and implemented to regulate infrastructural development and protect agricultural land, non-regenerative agricultural practices should be discouraged, and government and private sectors should empower the agrarian communities with modern soil management training and subsidized farm inputs

INTRODUCTION

Youths in Southwest Nigeria are constrained by lack of access to scientific and technological information that could enhance maize production capacity (Olaniyi and Adewale, 2012). Although they are said to be the future farmers who are expected to carry on farming as a profession for sustainable food production in the Country. Fawole (2008) posited that clamor for adoption of innovation in agricultural development may not be justified without availability and dissemination of innovative information. Olaniyan also posited that increase in maize production in Nigeria has been achieved greatly by expansion in area cultivated rather than increase in yield. The author further stated that the area cultivated and harvested increased from 2.8 million hectares in 1986 to over 3 million hectares in 2000 and over 6 million in 2010. However, the average yield of maize in Nigeria is 1.68 tons/hectare while it is average 9.3 t/ha in the United States of America over the same period (ATA, 2011)

Previous studies on maize production in Southwest Nigeria have done justice to the socio-economic aspect of maize production but no study has investigated the spatial-temporal land suitability evaluation of Southwest Nigeria for maize production (otherwise known as digital soil assessment) to achieve optimum yield and hence maximum profitability and to give credence to the principle of comparative advantage.

According to Akinbode et al. (2024), the production of systematic digital soil fertility mapping in Nigeria is of urgent national emergency in this era of digital advancement and precision agriculture as such has not been previously conducted for the optimum utilization of farm resources towards improving farm productivity. Until now, the country has maintained its conventional soil maps. However, digital soil mapping provides *in-situ* real-time information about the soil in a given location. Hence, it assists farmers' decision-making and impacts positively on agricultural productivity. This study is therefore set up to investigate holistically temporal and spatial land suitability of Southwest Nigeria for maize production. We explored the combined use of continuous soil attributes modeling and ordinal logistic regression through a two-stage mapping process to accomplish the land suitability assessment for maize in the Southwest. This way all covariate factors necessary for the holistic evaluation such as soil, climate, organism, relief, parent materials, age, and spatial position have been included as predictors. The results of this study will have implications for the cultivation of land for maize production in Southwest Nigeria in line with the sustainable development goals 2 (zero hunger), 11(sustainable cities and communities), and 12 (responsible consumption and production) of the United Nations in Nigeria. This study answered the following research questions – 1) What is the soil's native fertility status in Southwest Nigeria in terms of composite soil nutrients? 2) What is the status of environmental covariates in the study area? And 3) Which region within Southwest Nigeria is best suited for maize production?

The null hypotheses of this study are:

$H1_0$: The native soil nutrients of any two randomly selected geographical locations within Southwest Nigeria are not significantly different from each other.

$H2_0$: Any two randomly selected geographical locations within Southwest Nigeria are not significantly different from each other in terms of suitability for optimum maize production.

$H3_0$: Soil native nutrients have no statistical association with maize production in Southwest Nigeria.

MATERIALS AND METHODS

The study was carried out in six states of Southwest Nigeria comprising Ekiti, Lagos, Ogun, Osun, Ondo, and Oyo States between latitude 5º N and 9 º N of the Equator and longitudes 2.5 º and 6 º East of the Greenwich Meridian. It is bounded by the Atlantic Ocean in the South, Kwara, and Kogi states in the North, Anambra state in Eastern Nigeria, and the Republic of Benin in the West (Fig.1). The study area has a land area of about 114,271 km^2 representing about 12 percent of the country's total land area (Olaniyi and Adewale, 2012). The climate in southwestern Nigeria is predominantly humid with rainfall from 1500mm to 3000mm per annum. The mean monthly temperature ranges from 18 ºC to 24 ºC during the rainy season and 20 ºC to 35 ºC during the dry season (Sahib et al,1997).

Figure 1. Maps of the study area. Source: Akinbode et al. (2024).

The 30 m resolution land use and land cover map of the study area from 1st January 2022 to 31st January 2023 was downloaded from USGS website and was classified by supervised learning using the maximum likelihood algorithm in Qgis version 3.26.3 (QGIS Development Team, 2021) (Fig. 2). Then stratified sampling method was adopted at 10 km sampling distance within each stratum like Wang et al (2022). However, some sampling points were shifted to nearby distances from their georeferenced points when they fell on watersheds, water bodies, built-up areas, or road networks. At every georeferenced point sampled, the quadrant method of sampling was adopted by taking 3 composite samples at 0 – 40 cm depths in each quadrant which were then thoroughly mixed and from which representative sample was taken into a black cellophane sample bag which was properly labeled with the location's unique number identifier. Environmental and biophysical covariates used as predictors include precipitation, annual temperature, elevation, hill shading, terrain wetness index (TWI), topography positioning index (TPI), altitude above channel network (AACN), gamma radiometric potassium (radK), normalized difference vegetation index (NDVI), Mid slope position, slope, light insolation, and terrain ruggedness index. Also, the multiresolution index for valley bottom flatness (MRVBF) and multiresolution index for terrain top flatness (MRTTF) were included in the predictor variables because many areas within Southwest Nigeria are characterized by undulating landscapes. Soil native nutrients such as soil total nitrogen, phosphorus, potassium, organic matter content, and pH were the target or dependent variables. Soil total N was determined using the micro Kjeldhal method (Bremeмer and Mulvancy, 1982). Available P was analyzed using Bray-1 P extractant and determined colorimetrically by the molybdenum blue procedure. Exchangeable cations were extracted using 1M Ammonium Acetate pH 7.0 and the potassium in the extract was determined by atomic absorption spectrophotometer (AAS). Continuous soil attribute modeling, regressions, and land suitability modeling were carried out using R statistical software version 4.3 (R Core Team, 2019)

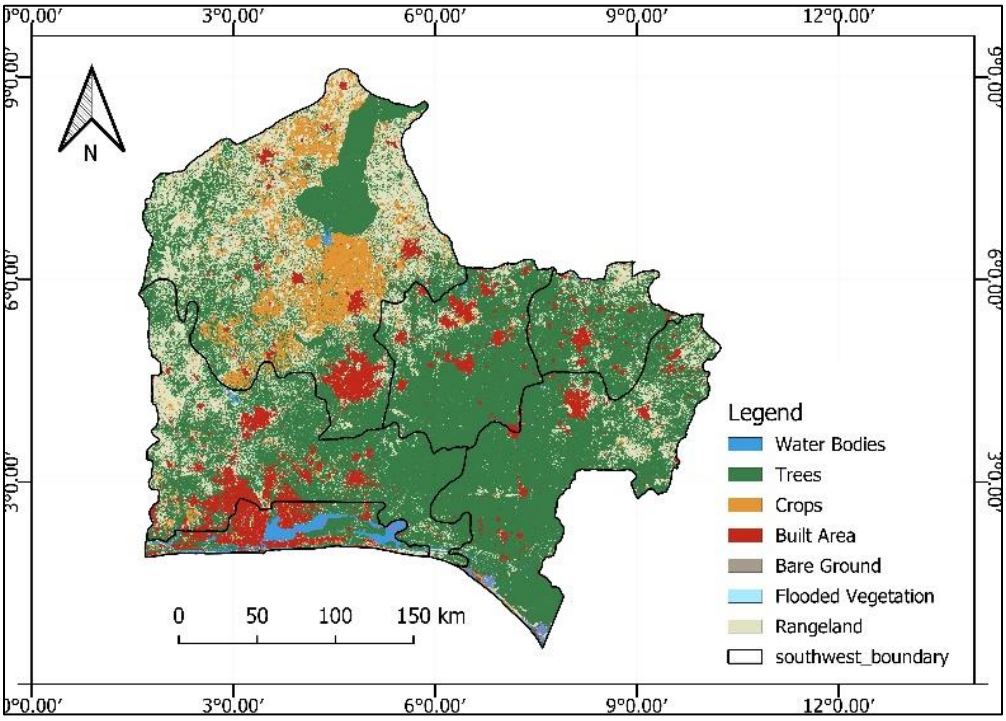

Figure 2. Southwest Nigeria land use and land cover.

RESULTS AND DISCUSSION

The translation of digital soil mapping outputs of soil native nutrients and climatic conditions, framed by the contextual expert-value system that addresses the optimum conditions for maize production, revealed that Southwest Nigerian soil fell only within 3 FAO land suitability categories (FAO, 1976) for maize production. These include Moderately suitable, suitable, and unsuitable (Fig. 3). The largest portion of Southwest Nigerian soil (69.078%) was within the moderately suitable category for maize production. This suitability category was found in all cardinal locations of the study area extending from north to south and east to west (Fig. 3). This agrees with the findings of Olaniyan who posited that an increase in maize production in Nigeria has been achieved greatly by expansion in area cultivated rather than increase in yield. The author further reiterated that Nigeria had to commit over 3 million hectares of land in 2000 which it later increased to 6 million hectares in 2010 to the production of maize as against 2.8 million it committed in 1986 to have higher quantitative yield. Such a huge land resource could have been allocated to more profitable crop enterprises if a land suitability assessment like this had been carried out. However, Olaniyan (2015) advocated that maize production in such areas could improve if fertilizer, land, and subsidized education could be provided by the government, private investors, and non-governmental organizations.

Larger percentage (29.865%) of the study area was unsuitable for maize production using the indices of soil native nutrients and climatic conditions fed into a computer algorithm that was

guided by agronomist prescriptions. The unsuitable categorized soil was also found localized in different parts of the study area. (Fig.3)

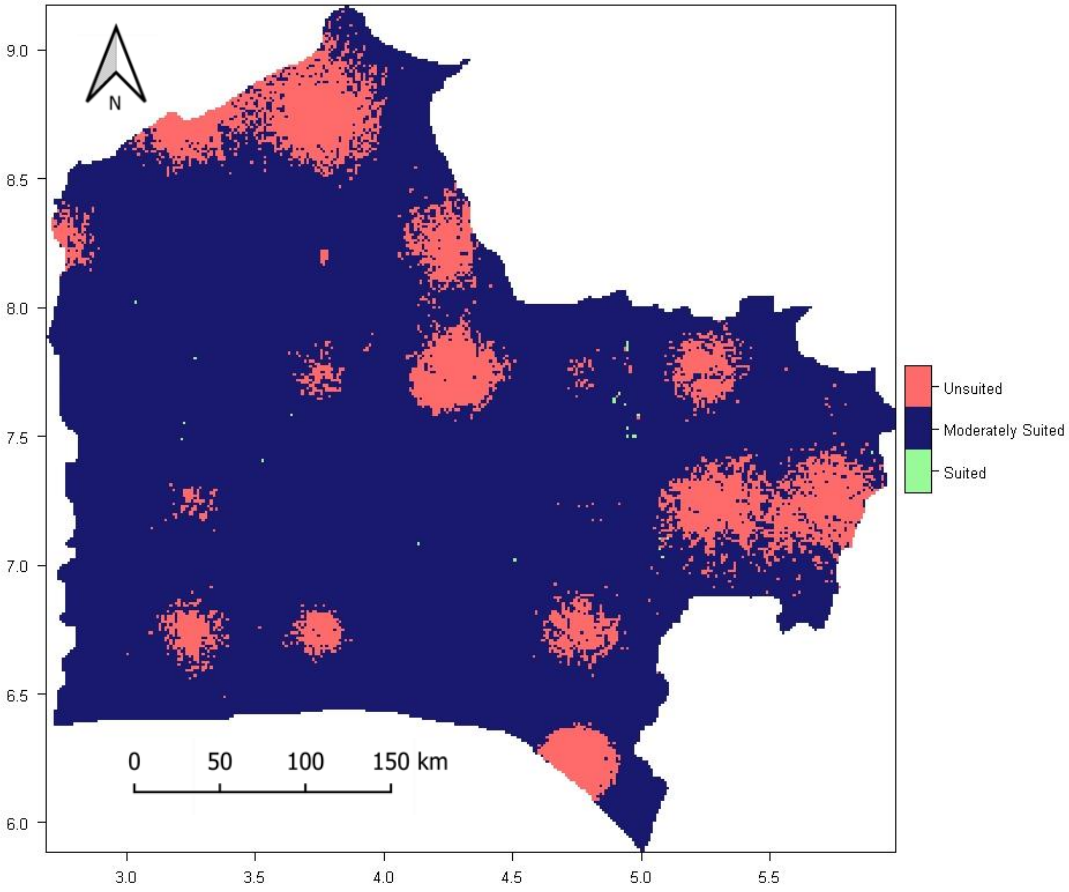

Figure 3. Land suitability map for maize (*Zea mays. Linn)* production in Southwest Nigeria using geographical information system and most-limiting soil nutrients.

The superimposition of land suitability prediction maps (Fig. 3) on initial land use and land cover maps revealed that the bulk of this unsuitable land fell in built-up areas, flooded vegetation, and heavily tree canopy-covered areas while some also fell within heavily crop-cultivated regions (Fig. 2). This revelation that some FAO classified unsuitable areas fell within built-up areas attests to the fact that the quest for urbanization which takes up space for residential, road networks and industrial development could render some land unsuitable. In a study conducted to evaluate the impacts of urbanization in Nigeria Makurdi town, Yusuf et al. (2020) reported that 336 km^2 representing 32% of the total landmass of the study area was taken up by built-up area while 200 km^2 representing 19% of the agricultural land was lost to urbanization.

Observation also revealed that only a few regions of the study area (1.056%) were suitable for maize production using the indices of soil native nutrients and climatic conditions. The suitable regions appeared as spots scattered at different parts of the study area. Most of the suitable land was observed as a cluster at the boundary of Osun State with Ekiti State while others were found as fragments of land in other regions.

CONCLUSIONS

The findings of this study revealed that the largest part of Southwest Nigeria is moderately suitable for maize production while the larger part is unsuitable. However, a few regions of the study area are suitable using the indices of native soil nutrients and climatic conditions. Some of the unsuitable regions were found in built-up areas suggesting indiscriminate and legitimate activities of man competing for agricultural land. Government can control this by putting regulations in place to prevent indiscriminate development and protect Agricultural land. Also, provision of modern soil management training and supply of farm input like organic fertilizer could encourage agrarian communities in regenerative agricultural practices that can improve the nutrient status of moderately suitable lands.

Moreover, digital land suitability assessment like this should be encouraged in other regions of the Country not only to produce maize but also for other crops to ensure adequate allocations of land resources for optimum yield and to comply with sustainable development goals of zero hunger, sustainable cities and communities, responsible consumption and production of United Nations. This study advocates for more research in digital land evaluation for sustainable agricultural production while acknowledging that both the resolution of data and methodology of this research could be improved upon in future studies

REFERENCES

Agricultural Transmission Agenda (ATA) (2011). Maize-Soybean Transmission Action Plan. Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

Akinbode, S.O., Folorunso, O., Olutoberu, T.S., Olowokere, F.A., Adebayo, M., Azeez, S.O., Hammed, S.G., and Busari, M.A. (2024). Farmers' Perception and Practice of Soil Fertility Management and Conservation in the Era of Digital Soil Information Systems in Southwest Nigeria. Agriculture. MDPI. 14, 1182. https://doi.org/10.3390/ agriculture14071182

Bremmer, J.M.; Mulvaney, C.S. (1982). Nitrogen-Total. Methods of soil analysis. Part 2. In: Chemical and Biological Properties; Page, A.L., Miller, R.H., Keeney, D.R., Eds.; American Society of Agronomy, Soil Science Society of America: Madison, WI, USA, pp. 526–595.

Fawole, O.P. (2008). Pineapple farmers' information sources and usage in Nigeria. Bulgarian Journal of Agricultural Sciences, 14(4): 381 – 389.

Food and Agriculture Organization (1976). A framework for land evaluation. Soils Bulletin, vol 32. Food and Agriculture Organisation of the United Nations, Rome

Olaniyan, A. B. 2015. Maize: Panacea for hunger in Nigeria. African Journal of Plant Science, 9 (3). Pp 155 -174. Doi: 10.5897//AJPS2014.1203

Olaniyi, O. A. and Adewale, J. G. (2012). Information on maize production among rural youth: A solution for sustainable food security in Nigeria. Library Philosophy and Practice, ISSN 1522-0222. Doi: http://unllib.unl.edu/LPP/

R Core Team, (2019). R: A Language and Environment for Statistical Computing. URL. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

QGIS Development Team (2021). QGIS Geographic Information System. Open Source GeoDPatial Foundation Project. http://qgis.osgeo.org.

Wang W, Duan M, Zhang X, Song X, Liu X, Cui D. (2022). Determining Optimal Sampling Numbers to Investigate the Soil Organic Matter in a Typical County of the Yellow River Delta, China. Applied Sciences. 12(12):6062. https://doi.org/10.3390/app12126062

Yusuf Mohammed Bakoji, Elijah Elizabeth, Anita Humshe Philip, Mohammed Salim Isa, Umar Jauro Abba. (2020). Urbanization and its Impact on Agricultural Lands in Growing Cities in Developing Countries: A Case Study of Makurdi, Benue State Nigeria. International Journal of Economy, Energy and Environment. Vol. 5, No. 4, 2020, pp. 41-46. doi: 10.11648/j.ijeee.20200504.11