

SUITABILITY ANALYSIS OF RICE CULTIVATION AND IMPLICATIONS FOR FOOD SECURITY IN NIGERIA: A CASE FOR OGUN STATE

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ABSTRACT

The paper aims at analyzing selected environmental variables in order to develop the suitability map for rice production in Ogun state, Nigeria. GIS multi-criteria Decision Model was used to assess climatic, soil and slope conditions and to create the rice suitability map, Analytical Hierarchical Process (AHP) was adopted to rank the selected variables suitable. Slope was generated from SRTM DEM data (90m) and processed to slope percentage using the 3-D spatial analyst function. Sixteen soil samples were taken at a mid-point of grid squares at two standard depths of 0-15cm for topsoil and 15-30cm for subsoil to assess soil texture and drainage. In addition, Soil information was obtained to provide vector polygon layers of soil physical properties. Ten (10) years data of temperature and rainfall of the study area were gotten for the year period of 1990-2000 and plotted in the ArcGIS environment for interpolation. Standardization of the suitability classes was done and the resulting weight was used to construct the map layers using weighted sum overlay tool within ArcGIS 10.3.1 environment. The result shows that highly suitable 29.58%, moderately suitable 16.43%, marginally suitable 34.90% and Not suitable being 19.09%. The analysis thus provide huge sum of information that would aid both federal and state government to make good decision and action that would increase rice production, understand the environmental factors and enhance better use of soil for increase income and sustainable food security.

Keywords: Suitability, analysis, rice cultivation, implications, food security

Introduction

Rice (*Oryza sativa*) is a cereal belonging to the Gramineae, a large monocotyledonous family with over 10,000 species and the most demanded food in Africa especially in Nigeria (Kihoro *et al*, 2013; Abdullahi, 1999). The demand for rice has been increasing at a much

faster rate in Nigeria than in other West African countries due to increasing population, changing consumers' preferences from traditional staples such as yams, garri, cocoyam among others and urbanization among others (Akpokodje *et al*, 2001). With

this increase demand, Nigeria produces an average of about 3.2 million tons out of about 5 million tons annually in all its geographical zones (Daramola, 2005; USDA-FAS, 2003), leaving a huge demand supply gap in the face of rapidly growing population of about 2.5% annually.

Efforts by national and state institutions in Nigeria to increase rice production through agencies, programmes, projects and strategies such as: National Accelerated Food production Program (NAFPP), National Cereals Research Institute (NCRI), Federal Rice Research Station (FRRS), Network for the Genetic Evaluation of Rice (INGER-Africa) among others launched to address the widening demand supply gap and attain food security through land use subsidy, seed and fertilizer supply, credit and mechanization and increase the sustainable productivity of intensified rice based cropping systems in a manner that improves the welfare of resource-poor farm families, conserves and enhances their natural resource base achieved a minimal result. Most of the efforts did not yield the desired results due to poor technology transfer, lack of solid support for science to address most of the problems facing rice production such as drought, soil fertility depletion, diseases and pests and delivery system and increasing dependency on imports among others (Emodi and Madukwe, 2008; FAO, 2004).

Thus, all efforts to increase rice production has not been enough to meet the consumption demand of the rapidly growing urban population (Longtau, 2003; NBS, 2005) and optimising rice production has not been considered as an important concerns because of limited knowledge on crop suitability evaluation especially based on climate, soil and topography interaction for maximum rice yield. The gap between farmers investment on rice, rice yield and farmers profitability has been increasing so immensely. Adopting land

suitability to improving the productivity of rice systems could provide better alternative strategies in order to contribute to hunger eradication, alleviating poverty, national food security and economic development (FAO 2004).

Land suitability evaluation is the classification of lands in terms of their suitability for a specific land use. According to Food and Agriculture Organization (FAO, 2003; Omojola and Soneye, 1993), suitability is a function of crop requirements and land characteristics. Suitability is a measure of how well the qualities of land unit match the requirements of a particular form of land use and could include the process of growing crops where all physical requirements for rice production suit best and for which first and the foremost requirement is to carry out land suitability analysis (Ahmed *et al*, 2000; Park, S., et al. 2011; Perveen et al 2007 and Prakash 2003), involving different factors like ecology, soil science, crop science, meteorology, social science, economics and management.

The objective of land suitability and evaluation is the prediction of inherent capacity of the land units without deterioration (Elaalem, et al, 2010). Physical land evaluation is a prerequisite for land-use planning, because it guides decisions on optimal use of land resources (Van Ranst et al 1996). A number of studies proved that increasing population and enhancing urbanization processes are converting softer green spaces into impermeable hard concrete surfaces. This trend is more serious particularly in developing countries (Shi, 2002). This is partly responsible for farmers not having arable land to cultivate thereby reducing agricultural productivity. There is therefore the need to examine the determinants of the productivity level attained by rice farmers in effort at improving their productivity so that the contribution of locally produced rice towards meeting the demand

for it will increase, thus saving foreign exchange on rice importation in the country.

The problem of selecting the correct land for the cultivation of certain agricultural product is a long-standing and mainly empirical issue. The increased need for food production and the shortage of resources stimulate a need for land evaluation to aid decision makers in their role to both preserve highly suitable lands and satisfy producers demand for increased profit. Suitability analysis is a prerequisite for sustainable crop production. Crops grow best in locations where the climatic conditions meet their growth requirements. Elevation, slope, aspect, soil, land cover and many climatic factors that affect crop growth, help in determining the most suitable crop growth areas. The study is therefore set to determine the suitable areas for the cultivation of rice based on climate and topographic factors of production. The problem of demand-supply gap in rice production in Nigeria and the attendant heavy import bill, prompted the need for improve rice output. Thus, this paper seeks to determine the suitable areas for the cultivation of rice using Ogun state as a based on climatic and topographic factors of production. Specifically, the papers sets to assess the climatic factors (temperature, rainfall) that best suit the production of rice in Ogun state; determine topography and soil (drainage and texture) characteristics and carry out a suitability mapping for rice cultivation in Ogun state. This is in order to understand the current rice production activities and the suitability of land that is most suited for rice cultivation and further serve as a preliminary planning information for rice farmers so as to achieve optimum utilization of the available land resources.

Materials and Methods

The Study Area

Ogun state is situated between latitude 7°00'00"N and longitude 3°35'00"E, found in south western Nigeria, and covers a total land mass of 16,762 square kilometers (Figure 1). It is located in the moderately hot, humid tropical climatic zone of south-western Nigeria. There are two distinct seasons in the state, namely the rainy season which lasts from March/April to October/November and the dry season which lasts from October/November till March/April. This city has a tropical climate. The temperature is relatively high during the dry season with the mean around 30°C. Low temperatures are experienced during the rains, especially between July and August when the temperatures could be as low as 24°C. The distribution of rainfall varies from about 1000mm in the western part to about 2000mm in the eastern part, especially Ijebu and Ogui Waterside LGAs. Soils in Ogun state are varied according to the geological history and soil formation processes in the different localities. Soils in the South Western part of the state and most of the western part are sandy and can only support savannah vegetation. The river valleys have alluvial soils. The climate and soil of the state are suitable for cultivation of a wide range of crops. Ogun State has been identified as one of the thirteen states with comparative advantage in rice production in Nigeria (FMAWR, 2008). Ogun state has a wide area of undulating lowlands belonging to the coastal sedimentary rocks of western Nigeria. There are scattered hills that are interfluvies between the different river valleys. Most of the state is well drained by these streams and rivers, much of which dry up during the dry season (Iloeje, 1983).

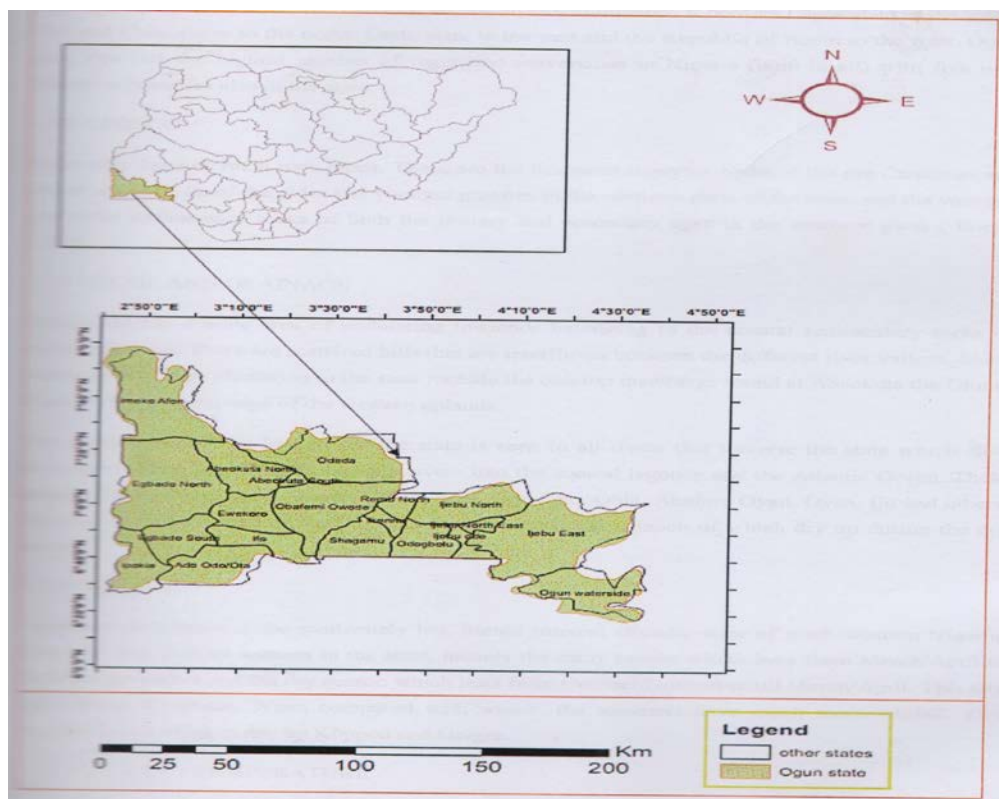


Figure 1: Map of Nigeria showing Ogun state

Reconnaissance and Field Surveys

A preliminary survey was carried out to help in the soil identification and establishment of the selection research procedure. The environmental factors considered for this research are: temperature, rainfall, slope and soil. These variables were considered due to the ease through which their crop land suitability mapping can be carried out (Wilson *et al*, 2000). The slope of the study area was generated from SRTM DEM data (90m) and processed to slope percentage using the 3-D spatial analyst function in ArcGIS. Slope was then generated from digital elevation model (DEM) with its data source from elevation information provided by the shuttle radar topography mission (SRTM) (Park, 2011). The Slope function of Spatial Analyst Toolbox of ArcGIS 10.3.1 was used to generate the slope layer and the slopes were calculated in percentage. Every cell in the output raster has

a slope value. The lower slope value indicates a flatter terrain and higher the slope value the steeper the terrain. Ninety meter (90m) spatial resolution DEM data of SRTM was acquired from <ftp://e0srp01u.ecs.nasa.gov>.

Laboratory and Data Analysis

Soil samples were collected from the field using the soil auger. A total of 16 soil samples were taken at a mid-point of grid squares at two standard depths of 0-15cm for topsoil and 15-30cm for subsoil. The soil samples were preserved in a nylon bag before taken to the laboratory for analysis. The soil properties investigated are the soil texture and drainage. In addition, Soil information was obtained from the GIS and Remote Sensing Lab, Geography Department, University of Lagos. It provides vector polygon layers of soil physical properties. The thematic layer for each of the

parameters was extracted from the polygon attribute table and reclassification was done in ArcGIS 10.3.1 environment.

Rice being a tropical and sub-tropical crop requires fairly high temperature to high rainfall regime, ranging from 20 to 40°C and 1250mm to 2000mm of annual rainfall (Samantha *et al.*, 2011). Ten (10) years data of temperature and rainfall

of the study area were gotten from The Nigerian Meteorological Agency (NIMET) station in Lagos for the year period of 1990-2000. The point data were transferred from MS excel and plotted in the ArcGIS environment in order to assign values to areas for interpolation. The analytic hierarchy process (AHP) based on pairwise comparisons as proposed by Saaty, (1980) was adopted

Table 1: Assigning of weight scores to variables

Goal	A	B	C	D	E	F	Weights	Ranking
A	1	2	7	3	5	3	0.365	1
B	½	1	6	3	5	2	0.264	2
C	1/7	1/6	1	½	¼	½	0.064	6
D	1/3	1/3	4	1	4	1	0.127	3
E	1/5	1/5	2	¼	1	1/3	0.073	5
F	1/3	½	4	1	3	1	0.125	4
$\lambda_{\max}=6.428$		CI =0.086		CI =0.086		$\Sigma=1$		

Source: Saaty, 1980.

Using Pairwise comparison matrix (PCM), factor weights were calculated by comparing two factors together at a time. The values of the pairwise comparisons in the AHP were determined using the scale introduced by Saaty (1980), which indicated that in relation to the column factor, the row factor is more important. As revealed on Table 1 and in the diagonal, elements are assigned the value of unity (i.e., when a factor is compared with itself). Other evaluation as applied by Saaty,

(1980) to estimated the intensity of importance is as indicated on Table 2 using Weighted overlay (Kuria D. *et al.*, 2011). The final land suitability map was thus based on the best outcome in context of the suitability of rice crop production which classified the study area into four land suitability classes, namely: highly suitable, moderately suitable, marginally suitable, and not suitable for rice production.

Table 2: Intensity of Importance of Values

Intensity of importance	Description
1	Equal importance
3	Moderate importance
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values
Reciprocals	Values for inverse comparison

Source: Saaty (1980)

Results and Discussion

Climatic Characteristics of the study area

As revealed on Figure 2, Ipokia, Imeko Afon, and parts of Egbado south, Egbado North Local Government Areas (LGAs) have temperature less than 20°C, while all other LGAs have temperature above 20°C to 32°C. This implies that only four LGAs have temperature less suitable for rice cultivation while all other LGAs within the study area suits well for rice cultivation. The findings agree with Sailesh *et al.*(2011), who posited that the need to consider temperature for rice

production in any area dwells on the importance of rice respiration and rich grain development, filling, high yields which temperature is key the determinant. Temperature is also significant in the life cycle of rice cultivation because not only does it enhances rice growth duration but in addition stimulates growth pattern of the rice plants as some rice varieties requires low temperatures during the cropping season while others requires moderate to high temperatures for cropping season.

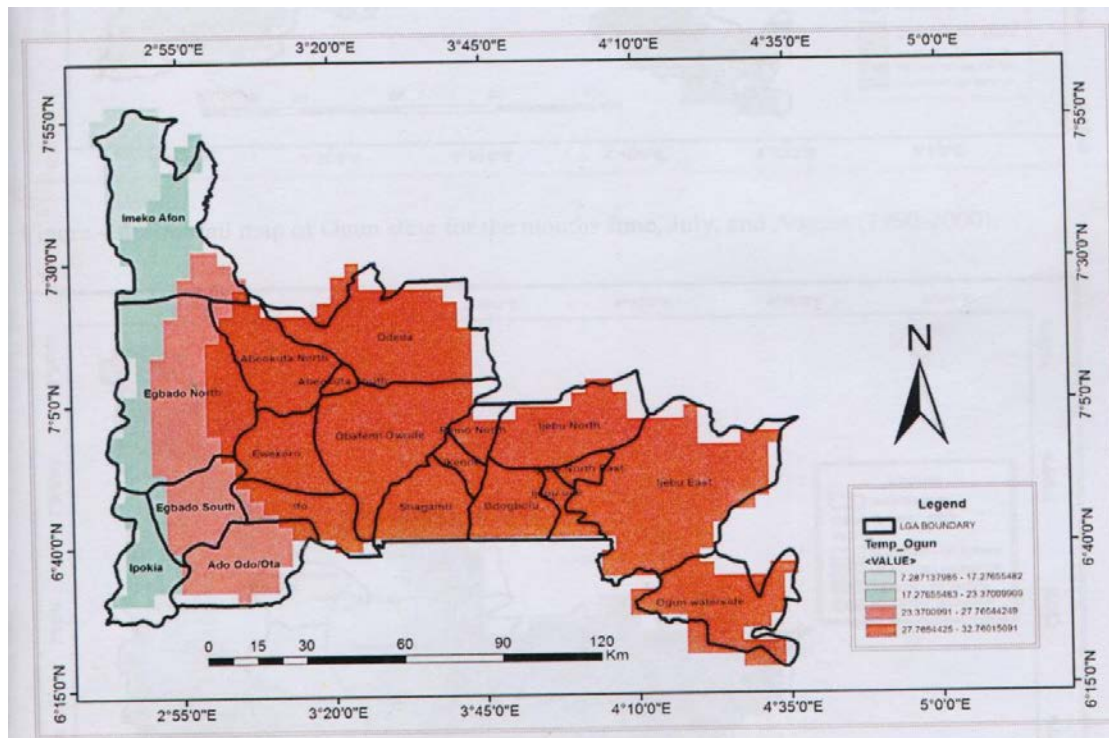
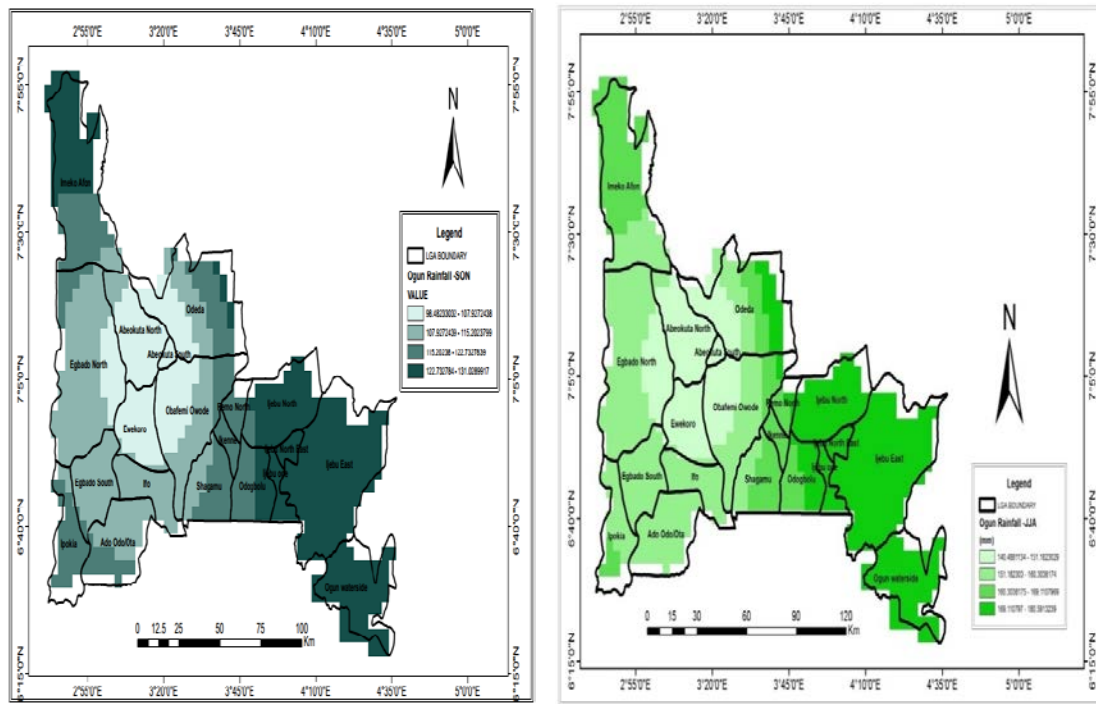


Figure 2: Temperature map of Ogun state (1990-2000)

As shown on Figures 3 and 4, Abeokuta south, Abeokuta north, Ewekoro, and parts of Obafemi-owode, and Odeda, Egbado north receives monthly rainfall of between 98.5mm to 107.9mm. While all other Local Government Area (LGAs) gets monthly rainfall of 100 to 200 mm. This finding reveals that Abeokuta south, Abeokuta north, Ewekoro, and parts of Obafemi-owode, and Odeda, Egbado are not favourable for rice cultivation and can only make a meaningful rice cultivation if the level of rainfall is supplemented with irrigation. Rice cultivation is possible only in

areas with immense rainfall as the rice requires standing water for its growth. The influence of rainfall on rice cultivation stretches through its length (long and short periods), the pattern of distribution and relative humidity in space and time.



Figures 3 and 4: Rainfall map of Ogun state for the months June, July, and August and Sept, October, and November (1990-2000).

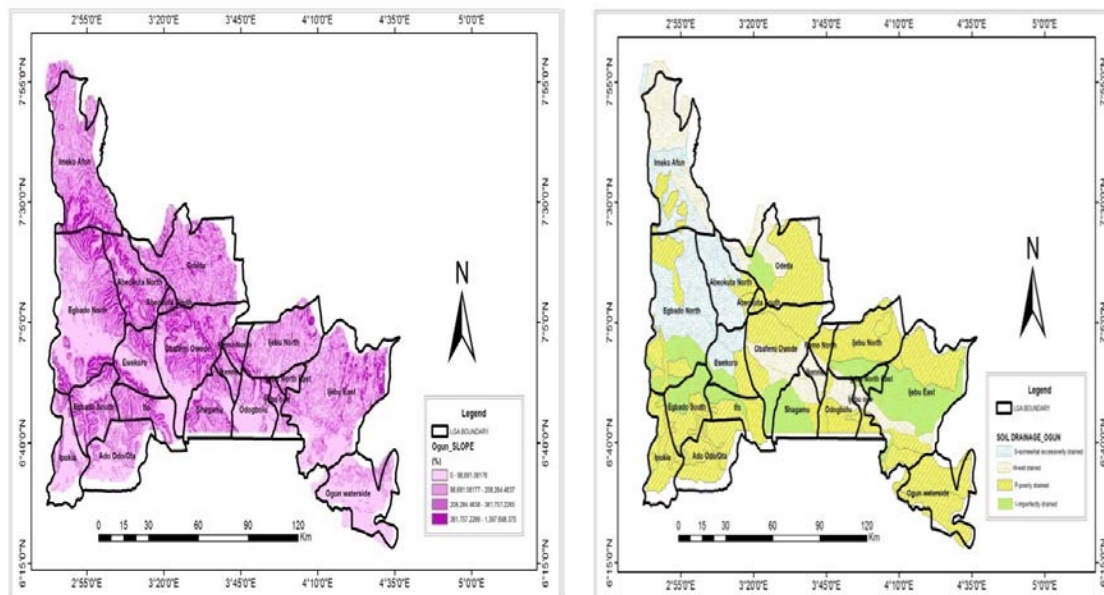


Figure 5: Slope map of Ogun state

Figure 6: Soil drainage map of Ogun state

Studies (Setter *et al.*, 1995; Xu *et al.* ,2004, have shown that varieties of rice cultivation takes place in river valleys, basins, deltas, estuaries, lake fringes and coastal plains where the surface are either level or gently undulating with slopes varying from 0 to 8% making rainfall and water supply to rice cultivation feasible. Slope also interferes with water availability for rice cultivation as it makes areas moderately suitable for rice cultivation. Rice grows on all types from sandy loam to heavy clay. However, heavy soil characteristic are better suited rice cultivation than lighter soils. The result thus revealed a lower/gentle slope value, flatter terrain and high slop. Plain lands or gentle slopes are suitable for the production of rice because stagnancy of water is a must for the cultivation of rice. Figure 5 shows that all the LGAs are favorable to rice cultivation but some LGAs are more favorable compared to others such as; Ogun waterside, Ado-odo/Ota, Ipokia, Ijebu east, Odogbolu, Egbado north, Ewekoro, and Obafemi-owode. Soil drainage is a function of soil pore size and texture. Larger pores hold more water but with less energy, thus they drain first. Conversely, smaller pores hold less

water but hold it more tightly. Rice requires soils that do not drain water easily. Figure 6 shows parts of some LGAs whose soil somewhat excessively drains; Imeko afon, Egbado north, Abeokuta north, and Ewekoro as well as those that are well drained, poorly drained, and imperfectly drained.

Twelve soil textural classes as identified by The United State Department of Agriculture (USDA) was adopted for suitability analysis in this study. They are S1 – Highly suitable; S2- Moderately suitable; S3- Marginally suitable, and N1- Currently not suitable. As revealed on Figure 7 and Table 3, highly suitable (S1) land covers an area of 4504.668Km²(29.58%) of the total land. S1(highly suitable) areas were characterized by: temperatures between 27.8-32.8°C, rainfall range > 170 mm per month for JJA and >122mm for SON, slope level of 0-98661%, The area was further characterise by imperfectly and poorly drained soils, textural class -silty clay loam, silty clay, clay. Moderately suitable areas (S2) cover an area of 2503.037Km² (16.43%), while marginally suitable (S3) covers an area of 5315.52Km² (34.90%).

Table 3: Characteristics Climate and Soil for Rice cultivation in Ogun state

CRITERIA	S1	S2	S3	N1
TEMPERATURE (°C)	32.8-27.8	27.8-23.4	23.4-17.3	17.3-7.3
RAINFALL (mm)– June, July, Aug.	180.6-169.1	169.1-160.3	160.3-151.2	151.2-140.5
_ Sept, Oct, Nov.	131.0-122.7	122.7-115.2	115.2-107.9	107.9-98.5
SLOPE (%)	0-98,661.0	98,661- 208,284.5	208,284.5- 361,757.2	361,757.2-1,397,693.4
SOIL DRAINAGE	Imperfectly drained	Poorly drained	Well drained	Somewhat excessively drained
SOIL TEXTURE	Silty clay loam, silty clay, clay	Loam, silt loam, clay loam, silt	Sandy loam, sandy clay loam, sandy clay	Sandy, loamy sand

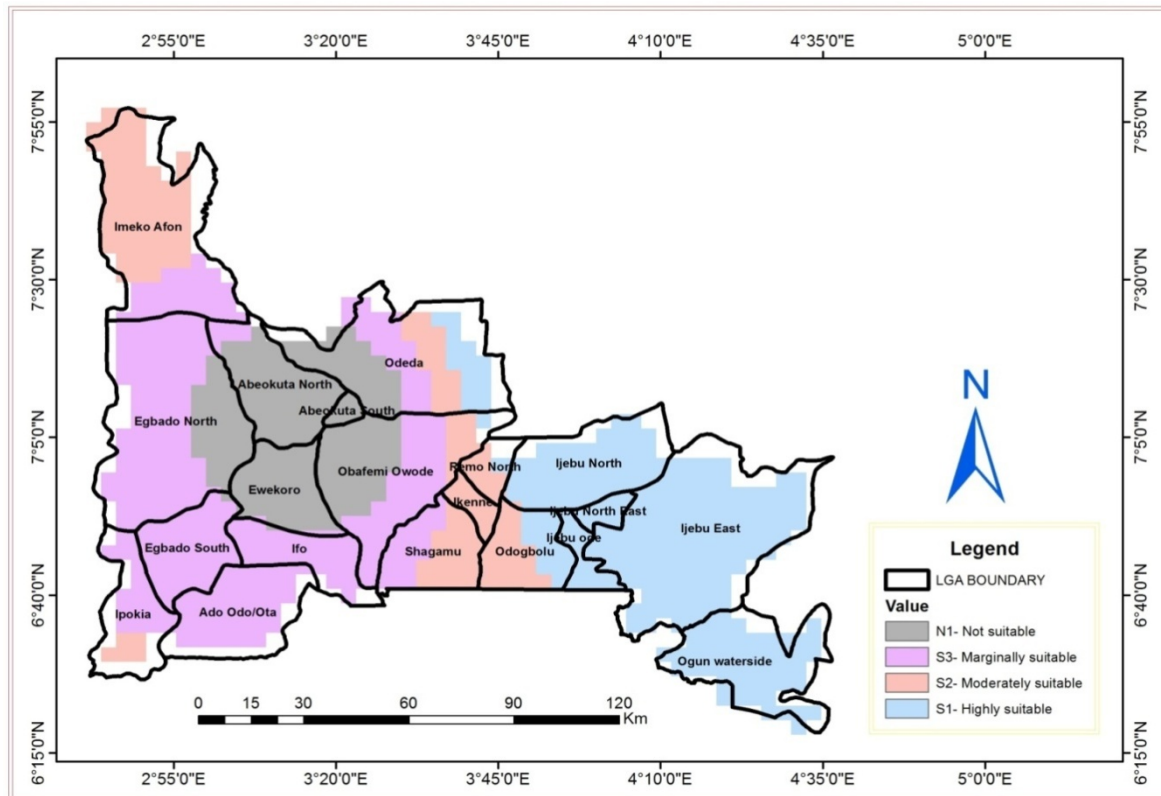


Figure 7: suitability map for rice crop in Ogun state

Table 4: Land suitability Classes for Rice cultivation in Ogun state

SUITABILITY CLASSES	AREA (Km ²)	PERCENTAGE	LGAs
S1- Highly suitable	4504.668	29.58	Ijebu north, Ijebu east, Ijebu north east, Ijebu ode, Ogun waterside, parts of Odogbolu, and Odeda.
S2- Moderately suitable	2503.037	16.43	Odogbolu, Ikenne, Remo north, parts of Shagamu, Odeda, and Imeko afon.
S3- Marginally suitable	5315.52	34.90	Ado-odo/Ota, Ipokia, Egbado south, Ifo, parts of Egbado north, Odeda, and Obafemi-owode.
N1- Not suitable	2906.9	19.09	Ewekoro, Abeokuta south, Abeokuta north, parts of Egbado north, and Obafemi-owode.

Areas Not suitable (N1) has an area of 2906.9Km² (19.09%) of land area. Generally not suitable areas (N1) were located in mountainous areas with a slope between 361,757.2-1,397,693.4%, low amount Suitability classes of Ogun state of rainfall as low as 98.5mm per month, and temperature less than 17.3°C).

Conclusion

The study has revealed varying degrees of suitability of rice cultivation in Ogun state based on selected physical characteristics of the area, indicating enormous opportunities and potentials for rice cultivation. This result is germane as a major challenge often encountered in ascertaining the food security situation through production in Nigeria is inadequate data and information about the environmental characteristics and land suitability. Revealing the production capacities levels a geographical space (Ogun state) into highly suitable (S1-29.58%) and moderately suitable (S2-16.43%), marginally suitable (S3-34.90%) and Not suitable (19.09%) areas provide huge sum of information that would aid decision makers and practitioners especially rice producers to make appropriate decisions and planning to increase rice production and enhance food security targets. Recognizing these environmental factors alone cannot solely determine increased rice

production as there are other non-environmental factors such as inputs, managerial ability, labour and capital among others which can be controlled by farmers and government, but the intent rests on the fact that past efforts to increase rice production to minimize import and meet up food security target have only dwelt on non-environmental factors and these have yielded only minimal results. Therefore, integrating both the environmental and non-environmental factors into decisions and plans could provide better options.

Another significant implication of this result is its link with the growing population and the changing consumption pattern witnessed in Nigeria currently. With nearly 3.0% population growth rate, strategies and options to increase and determine the necessary requirement to ensure sustainable production and food availability will have to be considered as there will be increasingly more mouth to be fed in the future. As the result provides information about where and extent of input, limited input and modifications in different locations as identified. Areas that require intermediate low-cost water and soil conservation technologies, irrigation and soil tillage, mulching, bunding, terracing would be identified etc.

References

- Abdullahi, A. (1999). Food Policy and Food Security in Nigeria In Food Demand and Market Studies in the Drier Savanna of Nigeria. Patrick Kormawa and Ernest Aiyedun (eds). Proceedings of a Methodology and Stakeholders' Workshop, 7-8 September 1999, Kaduna, Nigeria.
- Akpokodje, G, F. Lançon and O. Erenstein (2001). Nigeria's rice economy: State of the art. Paper presented at the NISER/WARDA Nigerian Rice Economy Stakeholders Workshop, Ibadan, Bouake: WARDA.
- Ahamed Nisar, Gopal Rao K, Murthy JSR (2000). GIS-based fuzzy membership model for crop-land suitability analysis. *Agricultural System* 63(2):75–95.
- Daramola, Biyi (2005). Government policies and competitiveness of Nigerian rice economy. *Paper presented at the workshop on rice policy and food security in Sub-Saharan Africa*. WARDA Cotonou, Republic of Benin.
- Elaalem, M., Comber, A., and Fisher, P. (2010). Land evaluation techniques comparing fuzzy AHP with TOPSIS methods. 13th AGILE International Conference on Geographic Information Science. Guimares, Portugal, pp. 1-8.
- Emodi I. A, and Madukwe M. C. (2008). A review of policies, acts and initiatives in rice innovation system in Nigeria Vol. 12 (2). Pp. 10-16.
- FAO, (2003). Sustainable Rice Based Production and People's Livelihood, International Rice Commission *Newsletter* (Special Edition) vol. 52, International Rice Commission, FAO, Rome, Italy,
- Food and Agriculture Organisation (2004). The State of Food Insecurity in the world. Rome. www.fao.org
- Hossain, M. S. S. R. Chowdhury, N. Gopal Das and M. M. Rahaman, (2007). Multi-criteria evaluation approach to GIS-based land-suitability classification for tilapia farming in Bangladesh, *Journal of the European Aquaculture Society Springer Science+Business Media B.V.* 2007.
- Kihoro, J. Bosco, N. , Murage, H., Ateka, E. 1 and Makihara, D. (2013). Investigating the impact of rice blast disease on the livelihood of the local farmers in greater Mwea region of Kenya *SpringerPlus*, Vol.32:308 pp 2-24
- Longtau S. R. (2003). A review and Description of Rice Production System in Nigeria. Eco-Systems Development Organisation. Jos, Plateau State, Nigeria pp 50. <http://www.odi.org.UK/resources/download/3045.pdf> retrieved 16/08/2018
- National Bureau of Statistics (2005),
- Mustafa AA, Man S, Sahoo RN, Nayan A, Manoj K, Sarangi A, Mishra AK (2011). Land suitability analysis for different crops. A multi criteria decision making approach using remote sensing and GIS. *Indian Agricultural Research Institute, New Delhi-110 012*
- Omojola, A. and Soneye, A. S. O. (1993). Applications of Remote Sensing and Geographic Information Sub-System Techniques for Land Use and Land Cover Mapping in the Middle-Sokoto River, northwestern Nigeria. *Nigerian Journal of Remote Sensing* Volume 1, No 1. NISORS 1993.
- Park, S., et al. (2011). Prediction and comparison of urban growth by land suitability index mapping using GIS and RS in South Korea. *Landscape and urban planning*, 99, 104–114.
- Perveen.F., Ryota.N., Imtiaz.U., Hossain K.M.D:(2007). Cropland suitability a Multicriteria evaluation and GIS Approach:5th International Symposium on Digital Earth. The University of California, Berkeley, USA, pp1-8.2007
- Prakash ,T.N (2003) : Land suitability Analysis for Agricultural crops :A fuzzy multi- Criteria Decision making Approach. International Institute for Geo-information Science and Earth observation Enschede , the Netherland pp 6-13.
- Saaty, T. L. 1980. The analytic hierarchy process: McGraw Hill International., New York.
- Saaty, T.L. (1977). A scaling method for priorities in hierarchical structure. *Journal of mathematical psychology*, 15 (3), 34–39.
- Saaty, T.L. (1980). The analytical hierarchy process. New York: McGraw Hill.
- Sailesh Samanta, Babita Pal, and Dilip Kumar Pal, (2011). Land Suitability Analysis for Rice

- Cultivation Based on Multi-Criteria Decision Approach through GIS. In Morobe province of Papua New Guinea. Vol-2 No.
- Sailesh Samanta., Pal, B., and Kumar, D (2011). Land Suitability Analysis for Rice Cultivation Based on Multi-Criteria Decision Approach through GIS Int. J Sci. Emerging Tech. Vol-2 No. 1
- Shi, S. (2002) Research on the Urban Spatial Structure Guided by the Urban Green Space System. Physical Geography., Central China Normal University Wuhan 112.
- USDA-FAS (2003). Gain Report: Mexico Tree Nuts Annual. Gain Report Number: MX3107.
- Van Ranst E, Tang H, Groenemans R, Sinthurath S (1996). Application of fuzzy logic to land suitability for rubber production in Peninsular Thailand. *Geoderma* 70: 1-19
- Wilson J. P. and J. C. Gallant (2000). *Terrain Analysis: Principles and Applications*. John Wiley and Sons, New York. pp. 87-131.