SOKOTO JOURNAL OF GEOGRAPHICAL STUDIES (SJGS) *E-ISSN: 3115-5812, PRINT ISSN: 3043-551X*

© DEPARTMENT OF GEOGRAPHY, SOKOTO STATE UNIVERSITY, SOKOTO

Volume 4, Issue 2, August 2026 Edition

SUITABILITY ASSESSMENT OF THE DIFFERENT AGROECOLICAL ZONES OF KANO REGION FOR RICE PRODUCTION

Umar, I. A.[1], Yusuf, M. A.[2], Salisu, K.[2] & Abubakar, A. U.[3]

[1]Department of Geography, Aliko Dangote University of Science & Technology, Wudil
[2]Department of Geography, Bayero University, Kano
[3]Department of Cartography and GIS, Kaduna Poly-technic, Kaduna State

Corresponding Author's Email: umarugurugu@gmail.com

Abstract **https://doi.org/10.65760/sjgs.v4.i2.6**

The study assessed the suitability of the different Agro-Ecological Zones (AEZs) in Kano region for sustainable Rice production. The prevailing biophysical conditions in the AEZs of the region were matched against the rice agronomic requirements for better understanding of the suitable locations for the crop. The major biophysical attributes considered were climatic conditions, soils and topography in the region. Cluster sampling method was employed and soil samples were collected using composite technique. Information on climatic variables were sourced from both documented and satellite sources. Data was analysed using Analytical Hierarchy Process (AHP) in the GIS environment for suitability classification. The findings revealed that, 8% (344,333.13 Ha) and 50% (2,280,253.34 Ha) was found at highly (S1) and moderately (S2) suitable classes respectively. The highly suitable land was in the Southern Guinea and parts of Northern Guinea AEZs and moderately suitable land was in the Northern Guinea and significant parts in the Sudan AEZ in the region. 38% (1,699,676.14 Ha) and 4% (192,943.07 Ha) mostly covering the Sahelian, Sudano-Sahelian and parts in the Sudan AEZs were marginally (S3) and not (N) suitable for the crop in the region. The study indentified moisture stress and low soil fertility as the major biophysical limiting factors to rice production in Sahelian, Sudano-Sahelian and parts of the Sudan AEZs whereas low soil fertility status been the major limiting biophysical factors in the moderately suitable areas for the crop. The study recommends that, early maturing cultivars/varieties be introduced for adoption in the Sahelian, Sudano-Sahelian and in parts of the Sudan AEZs and soil test based fertility management practice be encourage for improve and sustained rice production in the Kano region.

Keywords: *AEZ, Biophysical, Rice, AHP, Suitability*.

Introduction

Rice is rapidly becoming a major food in much of sub-Saharan Africa and is set to overtake maize, cassava, sorghum, and other cereals in the near future. In Nigeria setting, the demand for rice continues to grow as more Nigerians make changes in their eating habits, and as the urban population increases. Rice is currently the third most important cereal crop after maize and wheat. Rice is gaining popularity among the rural folk as well and its consumption has risen dramatically over the years.

In the 21st century, food security continues to be a critical global challenge and is highlighted in United Nations Sustainable Development Goal 2 (UN SDG), this calls for ending hunger and achieving food security by means of a sustainable intensification of agriculture (Beltran-Peña et al., 2020). Due to population growth, urbanization, climate change and land degradation, the amount of

arable land available and its productivity are declining globally, especially in semi-arid regions (Muluneh, 2021; Razvanchy and Fayyadh, 2022). Rice is an important staple grain and a primary source of livelihood; rice requires strong land management strategies to ensure that it yields sufficiently to sustain food supplies.

Land suitability assessment is a systematic approach for assessing the ability of a particular parcel to support a particular crop while preserving environmental sustainability (Ajala *et al.,* 2021; Devkota *et al.*, 2022). Through integrating soil, topography, climate and land use data, suitability modelling enables for targeted allocation of resources, reduces yield gaps and informs precision farming operations (Tadesse & Negrete, 2020; Daniel *et al*., 2022).

Suitability analysis is a function of crop requirements and land characteristics (Mustafa *et al.*2011). Matching the land characteristics against the crop requirements portrays how suitable is an area of land for optimum production of a particular crop. So, Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use (FAO 1976). Land suitability analysis has to be carried out in such a way that local needs and conditions are well reflected in the final decisions making.

Multi-Criteria Evaluation (MCE) approaches and GIS are useful because various production variables can be evaluated and each weighted according to their relative importance on the optimal growth conditions for crops. Despite these developments, there is a significant gap in GIS-based rice suitability research in semi-arid Africa. Recent studies have been conducted in Kano State, Nigeria, that have addressed broad soil classification but have not fully evaluated land suitability for rice using integrated AHP–GIS techniques (Danazumi et al., 2020; Ya'u et al., 2014; Ahmed, 2015). Consequently, farmers generally cultivate marginal lands without data-driven direction, leading to low yields, nutrient depletion, and unsustainable land use (Adenle & Ifejika, 2021; Ihediuche *et al*., 2022).

In this paper, Analytical Hierarchy Process (AHP) was applied for final production of suitability map in the study region. The specific objective of this research was to develop a suitability map for rice crop (*Oryza sativa*) productions based on physical and climatic factors of production in the Kano region.

Materials and Methods

Description of the Study Area

The study area covers the Kano region which combined Kano and Jigawa States of Nigeria, located at the eastern margin of the Northwest Geo- Political Zone of Nigeria consisting of 71 Local Government Areas (44 in Kano State and 27 in Jigawa State). This area is located between latitudes 10º 30′N and 13º02′N of the equator and longitudes 7º45′E and 10º35′E of Greenwich meridian. The area falls within the Semi-arid savannas of northern Nigeria. The region is bounded to the northeast by Yobe State, to the east and southeast by Bauchi State, to the southwest by Kaduna State, to the northwest by Katsina State and to the north by Niger Republic (Liman, 2014, and Olofin, *et al*., 2008 & 2016). The region covers the spatial extent of 45,792.5 sq kilometres (Ibrahim, 2014) Figure 1.

https://doi.org/10.65760/sjgs.v4.i2.6

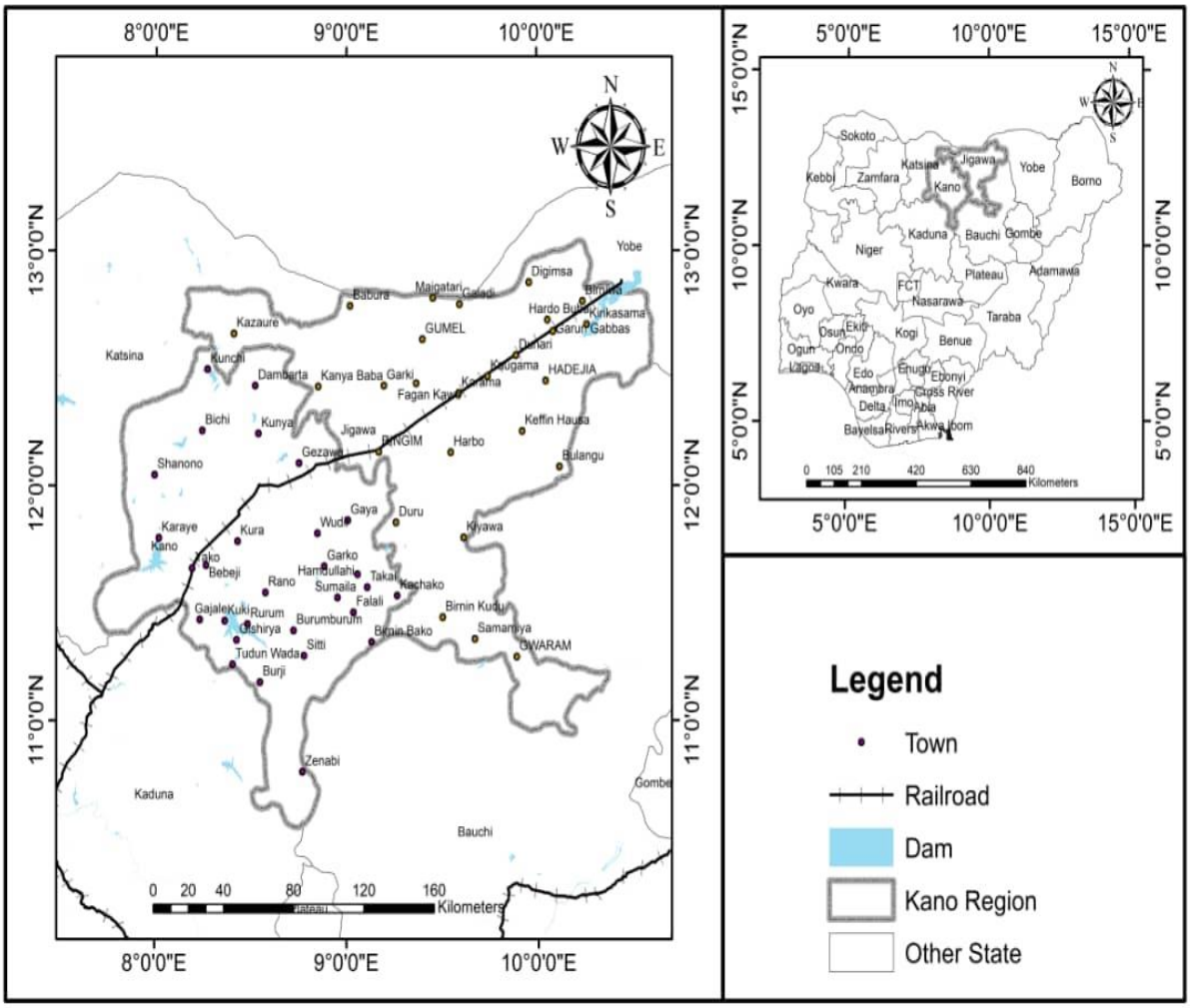

Figure 1: Map of the Kano Region (Study Area)
Source: GIS Lab., Geography Department, Bayero University, Kano

Types and Sources of Data

Quantitative and qualitative data were used which form the sources of data for the study. The primary data was derived from the laboratory analysis of soil samples while the secondary data was obtained from the review of relevant literature such as archival data from Global weather and climate records, Kano State Agricultural and Rural Development Authority (KNARDA), Jigawa State Agricultural and Rural Development Authority (JARDA), Nigeria Meteorological Agency (NiMET), International Institute of Tropical Agriculture (IITA), International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Institute of Agricultural Research (IAR) and digital elevation data was obtained from any other relevant sources and institutions.

https://doi.org/10.65760/sjgs.v4.i2.6

Reconnaissance Survey

The reconnaissance survey was carried out to be familiar with the study area, differences and similarities in terms of biophysical characteristics was observed for appropriate planning for the data collection.

Data Collection Techniques

This section consisted of soil sampling procedure, soil samples collection technique, technique of climatic data gathering. Digital elevation model was used to generate the slope and contour map of the study area.

Soil Sampling Techniques and Samples Collection Procedures

Cluster sampling method was adopted such that, a typical soil type identified within a particular agroecology was considered as the sampling cluster. Soil sampling points was located using simple random method within each cluster identified and several point composite samples were collected. The size/area of the identified clusters determined the number of sampling points (proportionate sampling) (figure, 2). One hundred and nine (109) soil samples were collected all together at 0 - 15cm (top soil) depth using soil auger, composited and put the required sample (1/2 kg) into indexed sample bag for onward submission to the Centre for Drylands Agriculture (CDA)' laboratory, Bayero University, Kano for soils physical and chemical analysis. The coordinates of the sampling points were taken and recorded using Global Positioning System (GPS) for subsequent mapping.

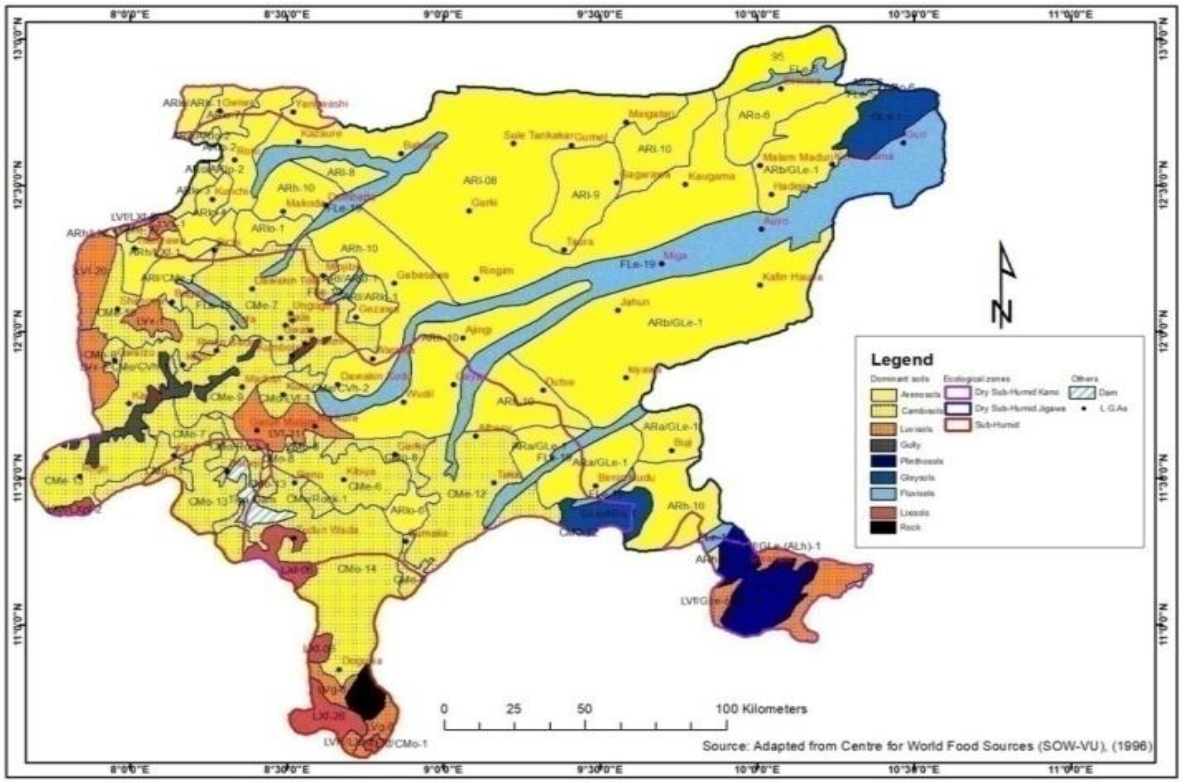

Figure 2: Soil sampling points in the study area
Source: GIS Lab., Geography Department, B.U.K

https://doi.org/10.65760/sjgs.v4.i2.6

Laboratory-Based Data Analysis

The soil samples collected were taken to the CDA's laboratory, Bayero University, Kano air dried and gently crushed with pestle and mortar and passed through 2mm sieve to remove coarse fragments. The fine earth samples (2mm soil portion) collected were analysed for physical and chemical parameters.

Physical Analyses

The physical parameter determined is the Particle size distribution analysis (PSD). Particle size distribution was determined using hydrometer method (Gee and Bauder, 1986). Sand, silt and clay were determined by dispersing the soil samples in 5% calgon (sodium hexameta phosphate) solution. The dispersed sample was shaken on a reciprocating shaker after which particle size distribution was determined with the aid of Bouyoucous hydrometer at progressive time intervals. After determination of the particles size distribution in to percentage of sand, silt and clay, the textural class of the soil of each sample location was determined with the aid of USDA textural triangle.

Chemical Analyses

The chemical parameters tested include; Soil Reaction (pH): The soil pH was determined both in water and 0.01M $CaCl_2$ solution, using a soil to water solution ratio of 1:2.5 (IITA, 1979). Organic Carbon/Matter: The Walkley – Black wet digestion method was used to determine the organic carbon content of the soil samples. The values of the organic carbon percent in each sample tested were multiplied by the constant value of 1.724 to generate percent organic matter content of the soil samples. Total Nitrogen (TN): Total nitrogen was determined using the Macro – Kjedhal method. Available Phosphorous (P): Soil available phosphorus was determined using the Bray I method calorimetrically.

Exchangeable Bases: Exchangeable Ca, Mg, Na and K were extracted with 1m ammonium acetate saturation method (1M NH_4OAc) as described by Anderson and Ingram (1998). The cation in the leachate was determined using Atomic Absorption Spectrophotometer (AAS) at appropriate wavelength. Effective Cation Exchange Capacity (ECEC): Cation Exchange Capacity (CEC) of the soil was determined using ammonium acetate saturation method, buffered at pH 7.0 (Soil Survey Staff, 2010).

Digital Elevation Model (DEM*)* Extraction

Digital Elevation Model (DEM) data was obtained using the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation (GDEM) which was downloaded from the Google Earth Engine (GEE) portal released on May, 2009 at a spatial resolution of 30 meter. The DEM was re-sampled to $1km^2$ and used to generate slopes and contour map in GIS software.

Climatic Data Collection Techniques

Information on climate of the region was obtained from archival documents**.** This was from all possible areas and sources in the study area. Documented data particularly on rainfall, temperature, potential evarpo-transpiration from 1991- 2020 was obtained from the relevant sources and institutes/ bodies such as; NiMET, KNARDA, JARDA and Satellite source. Appropriate locations

https://doi.org/10.65760/sjgs.v4.i2.6

(KNARDA and JARDA meteorological stations) were identified in the region (from the more arid north eastern, the centre and the southern tips of the region) and climatic information recorded and documented was used in this study.

Table 1: Factors Suitability Rating for Rice Production

Diagnostic factors	**Highly Suitable (S1)**	**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Not Suitable (N)**
Climatic Factors				
Rainfall (mm)	800-1200 (>1400)	700-800/1200-1400	600-700/1000-1200	<600/ <1000
Temperature (^{O}C)	31-35/24-31	30-32/22-24	18-22/32-35	<18/ >35
LGP	181-200	151-180	75-150	<75
Edaphic Factors				
Slope (%)	0-1	1-2	2-4	>4
Soil Texture	C, CL, SiCL, SiL	SC, L, SiC, SCL	Si, SL,	S, SL
Soil Drainage	Very Poor	Poor	Moderate	Excessive
Soil pH	5.0-7.3/5.5-8.0	7.4-7.8/8.0-8.5	4.0-5.0/7.9-8.4	<4.0 ->8.5
O. Carbon (g/kg)	2.0-4.0	1.0-2.0	0.5-1.0	<0.5
O. Matter (%)	3.5-5.0	2.0-3.5	0.5-2.0	<0.5
CEC (Cmol/kg)	>40/>25	25-40/13-25	15-25/6-12	<15/<6
ESP/Na	0-3.1 (10%)	3.2-4.0 (10-20%)	4.1-5.0 (>20%)	>5.1 (>20%)
TN (%)	>0.2	0.1-0.2	<0.1	<0.1
Avail. P (ppm)	>40 (>25)	20-40 (10-25)	10-20 (<10)	<10
Exch. K (ppm)	>60	30-60	<30	<30

Source: FAO (1983), Sys (1985), Payne *et al*. (1990), Dowswell, *et al*. (1996), Ajayi (1998), Shaw (1998), Adeoye (2006), Bennetzen & Hake (2009), ARCC (2014), Ahmed (2015), Jimoh (2016), Agber (2017), Hakeem et al (2018) and Kahsay (2018)

Table 1 was the rating scale (Rice requirements) that was used for comparisons with agroecological conditions in the region which enable final comparison for suitability classification.

Matching Crop Requirements against Biophysical attribute of the Agroecologies

Geographic Information System (GIS) and decision support tools were integrated in a GIS environment for matching. Biophysical requirements of rice crop were matched against the detailed surveyed agro-climatic and edaphic characteristics of the region. Analytical Hierarchy Process (AHP) was used to generate different layer (criteria map) for all the parameters. Weights were assigned to each of the parameters based on its importance and influence to rice growth and

https://doi.org/10.65760/sjgs.v4.i2.6

development. The criteria maps were then overlaid to develop final suitability map based on the crop requirements and land attributes of the respective agroecologies.

Table 2: Suitability rating and Intensity of limitations for classification

Symbol	Intensity of Limitations	Rating	Equivalent Suitability
S1	No to slight	86-100	Highly Suitable
S2	Moderate	61-85	Moderately Suitable
S3	Marginal	41-60	Marginally Suitable
N	Very severe	0-40	Not Suitable

Source: Sys, 1993

Table 2 was adopted from Sys (1993) and was used to classify the study region based on the prevailing conditions and severity of the limitations.

Results and Discussion

The section presents the result of matching the basic biophysical factors of climate and soil for the understanding of most suitable area for sustainable rice production in the Kano region. For optimum rice cultivation, the soil should maintain high moisture level consistently near saturated condition throughout most of the growing period. The soil should also be rich in organic matter with slightly acidic to neutral pH level indicating good fertility status (Alake, 2016). Clay or loamy soils with good water retention capacity are generally considered best for rice cultivation. It requires adequate nitrogen, phosphorous and potassium, which can be provided through organic manure or chemical fertilizers applied (Dengiz, 2015).

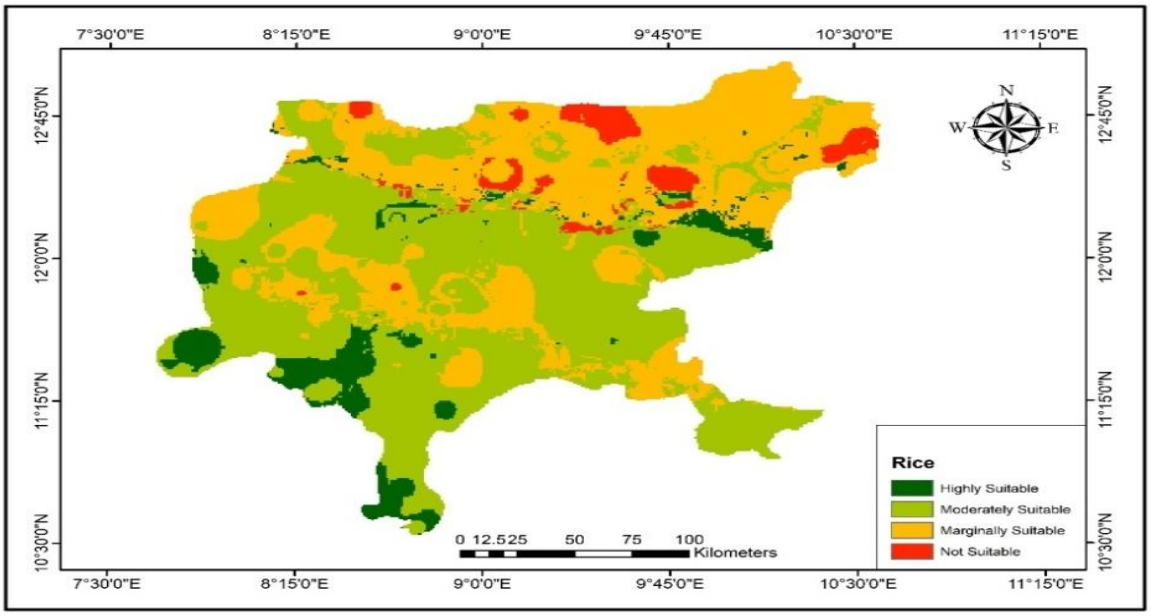

Figure 3: Rice Suitability Classification in the Kano Region
Source: Author's Work, 2024

https://doi.org/10.65760/sjgs.v4.i2.6

Table 3: Rice Suitability Classes

S/No.	Classes	Area (Ha)	Percentage
1	Highly Suitable	344,333.13	8
2	Moderately Suitable	2,280,253.34	50
3	Marginally Suitable	1,699,676.14	38
4	Not Suitable	192,943.07	4
	Total	**4,517,204.68**	**100**

Source: Author's Work, 2024

The suitability map for rice crop, identified by weighted overlay using spatial analyst tools is shown in Figure 3. The results indicate that half of the total land (50%) was moderately suitable (S2) and only 4% is not suitable (N) for rice production in the region. The predominance of S2 is more a reflection of manageable constraints on soil fertility than of climatic or topographical constraints. Climatic parameters and the slope conditions were generally favourable for rice cultivation in all areas. However, in several locations the low total nitrogen (TN), phosphorous and potassium of the soil and rough surface texture significantly reduced the suitability score.

The highly suitable land was observed mostly in Southern guinea agroecology; moderately suitable was predominantly in northern guinea and Sudan ecologies whereas marginally suitable and not suitable areas were found in Sudano-Sahelian and Sahelian ecologies of the region. The results showed that highly suitable and moderately suitable areas were found mostly in areas under current rice growing environments covering 58% of the region (Table 3). The predominance of moderately suitable (S2) land aligns with previous studies in northern Nigeria by Abdulkadir (2021) and Jimoh (2015) who reported that soils in the savannah zone are generally agro-viable but limited by nutrient depletion.

The finding agrees with (Ya'u, 2014) that rice was observed to be highly suitable in parts of the Kano region and contradicted that of Mukurgwe *et al* (2021) who stated that, very limited potential for rainfed rice production in Zambia with less than 20% of the land classified as either highly or moderately suitable. The major limitations to high suitability were identified as high moisture stress, low soil fertility status of the respective agroecologies. Areas where rice is marginally and not suitable were in the north eastern parts of the region (Sahel and Sudano-Sahelian agroecologies). Soil moisture deficiencies and sandy nature of the soil and very poor soil fertility constitute the most limiting biophysical factors to sustainable production of the crop in the region. Alake, (2016) revealed similar findings in the south west savanna ecology who in his study identified areas of high, moderate and non-suitable zones for upland rice production in Oyo state, Nigeria.

Similar patterns have been observed in Sub-Saharan Africa, where rice yield variability is driven more by soil fertility constraints than by climatic factors. For example, studies conducted in Ethiopia, Tanzania, Northern Ghana and India indicates that chemical properties of the soil often outweigh favourable topography and water availability in determining yield results (Tadesse and Negese, 2020 & Shaloo *et al*. (2022).

Conclusion and Recommendations

Generally, in the Kano region, the findings underscore how biophysical factors of both soil and elevation (edaphic factors) and climate (climatic factors) play important role in understanding the

https://doi.org/10.65760/sjgs.v4.i2.6

potentials and constraints of the different agroecological zones for rice production. This can be a vital tool for the choice of particular crop types that best suit the prevailing conditions of the natural environment for sustainable production. Understanding biophysical factors of the five different agroecological zones in the Kano region is a win-win solution for adoption of crop types, management approaches that best suit the peculiarities of the environment for sustainable yield and future food security in the region and similar environment.

Acknowledgement

The authors wish to express their special thanks to Aliko Dangote University of Science and Technology, Wudil and the Centre for Dryland Agriculture (CDA) - BUK for their maximum support during data collection and analysis.

Conflict of Interest

The authors declare no competing interests whatsoever.

References

Abdulkadir, N., Noma, S. S., Sanda, R. A., Yato, D., & Musa, B. (2021): Soil Survey and Land Suitability Evaluation for Sugar Cane Production at Zagga District, Bagudo Local Government Area, Kebbi State, Nigeria. *Asian Soil Research Journal*, https://doi.org/10.9734/asrj/2021/v5i430119

Adenle, A. A. & IfejikFa, S. C. (2021): Social-Ecological Archetypes of Land Degradation in the Nigerian Guinea Savannah: Insights for Sustainable Land Management. Remote Sensing 13(1):32. https://doi.org/10.3390/rs13010032

Adeoye, G. O (2006): Nutrient Rationalization in Nigerian Compound Fertilizers (NPK) with Special Focus on Phosphorus and Potassium Utilization, USAID MARKETS.

African and Latin American Resilience to Climate Change (ARCC 2014): Agricultural Adaptation to climate change in the Sahel- A review of fifteen crops cultivated in the Sahel, *United State Agency for International Development* (USAID).

Agber P. I, Adoyi A, Gani A. T. (2017): Suitability Evaluation of Soils of Ohimini Area of Benue State, Nigeria for Sustainable Rainfed Arable Crop Production, *International Journal of Environment, Agriculture and Biotechnology* (IJEAB) Vol-2, Issue-6, Nov-Dec- 2017.

Ahmed, M. (2015): Land Suitability Classification for Sorghum (Sorghum bicolor l. moench) in Bunkure, Kano State, Nigeria, An Unpublished M.Sc Thesis. Department of Geography, Ahmadu Bello University, Zaria, Nigeria.

Ahmed, M., Adamu G. K, and M.U. Mohammed (2015): Spatial Variation of Nitrogen, Phosphorus and Potassium for Fertilizer Usage in Part of Kano Drylands, presented at the 55th Annual Conference of ANG Held at Department of Geography Osun State University, Osogbo (UNIOSUN ANG 2015) between 23rd – 27th March, 2015.

Ajala, O. N., Adjadeh, T. A., Olaniyan, J. O., Isimikalu, T. O., Nartey, E. K. & James, F. O. (2021). Characterization, classification and suitability evaluation of soils under sugarcane (Saccharum officinarum L.) cultivation at the Sugar Research Farm, University of Ilorin, Nigeria. Agro-Science, 20(3) https://doi.org/10.4314/as.v20i3.3

Ajayi O, Owonubi J. J, Uyoybisere, E. O, Zafari, A. B (1998): Climatic, Edaphic and Biological Factors Limiting Millet Yield in Nigeria, Pearl Millet in Nigerian Agriculture (Production, Processing and Research Priorities) Edited by Emechebe, A.M, Ikwelle, M.C, Ajayi, O., Aminu Kano, M. and Anaso, A.B. Ramadan Press Limited, Bauchi.

Alake, A. M. (2016): Suitability assessment and mapping of Oyo State, Nigeria, for rice cultivation using GIS. Theor Appl Climatol DOI 10.1007/s00704-016-1852-4

Anderson, J. S. and Ingram, J. I. S. (1998): Tropical Soil Biology and Fertlity, A Handbook of Methods. 2nd Edition, *Information Press, U.K.* Pp. 221.

Beltran-Peña, A., Rosa, L., & D'Odorico, P. (2020): Global food self-sufficiency in the 21st century under sustainable intensification of agriculture, Environmental *Research Letters*, 15(9), 095004. https://doi.org/10.1088/1748-9326/ab9388

Bennetzen, J. L, & Hake, S. (2009): Handbook of maize: its biology. New York: Springer.

Danazumi, D. D., Alhaji, U. M. & Mustapha, M. (2020): Classification of Some Selected Soils of Chalama–Gorge Microwatershed in Kano, Nigeria. *African Scholar Journal of Agriculture and Agricultural Tech. 18(1), 227–236.*

Daniel, Y., Sani Noma, S., Abdulkadir, N., & Sanda, A. R. (2022): Semi-Detail Soil Survey and Land Suitability Evaluation for Sugarcane Production at Tungan Ahmadu District, Koko-Besse LGA Kebbi State Nigeria. *International Journal of Plant & Soil Science*, https://doi.org/10.9734/ijpss/2022/v34i630873

Dengiz, O. Ozyazici, M. A. Saglam, M. (2015): Multi-criteria assessment and geostatistical Approach for determination of rice growing suitability sites in Gokirmak catchment, *Paddy Water Environ 13(1):1–10.*

Dengiz, O. Ozyazici, M. A. Saglam, M. (2015): Multi-criteria assessment and geostatistical Approach for determination of rice growing suitability sites in Gokirmak catchment, *Paddy Water Environ 13(1):1–10.*

Devkota, K. P., Devkota, M., Rezaei, M. & Oosterbaan, R. (2022): Managing salinity for sustainable agricultural production in salt-affected soils of irrigated drylands Agricultural Systems 198. https://doi.org/10.1016/j.agsy.2022.103390

Dowswell, C. R., Paliwal, R.L. & Cantrell, R.P. (1996): Maize in the Third World. Westview Press, Boulder, CO, USA.

Food and Agricultural Organization of the United Nations (FAO, 1976): A frame work for land evaluation, Soil Bulletin, Vol. 32, FAO, Rome.

Food and Agricultural Organization of the United Nations (FAO, 1983): Guidelines: land evaluation for rain fed agriculture. FAO Soils Bulletin, No 52, FAO, Rome, Italy, pp. 237.

Gee, G. W. and J. W. Bauder. (1986): Particle size analysis. In 'Methods of soil analysis, Part 1, Vol. 9 (Ed. A. Klute) pp 91–100 *American Society of Agronomy*: Madison,WI.

Hakeem A. Ajeigbe, Folorunso Mathew Akinseye, Kunihya Ayuba, and Jerome Jonah (2018): Productivity and Water Use Efficiency of Sorghum [*Sorghumbicolor* (L.) Moench] Grown under Different Nitrogen Applications in Sudan Savanna Zone, Nigeria. Hindawi *Journal International of Agronomy* Volume 2018, Article ID 7676058, 11 pages https://doi.org/10.1155/2018/7676058

Ibrahim, M. A. (2014): Population Growth in the Kano Region, In A.I Tanko and S.B. Mumale (Eds.) Kano Environment, Society and Development, London and Abuja, Adonis and Abbey Publishers.

Ihediuche, C. I., Olayiwola, V. A., Ojelabi, O. K., Abiodun, F. O., Ojedokun, R. O., Ajiboye, O. O…. Isienyi, N. C. (2022): Characterization and Taxonomic Classification of Soils in Onigambari Forest Reserve South Western Nigeria. *Journal of Applied Sciences and Environmental Management*, 25(12), https://doi.org/10.4314/jasem.v25i12.7

International Institute for Tropical Agriculture (IITA, 1979): Selected methods for Soil and Plant Analysis. Manual series No:1, Kano, Nigeria.

Jimoh, A.I., Yusuf, Y.O. And Yau, S.L. (2016): Soil Suitability Evaluation for Rain-Fed Maize Production at Gabari District Zaria Kaduna State, Nigeria. *Ethiopian Journal of Environmental Studies & Management* 9 (2): 137 – 147, 2016. ISSN: 1998-0507.

Jimoh, I. A. (2015): Characterization and Suitability Evaluation of Kubanni Floodplain and Adjoining Upland Soils for Maize and Rice Production in Zaria, Nigeria. Unpublished M.Sc. Thesis. Department of Geography, ABU, Zaria.

Kahsay, A.; Haile, M.; Gebresamuel, G.; Muhammed, M. (2018): Land Suitability Analysis for Sorghum Crop Production in Northern Semi-Arid Ethiopia: application of GIS-Based Fuzzy AHP Approach. *Cogent Food and Agriculture, cogent OA, DOI http://dx.doi.org/10.1080*

Liman, M. A. (2014): Transition into the Information Era, In A.I Tanko and S.B. Mumale (Eds.) Kano Environment, Society and Development, London and Abuja, Adonis and Abbey Publishers.

Mukurgwe, Mirriam; Lydia Mumbi Chabala, Michiel Van Dijk, Benson H. Chishala, R. Murray Lark (2021): Assessing land suitability for rainfed paddy rice production in Zambia, *Geoderma Regional, journal* homepage: www.elsevier.com/locate/geodrs

Muluneh, M. G. (2021): Impact of climate change on biodiversity and food security: a global perspective - a review article Agric & Food Secur 10(36), https://doi.org/10.1186/s40066-021-00318-5

Mustafa, A. A. et. Al. (2011): Land suitability analysis for different crops: a multi-criteria decision-making approach using remote sensing and GIS. *Researcher* 3(12).

Oladimeji, J. (2024): Land suitability analysis for rice cultivation using a GIS-based analytical hierarchy process (AHP) multi-criteria decision-making approach: Kabba/Bunu Local Government Area, Kogi State, Nigeria. *International Journal of Science and Research*, 13(3), https://www.ijsr.net/archive/v13i3/SR24309115421.pdf

Olofin, E. A., Nabegu, A. B. and Dambazau, A. M (2016): Wudil within Kano Region: A Geographical Synthesis, *Ahmadu Ballo University Press Limited*, Zaria-Nigeria.

Olofin, E.A, Nabegu, A.B and Danbazau, A.M (2008): Wudil within Kano Region: a geographical synthesis, Published by Adamu Joji publishers on behalf of the department of Geography, Kano University of Science and Technology, Wudil.

Razvanchy, H. A. S., & Fayyadh, M. A. (2022): GIS and AHP Based Techniques for Agricultural Land Suitability Assessment in Erbil Province, Kurdistan region, Iraq. *Basrah Journal of Agricultural Sciences,* 35(1), https://doi.org/10.37077/25200860.2022.35.1.12

Shaloo, Singh, R. P., Bisht, H., Jain, R., Suna, T., Bana, R. S., Godara, S., Shivay, Y. S., Singh, N., Bedi, J., Begam, S., Tamta, M., & Gautam, S. (2022): Crop-suitability analysis using the analytic hierarchy process and geospatial techniques for cereal production in North India, Sustainability, 14(9), 5246. https://doi.org/10.3390/su14095246

Shaw, R. H. (1988): Climate requirement. In: Sprague G. F. and Dudly, J. W., (Eds.). Corn and Corn Improvement, 3rd Ed., Madison, WI: ASA 609.

Soil Survey Staff (2010): Keys to Soil Taxonomy, 8th edition. USDA Natural Resource Conservation Service, U.S. Government Printing Office, Washington DC.

Sys, C. (1985): Land evaluation. State University of Ghent, International Training Centre for post-graduate soil scientists; Algemeen Bestuur van de Ontwikkelingss, Ghent, Belgium.

Tadesse, M. and Negese, A. (2020): Land suitability evaluation for sorghum crop by using GIS and AHP techniques in Agamsa sub-watershed, Ethiopia Land suitability evaluation for sorghum crop by using GIS and AHP techniques in Agamsa sub–Cogent Foodand Agriculture, 6(1). https://doi.org/10.1080/23311932.2020.1743624

Ya'u, S. L., Manasseh, E. A. & Sharifai, A. I. (2014): Land Evaluation for Improved Rice Production in Watari Irrigation Project, Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences. 7(1), 116-120*