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Agricultural Land Use Suitability Analysis for Maize Production Using GIS and AHP Techniques in Bali Local Government Area, Taraba State, Nigeria

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ABSTRACT

The study assessed agricultural land use suitability for maize production in Bali Local Government Area, Taraba State, using GIS and AHP techniques. It aimed to examine the terrain's physical characteristics, soil physicochemical parameters, spatial variation in soil suitability, and the extent of land suitable for maize production. A descriptive survey design was employed, with a multi-stage sampling approach. Soil samples were collected at 50-meter intervals across nine political wards, air-dried, crushed, and filtered for analysis. Physical and chemical parameters were examined, and the analytic hierarchy process (AHP) was used to determine the relationship between five thematic layers and their attributes. The final suitability classes were analyzed using Weighted Sum Overlay in ArcGIS 10.3 to produce the final suitability map. Results revealed diverse topography with elevations ranging from 112 to 1558 meters, slope variations from 0 to 73.5 degrees, and land surface temperature (LST) ranging from 26.5° to 38.7°. Predominant soil types included Ferric Acrisol, Ferric Luvisols, Fluvisols, Lithosols, and Numic Nitosols, with distinct properties influencing maize cultivation suitability. Nitrogen levels ranged from 0 to 0.2, organic carbon content from 0 to 1.7, and soil depth from 15 to 42 centimeters. Analysis of sand, silt, and clay percentages, textural classes, bulk density, particulate density, and total porosity provided insights into soil structure. Soil type emerged as the most crucial criterion, followed by soil depth and slope. Approximately 50.75% of the land was highly or very highly suitable for maize production. The study recommended integrated land management practices and soil fertility enhancement programs for local farmers and commercial entities.

Keywords: Agricultural land use suitability, Maize production, GIS and AHP techniques, Soil physicochemical parameters, Suitability classes

INTRODUCTION

Maize (*Zea mays*) is the predominant food crop cultivated in all local government areas of Taraba State, including Bali. Numerous households plant this crop on all accessible land, including plots near to government buildings, residential zones, and commercial establishments. Maize is acknowledged as an essential crop for global food security and serves as a staple in the diets of many, especially in poor countries (FAO, 2016). Maize, the most extensively farmed grain globally, originates from the Andean region of Central America (FAO, 2016; FAO, 2021; Hamel & Dorff, 2015). In 2023, worldwide maize production totalled

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roughly 1,235.73 billion tonnes (OECD-FAO, 2023). Local biophysical characteristics are essential in determining the feasibility of crop cultivation, affecting soil fertility and the region's primary potentials and constraints (Mendas & Delali, 2012; Kazemi, Sadeghi, & Akinci, 2016).

The evaluation of site suitability constitutes the preliminary phase in formulating land-use plans and advancing sustainable agriculture practices (Falasca, Ulberich, & Ulberich, 2012; Baroudy, 2016). The primary determinants influencing studies on land suitability for agriculture in Bali are soil quality, climate, and topographic variation. The FAO (1990) asserts that a comprehensive examination of agricultural land units must prioritize critical attributes including soil, climate, and terrain at the local level. Historically, the majority of human activities have occurred in areas suitable for agriculture, habitation, and the exploitation of natural resources (Michael and Chris, 2013). Hossain (in Yang et al., 2020) observes that agriculture is the foremost consumer of meteorological and climatic data, as elements such as solar radiation, precipitation, and temperature profoundly affect crop growth. Thus, effective agriculture is significantly dependent on local meteorological conditions.

Land Suitability Analysis (LSA), a GIS-based methodology, assesses the appropriateness of an area for a particular application by examining its inherent characteristics. The Spatial Analytical Hierarchy (SAH) methodology, created by Saaty in the 1970s and refined in the 1980s, is an efficacious way for doing land suitability evaluations (Jafari and Zaredar 2010). The Analytical Hierarchy Process (AHP), a prominent multi-criteria methodology, is frequently used into GIS-based land suitability assessments to provide essential weightings for various criteria. The GIS-based Analytic Hierarchy Process (AHP) has become increasingly favored in research for its capacity to integrate extensive heterogeneous data and its ease of weight collection for analysis, even with many criteria (Feizizadeh et al., 2014).

Land evaluation, as articulated by Perveen, Nagasawa, Uddin, and Delowar (2012), constitutes a methodology for the strategic planning of sustainable agricultural land utilization. In Nigeria's Savanna region, soil fertility is diminishing due to intensive utilization, resulting in degradation and disruption of natural ecological equilibria (Ande, 2011). Maize cultivation necessitates particular weather circumstances, geographic features, and soil characteristics (Atiah et al., 2022). This crop is cultivated in many climatic conditions, namely in tropical and mild temperate zones, when temperatures exceed 15°C and annual precipitation varies between 600 and 1100 mm. Maize flourishes on deep, fertile subtropical soils with sufficient nitrogen (Shehu, 2018).

Badu-Apraku et al. (2012) indicate that maize was introduced to Africa in the sixteenth century and rapidly emerged as a vital food crop and economic asset throughout much of West and Central Africa. Currently, maize is extensively planted in this agro-ecological subregion, flourishing especially in savanna areas owing to advantageous precipitation patterns. It functions as an essential caloric source for both humans and cattle in Nigeria and worldwide, resulting in an expansion of area allocated for extensive agriculture (Udoh & Ogunkunle, 2012).

To satisfy the increasing demand for maize, alternatives include of enlarging farmed regions or employing efficient technical innovations. Nonetheless, the expansion of agricultural land may prove impractical in an environment where land resources are increasingly strained for several purposes. Focusing on farming maize in suitable areas with high-yield hybrid varieties and modern agricultural technologies could effectively meet market demands. Consequently, choosing appropriate site for maize cultivation is essential, especially in the nation's principal agricultural areas. Land evaluation constitutes the initial phase in the sustainable land use planning and management process (Baroudy, 2016; Tashayo et al., 2020).

Unregulated land use leads to issues such as soil degradation, water shortages, and climate variability, which impede agricultural advancement in drought-prone sub humid regions (Akpoti et al., 2019; Ujoh et al., 2019). Ineffective land and soil management undermines the health and productivity of global land resources (Cowie et al., 2018; Akbari et al., 2019). As a result, efficient land utilization has emerged as a critical global issue (Vasu et al., 2018; Massawe et al., 2019). Suboptimal land use practices presently jeopardize the sustainability of agricultural systems (Keesstra et al., 2016). The cultivation of crops in marginal or less productive areas, coupled with deforestation and insufficient management of slopes, soil, and water, are key contributors to the decrease in rain-fed agricultural production (Naseer & Pandey, 2018; Kumar et al., 2019).

Jiao et al. (2017) and Mesgaran et al. (2017) assert that comprehending the intrinsic potentials and constraints of land is crucial for alleviating improper land usage (Bagherzadeh et al., 2016; Mousavi et al., 2017). Land evaluation markedly improves land use planning by augmenting agricultural productivity and ensuring investment sustainability (Qureshi et al., 2018; Vasu et al., 2018; Seyed mohammadi et al., 2019). A comprehensive framework for land suitability analysis has been developed by synthesizing data from multiple scientific disciplines for multi-criteria selection (Kahsay et al., 2018a; Daneshvar et al., 2017; Otgonbayar et al., 2017). The integration of many elements (Harper et al., 2017) and alternative ranking methodologies (Zavadskas et al., 2018; Halder et al., 2020) has improved the decision-support functionalities of GIS systems via multiple-criteria decision-making (MCDM) instruments (Barakat et al., 2017). This amalgamation provides a methodical and geographically accurate assessment methodology (Singha & Swain, 2016; Owusu et al., 2017; Qureshi et al., 2018), resulting in enhanced precision for sustainable land management methods (Yalew et al., 2016b; Musakwa, 2018).

The Analytical Hierarchy Process (AHP) is commonly employed in multi-criteria decision-making (MCDM) methodologies for GIS-based suitability assessments, as it proficiently determines weightings for various land uses via pairwise comparisons of multiple factors according to their relative significance. The weighted overlay method integrated with AHP in GIS is especially appropriate for the hierarchical framework of multi-criteria analysis (Pramanik, 2016; Kazemi & Akinci, 2018; Negi et al., 2020). The AHP-based MCDM methodology with the weighted overlay model may efficiently evaluate agricultural land suitability (Burian et al., 2018; Hussien et al., 2019; Purnamasari et al., 2019).

The AHP-based MCDM combined with GIS has been employed worldwide to evaluate land suitability for agriculture. This methodology has been successfully applied in several countries, including China (Zhang et al., 2015; Yu et al., 2018; Geng et al., 2019), Ethiopia (Yalew et al., 2016a, b; Kahsay et al., 2018a; Nigussie et al., 2019), Iran (Kazemi & Akinci, 2018), Morocco (Barakat et al., 2017; Ennaji et al., 2018), North Africa (Mesgaran et al., 2017), Malawi (Li et al., 2017), and Cihanbeyli (Paul et al., 2020). A multitude of studies (Zolekar & Bhagat, 2015; Pramanik, 2016; Dadhich et al., 2017; Jamil et al., 2018; Parry et al., 2018; Shehu, 2018; Akram et al., 2019; Mistri & Sengupta, 2019; Singh et al., 2019) have utilized this multi-criteria GIS methodology to assess agricultural land suitability.

Land suitability study can improve agricultural output by assessing the intrinsic and potential capabilities of land for specific uses (Bandyopadhyay et al., 2009). Furthermore, it aids in pinpointing essential domains for prospective administration. In 2004, Saaty amalgamated geographic information systems (GIS) with remote sensing (RS) to formulate the analytical hierarchy process (AHP). This integrated methodology has been utilized in various studies globally to evaluate both general and specific agricultural land suitability (Chandio et al., 2011; Akıncı et al., 2013; Zhang et al., 2015; Pramanik, 2016; Yalew et al., 2016; Bozdağ et al., 2016; Aburas et al., 2017; Roy & Saha, 2018; Dedeoğlu & Dengiz, 2019; Tashayo et al., 2020).

Nigeria's varied terrain leads to considerable differences in soil types throughout its regions and states, shaped by multiple soil-forming forces. Nigeria has experienced a reduction in agricultural output, resulting in its status as a significant importer of agricultural commodities, including rice, wheat, vegetables, and fruits. As a result, agricultural land use planning has become crucial for local farming sectors, with the objective of enhancing productivity, sustainability, and food security. This study seeks to assess the appropriateness of agricultural land utilization in Bali local government area of Taraba State, Nigeria.

The aim of this work is to analyse agricultural land use suitability using GIS and AHP techniques in Bali Local Government Area, Taraba State. The specific objectives of the study include:

i. to examine the physical characteristics of the terrain of the land in Bali LGA;
ii. to ascertain the physicochemical parameters of the soil in Bali LGA;
iii. to determine the spatial variation in soil suitability for maize production in Bali LGA;
iv. to examine the extent of land suitable for maize production in Bali LGA.

MATERIALS AND METHODS

The Study Area

The Bali Local Government Area is located in Taraba State, Nigeria, in the northeastern part of the country. It extends from latitude 7° 30′ 00″ to 8° 10′ 00″ North of the equator and from longitude 5° 45′ 00″ to 6° 15′ 00″ East of the Greenwich meridian (Figure 1). Bali LGA, one of the 16 local government units in Taraba State, is among the largest, encompassing approximately 9,146 km². Its northern boundaries are next to the Ardo Kola and Gossol local governments, while Donga and Kurmi are situated to the west, and Gashaka is positioned to the south. Furthermore, it adjoins Adamawa State to the northeast (Bako, Oparaku & Flayin, 2016).

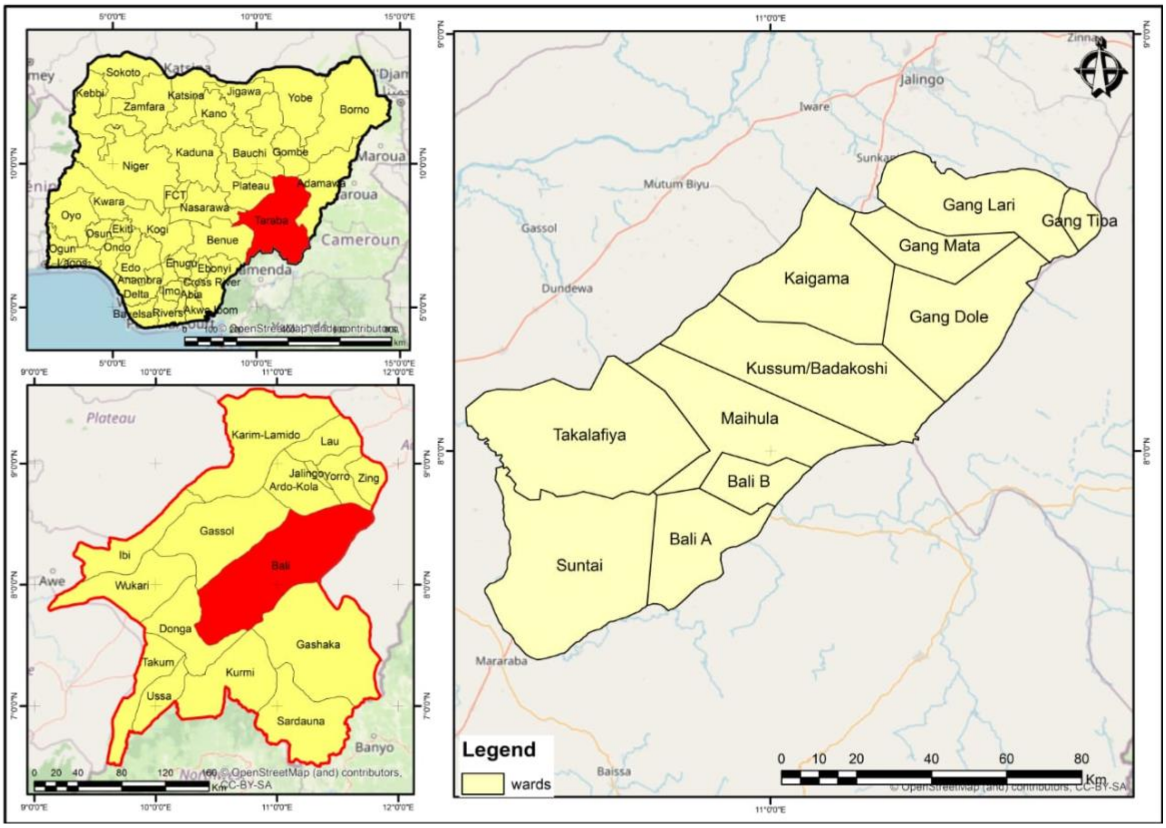

Figure 1: Map of the study area (Source: Authors Fieldwork, 2023)

Research Design

This study adopted a descriptive and analytical statistical design, utilizing GIS and AHP to assess agricultural land use suitability for maize production in the Bali Local Government Area. Research design functions as the essential framework that guides the data gathering and analysis phases of a research endeavor. It delineates the distinct phases of the research, specifying the information to be collected, the sources of that data, and the methodologies for data acquisition.

Types and Sources of Data

This study required both primary and secondary data sources. The primary data comprised field information, including soil samples and the coordinates of the sampling locations. Conversely, secondary data included academic articles, textbooks, and satellite photography.

Sentinel-2 satellite imagery (10m resolution, 2023) was obtained from the European Space Agency's Copernicus Hub to guarantee precise data gathering for the study. An Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) with a resolution of 30 meters was acquired from the United States Geological Survey (USGS) website (https://www.usgs.gov). This DEM was crucial for generating detailed slope, elevation, and aspect maps of the research area, offering significant insights into the terrain characteristics and enabling thorough topographic analysis.

Rainfall and temperature data were obtained from the Nigerian Meteorological Agency (NiMet) in Jalingo, Taraba State, to create a rainfall distribution pattern for the region. The soil texture map was scanned and imported into ArcGIS 10.3 for georeferencing purposes. Four Ground Control Points (GCPs) were designated and referenced utilizing the Universal Transverse Mercator (UTM) technique to guarantee precise georeferencing. Modifications were implemented to the chosen control points during the registration process to reduce errors in digitization. The map was subsequently projected onto the WGS 1984 coordinate system, employing the Minna datum and UTM zone 32, facilitating accurate spatial analysis and interpretation.

Sampling Procedure

This study utilized a multi-stage sampling method. Purposive sampling was employed to discern changes in slope and fertility gradients within the research area. A random sample technique was employed to choose sampling stations, each spaced 50 meters apart among nine political wards in the Bali Local Government Area of Taraba State.

Method of Data Collection

A reconnaissance survey and field observations were performed to acquire an in-depth understanding of the research area. This procedure yielded significant information regarding soil properties and topographical features. The researcher observed diverse land use categories, encompassing the closeness of structures to agricultural areas, rugged landscapes, and level terrains.

Field data collection and soil sampling were executed with regard to slope changes and fertility gradients in the region. Soil samples were collected from each location, and soil profiles were dug to evaluate soil depth. Soil samples were obtained from a depth of 0 to 30 cm to examine the physical and chemical characteristics of the soil.

GPS coordinates were recorded at each sampling point using a Garmin 76x model. A minimum of 10 to 15 subsamples was collected at each location, composited within a 50-meter radius between sampling stations using a random sampling method each month. As a result, eight composite soil samples were collected during the rainy season from April to November

2023, employing an Edelman auger to sample the surface layer (0–30 cm) for the evaluation of agricultural land use suitability. The gathered soil samples were air-dried, meticulously pulverized with a mortar and pestle, uniformly mixed, and sieved through a 2-mm mesh. A 0.5-mm sieve was utilized for the examination of total nitrogen (N) and organic carbon (OC). Approximately one kilogram of the composite fine soil sample was subsequently transported for analysis following conventional protocols (Wogi et al., 2021).

Technique of Data Analysis

Laboratory Analysis

Soil samples collected from the research region were air-dried and meticulously ground with a porcelain pestle and mortar to achieve a uniform texture. Particles less than 2 mm were isolated and examined for particle size distribution utilizing the hydrometer method, as described by Gee and Bauder (1986). Conventional methods were utilized to ascertain the ratios of sand, silt, and clay in the samples. Following dispersion, the samples were meticulously blended utilizing a reciprocating shaker, and particle size distribution was assessed at multiple time intervals using a Bouyoucos hydrometer. The USDA textural triangle was employed to categorize the soil samples according to their sand, silt, and clay composition.

Soil pH was evaluated in both water and a 0.01M CaCl2 solution, according to a soil-to-solution ratio of 1:2.5 (IITA, 1979). Following equilibration, pH measurements were obtained using a glass electrode on a Pye Unicam model 290mk pH meter, and delta pH (dpH) values were computed. The organic carbon content was quantified using the Walkley-Black (1934) wet digestion technique, whereas total nitrogen was assessed by the micro-Kjeldahl method. The calorimetric determination of available phosphorus was conducted using the Bray I method. The electrical conductivity of the saturated paste extract was assessed using a rheostat-based Wheatstone bridge at 25°C, following the methodology outlined by Bower and Wilcox (1965).

Exchangeable calcium, magnesium, sodium, and potassium were extracted using a 1M ammonium acetate solution buffered to pH 7.0, as described by Anderson and Ingram (1998). A GallenKamp flame analyzer was utilized to quantify potassium and salt in the extract. To mitigate ionic interference in the assessment of calcium and magnesium levels, the extracts were diluted twofold by including 2 ml of a 6.5% lanthanum chloride solution. The contents of calcium and magnesium were evaluated using atomic absorption spectrophotometry (AAS) at wavelengths of 423 nm and 285 nm, respectively, with a PyeUnicam model SP 192. The total of exchangeable bases (Ca, Mg, Na, and K) was computed. Soils were leached using a 1M KCl solution, and the exchangeable acidity (Al+H) in the extract was quantified via titration with 0.1M sodium hydroxide, as outlined by Anderson and Ingram (1998). The Cation Exchange Capacity (CEC) was assessed utilizing 1M NH4OAc buffered to pH 7.0 (Chapman, 1965; Rhoades, 1982). Surplus acetate was eliminated using alcohol washing, and absorbed ammonium ions were displaced using 10% sodium chloride (pH 2.5), with quantities quantified via the Kjeldahl method (Soil Survey Staff, 2014).

Generation of Elevation

The Digital Elevation Model (DEM) for the region was acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). This entailed transforming the raster Digital Elevation Model into point data via the conversion tool in ArcGIS 10.3. The resultant points were subsequently interpolated via the Kriging approach, generating a new raster surface that depicted the elevation fluctuations throughout the study area, which functioned as the elevation map.

Generation of Slope and Aspect

The slope of a region signifies the changes in its topography, whereas the aspect denotes the orientation of the slope. Slope and aspect data for the Jalingo region were automatically extracted from the ASTER-DEM. In the GIS environment, the ASTER-DEM was subjected to spatial analysis with the 3D Spatial Analyst tool in ArcGIS 10.3 to generate slope and aspect data in raster format.

Generation of Drainage Map

The Digital Elevation Model (DEM) and high-resolution QuickBird photos were employed to obtain data regarding the area's drainage. The initial iteration of the map was scanned and loaded into ArcGIS 10.3, where it was georeferenced with the UTM Zone 32 North projection and the WGS 1984 datum. The Jalingo Local Government Area was subsequently extracted from the map, and its drainage network was digitized. This procedure entailed generating a line feature in ArcCatalog and employing the editing tool to delineate the drainage network of the research area.

Generation of Soil Textural Map

The soil textural map of Nigeria was scanned and imported into the ArcGIS 10.3 environment, where it was georeferenced with the UTM Zone 32 North projection and WGS 1984 datum. The soil texture data was acquired by digitizing the current soil map of the region.

Distribution of Physical and Chemical Parameters

The laboratory results, along with their corresponding coordinates (longitude and latitude), were inputted into Microsoft Excel and subsequently transformed and imported into the ArcGIS 10.3 environment to analyze the spatial distribution of selected physicochemical parameters (pH, N, Ca, Na, Mg, CEC, OM, K, and P) in the study area. Thematic maps for each physicochemical parameter were created using Inverse Distance Weighted (IDW) interpolation in ArcGIS 10.3. IDW reads spatial autocorrelation literally, guaranteeing that the generated surfaces remain within the established value range and do not intersect any sample points. This approach is efficacious for phenomena exhibiting distributions closely associated with distance. An advantage of IDW is the precise control it provides over distance influence, which is superior to Spline or Kriging approaches (Mustafa et al., 2011). All physicochemical parameters were classed and thereafter transformed into raster format.

Analytic Hierarchy Process

The Analytic Hierarchy Process is a prevalent environmental planning tool established by Saaty in 1977. Baniya (2008) asserts that the fundamental premise is that the comparison of two elements relies on their present significance. Within the AHP framework, all pertinent criteria or factors are assessed via pairwise comparisons, yielding a matrix that illustrates the relative preferences among these factors (Lupia, 2014). According to Dadfar (2014), the Analytic Hierarchy Process (AHP) comprises three primary steps: identifying biophysical elements, doing pairwise comparisons of these factors, and deriving weights from the comparisons.

The correlation among the five thematic layers and their characteristics was determined through the Analytic Hierarchy Process (AHP). The process for establishing the weights of the thematic layers and their associated features entailed assessing the relative significance of the criteria (Table 1). The process encompassed the subsequent steps:

Table 1: Explanation of the intensity scale

Scale	Degree of Preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

Source: Saaty and Vargas (2012)

Step 1: Classify the different suitability levers and determine the criteria for evaluation.

Step 2: Generate pairwise comparison matrices (PWCM): The relative importance of each criterion was assessed based on its significance for maize production, using Saaty's 1-9 scale. For the physicochemical parameters—N, P, K, and OM—a rating of 1 was assigned, indicating equal importance. In contrast, CEC, Mg, Ca, Na, and pH were rated at 1/3, denoting lesser importance. Additional criteria considered in this study included elevation, slope, aspect, and other physical parameters such as soil texture and drainage.

Step 3: The suitability ratings for the sub-criteria were incorporated into the land suitability analysis, with a map representing each evaluation criterion using ordinal values (S1, S2, S3, and N1) to indicate the degree of suitability regarding each sub-criterion, based on maize requirements (see Table 2) (Sehgal, 1999).

Table 2: Factor Suitability Rating for Maize

Land Characteristic / diagnostic factor	Highly suitable (S1)	Moderately Suitable (S2)	Marginal Suitable (S3)	Not Suitable (N)
Climate				
Rainfall (mm)	>800	700 – 800	600 – 700	< 600
Temperature (°C)	24 – 30	20 - 24, 30 – 32	15 - 20, 32 – 35	<15, >35
Land/Soil Physical Property				
Slope (%)	0 – 2	4 – 8	8 – 16	<16
Soil Texture	CL, L	SL, LS	LCS	CS
Drainage	Well	Moderately Well	Imperfect	Poor
Nutrient availability (top soil)				
Ph	6 - 6.5	5.5 - 6.0, 6.5- 7	5.0 - 5.5,7.0-8.2	<5.0 - >8.2
N (g kg-1)	0.8-0.4	0.4-0.2	< 0.2	Any
P (mg kg-1)	> 40	10-40	3-10	<3
Ca (mol kg-1)	> 0.5	0.4-0.5	0.2-0.34	<0.2
Na (mol kg-1)	> 0.5	0.4-0.5	0.2-0.34	<0.2
Mg (mol kg-1)	> 0.5	0.4-0.5	0.2-0.34	<0.2
OM (%)	> 1	0.5-1	<0.5	
K (mg kg-1)	> 0.3-0.5	0.2	0.1-0.2	<0.1
CEC (cmol (+) kg-1)	>25	13 - 25	6 – 12	<6

Adopted from FAO (1983), Sys et al. (1993)

Key: CL=clay loam, L=loam, SL=sandy loam, LS= loam sand, LCS=loam clay sand, CS=clay sand

Step 4: Ranking: In this final step, the weights assigned to the physicochemical parameters are combined with those of the physical characteristics to create an overall suitability rating. Attributes with the highest weights are ranked as the most favorable options. To prevent bias in the criteria weighting, the Consistency Ratio (CR) was applied. Generally, a CR value of 10% (0.1) or lower is deemed acceptable, as noted by Mustafa et al. (2011).

The formulas used are:

- **CI = (λ - n) / (n - 1)** (1)
- **CR = CI / RI** (2)

Where:

- **λ** = Average of the consistency vector
- **CI** = Consistency Index
- **CR** = Consistency Ratio
- **RI** = Random Index
- **n** = Number of criteria or sub-criteria in each pairwise comparison matrix.

The final suitability classes were analyzed using the Weighted Sum Overlay method in ArcGIS 10.3, integrating all raster layers to produce the suitability map.

RESULTS AND DISCUSSION

This section delineates the study's findings, emphasizing the physical attributes of the topography in the Bali Local Government Area (LGA) and the physicochemical properties of the soil.

The Physical Characteristics of the Terrain of the Land in Bali LGA

The physical attributes of the terrain in Bali LGA were assessed to comprehend the topography and landforms affecting agriculture practices. The outcomes of the GIS analysis are detailed in the subsequent subsections below.

Elevation

Figure 2 illustrates the elevation of the study area, a crucial element of geographic analysis that defines the physical features of the Earth's surface and significantly influences climates, ecosystems, and human activities.

In Bali LGA (Figure 2), elevation varies from 112 meters to 1,558 meters above sea level. This notable elevation range contributes to the region's varied topography. The lowland areas are conducive to accessible agriculture, while the higher elevations may present challenges for some farming practices.

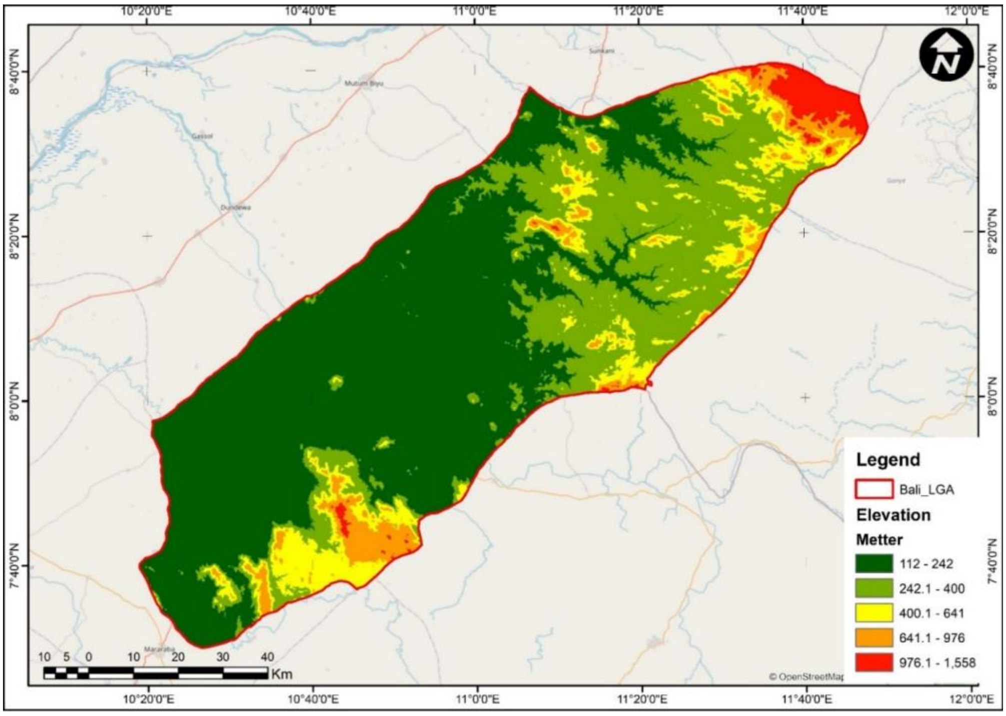

Figure 2: Elevation of Bali LGA (Source: Authors Fieldwork, 2023)

Slope

The map presented in Figure 3 shows the slope of Bali LGA, which is the steepness or elevation change relative to horizontal distance traveled. The slope is classified into five, ranging from 0 to 73.5. Slope influences soil erosion, water runoff, and crop productivity. Farmers and land managers consider slope when making decisions about land use, irrigation, and erosion control practices.

The slope analysis (Figure 3) reveals that the slope in Bali LGA varies from 0 to 73.5 degrees. Areas with gentle slopes are conducive for agriculture, facilitating water drainage and minimizing soil erosion. The identification of steeper slopes is crucial for implementing appropriate land management practices to prevent soil degradation.

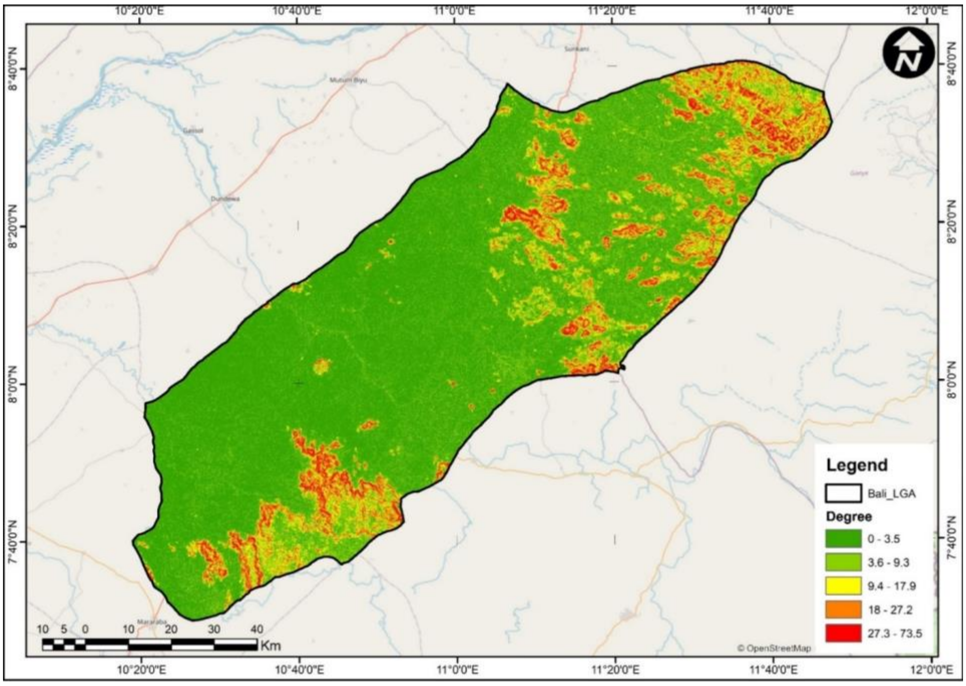

Figure 3: Slope map of Bali LGA (Source: Authors Fieldwork, 2023)

Land Surface Temperature

Figure 4 displays the results of the land surface temperature (LST) analysis, an important factor for understanding various environmental processes and evaluating agricultural conditions suitable for maize production in Bali LGA. The LST is categorized into five ranges, from 26.5 to 38.7° C.

Land surface temperature (Figure 4), a key climatic parameter, was monitored across Bali LGA. The range of land surface temperatures recorded varies from 26.5 to 38.7 degrees Celsius. These temperature variations influence crop growth and development, with higher temperatures potentially affecting water availability and evaporation rates.

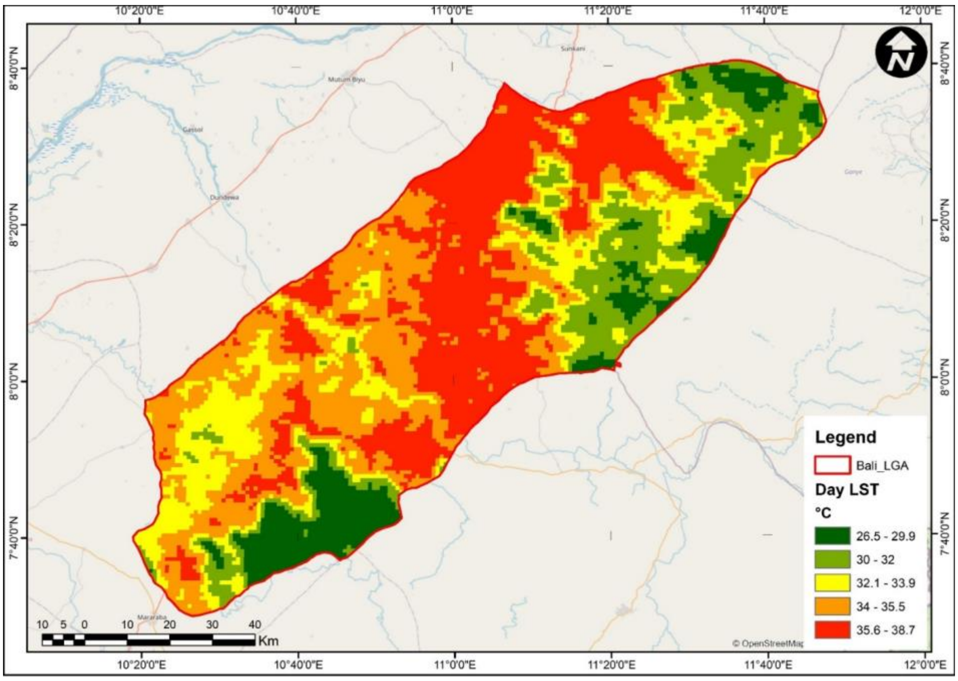

Figure 4: Land Surface Temperature of Bali LGA (Source: Authors Fieldwork, 2023)

Mean Rainfall

The result presented in Figure 5 shows the mean rainfall in Bali LGA. The mean rainfall is classified into five; 3.5 – 3.9, 4 – 4.2, 4.3 – 4.4, 4.5 – 4.8, and 4.9 – 5.5. The data on mean rainfall in the study area is a crucial metric in agriculture, especially in maize production.

The average rainfall (Figure 5) is a key climatic factor for maize production. Bali Local Government Area is situated in Nigeria's Guinea Savanna zone, which receives annual rainfall ranging from 750 mm to 1,100 mm. For optimal growth, maize needs sufficient warmth and moisture from germination up to flowering, particularly a well-distributed rainfall of 500 mm to 750 mm (Shewane & Khadke, 2023).

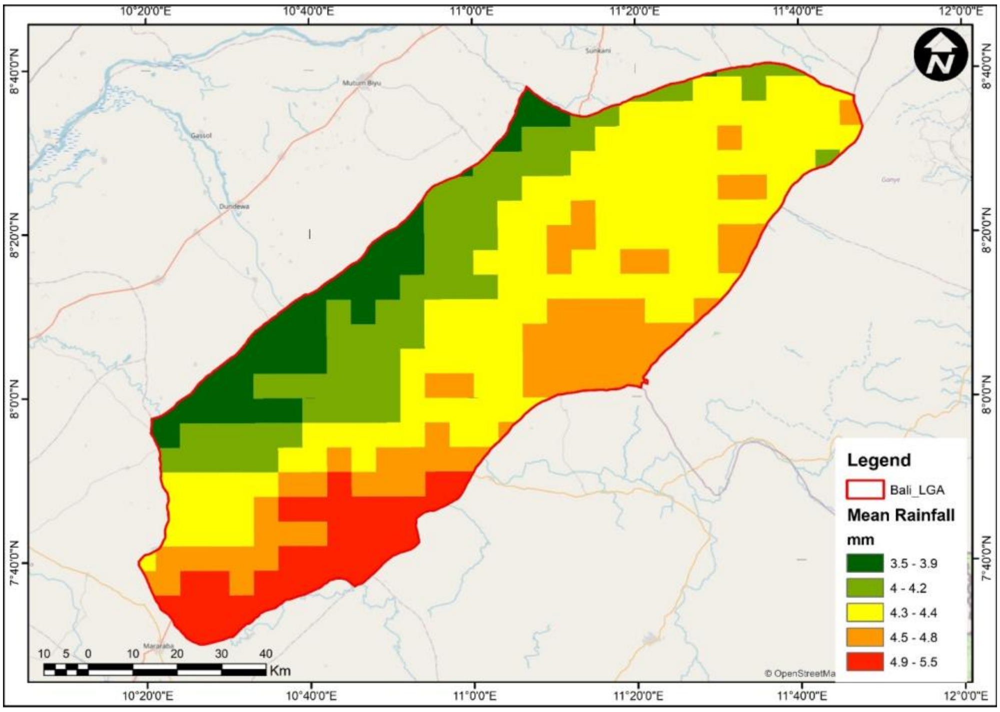

Figure 5.: Mean Rainfall of Bali LGA (Source: Authors Fieldwork, 2023)

Physicochemical Parameters of the Soil in Bali

Soil Types

The predominant soil types in Bali LGA (Table 3 and Figure 6) include Ferric Acrisol, Ferric Luvisols, Fluvisols, Lithosols, and Numic Nitosols. Each soil type has specific characteristics that influence its suitability for various crops. Understanding the soil types is crucial in planning land use and determining suitable areas for maize cultivation.

Table 3: Distribution of Soil Types in Bali LGA

Soil Type	Percentage of Area (%)
Ferric Acrisol	20
Ferric Luvisols	15
Fluvisols	10
Lithosols	30
Numic Nitosols	25
Total	**100**

Source: Author Field Survey (2024)

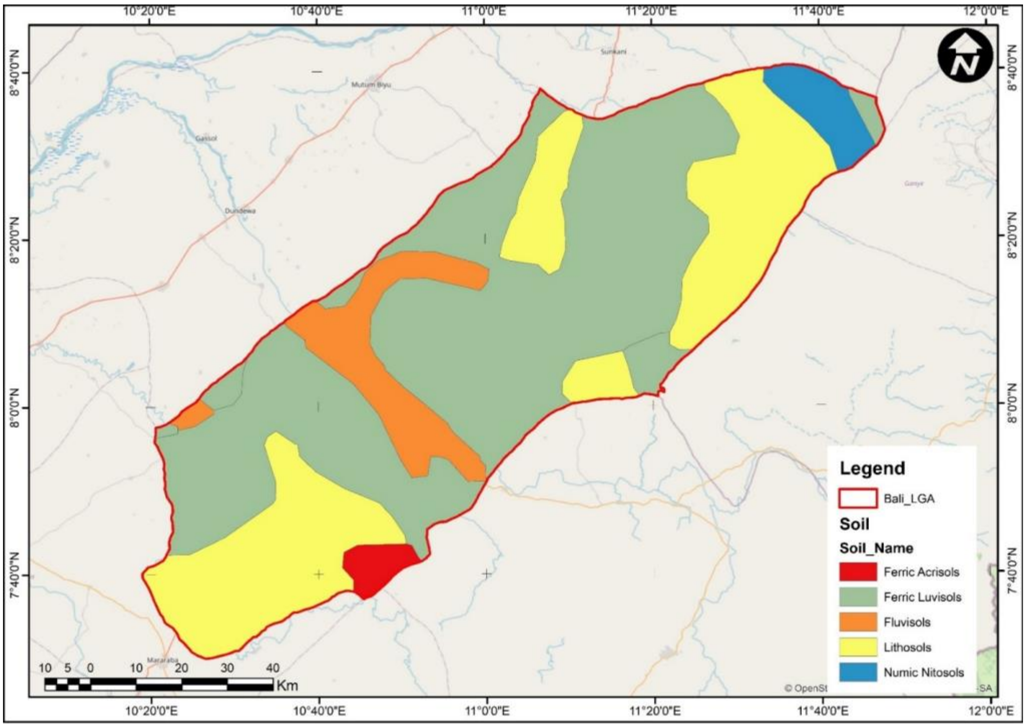

Figure 6: Soil Classification Map of Bali LGA (Source: Authors Fieldwork, 2023)

Figure 6 shows the soil classification map, which illustrates the distribution of various types of soil in Bali LGA as a percentage of the total land. Lithosols, accounting for 30% of the total area, are the most prevalent soil in Bali LGA. These are shallow soils characterized by a significant presence of rock fragments. They are typically found in areas with rocky terrain. Numic Nitosols soil occupies 25% of the area, making it the second most prevalent soil type after Lithosols. Ferric Acrisol soil, which is characterized by its high iron content and acidity, occupies 20% of the total area. Ferric Luvisols soils covers 15% of the area, indicating a substantial but slightly smaller presence compared to Ferric Acrisols. Fluvisols soils, occupying 10% of the area, represents a smaller proportion compared to the Ferric soils.

Soil Properties

The analysis of soil properties Figure 7 to 9 indicates variations in key factors influencing agriculture. Nitrogen levels range from 0 to 0.2, with different soil types exhibiting distinct nutrient profiles. Organic carbon content of the soil varies from 0 to 1.7, influencing soil fertility and structure. Soil depth, ranging from 15 to 42 centimeters, is a crucial factor for root development and nutrient uptake (Table 4).

Table 4: Soil Properties in Bali LGA

Soil Property	Range	Unit
Nitrogen	0 – 0.2	ppm
Organic Carbon	0 – 1.7	ppm
Soil Depth	15 – 42	cm

Source: Researcher’s Analysis (2024)

These factors are vital for assessing the land’s suitability for maize cultivation. The differences in soil types and characteristics emphasize the importance of a customized approach to planning land use and sustainable agricultural practices in various regions of Bali LGA.

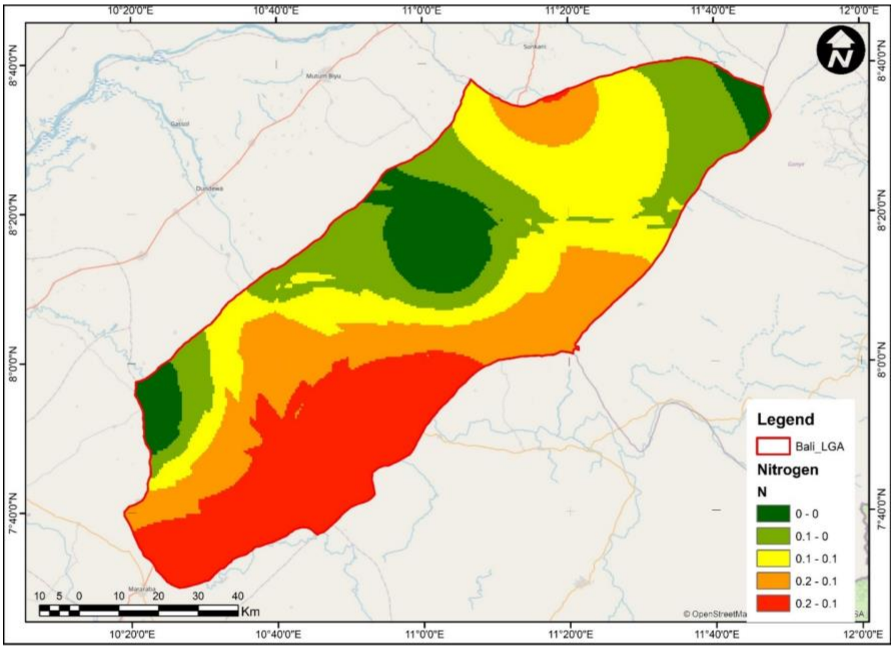

Figure 7: Nitrogen Map of Bali LGA (Source: Authors Fieldwork, 2023)

Figure 7 provides information on soil properties in Bali Local Government Area (LGA), particularly focusing on nitrogen content. Nitrogen is a vital nutrient for plant growth, and maize requires a significant amount of nitrogen to thrive. The range provided (0 - 0.2 ppm) suggests that the nitrogen content in the soil of Bali LGA may be relatively low. Low nitrogen levels can negatively impact maize production, leading to stunted growth, reduced yield, and poor overall plant health. Farmers may need to apply nitrogen-rich fertilizers to supplement the soil's nitrogen content and promote better maize growth and yield. This result is in tandem with the finding of Sharu et al. (2013) in Dingyadi District of Sokoto state, which revealed that total Nitrogen contents of the soils was generally low. On the other hand, the finding of the present study is in contrast with the result of Shehu (2018) which found higher Nitrogen value of 0.617g/kg in Basawa, Sabon Gari Local Government Area of Kaduna State.

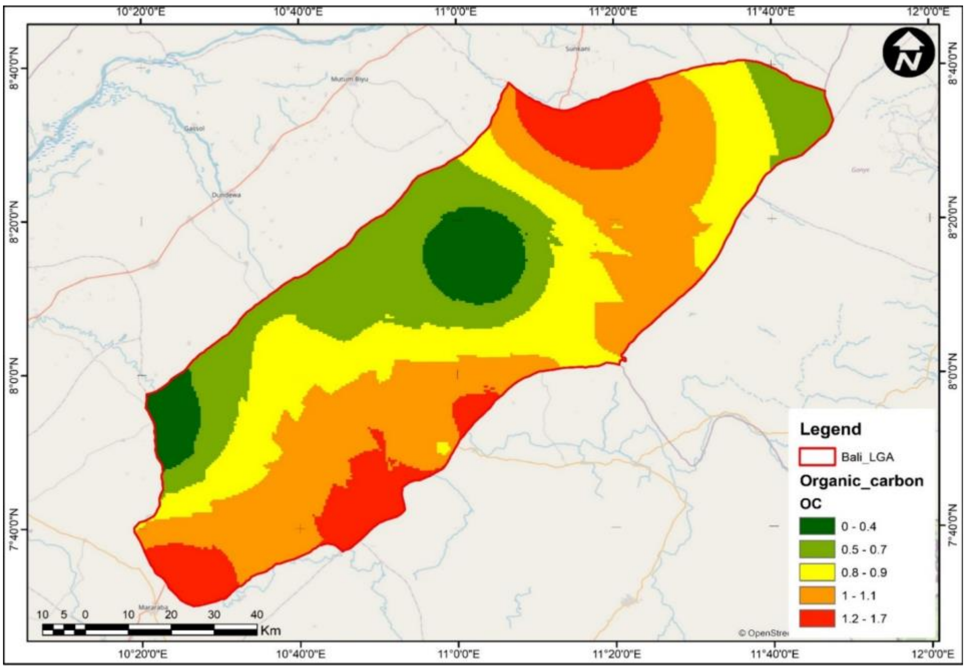

Figure 8: Organic Carbon Map of Bali LGA (Source: Authors Fieldwork, 2023)

The results shown in Figure 8 detail the organic carbon content of the soil in Bali LGA. Organic carbon is vital for soil fertility and structure, significantly influencing nutrient retention and microbial activity. The reported range (0 - 1.7 ppm) suggests that the organic carbon content in Bali LGA's soil varies but is generally low. Such low levels of organic carbon can lead to poor soil structure, diminished water retention capacity, and reduced nutrient availability for maize plants. Farmers can enhance soil quality by incorporating organic matter through crop residue mulching, the use of cover crops, and organic amendments.

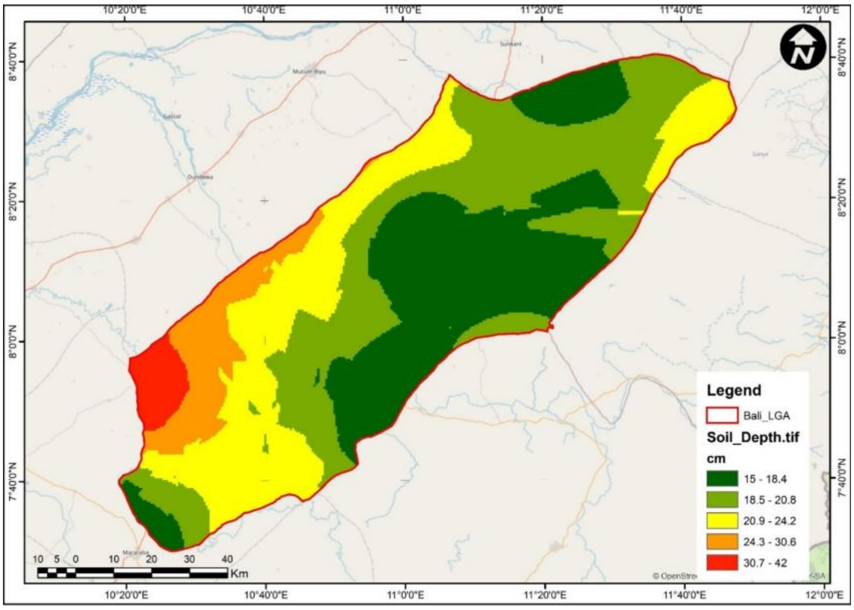

Figure 9: Soil Depth Map of Bali LGA (Source: Authors Fieldwork, 2023)

The result in Figure 9 provides information on soil depth in Bali Local Government Area (LGA). Soil depth is important for plant root development, water infiltration, and nutrient availability. The range of soil depth in Bali LGA varies from 15 to 42 cm, indicating some variability in the depth of the topsoil layer. Shallow soils may limit root penetration and water storage capacity, particularly during dry periods, which could affect crop productivity and resilience to drought. Farmers may need to implement soil conservation practices to prevent soil erosion and maintain soil depth, such as contour plowing, terracing, and agroforestry.

The Physiochemical Parameters of the Soil

Table 5 displays the essential parameters, including the percentages of silt, sand, and clay, textural classes, bulk density, total porosity, and particulate density.

Table 5: Mean Physical Parameters of the Soil

Location	Sand %	Silt %	Clay %	Textural Classes	Bulk Density (gem 3)	Particulate Density (gem 3)	T. Porosity (%)
Bali A	57.13	19.98	22.90	Sandy Clay Loam	1.43	2.66	46.03
Gandole	60.94	25.95	13.11	Sandy Loam	1.53	2.58	40.66
Badakochi	66.25	20.40	13.35	Sandy Loam	1.52	2.58	40.66
Ganglari	74.5	15.65	9.85	Sandy Loam	1.58	2.60	39.37
Gangmata	71.25	18.7	10.05	Sandy Loam	1.58	2.60	39.17
Kaigama	65.85	17.75	16.43	Sandy Loam	1.49	2.70	44.54
Gangtiba	75.63	7.65	16.75	Sandy Loam	1.51	2.49	39.61
Maihula	56.5	19.9	23.6	Sandy Clay Loam	1.42	2.64	46.02
Takalafiya	71.38	15.13	13.5	Sandy Loam	1.54	2.65	41.61

Source: Author Field Survey (2024)

The primary textural classes found are Sandy Loam, Sandy Clay Loam, and Loamy Sand, reflecting differences in soil composition. Sandy Clay Loam comprises a harmonious blend of sand, silt, and clay, providing excellent fertility and drainage capabilities. Sandy loam, characterized by a greater sand composition, facilitates superior drainage while exhibiting moderate fertility. Loamy sand possesses a significant sand composition, facilitating swift drainage, although may require enhanced nutrient management.

Bulk density is defined as the mass of soil per unit volume, whereas particulate density denotes the weight of soil particles per unit volume, excluding pore spaces. The results indicate that bulk density values vary across different locations and sampling points, ranging from 1.36 to 1.65 g/cm³. The particulate density varies between 2.40 and 2.90 g/cm³. A lower bulk density and a greater particle density are typically favored for agricultural soils. Low bulk density enhances root development and aids water infiltration, whereas high particle density signifies well-structured soil with effective aggregation.

Total porosity denotes the volume of voids within the soil matrix. Total porosity values range from 36.19% to 48.58%. The Total porosity is essential for soil aeration and water retention capacity. Elevated porosity values indicate enhanced aeration and water retention, promoting plant growth.

Table 6: Mean Chemical Parameters of the Soil

Location	pH (1:2)	EC (dS/M)	Org. C (%)	Org. M	TN	Av.P (mg/kg)	Ca	Mg	Na	K	H	AI	TEB	TEA	ECEC	PBS (%)	ESP (%)
							cmol/kg										
Bali A	6.7	0.053	1.29	2.22	0.12	9.22	2.85	2.09	0.51	0.48	0.31	0.58	5.95	0.89	6.84	85.97	7.77
Gandole	6.75	0.05	1.40	2.42	0.13	8.66	2.64	1.23	0.49	0.49	0.57	0.7	4.84	1.27	6.11	75.32	8.17
Badakochi	6.63	0.055	1.41	2.44	0.12	6.83	3.29	1.4	0.58	0.65	0.55	0.56	5.92	1.11	7.03	82.36	8.33
Ganglari	6.35	0.046	1.29	2.23	0.12	8.68	3.29	1.94	0.47	0.56	0.49	0.9	6.25	1.39	7.64	82.38	6.45
Gangmata	6.6	0.05	1.24	2.27	0.12	6.83	2.75	1.55	0.48	0.59	0.46	0.72	5.36	1.18	6.54	80.44	5.80
Kaigama	6.53	1.29	1.30	2.25	0.12	6.43	4.18	2.93	0.49	0.69	8.29	0.55	1	1.55	9.84	84.18	4.99
Gangtiba	6.67	0.05	1.33	2.29	0.13	9.88	3.8	2.18	0.91	0.62	7.26	0.51	1	1.51	8.77	82.36	8.03
Maihula	6.54	0.04	1.26	2.18	0.12	9.38	4.83	2.52	0.66	0.69	8.70	0.52	0.56	1.32	9.84	88.97	6.87
Takalafiya	6.59	0.09	1.21	2.09	0.11	6.67	2.98	3.07	0.51	0.61	7.15	0.58	0.93	1.51	8.66	82.76	5.89

Source: Author Field Survey (2024)

Table 6 presents the mean chemical parameters of the soil from diverse locations, encompassing pH, available phosphorus (Av.P), electrical conductivity (EC), total exchangeable acidity (TEA), magnesium (Mg), organic carbon (Org.C), organic matter (Org.M), total nitrogen (TN), calcium (Ca), sodium (Na), hydrogen (H), aluminum (Al), total exchangeable bases (TEB), potassium (K), effective cation exchange capacity (ECEC), percent base saturation (PBS), and exchangeable sodium percentage (ESP).

The findings demonstrate that pH values vary from 6.35 to 6.75 across various sites. Soil pH profoundly influences nutrient availability, microbial activity, and overall soil health. The measured pH levels are within the ideal range for the majority of crops, indicating that soil acidity or alkalinity is not a major concern in these regions. The organic carbon percentage ranges from 1.21% to 1.41%, whereas the organic matter content ranges from 2.09% to 2.44%. Organic carbon and organic matter are essential for soil fertility, structure, and moisture retention. The observed moderate levels signify a beneficial quantity of soil organic matter, which promotes crop development and improves soil health. Total nitrogen (TN) ranges from 0.11% to 0.13%. Nitrogen is essential for plant growth and often serves as a limiting element in agricultural yield. The measured nitrogen levels are comparatively low, suggesting a potential requirement for nitrogen fertilization to enhance crop output and soil fertility. Available Phosphorus (Av.P) varies from 4.84 mg/kg to 9.88 mg/kg. Phosphorus is essential for root development, blooming, and fruiting in plants. The measured levels fall below permissible limits for the majority of crops, indicating sufficient phosphorus availability for plant development. The Exchangeable Sodium Percentage (ESP) varies between 4.99% and 8.33%. ESP quantifies soil sodicity, influencing soil structure and water infiltration. The detected levels are comparatively modest, signifying a little danger of soil sodicity and related issues such as soil crusting or diminished water infiltration.

The findings indicate that the soil in these areas typically possesses advantageous chemical characteristics for agriculture. Nonetheless, careful nitrogen management and the preservation of organic matter levels may be essential to maintain long-term soil fertility and productivity. Furthermore, regular soil testing and monitoring can enhance nutrient management strategies customized to particular crop needs and local soil conditions.

The Spatial Variation in Soil Suitability for Maize Production

AHP Results

Table 7: Aggregation of individual judgments

Criteria	1	2	3	4	5	6	7	8	9	Priority	Rank
Slope	1	3.00	0.13	0.17	3.00	3.00	3.00	3.00	2.00	8.2%	3
Elevation	0.33	1	0.13	0.20	1.00	1.00	1.00	1.00	1.00	3.5%	6
Soil Type	8.00	8.00	1	8.00	8.00	8.00	8.00	8.00	8.00	47.0%	1
Soil Depth	6.00	5.00	0.13	1	7.00	7.00	7.00	7.00	7.00	22.6%	2
pH	0.33	1.00	0.13	0.14	1	2.00	2.00	2.00	2.00	4.8%	5
Organic Carbon	0.33	1.00	0.13	0.14	0.50	1	3.00	3.00	3.00	5.0%	4
Nitrogen	0.33	1.00	0.13	0.14	0.50	0.33	1	2.00	2.00	3.4%	7
Mean Rainfall	0.33	1.00	0.13	0.14	0.50	0.33	0.50	1	2.00	2.9%	8
LST	0.50	1.00	0.13	0.14	0.50	0.33	0.50	0.50	1	2.7%	9

Consistency Ratio CR: 8.8%

Source: Researcher's Computation (2024)

Table 7 delineates the criteria, their priority levels, and rankings, presumably within a decision-making or evaluation framework. The "Consistency Ratio (CR)" at the bottom signifies a relation to a decision-making methodology like the Analytic Hierarchy Process.

The Criteria column delineates the many criteria under consideration for evaluation or decision-making, emphasizing the distinct aspects that require assessment. There are nine criteria being evaluated in this instance.

The Priority column indicates the importance attributed to each criterion in the decision-making process. The percentages represent the significance of each criterion in the comprehensive evaluation. "Soil Type" possesses the highest importance at 47.0%, whereas "LST" has the lowest priority at 2.7%.

The Rank column indicates the prioritized sequence of criteria, with higher-priority items located towards the top, reflecting their increased significance in the decision-making process.

The Consistency Ratio (CR) assesses the reliability of the pairwise comparisons employed to determine the priority of the criteria. In decision-making methodologies such as the Analytic Hierarchy Process (AHP), preserving consistency is essential to guarantee the reliability of the process and to eliminate conflicts or errors. A low CR signifies strong consistency, while a high CR implies possible inconsistencies.

The following is an overview of the prioritization of criteria according to their designated priority and rankings:

Soil type is the paramount criterion, assigned the highest priority (47.0%) and placed first.

Soil depth is the second most significant factor, accounting for 22.6%, and is rated second.

Slope is the third most significant factor, accounting for 8.2%, and is rated third.

Organic Carbon and pH hold modest significance, with priorities of 5.0% and 4.8%, respectively, ranking 4th and 5th.

Elevation, Nitrogen, Mean Rainfall, and LST are deemed less significant in this decision-making process, with priorities varying from 2.7% to 3.5%.

The Consistency Ratio of 8.8% indicates potential inconsistency in the pairwise comparisons conducted during prioritization, necessitating evaluation and rectification to enhance the reliability of the decision-making process.

This table offers a systematic method for assessing and prioritizing decision-making factors, with "Soil Type" identified as the most critical component in this context. The designated priorities and rankings indicate the comparative significance of these criteria in the decision-making process.

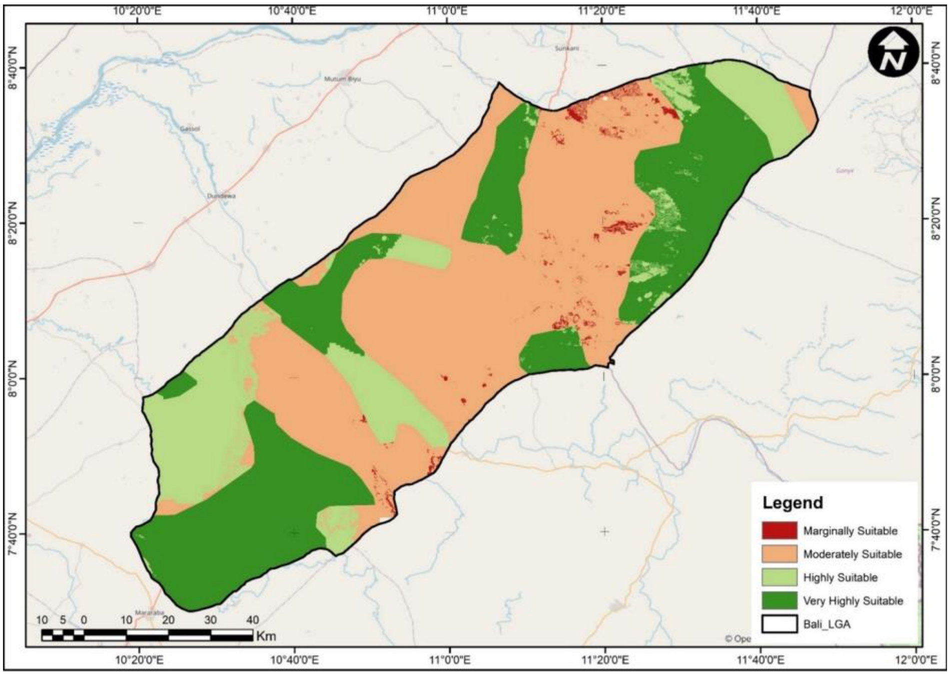

Figure 10: Maize farming suitability map (Source: Authors Fieldwork, 2023)

Table 8: Suitability Classification

Suitability Class	Area (Hectare)	Percentage
Marginally Suitable	8363.52	0.92
Moderately Suitable	439483.23	48.33
Highly Suitable	162002.7	17.81
Very Highly Suitable	299560.68	32.94
Total	**909410.13**	**100.00**

The Extent of Land Suitable for Maize Production in Bali LGA

The data outlines the extent of land suitable for maize production in Bali Local Government Area (LGA), categorized into different suitability classes, along with the area in hectares and the percentage of land in each class. Let's explore the suitability of land for maize cultivation in Bali LGA based on this information (Figure 10 and Table 8).

Marginally Suitable (0.92%): This represents the smallest segment, with 8,363.52 hectares of land classified as marginally suitable for maize production. This classification indicates that the land may need additional inputs or improved management practices to enhance maize yields. It's crucial to identify the specific challenges and constraints in this category to increase productivity.

Moderately Suitable (48.33%): The majority of land in Bali LGA falls into this category, covering 439,483.23 hectares. While this land is relatively suitable for maize cultivation, there is still potential for improvement in soil quality and management practices to optimize yields.

Highly Suitable (17.81%): A significant portion of the land, totaling 162,002.7 hectares, falls into the highly suitable category. Maize cultivation in this area is likely to face fewer challenges, allowing farmers to focus on efficient farming practices to maximize the benefits of this suitability.

Very Highly Suitable (32.94%): This class includes a substantial area of 299,560.68 hectares, where maize production is expected to be particularly productive. This land presents excellent opportunities for achieving high maize yields.

The analysis indicates that a considerable portion of land in Bali LGA is conducive to maize production, with a combined total of 50.75% classified as highly or very highly suitable. However, there are still areas categorized as marginally and moderately suitable, which may require additional effort and resources to reach optimal maize production levels. Agricultural planning and investment in the region should take these suitability classes into account to enhance maize production and ensure food security.

Discussion of Findings

The elevation in Bali LGA varies from 112 meters to 1,558 meters above sea level, resulting in a varied landscape. Lowland regions provide potential for accessible agriculture, whereas elevated areas may pose obstacles for specific farming methods. Slope study reveals that the topography ranges from 0 to 73.5 degrees; moderate slopes are advantageous for agriculture as they enhance water drainage and mitigate soil erosion. Recognizing steeper gradients is crucial for executing efficient land management measures to avert soil degradation.

Land surface temperature, an essential environmental variable, was measured throughout Bali LGA, with values spanning from 26.5 to 38.7 degrees Celsius. Temperature changes can influence crop growth, as elevated temperatures may affect water availability and evaporation rates. This observation corresponds with Shehu (2018), who indicated that the majority of savannah soils are typically linked to well-drained upper to intermediate slopes, favored for agricultural cultivation, in contrast to wetland soils that are frequently waterlogged and less fertile.

The primary soil types of Bali LGA consist of Ferric Acrisol, Ferric Luvisols, Fluvisols, Lithosols, and Numic Nitosols. Each variety possesses distinct properties that influence its appropriateness for different crops. Comprehending different soil types is essential for efficient land use planning and determining appropriate regions for maize agriculture. Soil property study indicates discrepancies in essential agricultural parameters, with nitrogen concentrations varying from 0 to 0.2%, organic carbon levels from 0 to 1.7%, and soil depth ranging from 15 to 42 cm. These factors substantially affect land suitability for maize cultivation.

The variety of soil types and characteristics underscores the need for a customized strategy in land use planning and sustainable farming methods within Bali LGA. Soil Type is recognized as the paramount criterion, with the highest priority (47.0%) and rated first. Soil depth is the second most significant criterion at 22.6%, while slope ranks third with a priority of 8.2%. Organic Carbon and pH hold moderate significance, positioned fourth and fifth with priorities of 5.0% and 4.8%, respectively. Elevation, Nitrogen, Mean Rainfall, and Land

Surface Temperature are deemed less significant, with priorities varying from 2.7% to 3.5%. The Consistency Ratio of 8.8% indicates a degree of inconsistency in the pairwise comparisons employed in the prioritization process, highlighting the necessity for evaluation to improve the dependability of decision-making. This discovery corresponds with Shehu (2018), who documented discrepancies in soil depth, drainage, and texture among several places.

This structured review offers a definitive framework for prioritizing variables in decision-making, with Soil Type identified as the most critical component in this context. The designated priority and rankings indicate the comparative significance of these factors.

The physicochemical properties of the soil were examined at multiple sampling locations across Bali LGA. The principal textural classes found are Sandy Clay Loam, Sandy Loam, and Loamy Sand, reflecting differences in soil composition. Sandy Clay Loam consists of a harmonious blend of sand, silt, and clay, providing excellent fertility and drainage capabilities. Sandy loam possesses a greater sand composition, facilitating drainage while yielding moderate fertility. Loamy sand possesses a significant sand composition, facilitating swift drainage; yet, it may require enhanced nutrient management.

Bulk density estimates differ by region, spanning from 1.36 to 1.65 g/cm³, whereas particle density ranges from 2.40 to 2.90 g/cm³. Lower bulk density and higher particle density are typically favored for agricultural soils, as reduced bulk density enhances root development and improves water infiltration. Elevated particle density signifies well-structured soil exhibiting favorable aggregation. The results align with Lawal et al. (2012), who indicated that soils in the lower Oshin River floodplains exhibited intermediate bulk density favorable for agricultural development, alongside medium to high levels of organic carbon, accessible phosphorus, and cation exchange capacity (CEC). All soil units were categorized as reasonably suitable (S2) for maize cultivation. Correspondingly, research by Shobayo (2010) and Sharu et al. (2013) demonstrated that savannah soils generally display elevated bulk density at the surface, which diminishes in the subsoils and then increases in the deepest layers, with high bulk density ascribed to compaction resulting from grazing and ploughing.

Total porosity values vary between 36.19% and 48.58%, which is essential for soil aeration and water retention. Elevated porosity values indicate enhanced aeration and water retention, promoting plant growth. This is consistent with Sharu et al. (2013), who observed comparatively low porosity in soils examined in the Dingyadi District of Sokoto.

The assessment of land suitability for maize cultivation in Bali LGA classifies land into many suitability categories, specifying the area in hectares and the percentage for each category. The findings reveal that a substantial area of land is appropriate for maize agriculture, with a total of 50.75% categorized as extremely (162,002.7 ha) or very highly suitable (299,560.68 ha). The cultivation of this land is anticipated to be fruitful, offering exceptional prospects for optimizing maize production. Nonetheless, certain regions persist in the marginally and moderately suitable classifications, necessitating further work and resources for optimal maize cultivation. This differs with Shehu (2018), who identified merely 8.91% of land as very appropriate for maize in the Basawa region of Kaduna State, with the balance categorized as moderately or marginally suitable. Adesemuyi (2014) also noted an absence of extremely suitable land for maize in Akure, identifying certain parts as moderately acceptable and others as unsuitable. Tinguely (2012) asserts that land classification as suitable or unsuitable encompasses technical elements (e.g., slope and soil fertility), environmental considerations (such as potential effects on biodiversity and aquifers), and economic aspects (including investment costs and anticipated returns).

CONCLUSION

This comprehensive investigation of agricultural land use suitability for maize production in the Bali Local Government Area (LGA) has provided significant insights into the parameters influencing maize agriculture. Through the integration of Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) approaches, we have acquired a comprehensive understanding of the physical topography and soil properties, thereby enabling informed agricultural planning. The principal findings of this study are as follows:

Diverse Landscape Dynamics: The Bali LGA exhibits a heterogeneous topography, characterized by variations in elevation, slope, and land surface temperature, which substantially affect the land's suitability for maize agriculture.

Soil Heterogeneity: The region encompasses several soil types, such as Ferric Acrisol, Ferric Luvisols, Fluvisols, Lithosols, and Numic Nitosols, resulting in a heterogeneous agricultural environment. Comprehending these soil characteristics is crucial for maximizing land utilization. Essential Soil Properties: Factors including nitrogen concentrations, organic carbon levels, soil depth, and physicochemical characteristics—such as pH, electrical conductivity, and cation exchange capacity—are vital for evaluating site suitability for maize cultivation.

AHP Priorities: The Analytical Hierarchy Process (AHP) established soil type, soil depth, and slope as the paramount criteria for assessing site suitability. This methodical technique facilitates a systematic assessment of several elements.

Suitability Classes: Approximately 50.75% of the area in Bali LGA is designated as very or very highly suitable for maize cultivation. This classification functions as a pragmatic reference for agriculturists and policymakers to enhance agricultural practices.

Sustainable Agricultural Planning: The results underscore the necessity for sustainable agricultural planning that considers both physical and edaphic elements. Implementing optimal practices and efficient agricultural management techniques can increase yield while reducing ecological consequences.

Prospective Research Avenues: Future research should investigate dynamic elements, including climate change, land use modifications, and technical innovations, that may influence the long-term viability of land for maize agriculture. Following these results, the subsequent part will delineate measures designed to enhance maize output in Bali LGA, fostering agricultural sustainability and resilience.

RECOMMENDATION

Following a comprehensive examination of agricultural land use suitability for maize production in the Bali Local Government Area (LGA), the subsequent recommendations are presented to aid agricultural stakeholders, policymakers, and farmers in optimizing productivity while maintaining sustainable land use practices:

i. Local farmers should adopt integrated land management techniques that take into account the region's varied terrain and soil types. Techniques such as contour ploughing, cover cropping, and agroforestry can mitigate soil erosion and enhance soil fertility. Furthermore, governmental bodies and commercial agronomists ought to implement soil fertility improvement initiatives, especially in regions designated as fairly suitable for maize cultivation. This may entail the application of organic amendments, the use of precision agriculture techniques, and the implementation of tailored nutrient management to rectify specific soil inadequacies.
ii. The government and pertinent NGOs should conduct training sessions and awareness campaigns for local farmers, emphasizing the determinants of land suitability and optimal techniques for sustainable maize growing. Disseminating this knowledge is

essential for enabling farmers to make educated decisions. It is crucial to advocate for governmental support and incentives for farmers practicing sustainability, including subsidies for soil testing, access to superior seed varieties, and financial aid for environmentally friendly agricultural techniques.

iii. The government should develop a mechanism to track alterations in land use patterns, soil quality, and crop performance over time. This data will facilitate the formulation of adaptive management systems that enable real-time modifications to agricultural practices in response to evolving conditions. Investing in continuous research and development activities to investigate new technologies and innovations in agriculture is essential for advancing sustainable practices. This encompasses the integration of precision agriculture technologies, climate-resilient crop types, and sustainable irrigation techniques.

iv. The partnership between local agricultural extension agencies and research institutes is crucial for equipping farmers with the most current knowledge and expertise. This collaboration guarantees that farmers may access the latest developments in agricultural research. Furthermore, fostering community engagement in decision-making processes about agricultural land utilization is essential. Involving stakeholders such as farmers, community leaders, and environmentalists in dialogues regarding sustainable practices and land management will promote a collaborative strategy. By adopting these ideas, Bali LGA can augment agricultural output, bolster environmental sustainability, and promote the overall welfare of the farming community. The successful implementation of these projects necessitates a coordinated effort by government agencies, NGOs, research institutions, and the local population.

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