ANALYSIS OF AGRICULTURAL LAND SUITABILITY USING GEOGRAPHIC INFORMATION SYSTEM (GIS) AND REMOTE SENSING IN KAMPE-OMI IRRIGATION SITE, KOGI STATE, NIGERIA

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Abstract
Land suitability measurement is essential for land managers, land users and agriculturists to identify limiting factors for any agricultural production and it also enables decision-makers to develop crop management that will increase land productivity. This paper assessed Kampe-omi irrigation scheme site and developed a map for agricultural land suitability. The study employed a GIS and remote sensing method by examining factors namely soil, climate, land use and topography of the area. Each factor was assigned a weighting factor according to the degree of importance in land suitability analysis. The land suitability map was carried out by running the standard weighted overlay of the land use, landforms and slope map using ArcGIS 10.1. Based on land use analysis, only 74.9 % of the study area is available for agricultural purposes and the digital elevation model, elevation 201-280m are highly suitable for agriculture. From the Land suitability map, four classifications were identified namely, highly suitable, suitable, slightly suitable and unsuitable. The percentage of land that is highly suitable for agricultural purposes is 20.2%, 52.4% is suitable, 18.7 is slightly suitable and 8.7% is unsuitable. Farmers should be empowered and encouraged to maximize the rich soil, water-bodies and suitable agricultural lands and there should be proper control of urbanization in the study area to maintain the agricultural suitable lands.

Keywords: Digital elevation model; Kample-omi; Land-use map, Land suitability maps; Geographic information system

Introduction

The land is the solid surface of the Earth that is not permanently covered by water. Land is one of the most important natural resources since life and developmental activities are based on it. The vast majority of human activity occurs in inland areas that support agriculture, habitat, and various natural resources. Management of these natural resources (Land) is essential for food security and stability (Sebnie *et al.*, 2020). Agricultural land is typically land devoted to agriculture, the systematic and other forms of life particularly the rearing of livestock and production of crops to produce food for humans (Adejumobi *et al.,* 2014). Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The assessment of land suitability of specific areas shows how well the qualities of land will match the requirements of a particular form of land use and to know the capacity of the land to sustain specific land uses such as cropping, irrigated agriculture and forestry (Albaji *et al.*, 2013).

Agricultural land suitability entails the process of evaluating the performance of a unit of land concerning sustainable crop production (Rabia, 2012). Proper and adequate mapping of agricultural land suitability is needed to manage both the present and future land use, sustainable use of land resources, increasing production and planning sustainable agriculture (Li *et al*., 2017; Taghizadeh-Mehrjardi *et al*., 2020.). Land suitability involves the integration of information from various sources. There are many criteria, both qualitative and quantitative, upon which land suitability depends. Land suitability assessment is, therefore, a multiple criteria decision-making (MCDM) process. The attributes of land suitability criteria are usually derived from both spatial and non-spatial information under diverse conditions. Some of the factors affecting land availability for agriculture in Nigeria are land tenure system, population pressure, the size of useful land, climatic factors, soil factors, cultivation practices, topography, government policy and environmental pollution. Everest *et al*. (2020) determine agricultural land suitability with a multiple-criteria decision using two cartographic materials; a soil map from where land use capability classes (LUCC) were obtained and a topographical map from where elevation, slope and aspect were generated.

The LUCC considers land characteristics and sub-parameters such as drainage properties, soil, climate and topography. Besides, it classifies and evaluates the suitability of lands for all types of cultivated plants. For classification, there are two orders and eight classes; the two orders are described as suitable for cultivation order and not suitable for cultivation order while the eight classes range from I to VIII in LUCC. The first four classes are capable of producing adapted plants if it is well managed and the last four classes are not suitable for agricultural practices. The slope is also an important factor in land suitability assessment; slope degree has a direct effect on the susceptibility of soil to erosion, soil tillage, use of agricultural machines, soil depth irrigation and plant adaptation. The steepness, length and sharpness of the slope directly affect the soil and water loss in an area. The elevation is also a fundamental element for agricultural land suitability.

A lot of models have been used for Agricultural land suitability assessment; Geographic Information System allows a record of a base map with a geographical referencing system such as longitude and latitude and then to add additional layers of other information. Remote sensing is the art and science of Earth observation of material objects, surface or phenomenon to acquire information (radiometric and spectral) from an overhead perspective, that is, satellites or aerial platforms without actually being in physical contact with it (Lillelsand, 2004). The term embraces several observation of sensor techniques ranging from; photography, multi-spectral, thermal and hyperspectral sensing. It is based on the principle that terrestrial objects reflect or emit radiation in different wavelengths and intensities depending on specific conditions. The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitat for animal and plant species (Store & Kangas, 2001), geological favorability and suitability of land for agricultural activities (Kalogirou, 2002).

The continued dependence on rainfall in agriculture has proved incapable of sustaining the population increase (Opeyemi *et al*., 2015) and the creation of the reservoir using the dam construction has disrupted the equilibrium state of the ecosystem, the quantity and quality of the available food items, inter-and intra-specific competition, the limnological conditions, living space and the flora and fauna composition Kampe-omi irrigation scheme site (Araoye & Owolabi, 2001). Hence, this study examined the Agricultural Land Suitability of Kampe-Omi irrigation scheme site, using Geographic Information System (GIS) and Remote Sensing and the objectives are to generate the land use map, DEM and slope maps and the land suitability map of the study area

Materials and Methods

Description of the Study Area

Kampe-Omi Dam Irrigation Scheme is located in Yagba Local Government Area of Kogi State, Nigeria (Figure 1). It is about 146 km from Ilorin the capital of Kwara State. It lies between Longitude 6° 37^1 and 6° 43^1 E of the Greenwich and Latitude 8° 34^1 and 8° 38'N of the equator. Kampe-Omi Dam Irrigation Scheme (KODIS) was first conceived in 1979. Then the construction work started in 1983. It involves the construction of 42 meters dam with a reservoir capacity of about 250 million cubic meters. The irrigation network consists of 39km length of the main canal and about 300km length of feeder canals and complimentary drainage lines (Opeyemi *et al.,* 2015). Phase 1 of the now completed comprises the main dam, spillway, headwork, and 16 km out of the 39 km length of the main canal commanding 2000 hectares of irrigable land. This phase allows for agricultural production of maize, vegetables, sorghum, and rice all year round (Adeniran *et al*., 2010).

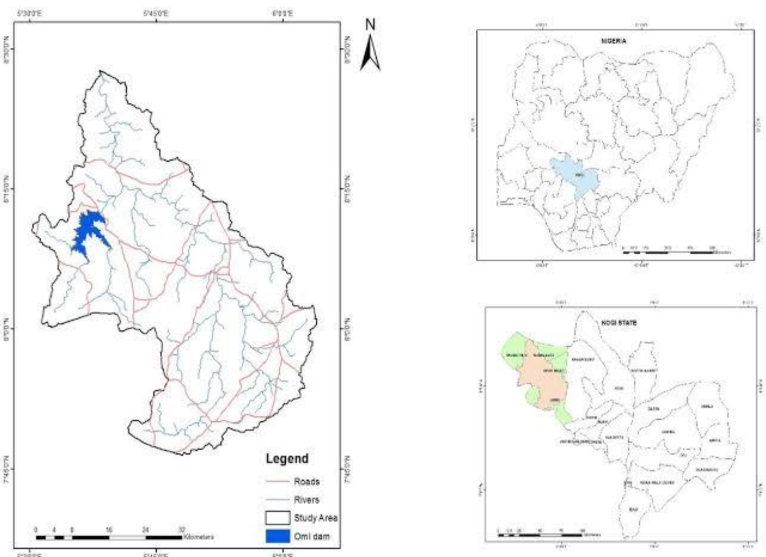

Figure 1: Map of Nigeria, showing Kogi- State, Yagba local Government and Kampe-Omi dam

Data Acquisition

The data used for this study include; Soil Data, Climatic Data, Land Data and Topographic data. Ten years of climatic data (2009-2014) of rainfall and temperature of the study area were acquired from the Nigerian Meteorological Agency in Ilorin, Kwara State. The map of the study area was obtained from the River Basin Development Authority; the map was taken in the year 2016. The Land satellite Imagery of the Kampe-Omi Irrigation Scheme was acquired through remote sensing using Google Earth remote sensing technology at high resolutions. They were obtained in the year 2016.

Method of Data Analysis

The land-use suitability of Kampe-Omi Irrigation Scheme was done using Remote Sensing and ArcGIS. Remote Sensing was used to retrieving satellite imagery of Kampe-Omi Irrigation Scheme and then processed by ArcGIS to produce the land-use map. Goggle earth was employed as the Remote sensing software to retrieve the satellite imagery of the study area. These satellite imageries were obtained at a magnified resolution to ensure accurate details.

The satellite imageries were imported into ArcGIS environment through the Add Data tool. The acquired data were geo-referenced, within the ArcGIS environments. The extraction of the land use data from the inputs involved rectifying, digitizing, laying-out and exporting.

Extraction of Digital Elevation Model (DEM)

Remote Sensing technology was adopted to retrieve the elevations of the selected stations within the Kampe-Omi Irrigation Scheme. The DEM was generated from these elevation data by interpolating tool of the ArcGIS. The elevation data are first attributed to a point shape-file. The point features were then interpolated using the Natural Neighbor method to produce a spatial variation of elevation within the catchment.

Mean Rainfall

From the mean rainfall and temperature gradient lines (Figures 2a and 2b) respectively, rainfall and temperature were predicted. Rainfall and temperature linear equations are presented in Equations 1 and 2 respectively

$R_n = -2.62n + 160.78$ (1)

where R is Rainfall in mm…….. n = Year - 2014

$T_n = 0.333n + 24.367$ (2)

where T is Temperature in ^{0}C…..n = Year – 2014

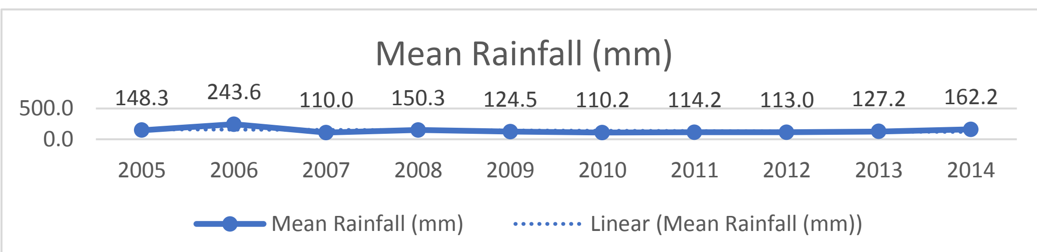

Figure 2a: Mean Rainfall Graph

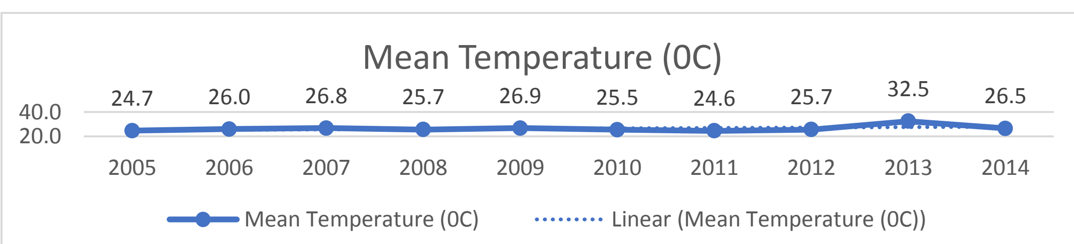

Figure 3b: Mean Temperature Graph

Figure 2: Mean rainfall graph and mean temperature graph

Preparation of Land Suitability Map

The Land suitability map of Kampe-Omi was based on two parameters. Lands that are available for agricultural purpose and lands that are viable for agricultural purpose. Land that is available for agricultural purpose is dependent on the Land-use pattern of Kampe-Omi while the soil, landform and slope maps determine the land that is viable for agricultural purpose. The Land suitability map of Kampe-Omi is, therefore, a combined function of land use, slope and landform classification maps. The ArcGIS software was used to analyze and classify Kampe-Omi land based on its suitability for agricultural purpose. The flow diagram showing the process of the land suitability map is shown in Figure 3

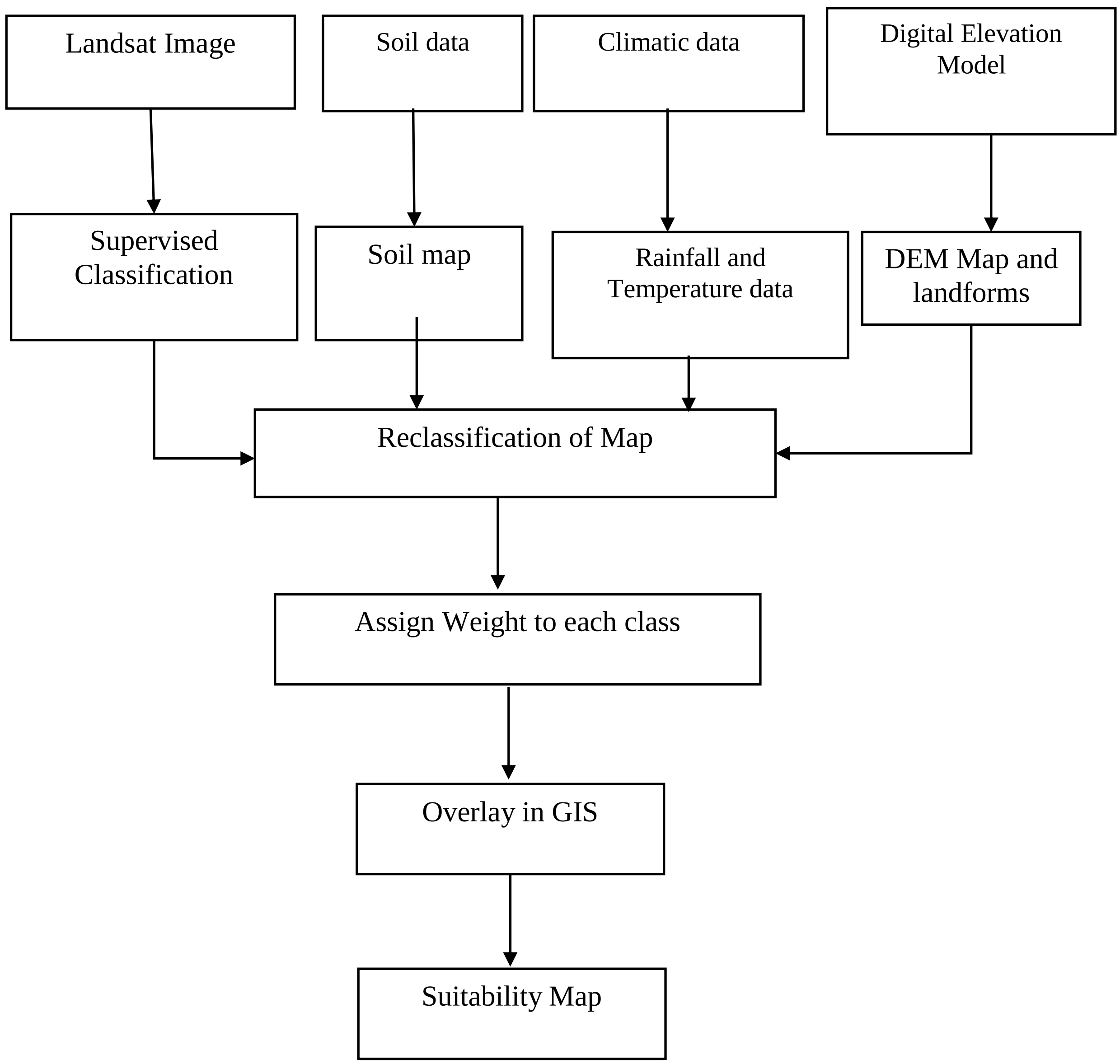

Figure 3: Flow-Chat showing Agricultural land suitability mapping process

Results and Discussion
Soil and Weather Data

Kampe-Omi Irrigation Scheme primarily composes of sandy loam soil. The sand, loam ratio is 3:2. The presence of sand in the soil makes the soil to be loosed enough for irrigation purpose. The rich loam supply nutrients into the soil to be used by plants and crops for their healthy growth. The mean rainfall ranges from 110.0-243.6 mm. The year 2007 have the least mean rainfall value while the year 2006 has the highest mean rainfall value.
All the years record zero rainfall in December. Rainfall amount was found to be a peak in June, July, August and September within the years. November to February have rainfall variations below 150mm. These months should be well catered for by ensuring an adequate and constant irrigation system to promote all year farming system. There is a slight variation in temperature over the years. The mean temperature is a peak in the year 2013 and it is least in 2005.

Land-use Map
The total area covered by the assessed land is 581.79 km^2. The land use map (Figure 4) has four classifications; the vegetal areas, the rocky/paved areas, built-up areas and water-bodies respectively. The vegetal areas (Figure 4) cover the majority of the assessed area. This is followed by water-bodies, built-up areas and paved areas. Settlements such as Tiv Village, Ogbe, Isanlu and Lapa are exclusively vegetal. Some settlements (Okoto, Eri, Ejigba, Odosin, Omi and Foot Bridge) have a mixture of two to four land-use classes but Egbe settlement is an exclusive built-up area. The paved/rocky areas include Idofin, Igbaruku, Pategi-Egbe Road, Egbe-Lokoja Road, Ogbe-Kwara Road and Isanlu-Egbe Road.

The water-bodies include Omi Reservoir, River Eri, River Ogbe, River Oga, Tiv River, River Ara and River Oyi. The percentage of area covered (Table 1) shows that the vegetal cover is just 55.6% of the total assessed area while the water-bodies, built-up areas, rocky/paved areas cover 19.3%, 17.7% 7.4% respectively. This is an indication that Kampe –Omi has a higher percentage of land available for agricultural purposes. The water bodies are suitable for irrigation farming and the vegetal covers are available for crop production.

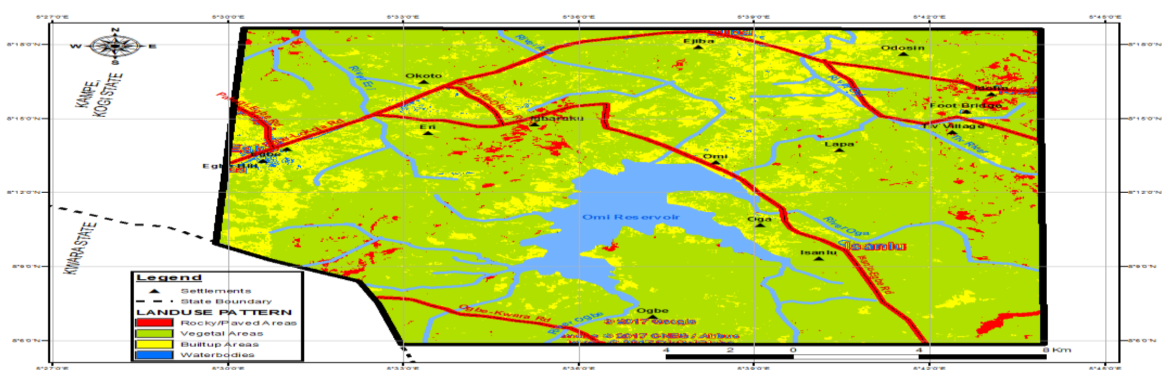

Figure 4: Kampe-Omi Land-use Classification Map

Table 1: Kampe-Omi Land-use Area Covered

S/N	Land-use Pattern	Total Area Covered (km^2)	Total Area Covered (%)	Remarks
1	Rock/Paved Areas	43.05	7.4	The land is not available for agricultural purpose
2	Vegetal Areas	323.48	55.6	The land is available for

				agricultural purpose
3	Built-up Areas	102.98	17.7	The land is not available for agricultural purpose
4	Water-bodies	112.29	19.3	The land is suitable and available for irrigation farming

Digital Elevation Map

The Digital Elevation Model (Figure 5a) shows that the Elevations are within the range from 201-540 m. Settlements in the southern part of the map are of higher elevations while those on the northern part are of lower elevations. The elevation variation reduces in a north-eastern direction. Settlements (Table 2) such as Omi, Lapa, Tiv Village, Idofin and Odosin have elevations ranging from 201-240m, Ejiba and Omi Reservoir have elevation range of 241-280 m, Ogbe, Oga, Isanlu and Okoto have elevations range of 281-320 m while Egbe and Eri have elevation range of 321-400 m. Settlements such as Egbe Hill and Igbaruku are highlands with a peak elevation of 440 m and 540 m respectively.

Figure 5b shows the classification of the DEM of Kampe-Omi into different landforms. Places with an elevation range of 201-280 m are of lowland landform (Figure 5b) covering an area of 239.70 km^2; 281- 320m are of normal landform covering an area of 218.17 km^2 while places with an elevation greater than 320 are of highland landform covering an area of 123.92 km^2. Lowlands are categorically more suitable for the agricultural purpose as compare to normal lands or highland. This is because crops planted on low lands have faster access to nutrients such as water in the soil while highlands are usually rocky making them poorly suitable for agricultural purpose.

The slope map (Figure 5c) shows that most of the areas have a gentle slope followed by flatlands. The flatland settlements include; Odosin, Omi Reservoir and Foot Bridge, the gentle slope are Egbe, Okoto, Idofin, Ejiba, Lapa, Isanlu and Eri while the steep slope is Igbaruku and Ogbe. The most suitable area for agricultural purpose is Flatlands and gentle slope.

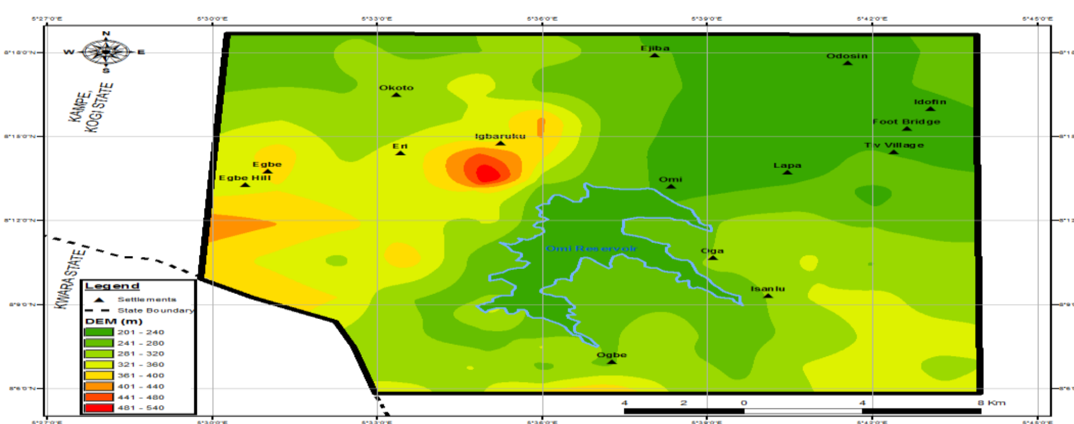

Figure 5a: Kampe-Omi Digital Elevation Model (DEM)

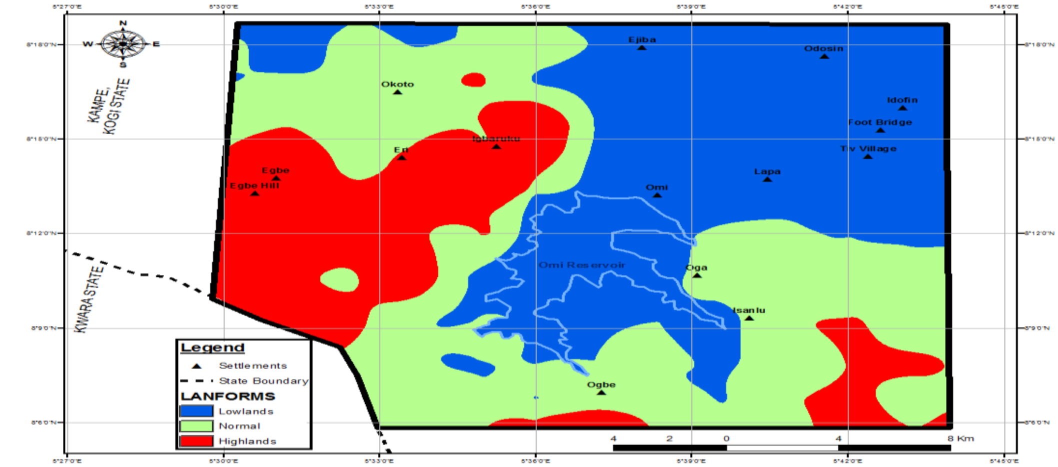

Figure 5b: Kampe-Omi Landforms Map

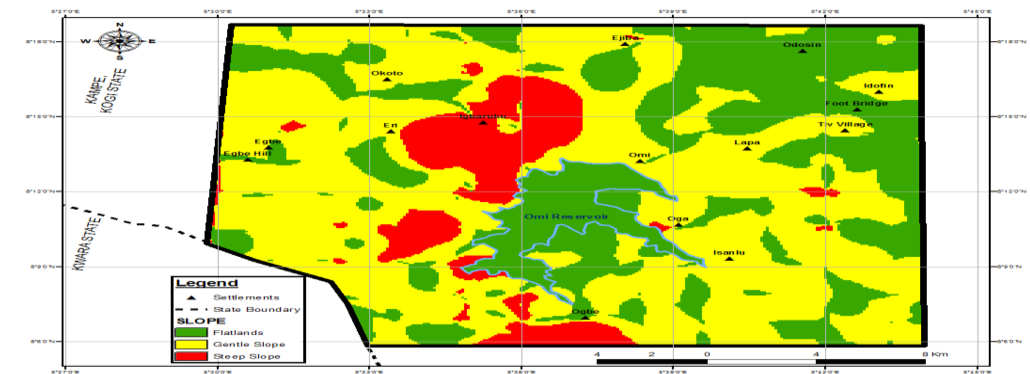

Figure 5c: Kampe-Omi Slope Map

Figure 5: The DEM map, landforms map and slope map

Table 2: Kampe-Omi Settlements Elevation Range

S/N	Elevation Range (m)	Colour Code	Settlements with Elevation Range	Remarks
1	201-240	Deep Green	Omi, Lapa, Tiv Village, Idofin, Odosin	Areas are highly suitable for agriculture
2	241-280	Green	Ejiba, Omi Reservoir	Areas are highly suitable for agriculture
3	281-320	Light Green	Ogbe, Oga, Isanlu, Okoto	Areas are suitable for agriculture
4	321-360	Lemon	Eri	The area is poorly suitable for agriculture
5	361-400	Yellow	Egbe	The area is poorly suitable for agriculture
6	401-440	Orange	Egbe Hill	The area is poorly suitable for agriculture
7	441-540	Red	Igabaruku	The area is poorly suitable for agriculture

Land Suitability Map

The Agricultural Land Suitability map (Figure 6) of Kanpe-Omi based on the weighted overlay of the land-use, landforms and slope maps shows four classes of land suitability; unsuitable, slightly suitable, suitable and highly suitable. From Figure 6, Egbe Hil and Igbaruku are found to be unsuitable for agricultural purposes because their land-use pattern, landforms, and slope show a rocky area with mountainous/highland landforms and steep slope. Settlements such as Ogbe and Eri were found to be slightly unsuitable for agricultural purpose. This is perhaps because Ogbe is a slopy area and Eri is a highland. Agricultural Suitable settlements include Okoto, Ejiba, Isanlu, Oga, Lapa, Omi and Tiv Village. These settlements are gently sloped, vegetal and of the mixed land-use pattern. The highly suitable areas for agricultural purposes are Odosin and Foot Bridge; they are flatlands and lowlands. The percentages of suitability (Table 3) show that 20.2 % of the total area is highly suitable, 52.4 % is suitable, 18.7% is slightly suitable and 8.7% is unsuitable for agricultural purposes.

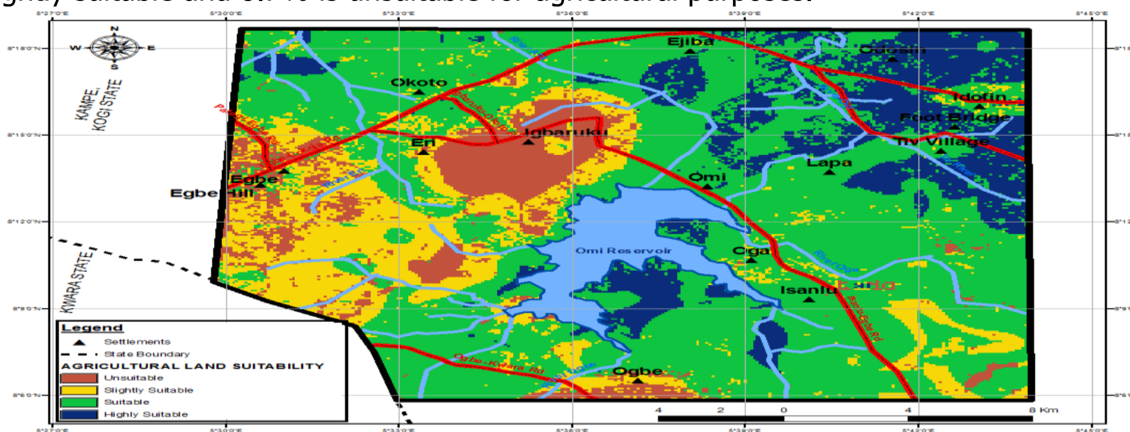

Fig. 6: Kampe-Omi Agricultural Land Suitability Classification Map

Table 3: Kampe-Omi Suitability Classification Area Covered

S/N	Suitability Class	Colour Code	Area Covered (km^2)	Settlements Affected	Remarks
1	Unsuitable	Brown	50.62	Egbe Hill, Igbaruku	8.7% of the region is unsuitable
2	Slightly Suitable	Yellow	108.79	Ogbe, Eri	18.7% of the region is slightly unsuitable
3	Suitable	Green	304.86	Okoto, Ejiba, Isanlu, Oga, Lapa, Omi, Tiv Village	52.4% of the region is suitable for agricultural purpose
4	Highly Suitable	Blue	117.52	Odosin, Foot Bridge	20.2% of the region is highly suitable for farming

Conclusion

Kampe-Omi has rich sandy loam soil which is viable for agricultural purpose. The soil composition is made up of 60% sand and 40% loam. Irrigation farming in Kampe-Omi is indispensable to ensure sufficient water supply during the dry season. The land-use pattern map of Kampe-Omi has vegetal areas and water-bodies covering 55.6% and 19.3% of the total accessed area. Kampe-Omi thereby has a higher percentage of land that is available for agricultural purpose. The landform of Kampe-Omi is made up of 41.2% lowlands, 37.5% normal lands and 21.3% highlands. Settlements such as Odosin and Omi reservoir are flatlands which are suitable for agricultural purpose. The percentage of area suitable for agricultural purpose is 52.4% with an extra 20.2% that is highly suitable.

It recommended that a total of 72.6% of land suitable for agriculture should be adequately utilized for agricultural purpose. Slightly suitable agricultural lands should also be improved to increase the available lands suitable for farming. There should be deliberate control of urbanization in Kampe-Omi to maintain the agricultural suitable lands. Farmers should be empowered and encouraged to maximize the rich soil, water-bodies and suitable agricultural lands and there should be proper control of urbanization in the study area to maintain the agricultural suitable lands.

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