Web-Based Geospatial Information System to Access Land Suitability for Arable Crop Farming In Ekiti State, Nigeria

Israel TAIWO, Lawrence ADEWOLE, Mofoluso FAGBEJA & Ifeoluwa BALOGUN, Nigeria

Keywords: Land Managment; Remote Sensing; Sustainable Agriculture; Non-Speculative Land Use, Land Suitability

SUMMARY

This work identifies suitable locations for growing arable crops such as cassava, maize and yam to enhance crop yield in Ekiti state. It describes the use of geoinformation and web technology as efficient and effective tools for managing land suitability information in meeting the goals of food security while ensuring sustainable development. Land suitability evaluation for cassava maize and yam was carried out to evaluate the viability and sustainability of the area to grow arable crops. The potentials of the web were leveraged to aid easy access to crop-land suitability information for agriculture extension workers, farmers, and the general public. Accessibility to road, access to water supply, climate, land use/land cover, soil slope, soil available water capacity, pH, soil texture, and topsoil organic carbon content, were used in a combined fuzzy membership, weighted overlay, and fuzzy overlay operation in conformity with FAO guidelines to determine the suitability of the area for the crops. Climate data was acquired from the WorldClim database, land use/land cover information was derived from a classification process of Landsat 8 imagery, soil data were obtained from the Harmonized World Soil Database and topographic data were derived from the Shuttle Radar Topographic Mission (SRTM) satellite imagery. The SCP plugin version 5.3.8 of QGIS 2.14.17 was used in the land use classification process, and ArcGIS 10.2 was utilized in the suitability determination processes. Information on land suitability was made available on the web for easy accessibility to users from a spatially enabled QGIS cloud webserver The research reveals that despite the unfavourable soil slope condition, more than 64% of Ekiti state land is highly suitable for common arable crops, and less than 10% of Ekiti state land is permanently not suitable for agriculture. The work emphasizes that to reduce environmental degradation, negative effects of climate change and the cost incurred by farmers in obtaining land suitability information, the role of spatial data, non-speculative methods of identifying land-use suitability and web technology cannot be overemphasized.

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1. INTRODUCTION

Cultivating crops on viable land is the hallmark of arable farming (Feng et al., 2017). The capability and suitability of land for particular purposes determine the viability of the land for that purpose. Land as a non-increasing factor of production that houses an increasing population whose well-being largely depends on food needs to be managed, such that its resources are conserved and the food requirements of man and animals are met. (Taiwo, 2015). If food security will be ensured, agricultural lands must be well administered to aid farming activities, such that access to sufficient, safe and nutritious food must be achieved. Until all people have physical and economic access to adequate, safe and nutritive food to meet dietary needs and food preferences for an active and healthy life at all times, the goal of food security remains unattained. In a world of varying economic class, achieving the above goal of easy physical and economic access to food will require that more agriculturally viable lands are identified, and preserved (Corsi, Marchisio, & Orsi, 2017; Obeng-Odoom, 2017; Sadler, 2016; Wittman, Dennis, & Pritchard, 2017). Matching the characteristics of land with that of crops produces the suitability of the land for the tested crops (Chiranjit & Kishore, 2016). Land suitability recommends the cultivation or non-cultivation of crops under certain circumstances. Land suitability is a product of land evaluation, whose objectives are to reduce the effects of human on the ecosystem and to identify appropriate land use (AbdelRahman, Natarajan, & Hegde, 2016). Assessing crop biophysical suitability to agro-environmental conditions is valuable to crop production (Confalonieri et al., 2013). Production goals and environmental sustainability are key goals of performing land suitability assessment. Depending on the type of suitability to be determined, several factors are usually combined to determine the suitability of land for different purposes for either a quantitative or qualitative evaluation of land suitability (Baja, Chapman, & Dragovich, 2007). Land suitability maps show suitability degrees, an information whose significance will be relevant only when in the hands of appropriate users. Agricultural land suitability and capability information need to get to farmers, agriculture extension workers, and prospective farmers.

A typical web-based system is a system that can be accessed by users within the range of the internet network. The web enables easy, scalable and cost-effective sharing of geospatial information, such that; useful information that would otherwise be stored away from its respective users is easily accessible, and more available to a larger audience than information not on the web. The internet offers Web-based information systems a robust platform for data and information processing, data storage and consequently, a performance that supersedes its non-web based desktop and mobile counterpart. Accessibility, scalability and interoperability are key comparative advantages of Web-based systems (Elsheikh et al., 2013; Oliveira, Painho, Santos, Sian, & Barriguinha, 2014; Yalew, van Griensven, & van der Zaag, 2016). Data used by various users can be utilized by several other users, whereby reducing redundancies and promoting reusability. These are pros of web-based systems among others yet to be extensively leveraged, especially for agriculture. Farmers and agriculture extension workers need land suitability information to guide, and improve their operations, prospective farmers require such information as a guide to their decision of where and what is appropriate to plant and the general public requires such information to know of where they need to preserve for agricultural purposes.

The need for optimum land use cannot be overemphasized, owing to the ever-increasing population of man, and the static or deterioration of quality land. Scientific land evaluation will reduce unsuitable cultivation practices that cause accelerated soil erosion, soil degradation, and ecosystem disruption among others. Likewise, the scientific land evaluation will lead to the realization of food security objectives with lesser efforts (Boje, Ru, Senzige, & Skowronek, 1998; Elsheikh et al., 2013; Zabel, Putzenlechner, & Mauser, 2014) Ekiti state is noted with Cassava, Maize and Yam cultivation (Olorunfemi & Fasinmirin, 2017), However, there is no evidence of comprehensive scientific land suitability determination in the state. It is observed that aside the few suitability assessments carried out at global scales, which obviously represents Ekiti at a very coarse scale, land suitability assessment information are not readily available for the state. Several authors have reported the products of their works in journals, conferences, and technical reports etc., meanwhile, the availability and easy accessibility of such information to farmers and prospective users of the information for implementation is an important aspect that has gained very little attention (Yalew et al., 2016). Premised on the need for food security, and non-speculative management of land resources, this research delves the capability of the web in making land suitability information available to relevant stakeholders, as a panacea to aid optimum production and sustainable cultivation of some arable crops in Ekiti state. This work is aimed at designing and developing a web-based Geospatial Information System to access land suitability information for arable crop farming in Ekiti State, Nigeria. The specific objectives of the study include to acquire suitable variables that affect arable crop farming, and to develop a web-based system that can convey information on Land Suitability for arable crop farming to farmers. The proposed system is to provide a web-based interface where information on land suitability for Cassava, Maize and Yam could be accessed by farmers, Agriculture extension workers and other prospective users of the system. The system is expected to interest prospective users, such that more interested users will venture into agriculture, owing to the amount of quality information readily available to guide their practice.

2.1 Land Suitability

Land Suitability is a product of land evaluation. Land evaluation is *the process of estimating the potential of land for alternative kinds of use* (AbdelRahman et al., 2016). It is often done to measure the capacity and extensibility of land, for particular purposes. Land evaluation is carried out by comparing the requirements of land use with the resources land offers. It often involves the acquisition, storage, processing, analysis and interpretation of huge data that often cut across several fields of endeavour. Land suitability classes reflect the degree of suitability of land for a particular purpose within a defined range. It is a further classification of land suitability order. Land suitability orders are further classified by FAO (2007) into the following 5 classes:

1. Highly Suitable S1: Land classed as S1 are firstly ensured to possess sustainable usage, without any significant disruption to the ecosystem. They are identified with no or minor limitations, that does not significantly decrease efficiency or produce, and which do not require the increase of input above a reasonable level.
2. Moderately Suitable S2: Land having such limitations, which could be referred to as moderate, owing to the attractiveness of the productivity potentially derivable from the application of the land for the said use. Such limitations make the use of land for that purpose lesser in efficiency than being highly suitable.
3. Marginally Suitable S3: Land which has severe limitations for sustained application of particular use, therefore, reduces productivity or benefits, or which increase inputs, that this limitation makes it applicability only marginally suitable for the said purpose.
4. Currently Not Suitable: These are areas of land having limitations that may be controllable in time, but the correction does not exist at an acceptable cost currently. Successful sustained use of the land is precluded by the severity of the limitations.
5. Permanently Not Suitable: Land whose successful sustained use is precluded by the limitations to the usage.

Land suitability analysis for agriculture is carried out to determine how proper or appropriate land is for a particular agricultural practice. Aside from determining the current potential of land in producing sustainable benefits, land suitability for agriculture helps in deciding future agricultural cropping pattern (Corsi et al., 2017; FAO, 2013; Zabel et al., 2014). Matching land characteristics with crop requirements gives suitability for the analysed crop.
Remote Sensing (RS) and Geographic Information Systems (GIS) are tools that have proven results in determining current and future land suitability for crops. AbdelRahman et al., (2016) describes a way of using data from remote sensing in a GIS to determine land-use suitability for agricultural planning. GIS was used in matching suitability for main crops, based on requirements of the crops, and land characteristics. GIS employs statistical and geostatistical techniques in determining land suitability. Various methods exist in determining land suitability. Except for variants of the below under listed, the list below shows major techniques used for determining land suitability for particular purposes:

i. Analytical Hierarchy Process (AHP).
ii. Multi-Criteria Decision Analysis (MCDA)
iii. Simple Limitation Method (SLM) and Parametric Method – Storie and Square root Methods
iv. Genetic Algorithm (GM)
v. Fuzzy logic

AHP was identified by Zhang et al., (2015) as an effective and better method in determining weights of multiple factors in systematic ways. MCDA is as well found efficient when integrated with a GIS for making decisions requiring multiple factors (Yalew et al., 2016). Weighted overlay was utilized with the Simple Limitation Approach (SLA) by Esa, (2014) to determine land suitability for sorghum and maize. The Square root and Storie methods were as well used in a GIS model by El Baroudy, (2016) to map and evaluate land suitability.
Fuzzy logic is contrasted to traditional logic. Between two extremes lies an infinite range of values, depending on the unit of measurement. States such as True/False, Hot/Cold, Long/Short are discrete values used in representing the state of a system in traditional logic. When the

system extends into warm, lightly hot, or lightly cold, then the fuzzy approach is being utilized. Agricultural land suitability requires making decisions with factors whose detailed description are not entirely definite. These factors are most times quite complex such that it becomes impossible to represent the entire range explicitly with discrete values. The functionality and accurateness of such systems are usually limited when discrete values are adopted in representing such systems. In contrast, fuzzy logic models the range of data and transforms them into a continuous variable that better accounts for more variability between the inputs, hence, representing the input better. Regardless of whatever values of the input, Fuzzy logic transforms numerical data with various magnitudes into grades of membership functions(Zhang et al., 2015), by calculating a suitability index with values ranging from 0 to 1, where 0 is same as not suitable and 1 same as most suitable. Below is a representation of the difference between traditional and fuzzy logic approaches.

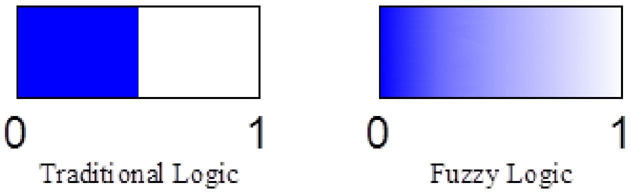

Figure 1: Difference between Traditional and Fuzzy Logic

The work of Chiranjit & Swain (2016) titled *"Land suitability evaluation criteria for agricultural crop selection: A review"* reveals that fuzzy logic is most efficient for crop-land suitability analysis. The advantage of Fuzzy logic in determining agricultural land suitability is premised on its ability to compensate for the uncertainty in the input data and expert knowledge on which suitability is based. (Prakash, 2003)

2.2 CROP GROWTH REQUIREMENTS

The genomic potential of plants and it's above and below-ground environmental conditions are factors that affect the growth and hence yield of plants (Iles, 2001). These factors majorly affect the quantity and quality of crop growth, as well as its growing seasons. Such variables include climatic factors, soil physical and chemical properties, accessibility to water, roads, land use/land cover and topographic factors, etc. Some of the factors can be represented using membership functions according to Zabel et al., (2014) which includes; 'more is better', 'less is better' and 'optimum' (Gaussian).

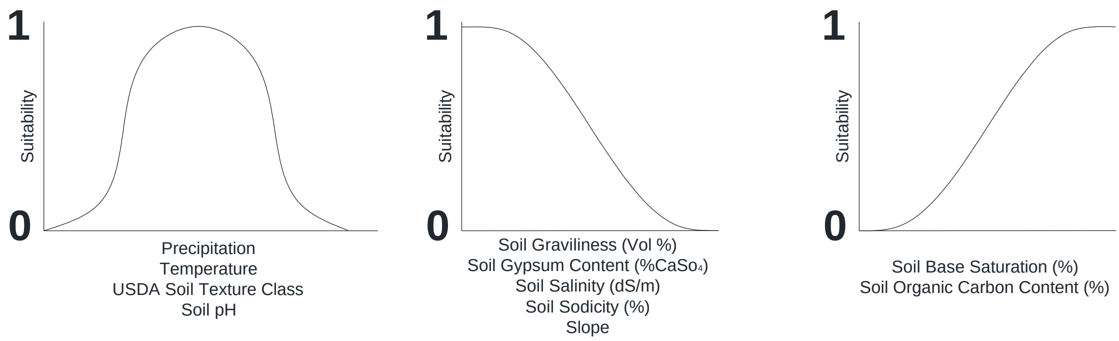

Figure 2: Membership Functions for Soil, Climate and Topographic Conditions. Source: (Zabel et al., 2014)

2.2.1 Cassava

Cassava is a root crop grown in the tropics, providing food for an estimated population of 800million people in the world. It has the resilience to unpredictable climate and the ability to grow on poor soils. Cassava grows as much as 90cm deep into the soil for tuber formation, hence, the need for soils with deeper depths for cassava plantation.

Table 1: Cassava Crop Growth Requirements

	Seesahai et al., (2008)	FAO, (2013)
Temperature	25 to 32^{o}C	> 32^{o}C
Rainfall	Moderate and non-erratic 400mm-1700mm	800-1700mm
Soil depth		100cm,
Texture	Sandy clay loams	
pH	5.5 - 6.5	> 4.2
Drainage	Well-drained	Well-drained

2.2.2 Maize

Maize is the most common cereal crop grown in Ekiti state Nigeria. Although suitability information for maize in Ekiti state is not readily available for the study area, the following were extracted from existing related works.

Table 2: Maize Crop Growth Requirements

	Singh (1983)	Girl et al. (1994)	Esa (2014)
Temperature	21-32^{o}C		15-32^{o}C
Rainfall	900mm		300-1600mm
Soil depth	> 25	100 cm	
Texture	Sandy loam to silty loam	Sandy clay loam to clay loam	loamy, silty loam, clay loam, silty clay, clay
pH	5.5-7.5		5.2 -7.8
Drainage	Well-drained	Good	Moderate

2.2.3 Yam

Yam is best cultivated at an average temperature of 27^{o}C and can be cultivated at 1000-1200mm rainfall (Andres, AdeOluwa, & Bhullar, 2017). The Nitrogen content of the soil used in cultivating yam is very important, it is affected by the following factors; soil texture, soil temperature, soil moisture, soil organic matter, and plant residues (Jemo, Jayeoba, Alabi, & Montes, 2014). Staking and weed control is a very important necessity in yam plantation. It has been established that the more the exposure of yam leaves to sunlight, the better the yield (Andres et al., 2017).

Table 3: Yam Crop Growth Requirements

	(Andres et al., 2017)	(Jemo et al., 2014)
Temperature	27^{o}C	27^{o}C (8^{o}C range)
Rainfall	1000-1200mm	1200-1800mm
Soil depth	-	> 30
Texture	-	Sandy clay loam to clay loam
pH	-	4.5 – 7.5
Drainage	-	Good

3 METHODOLOGY

3.1 Description of the Study Area

Ekiti state is located between latitudes 7^o 16'N and 8^o 7'N and longitudes 4^o 51'E and 5^o 48'E. It is bounded by Kwara state in the north, Ondo State in the south and part of the south-east, Kogi state in the east and Osun state in the west. With an approximate area of 5873 square kilometres(Ekiti, 2001; Taiwo, Babalola, & Aduloju, 2016), Ekiti accounts for only 0.57% of the total landmass of Nigeria, which makes it bigger than Lagos, Anambra and Abia states. Deriving its name from the Yoruba word for hills i.e. "Okiti", Ekiti is an upland zone, rising over 250m above the mean sea level, characterized by a rhythmic undulating terrain, with a variation of about 474m, The lowest point is found towards the northeastern part of the state, around Iye – Ekiti, in the Ikole local government area, with an elevation of 291m of ellipsoidal height, while its highest point of 765m ellipsoidal height is found around Ogotun – Ekiti, of the Ekiti southwest local government area.

Ekiti state climate is tropical with two distinct seasons (rainy season between April and October and dry season between November and March). The mean air temperature ranges between 21°C and 28°C with high humidity (Olorunfemi & Fasinmirin, 2017). The southwesterly wind and the northeast trade winds blow in the rainy and dry (Harmattan) seasons respectively. The southern part of Ekiti state is dominated by Tropical forests, while guinea savannah occupies the northern peripheries. Ekiti landscape consists of ancient plains broken by steep-sided outcropping dome rocks. These rocks occur singularly or in groups or ridges and the most notable of these are to be found in Efon, Ikere and Ekiti West Local Government Areas (Ekiti, 2001). The State lies on an area underlain by metamorphic rock and is potentially rich in mineral deposits, which include kaolin, columbite, channockete, iron ore, barite, aquamine, gemstone, phosphate, limestone, gold among others, largely deposited in different towns and villages within the State (Olorunfemi & Fasinmirin, 2017). The dominant soils in Ekiti state are the Ferric Luvisols, Eutric Nitosols, and Luvic Arenosols (Nachtergaele et al., 2009). The State consists of guinea forest vegetation with its attendant climate, flora and fauna.

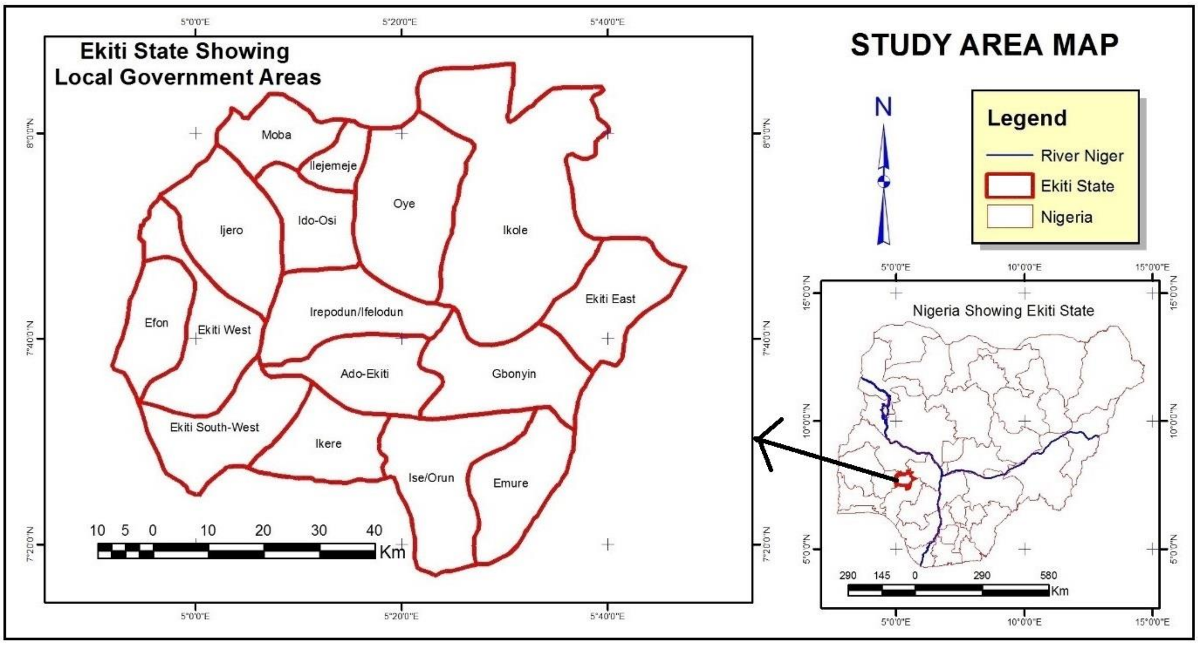

Figure 3: Study Area map

3.2 Land Suitability Determinant Factors

Combinations of soil physical, chemical and topographical properties, as well as climatic factors, affect crop growth and land suitability evaluation (Bandyopadhyay, Jaiswal, Hegde, & Jayaraman, 2009; Nouri, Mason, & Moradi, 2017; Rhebergen et al., 2016; Rossiter, 2007; Taiwo et al., 2017). Using Remote Sensing and GIS techniques, data about the climate, topography, land use/land cover and soil necessary to determine the suitability of the area for agriculture were obtained. Table 4 shows the data sources and vendors used in this research and the figure below shows the variables used in the land suitability determination process.

Table 4: Data Sources

	Data	Name	Resolution	Source
1	Land Use & Land Cover	Landsat 8	30m	https://earthexplorer.usgs.gov/
2	Topography (Slope)	SRTM	30m	https://earthexplorer.usgs.gov/
3	Climate (Precipitation and Temperature)	WorldClim	1 km^2	http://www.worldclim.org/bioclim
4	Soil	HWSD	30 arc seconds	Harmonized World Soil Database
5	Accessibility (Rivers)	SRTM	30m	https://earthexplorer.usgs.gov/
6.	Accessibility (Roads)	OSM		Open Street Maps

Figure 3 shows the variables used in the land suitability determination process.

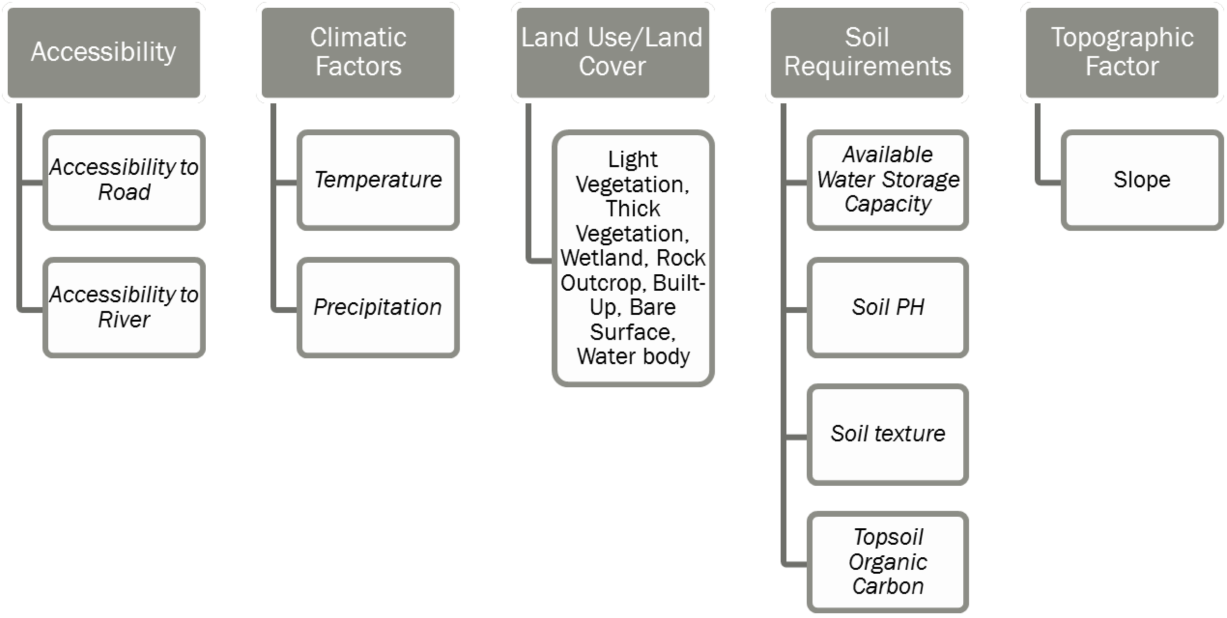

Figure 3: Land Suitability Determination Factors

3.3 Land Suitability Determination

Land suitability determination requires a multi-disciplinary approach (Rossiter, 2007). Cropland suitability is a function of several factors, depending on the scale of the determination (Taiwo et al., 2017), and the required kind of use (Rossiter, 2007).

The Semi-Automatic Classification Plugin of QGIS was used in the satellite image acquisition and Digital Image Processing. Radiometric and geometric corrections were performed on the imageries. Image enhancement, colour composites, and supervised classification were as well performed on the SCP plugin of the QGIS software. Climate data were acquired from the WorldClim database, Soil data was obtained from the HWSD, Boundary and road data were acquired from OSM databases, while topography and river data were acquired from SRTM imageries. The Semi-Automatic Classification Plugin of QGIS was used in the satellite image processing. Fuzzy Membership, Weighted Overlay and Fuzzy Overlay techniques were used on ArcGIS 10.2 in determining the suitability level of areas for particular crops. The raster calculator tool of ArcGIS was used in multiplying each raster by 100, to aid easy classification with the reclassify tool, which eventually produced a suitability level information ranging from 1 to 5. The resulting information was symbolized from a scale of red to green equivalent to permanently not suitable to Highly suitable. The values utilised in the combined fuzzy membership, weighted overlay, and fuzzy overlay operation to determine suitability for Cassava, Maize and Yam will be attached in the appendices section. Figure 4 is a schematic of the suitability determination processing phase as extracted from ArcGIS Model Builder:

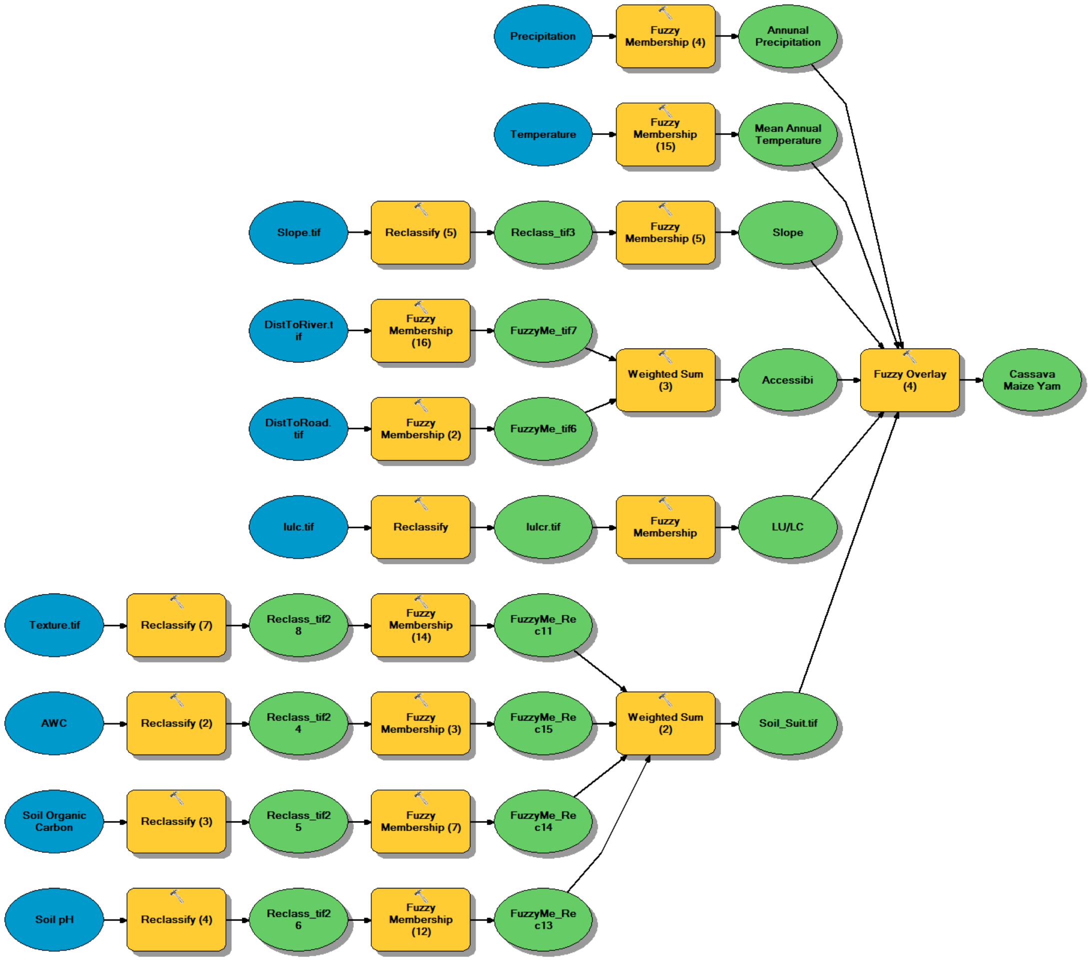

Figure 4: Land Suitability Determination Process

The land suitability factors used in the determination of the suitability levels as shown in the results obtained are attached in appendix 5, 6 and 7 sections of the supporting document.

3.4 Website Setup

A survey was carried out to identify the modalities for setting up the web-based system. Stratified random sampling was utilized in the sampling process. A questionnaire was designed and served to two categories of users, which includes; the prospective users of the system (Farmers, prospective farmers), and the developers (Program developers). A sample size of 300 was adopted for the survey. The questionnaire was made available to offline and online respondents for 128 days. 43 opinions of developers were gathered and about 267 opinions of practising and prospective arable crop farmers were sampled. The questionnaire used in conducting the survey is attached in appendix 1 of the supporting document. Links to the questionnaire, responses and different analysis carried out on the questionnaire are as well in the Appendix 2 section of the supporting document attached. To aid quick and easy accessibility of the suitability information to the public, the information was hosted on a free QGIS cloud user account. The public users of the system are expected to have the following access rights to the system:

1. View Land suitability information on the web
2. Print land suitability information

Further functionalities identified for further research include:

1. Identify places available for farming practices on the web
2. Inquire history of land use on the web
3. Allow interaction with Agriculture Extension workers on the web
4. Allow interaction with other Clients on the web

4 RESULTS & DISCUSSIONS

4.1 Results of Variables

4.1.1 Accessibility

The accessibility criterion produced shows how accessible the area is for easy transportation of raw materials and farm products, and for irrigated agriculture. The accessibility criterion was generated from two criteria of distance to road and distance to river.

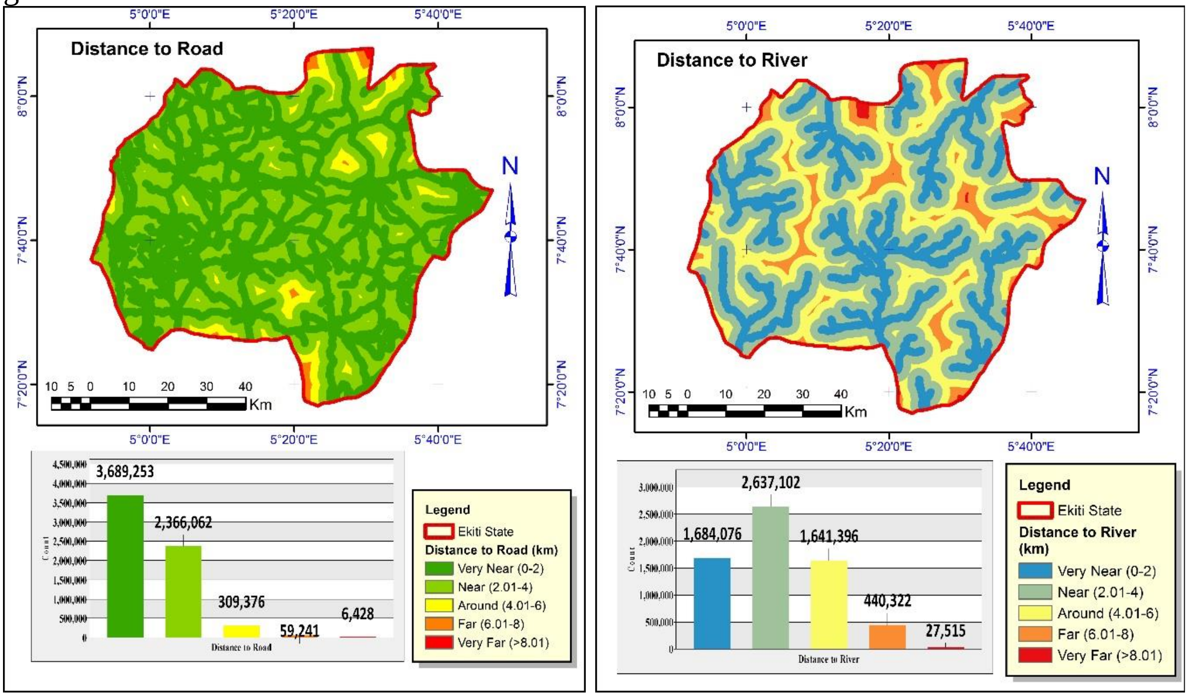

Figure 5: Access to Road and River

The result obtained shows that 57% of the area lies very close to a road. 94% is near to a road by at least 4 kilometres, except for areas around Uro-Elemo (South) and Omu-Ijelu (North-east) communities, which are not within 6km roads. 26% falls within the 2km radius of a water body, while 67% of the area falls within the 4km radius of a water body. The nearness of the area to water tributaries indicates a high possibility of engaging in irrigated farming within parts of the area. Areas identified as 2km radius to water tributaries are identical with areas classified as wetland in the land use/land cover classification.

4.1.2 Climatic Factors

The suitability of land for agriculture is greatly affected by changing patterns of temperature and precipitation among others (Zabel et al., 2014). Annual mean temperature and annual precipitation were considered for the purpose of this work. As extracted from the Worldclim database annual mean temperature varies between 23.5 and 26.1°C within Ekiti state. The central part of the state is observed to have lower records of temperature, while the southern and northern parts experience higher temperature values than other parts of the state. Annual precipitation varies between 1211mm and 1445mm in the state. The little variability observed in the data can be attributed majorly to the small size of Ekiti state. Maximum rainfall is experienced at the southern part of the state, while it reduces towards the north-eastern side of the area. The variability in rainfall aligns with the change in the amount of rainfall observed from the tropical rainforest-savanna region.

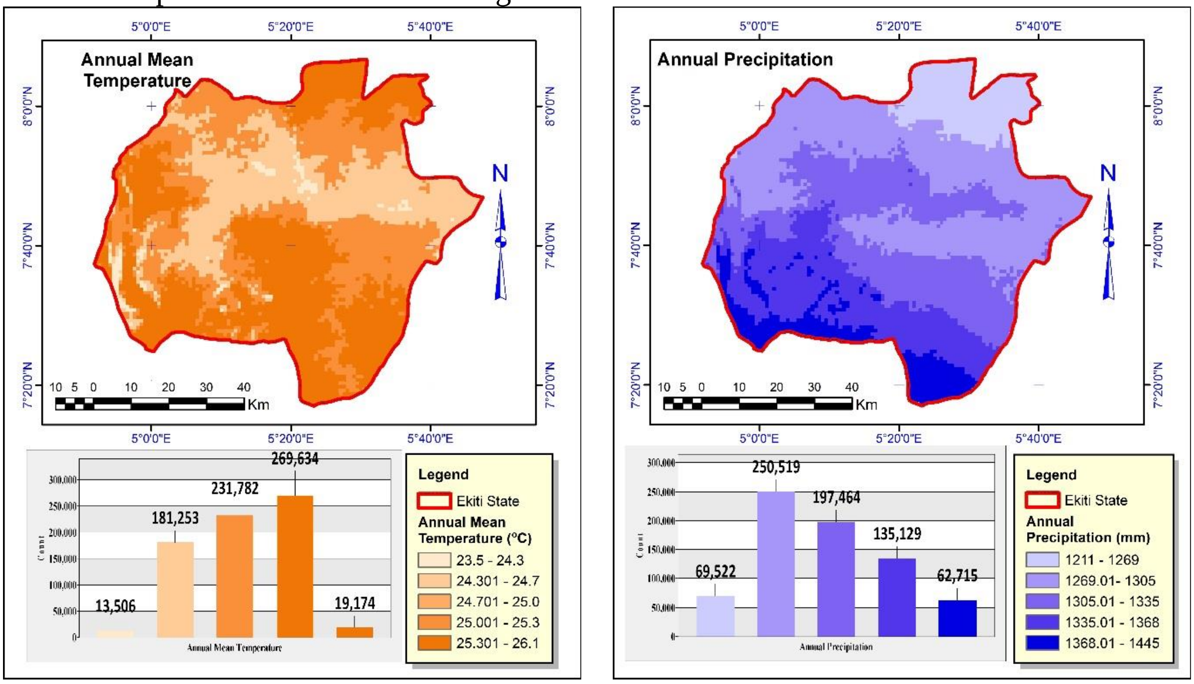

Figure 6: Climatic Factors: Annual Mean Temperature & Precipitation Distribution

4.1.3 Soil Characteristics

The Ekiti state soil data extracted from the HWSD consists of 6 classes, with spatial variations of agronomic significance in all six classes. The four fields used for the purpose of this work includes Soil average water capacity, pH, texture and Topsoil Organic Carbon. The types of soil and percentage constituent of each are tabulated in Table 5:

Table 5: Soil and percentage constituent in Ekiti State (Nachtergaele et al., 2009)

Soil Class	Percentage / Soil Type				
1277	34%	33%	33%		
	Lithosols	Dystric Regosols	Dystric Nitosols		
1475	40%	20%	20%	10%	10%
	Ferric Luvisols	Lithosols	Ferric Acrisols	Plinthic Luvisols	Eutric Gleysols
1484	60%	30%	10%		
	Ferric Luvisols	Eutric Nitosols	Luvic Arenosols		
1485	50%	30%	10%	10%	
	Ferric Luvisols	Eutric Nitosols	Luvic Arenosols	Lithosols	
1490	60%	30%	10%		
	Ferric Luvisols	Lithosols	Luvic Arenosols		
1588	60%	30%	10%		
	Eutric Nitrosols	Eutric Cambisols	Lithosols		

Most locations in the area are dominated by 50mm/m available water capacity. The core west is dominated by 15mm/m AWC, while some places in the north are dominated by 150mm/m AWC. The more the AWC, the better the resilience of the area against flood and drought, and the higher the potential for agriculture. Soil pH reflects the acidity/alkalinity of the soil, which is an important requirement for crop growth. Extremely acidic soils are characterized by an inability to drain water, extremely alkaline is badly structured and easily dispersed. The soil pH values observed within the area range between 6 and 7.5, which falls within the range of soils categorized as best for agricultural purposes, because of their rich carbon and nutritive contents (Nachtergaele et al., 2009). The soil texture of Ekiti state is dominated by the FAO's medium classification of soil texture, which comprises of *sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams with less than 35 % clay and less than 65 % sand*; *the sand fraction may be as high as 82% if a minimum of 18% of clay* (Nachtergaele et al., 2009). Other classes present are the fine and coarse-textured soils. Coarse soils are*; sands, loamy sands and sandy loams with less than 18% clay and more than 65% sand*, while fine-textured soils are *clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35% clay*. Topsoil organic content for Ekiti state as at the time of measurement ranges between 0.74 and 1.74. Generally, fertile soils with a good structure are identified with moderate to high amounts of organic carbon. Soils above >1.5, 1.0-1.49, 0.5-0.99 are classified as highly suitable, suitable and marginally suitable for agriculture respectively.

4.1.4 Land Use Land Cover

Substantial constraints are given to rural and urban planning as a result of the distribution of land-use types (Lingjun & Zong, 2008). Although Ekiti is heavily characterized by an irregular terrain due to hills and mountains, it is observed that the area is characterized by about 72.47% vegetation, part of which about 40% is classed as light vegetation, comprising of (arable lands and farmlands). Overall classification accuracy of 96.56% and Kappa hat classification of 0.9482 was achieved during the classification process. The result of the accuracy assessment carried out on the Land Use Land Cover classification is attached at appendix 3 section of the supporting document.

Table 6: Land Use Classes in Ekiti State (2017)

Land Use	Area Covered	Percentage Coverage
Light Vegetation	25606.35	39.81%
Thick Vegetation	21011.13	32.66%
Wetland	9430.92	14.66%
Rock Outcrop	4445.91	6.91%
Built-Up	2595.24	4.03%
Bare Surface	1138.86	1.77%
Water body	96.21	0.15%

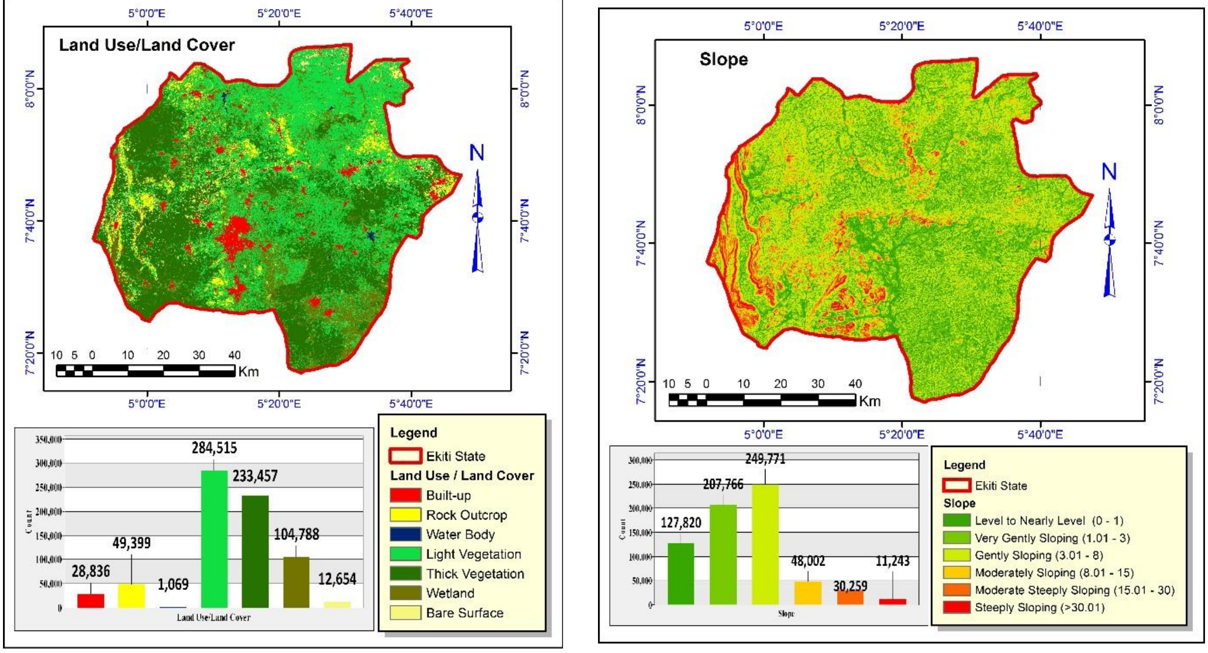

Figure 7: land Use Land Cover and Slope Map

4.1.5 Topography

Slope classes of soil in Ekiti state are distributed as; steeply sloping (>30%), moderate steeply sloping (15–30%), moderately sloping (8–15%) which covers the south-western part of the state, because of its characteristic hilly, mountainous and undulating terrain. Level to nearly level (0–1%), very gently sloping (1–3%) and gently sloping (3–8%), which has a high potential for agriculture covers the rest of the area as shown in slope map shown above.

4.2 Land Suitability for Arable Crops

Five suitability classes ranging from 'Highly Suitable' to 'Permanently Not-Suitable' were obtained from the land suitability assessment conducted for the selected crops. The results produced is expected to be a cost-effective guide for farmers in the state in making decisions concerning where to plant any of the tested arable crops, and which of the arable crops tested is best planted at a particular location. The work is expected to significantly reduce the cost incurred by farmers in obtaining land suitability information, as well as reduce speculative methods of choosing land for certain farming activities in the state.

Results obtained show that the western and southwestern parts of the state such as Efon, Ijero, Ekiti South West, Ekiti West and Ikere local government areas have lower suitability for the crops tested, especially for cassava and yam. As observed from the slope map produced, these locations are more steeply sloped than other areas in the study area. From the local evidence gathered, these places are more known for the production of cash crops like banana, plantain, cocoa, palm trees etc. than arable crops.

Figure 8, Figure 9 and Figure 10 show the suitability maps obtained from matching cassava, maize and yam crop growth requirements with land qualities obtained in Ekiti State. Results of the suitability assessments for cassava, maize, and yam are presented in the following subsections. The combined suitability assessment conducted shows that more than 65% of the area is highly suitable for most crops. Areas shown as not suitable are basically areas identified with thick vegetation which aids the sequestration of carbon in the atmosphere to limit the effects of environmental pollution on climate change. Water bodies and rock-outcrop as well are inclusive of areas identified as not suitable. Steeply sloping areas as well are part of places identified as permanently not suitable. Almost all the wetland and light vegetation areas of Ekiti State are highly suitable for arable crop farming.

4.2.1 Land Suitability for Cassava

65.03% of the area is highly suitable for cassava, 4.82% is moderately suitable, 18.51% is marginally suitable, 1.95% is currently not suitable, while 2.63% is permanently not suitable for cassava aside the 0.15% and 6.91% that has been classified as waterbody and rock outcrop respectively. Figure 8 shows the land suitability for cassava in Ekiti State.

4.2.2 Land Suitability for Maize

64.64% of the area is highly suitable for maize, 24.48% is moderately suitable, 1.1% is marginally suitable, 1% is currently not suitable, while 1.72% is permanently not suitable for maize. Figure 9 shows the land suitability for maize in Ekiti state

4.2.3 Land Suitability for Yam

70.63% of the area is highly suitable for yam, 4.67% is moderately suitable, 13.9% is marginally suitable, 1.78% is currently not suitable, while 1.97% is permanently not suitable for yam.

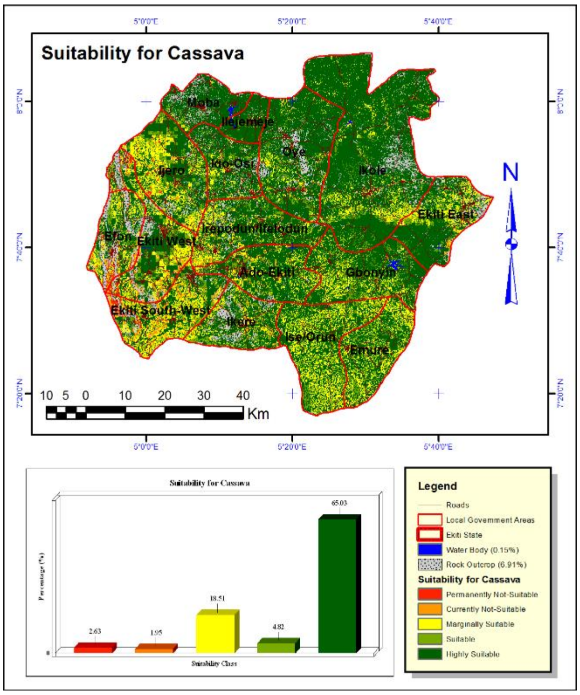

Figure 8: Land Suitability for Cassava

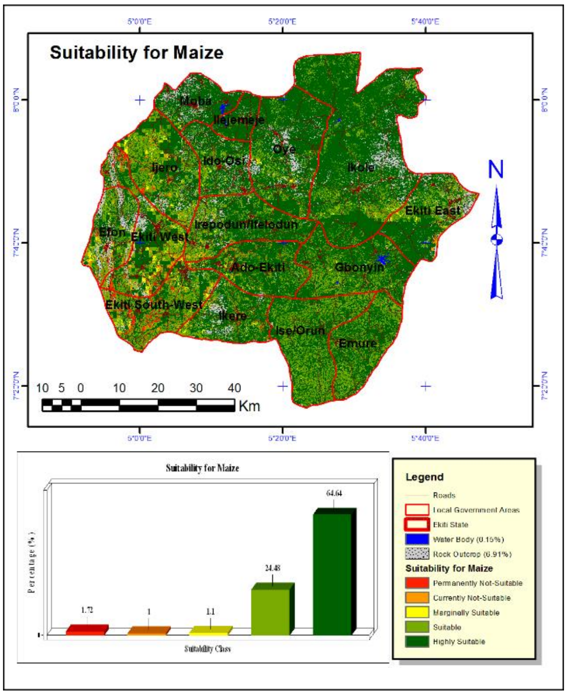

Figure 9: Land Suitability for Maize

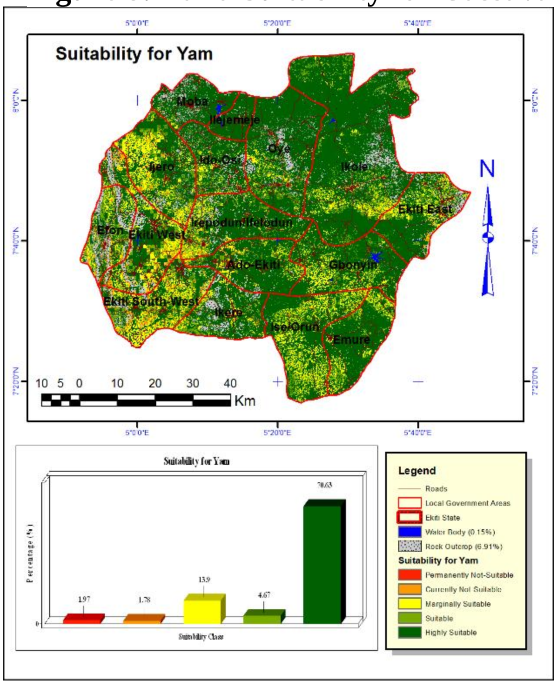

Figure 10: Land Suitability for Yam

4.3 Land Suitability User Interface

Certain inferences were made from the pre-analysis carried out to determine best practices and modus operandi for the proposed system. Implementing the system was made according to the observed situations, except for some situations where important constraints necessitated modifications. The spatial layers of the prototype system were overlaid and symbolized in the Quantum Geographic Information System (QGIS) software. QGIS Cloud plugin was used in creating the web map. The link to the web map is https://qgiscloud.com/IsraelTAIWO/QCloud_Suitability/ . As shown in Figure 11, the interface produced shows the slope map of the area, the three suitability maps produced for cassava, maize and yam, and other layers delineating the study area. The maps are overlaid on each other, and it is expected that the system will be an effective tool in determining which of the crops produced is most suitable at a particular location of interest.

The interface is capable of presenting information concerning land suitability for cassava, maize, and yam to the public. Additional functionalities of the system are the possibility to measure distances, calculate areas and determine bearings on the web map. Furthermore, the web page integrates the Open street map layer as a base map, where communities and roads can be identified. Different levels of transparency could as well be set for the various uploaded layers.

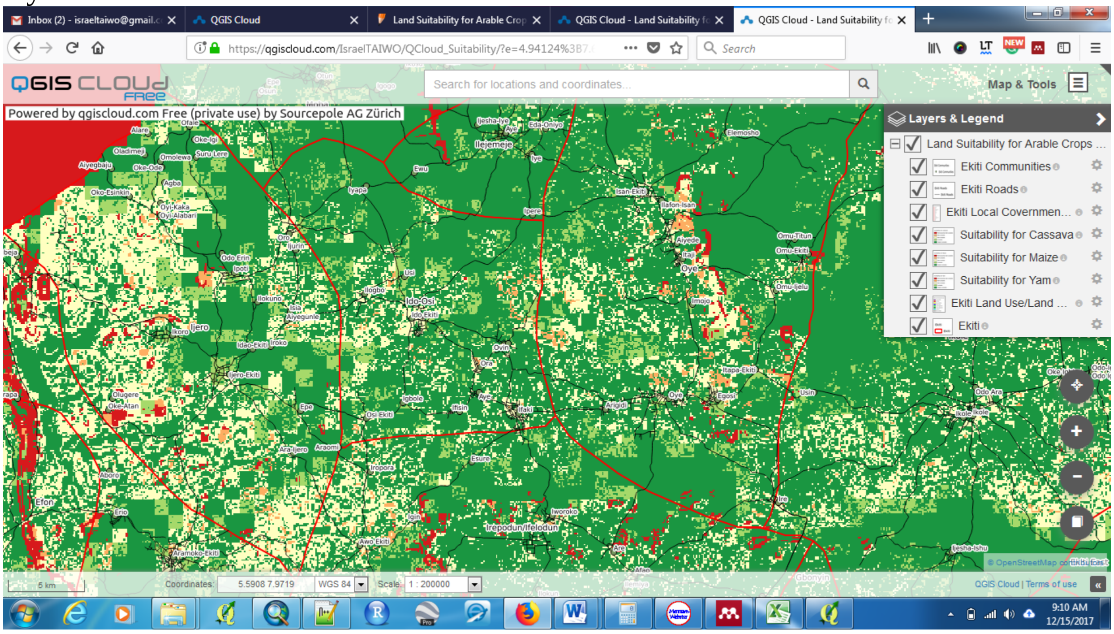

Figure 11: Land Suitability for Arable Crops in Ekiti State Web-Interface

4.4 Validation/Verification of Results

Cassava, maize and yam are arable crops grown in several places across Ekiti state (Olorunfemi & Fasinmirin, 2017; Oso & Ayodele, 2014; Toluwase & Sekumade, 2017). From existing studies, cassava, maize and yam are known to have relatively high yields in Ekiti state compared to other parts of Nigeria (Fayemi, 2012). Unfortunately, data about different yields of crops at the various locations were not readily available for an objective comparison between suitability of places as displayed on the suitability maps produced and the yields obtained. Nevertheless, the results of the land suitability assessment carried out were compared with three local government areas known with arable crop farming practices in Ekiti State to further validate and verify the suitability assessment process. Field observations were carried out at Ido/Osi, Ikole and Moba Local Government Areas, results obtained indicates a high level of agreement between the land suitability assessment carried out for the crops and existing farm practices in the area, it as well validates the fuzzy logic approach for determining land suitability for arable crop farming. The suitability assessment carried out corroborates the fact that Ekiti has a high potential for planting cassava, maize and yam among other food and cash crops (Fayemi, 2012). Ekiti was noted to have an average cassava production of 1,674,450 metric ton over an area of 80,100 hectares which amounts to a yield of 20.9 MT/ha when compared with the entire yield in Nigeria which used to be at 11.1 MT/ha in 2012 (Fayemi, 2012). As observed from the suitability maps, waterbodies, steeply sloping areas and rock outcrops which majorly lies across the western and southwestern parts of the state were the major places below the marginal suitability for crops.

5 CONCLUSION

The research project provides a Web-based Geospatial Information System to access land suitability information for cassava, maize and yam in Ekiti State, Nigeria. The results produced from the suitability assessment carried out prove that; if well managed, fuzzy logic is an appropriate methodology for determining land suitability for arable crops. The web-based system will assist Farmers, Agriculture extension workers, and Prospective farmers to make informed decisions concerning what arable crops (cassava, maize and yam) should be planted on particular lands. As observed from the system, the web-based interface for conveying suitability information will aid easy accessibility of the information to farmers and agricultural extension workers among other advantages it seeks to avail. Conveying the information on the web reduces the complexity of gaining easy access to such information, and gives farmers access to scientifically driven information for agriculture.

A comparison between the land-use land cover map and the land suitability maps show that forest was not identified as suitable locations for farming. This is to ensure that deforestation and environmental degradation is not encouraged. Preserving the forest will help sequester carbon thereby reducing the negative impacts of climate change in the society. Unlike speculative methods of choosing crops and land for farming, the method implemented has the potential for better yield to promote the goal of food security and less environmental hazards to ensure sustainable development. The comparative advantage of the method utilised was validated using on-site based observation of local and scientific evidenced farming practices in Ido-Osi, Ikole and Moba Local Government Areas of the state. The research recommends the use of scientific evidence in site selection processes above the speculative method popularly used by Ekiti farmers.

The study was initially designed such that land suitability for arable crops could be determined on a web-based GIS platform so that users will be able to dynamically choose factors with which they wish to utilise for determining the suitability of land for various uses. Constrained by requisite knowledge and processing time, the work was adjusted such that; land suitability information for cassava, maize and yam would be determined on conventional software, and the result published on the web. The above challenge is positioned for further research.

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BIOGRAPHICAL NOTES

Israel TAIWO is a Lecturer with the Surveying & Geoinformatics department of the Federal Polytechnic Ado-Ekiti, a surveyor registered with the Surveyors Council of Nigeria, and a full member of the Nigerian Institution of Surveyors. He holds National Diploma and Higher National Diploma degrees in Surveying and Geoinformatics from the Rufus Giwa Polytechnic Owo and The Federal Polytechnic Ado-Ekiti, both in Nigeria. He as well holds a Post Graduate Diploma in Computer Science at the Federal University of Technology Akure and a Master of Space Science and Technology degree (Remote Sensing and GIS option) at the Federal University of Technology in Collaboration with the African Regional Centre for Space Science and Technology Education in English (ARCSTEE), Obafemi Awolowo Campus, Ile-Ife, Osun State. His area of interest is Land Administration, Remote Sensing Geoinformation Science.

CONTACTS

Israel TAIWO
The Federal Polytechnic Ado-Ekiti
Surveying and Geoinformatics Department
Ado-Ekiti, Ekiti State.
NIGERIA
+2348062865973
israeltaiwo@gmail.com, taiwo_io@fedpolyado.edu.ng

Lawrence ADEWOLE
Federal University Oye-Ekiti
Computer Science Department
Oye-Ekiti, Ekiti State.
NIGERIA
+2348066407161
bunmi.lawrenze@gmail.com, lawrence.adewole@fuoye.edu.ng

Mofoluso FAGBEJA
African Regional Centre for Space Science and Technology Education in English (ARCSTEE)
(Affiliated to the United Nations)
Obafemi Awolowo University (OAU) Campus,
Ile-Ife, Osun State.
Nigeria
+2348157564775
mfagbee@gmail.com

Ifeoluwa BALOGUN
Federal University of Technology Akure
Centre for Space Science and Research Applications (CESRA)
Akure, Ondo-State.
Nigeria
+2348039194212
iabalogun@futa.edu.ng