Vol. 12(2), pp. 19-33, July-December 2020
DOI: 10.5897/JABSD2019.0345
Article Number: 0B665DB64425
ISSN: 2141-2340

http://www.academicjournals.org/JABSD

ACADEMIC JOURNALS
expand your knowledge

Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research

Land suitability for cocoa production in Idanre, Ondo State, Nigeria

P. E. Tenkap[1*] and B. O. Balogun[2]

[1]Letters and Humans Sciences, Faculty of Arts, Geography Department. University of Yaoundé, Cameroon.
[2]African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E), O.A.U., Nigeria.

Received 2 February, 2019; Accepted 29 April, 2019.

In Nigeria, cocoa is an important cash crop that contributes to wealth creation and poverty alleviation. This study combined a Geographic Information System (GIS) application and Multi-Criteria Evaluation (MCE) to assess land suitability for cocoa cultivation. Based on the FAO rating standard Landsat ETM (2002) and Landsat 8 (2015) images, AsterDEM data, rainfall data, soil map, and the administrative map of Idanre were processed, classified, and reclassified into four (4) suitability classes. Different weights were generated through Analytic Hierarchic Process, based on the crop requirements. The result of the GIS-MCE analysis shows that 71.34 % (1401.79533 km²) of the study area are moderately suitable, 26.48% (520.31876 km²) marginally suitable, and only 2.18% (42.83591 km²) is not suitable for cocoa production. The results shows that the major limiting factors for good cocoa production and yield were poor land use management and insufficient rainfall.

Key words: Cocoa, land suitability, urbanization, satellite images, Geographic Information System (GIS), multi-criteria evaluation.

INTRODUCTION

Cocoa is among the leading export crop in the world with a world production of 4,645 thousand tones for the year 2017/2018 (ICCO, 2018). On a global scale, Africa remains the largest cocoa producing region accounting for 75.9% of the world cocoa production in 2017/2018, followed by America (17%), and Asia and Oceania (7.1%). According to Afoakwa (2014), cocoa is grown mostly in humid tropic areas such as Central and South America, Asia and Africa. The introduction of cocoa to West Africa after its discovery in the Amazon basin has resulted in its commercial cultivation and production in Nigeria. Cocoa has therefore contributed to the generation of cash income and revenue for the nation, and creates employment for the citizens.

*Corresponding Author E-mail: tenkapeugenie@gmail.com. Tel: +237-98-714-152.

According to FAO (1985), land suitability for agricultural use is the process of assessing land potentials for specified type of crop. It gives information on the limitations and advantages of a land and guides decisions on efficient use of land resources. Thus, it is fundamental to attribute the most favorable land to a particular crop, and to use the land according to its biophysical potentialities (Amin, 2013). An assessment of soil among other important factors such as rainfall and the existing land management practice system is required to determine the suitability of an area for agricultural purpose. Fertile soil is an essential factor that cocoa yield depends on (Jiska et al., 2015), and it varies from location to location. Information on soil texture is important in land suitability evaluation, as it is a soil property that determines its retentive capacity for nutrient and water, necessary for a healthy plant growth (Halder, 2013).

The use of Geographic Information System (GIS) and relevant ancillary data can provide relevant information about land suitability, and help with site selection and production of land suitability map for a particular land use. This is possible by combining different spatial data and/or information in Multi-Criteria Evaluation (MCE) to map crop suitability areas for cultivation (Kuria et al., 2011). The combination of GIS with MCE can help decision-makers to better the quality of their decisions by making them more specific, logical and adequate. GIS enables the assessment of the factors and MCE regroups them into land suitability criteria. The purpose of MCE is to assess factors and weigh each according to its importance, relative to other factors on the growth conditions for crops (Perveen et al., 2007). The output of a MCE is the production of suitability maps, which are used to determine the best location for the cultivation and production of a particular crop.

This study is aim at studying some land suitability criteria in cocoa cultivation in Idanre Local Government Area. Idanre is known as the major cocoa producing area in Nigeria. This is due to its fertile soils made up of a good distribution of sand and clay. As mention by Udo (2001), Idanre is composed of a variety of basement that gives rise to ferruginous soils that have high clay content. Sandy soil and other minerals washed down the valley form an alluvial clayey soil favorable for good cocoa growth. Between January and July the temperature averages 78 and 83°C, respectively and cool breeze reigns within this period. The humidity which is always high in January rises up to 80% in July. This peculiar equatorial climate facilitates cocoa cultivation and explains the town's reputation as one of the main centers of cocoa production in Nigeria. Despite its fertile soils and good climate, the growth rate of that cash crop has declined in the phase of production and cultivation. The decline was attributed to the poor quality of the soils. Soil nutrients under cocoa have reduced enormously through cultivation and harvesting over a long period of time, thus, affecting the capacity of soils. Non replacement of nutrients lost such as iron, Nitrogen, Phosphorus, by fertilizers decreased the production rate of cocoa. Climate change is another factor affecting cocoa cultivation and production during dry and rainy season. Climate changes can also alter bio-physiological processes of the crop and the development rate of pests and insects, which may reduce yields (Codjoe et al., 2013). In addition, 60% of areas have been under cultivation for more than 40 years, thus reducing the productivity. Thus, with the view to improve its production through the efficient use of land resources the specific objectives are (i) to assess the land use dynamic over the period of thirteen years; (ii) to ascertain the factors affecting cocoa cultivation; and (iii) to generate a land suitability map for cocoa cultivation.

Study area

Geophysical characteristics

Idanre Local Government Area of Ondo State is located between Longitude 5°0’0’’ and 5°40’0’’ East of the Greenwich Meridian and Latitude 6°50’0’’ and 7°10’0’’ North of the Equator (Figure 1). Idanre occupies an area of 1964.95 km² in spatial coverage.

Physical characteristics

The landscape of the study area is characterized by lowlands and rough hills (Adefila, 2013). Most of the study area is composed of the great variety of basement complex rocks, giving rise to ferruginous soils that have high clay content and of good retentive capacity (Udo, 2001). Soils are an end product of chemical weathering of the granite rocks. The sand adjudged salty, mingles with clay soil to form dark brown color, which is very fertile for agricultural activities. The equatorial climate of the area facilitates good cocoa growth. Humidity in the area can reach 80% in July, whereas, temperature rises up to 83%.

Socio-economic characteristics

The population is about 176,372 at the 2006 census. Idanre is mostly composed of the Yorubas. However, there are many local dialects spoken such as the Ekitis, Akokos, Owos, Ondos, Akures, Ikales and the Ilajes. Agriculture is the mainstay of the economy and means of livelihood of the population. The major industrial cash crops are cocoa, palm and kola-nut. Idanre is naturally blessed with wide cultivable land, good for production of several food and cash crops. The subsistence food crops include cocoa, yam, cassava, plantain, beans, maize and

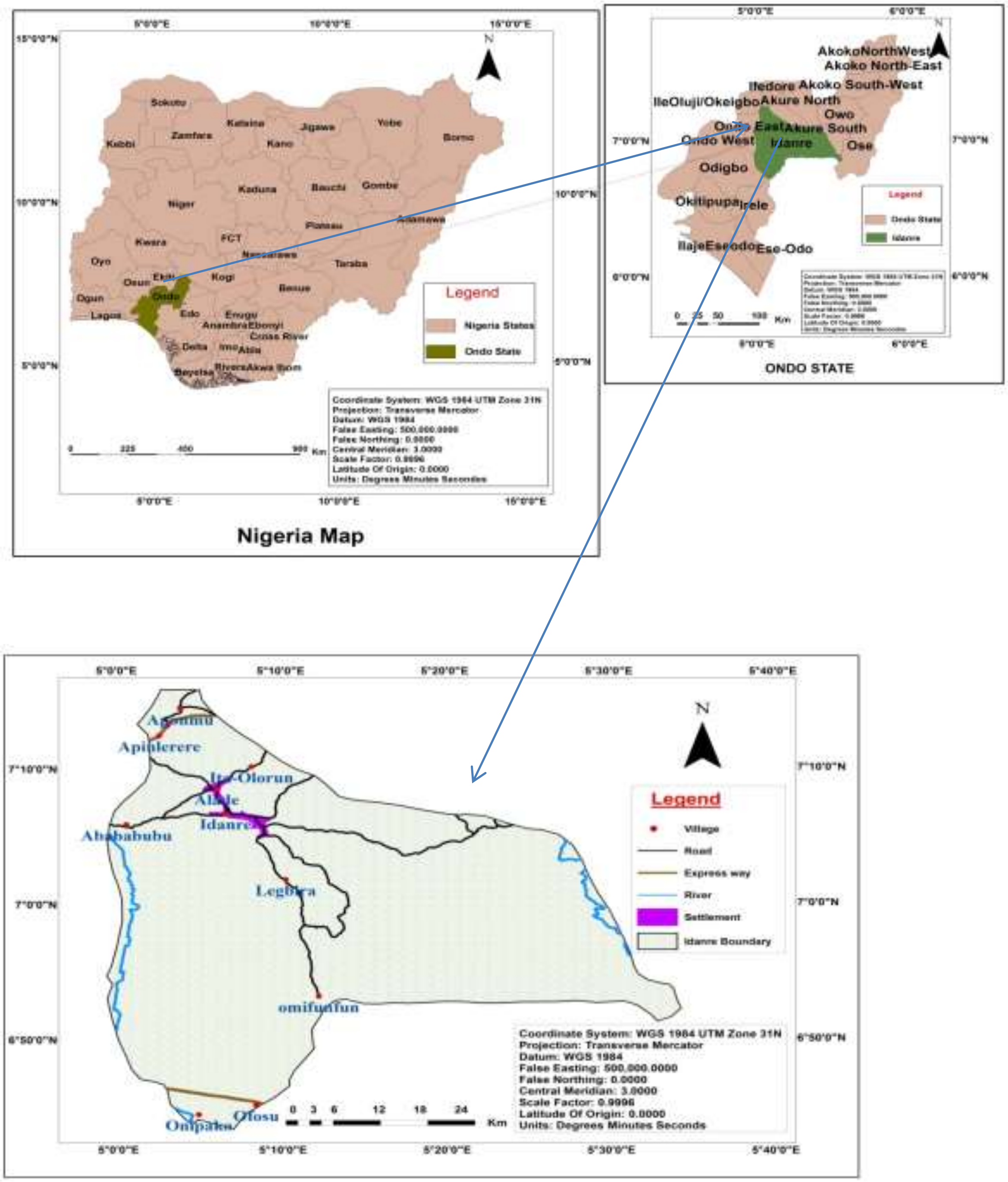

Figure 1. Map of Idanre.

varieties of vegetable. However, Idanre is well known for cocoa production that serves as a source of income.

MATERIALS AND METHODS

Data types, sources and preparation

The data used for analysis included the administrative map of Idanre: Bands 4, 3 and 2 (that is, near infrared, red, and green) of Landsat Enhanced Thematic Mapper (ETM) of 2002; and bands 5, 4 and 3 (that is, near infrared, red, and green) of Landsat 8 of 2015. Both Landsat types have spatial resolution of 30 m and were downloaded from the Global Land Cover Facility (GLCF) archive. The soil map of Nigeria at 1:300,000 scale was obtained from the Nigeria Geological Survey. Rainfall data (1998 to 2007) was received from Ondo State Development Project (Tunde, 2011); and AsterDEM data with 30 m resolution was downloaded from the United States Geological Survey (USGS) archive. All the datasets

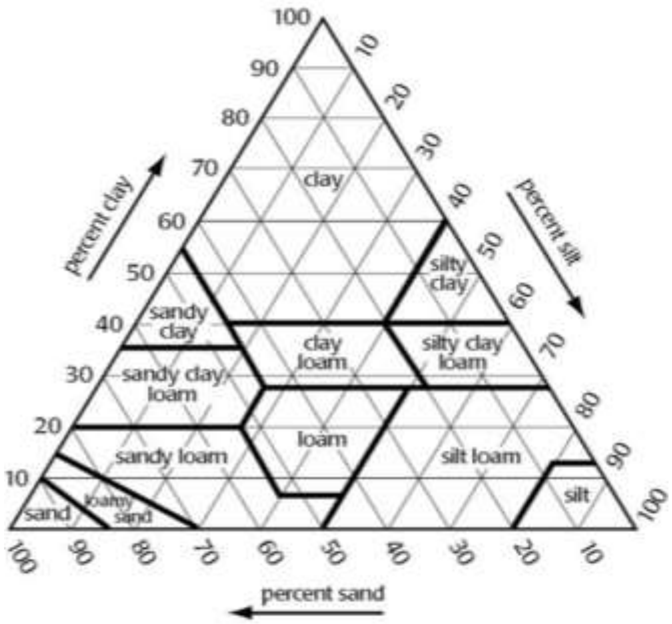

Figure 2. Soil triangle (*Source*: www.nbcsd.org).

were regularized into the same coordinate system and projected to WGS 1984 UTM Zone 31N. The multiple bands of each Landsat data type were further stacked into a single image respectively, using the ERDAS Imagine Software. Using the ArcMap software, two sub-images of the study area were created from the stacked Landsat ETM (2002) and Landsat 8 (2015) images, respectively.

Land use and land cover classification

Unsupervised thematic classification was performed on the two sub-images to generate the land use and land cover information on the study area and to identify the changes that occurred over a period of thirteen years. The Google Earth image of the study area was downloaded and used to carry out the accuracy assessment and correct the unsupervised classification. The land use and land cover classes identified in both images were classified into four land use classes: Built up, cultivated area, forest, and rock.

Change detection

The average rate of change over a period of thirteen years was analyzed using the formula expressed as:

$$\Delta LULC = LULC2 - LULC1 \qquad (1)$$

Where, ∆LULC = change in land use and land cover types; LULC2 = current extent of a particular land use and land cover type, and **LULC1** = previous extent of a particular land use and land cover type

Factors affecting cocoa cultivation

Soil types

The soil of the study area was extracted from the Nigeria soil map in ArcMap. Five types of soil were identified and the soil textural triangle (Figure 2) was used to determine the proportion of sand, silt and clay of each type of soil. Based on the soil texture requirement the best soil for cocoa cultivation was determined.

Slope

The slope information was obtained from Digital Elevation Model (DEM). The shapefile of the study area was overlaid on the AsterDEM data and the clip tool was used to extract the relevant portion of the AsterDEM imagery falling within the boundary of the study area. The extracted image was corrected using Focal Statistics tool. The DEM was then converted to slope using Surface Analyst tool in GIS environment.

Rainfall

Rainfall data for the study area was interpolated using Inverse Distance Weight (IDW) Method expressed as:

$$\lambda = \frac{1/(d)^{P}i}{\sum_{i=1}^{n} = 1/(d)^{P}i} \qquad (2)$$

Where d is the distance between the sampled points, p_i the power parameter, and n the number of sample points used for the estimation.

Land suitability map

Weighted spatial factors in multi-criteria evaluation

Based on the climatic, soil and land requirements for cocoa production (Table 1), a specific level of suitability was defined for each factor and used to generate the criteria map for each factor. The factors were reclassified according to the FAO rating standard for land suitability into 4 different classes of suitability (Table 2). Different weights were generated through Analytic Hierarchic Process (Saaty and Vargas, 1980). The purpose of weighting was to determine the importance of each factor relative to the effects of other factors on cocoa cultivation and yield. This involves assigning a value to the criterion based on their relative importance. The process often involves expert's opinions, indigenous knowledge and comparison of existing land use with location specific characteristics. All the reclassified maps were overlaid in ArcGIS and Weighted Overlay tool was used to generate the final suitability map for cocoa cultivation in the study area.

RESULTS AND DISCUSSION

Land use land cover 2002

The identified features include built-up, cultivated area, forest, and rock, based on the USGS classification scheme (Figure 3). The classification result of 2002 image showed that built-up occupied 3% (58.9485 km²) of the study area, cultivated area 10% (196.495 km²), forest 84% (1650.558 km²), and rock 3% (58.9485 km²) (Table 2). The area was dominated by forest, showing that it is still fairly vegetated. The growth rate of the

Table 1. Climatic, soil and land requirement for cocoa (Kappo et al., 2014).

Cocoa requirement	S1	S2	S3	N1
Average annual temperature (°C)	25 - 28	28 - 32	32 - 35	35 - 37
Average annual rainfall (mm)	1600 - 2500	1400 - 1600	1200 - 1400	1000 - 1200
Average annual relative humidity	40 - 65	65 - 75	75 - 85	85 - 95
Soil texture	Fine, slightly fine, medium		Slightly coarse	Coarse
Coarse materials %	<15	15 - 35	35 - 55	>55
Nitrogen	>1.8	1.5	1.0	0.5
Phosphorus				<0.02
C.E.C-clay (Cmol/kg)	>24	20 - 24	16 - 20	12 - 16
Base saturation %	>50	45 - 50	40 - 45	35 - 40
pH	6.0 - 7.0	5.5 - 6.0	<5.5	
Organic matter %	2.5 - 3.5	2.0 - 2.5	1.5 - 2.0	1.0 - 1.5
Slope (%)	<4	4 - 8	8 - 16	16 - 20

S1 = Highly suitable; S2 = Moderately suitable; S3= Marginally suitable; N1= Not suitable.

Table 2. FAO framework land suitability classes.

Suitability order	Suitability classes	Significance
Orders (suitable)	S1 (Highly suitable)	Land having no significant limitations to sustained application of a given use.
	S2 (moderately suitable)	Land having limitations, which in aggregate are moderately severe for sustained application of a given use.
	S3 (marginally suitable)	Land having limitations, which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits
Order N (not suitable)	N (Not suitable)	Land, which has qualities that appear to preclude sustained use of the kind under consideration.

population and urbanization was still low since built up occupied only 3% of the study area, resulting in only 10% of the study area being used for farming.

Land use land cover 2015

Features identified in the 2015 image were classified into built-up, cultivated area, forest, and rock (Figure 4). The result shows that built up covered the study area by 6% (117.897 km²), cultivated area 19% (373.3405 km²), forest 72% (1414.764 km²), and rock 3% (58.9485 km²) (Table 2). The result also revealed that the area was mainly occupied by forest (72%). The majority of the area was still in a high vegetated form, while 6% of the study area was occupied by built-up, showing an increase in human population that has increased farm land to 19% of the study area.

Change detection between 2002 and 2015

LULC dynamics are important indicators of the prevailing land management practices by human population in a specific area (Audrey et al., 2016). Change detection is the process used to measure how the attributes of a particular area have changed over time. It often involves a comparison between two or more images, and has been used to evaluate deforestation (McRoberts and Walters, 2012), urban growth (Hegazy and Kaloop, 2015), farm land (Poongothai et al., 2014) and land use and land cover changes. The result of the change detection shows a decrease of 12% (235.794 km²) in forest, an increase of 3% (58.9485 km²) in built up, and an increase of 9% (176.8455 km²) in cultivated area (Table 3). As mentioned by Nuwagaba and Namateefu (2013), one of the major effects of land use and land cover dynamics is deforestation. The conversion of forest into urban area destroyed fertile area that could have been used for cocoa and other related farming activities (Musa and Odera, 2015). Vegetation is the only land cover that experienced negative absolute change (Olaniyi and Atalor, 2018). Human installation has altered the possibility of restoration of those areas to forest lands (Delgado et al., 2015). The LULC changes took place at

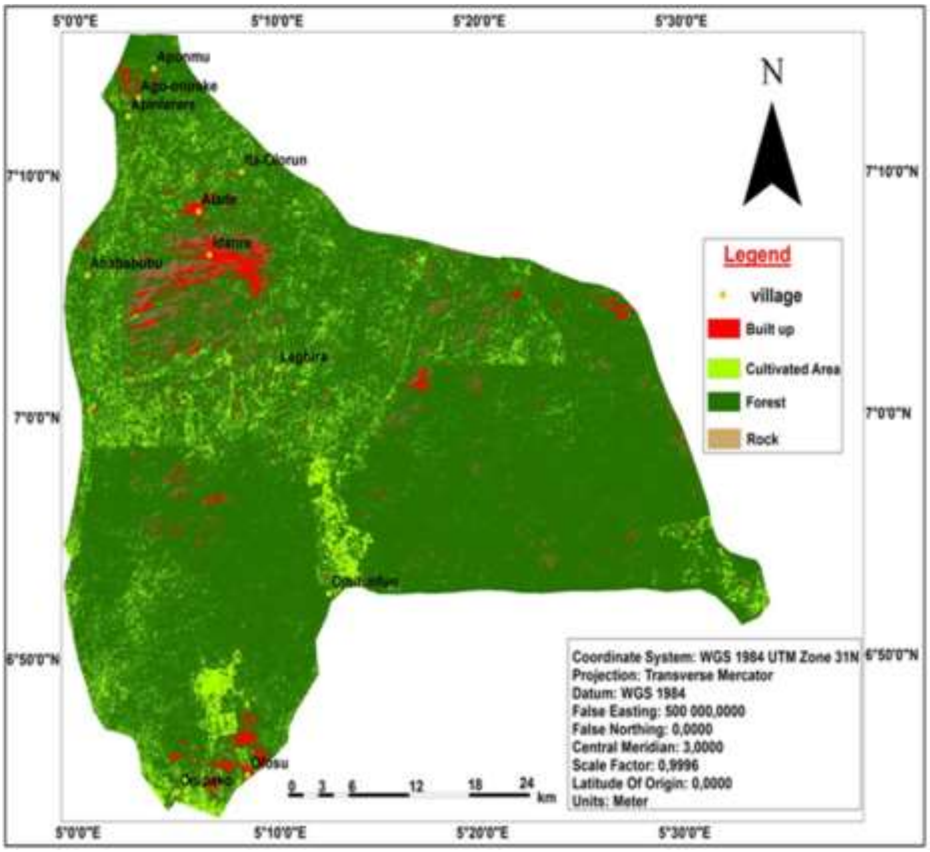

Figure 3. LULC in 2002.

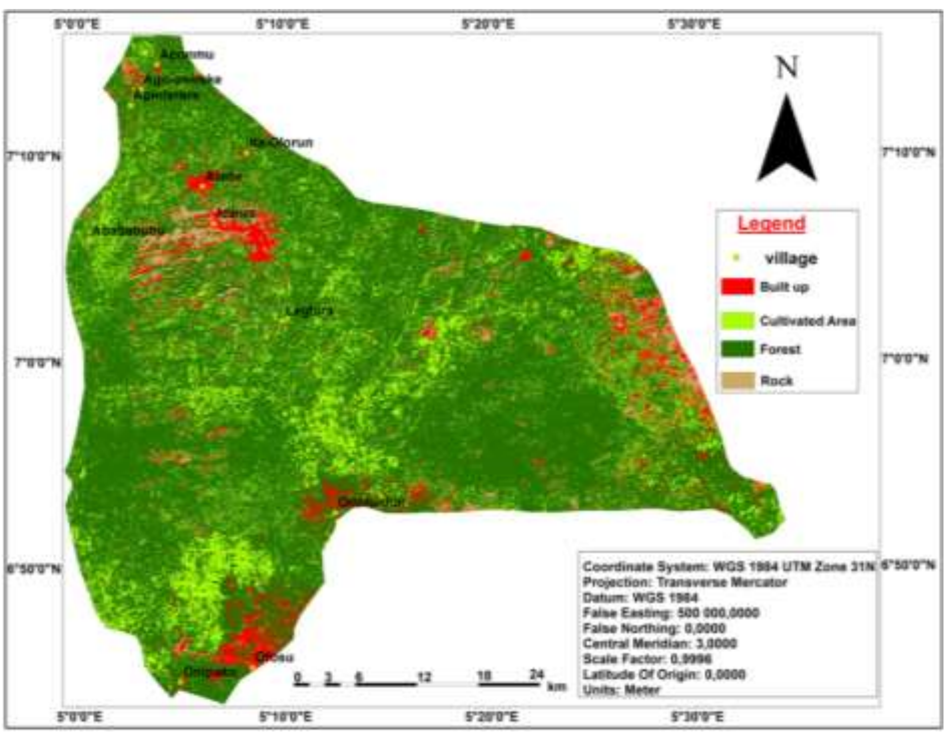

Figure 4. LULC in 2015.

Table 3. Difference in LULC (2002 - 2015).

Classified thematic features	2002 (%)	2015 (%)	Difference (%)
Built up	3	6	+ 3
Cultivated area	10	19	+ 9
Forest	84	72	- 12
Rock	3	3	-
Total	100	100	-

the expense of other land cover types. Built up and agricultural development for cash production are the main reason for LULC dynamics (Gonga et al., 2018) and they took place at the expense of forest (Shi et al., 2018). This was acknowledged by Sharma et al. (2015) who noted that areas quickly shift into built up due to fast urbanization. Man intervention has exercised a great deal of pressure on land use, which has drastically reduced fertile land, thus, leading to a decrease in crop yield. As population is increasing, the demand for forest and land for urban expansion and agriculture also increases. Deforestation also has a huge negative effect on the properties of the soil, such as, decrease of organic matter content and nutrients depletion; accelerated land sensitivity to degradation; and loss of resources and ability to stabilize the environment. Agriculture, and especially cocoa farming being the main activity in the study area, serves as a source of income and means of livelihood to the people who are predominantly farmers. Therefore, the need to ensure food security and supply the need of the growing population, has led to the conversion of forest into farmland. This was acknowledged by Oyinloye and Oloukoi (2012) where it was observed that an increase of 10.77% per year in cultivated area for food production was needed to feed the rapidly increasing population. Land resource will be limited due to high demand of agricultural product and increasing population pressure (Yadav et al., 2012). FAO (2016) defines land cover as the observed bio-physical cover on the earth’s surface, whereas land use is the designated usage of the land cover. Land use and land cover (LULC) change is one of the most important variables in determining gradual change in the environment, which may result from rapid population growth, which is capable of affecting some fertile agricultural areas, and in turn hampers agricultural production. This aligns with the statement of Cheruto et al. (2016) that land cover and land use changes and socio-economic dynamics have a strong relationship. As the population grows, the need for farm land and built up area grows correspondingly, in order to meet the demands of the growing population. The result of all these has definite impact on the soil and suitability of the land. Thus, timely information on LULC is necessary in order to plan the use of land and manage humans’ overexploitation.

Soil, slope, and rainfall requirements for cocoa

Types of soil within the study area

The result of the soil analysis of the study identified five types of soil including clay loam, loamy sand, sandy clay, sandy clay loam, and sandy loam (Figure 5). The proportion of silt, clay, and sand in percentage of each type of soil is shown in Table 4. FAO standard was used to determine the most suitable soil for cocoa cultivation, which includes sandy loam, sandy clay loam, and sandy clay. This is due to the good distribution of clay, sand, and silt in each type of soil that promotes aeration, root penetration and water retention. Loamy sand is not favorable for cocoa cultivation due to the highest percentage of sand (80%) that can cause leaching despite the fact that they have good drainage; and the lowest percentage of clay (20%) which is not sufficient to retain water for the plant and hold moisture. Clay loam soil is favorable for cocoa cultivation but at a medium level due to the highest percentage of clay (65 %) that does not promote good aeration. The result of the soil texture obtained aligned with the findings of Afolayan, (2016) that identified similar texture in the study area.

Information on soil texture is important in land suitability evaluation. Texture is one of the most important properties of soil that determines the availability of water and nutrient to plants. Changes in soil texture with depth can have a great impact on root penetration. Sand, silt and clay generally make up the soil texture classes and refer to relative sizes of the soil particles. Ideal soils for cocoa cultivation are soils which have equal proportion of sand, silt, and clay sized particles. The impact of each type of soil on the suitability of the site for cocoa is interrelated. Texture is very important for water retention during the dry season. Cocoa requires a deep well drained soil with a high nutrient content. Cocoa soils should have a clayey soil texture with sandy clay loam and sandy clay to ensure an adequate moisture supply during the dry month. Clayey soils increase the vigor of the tree and have a higher content of nutrients and organic matter as they tend to have a high positive correlation with chemical fertility. Sandy soils promote aeration, good drainage, and penetration of root, but have a very low capacity for moisture retention. According to Zuidema et al. (2005), loamy soils that are

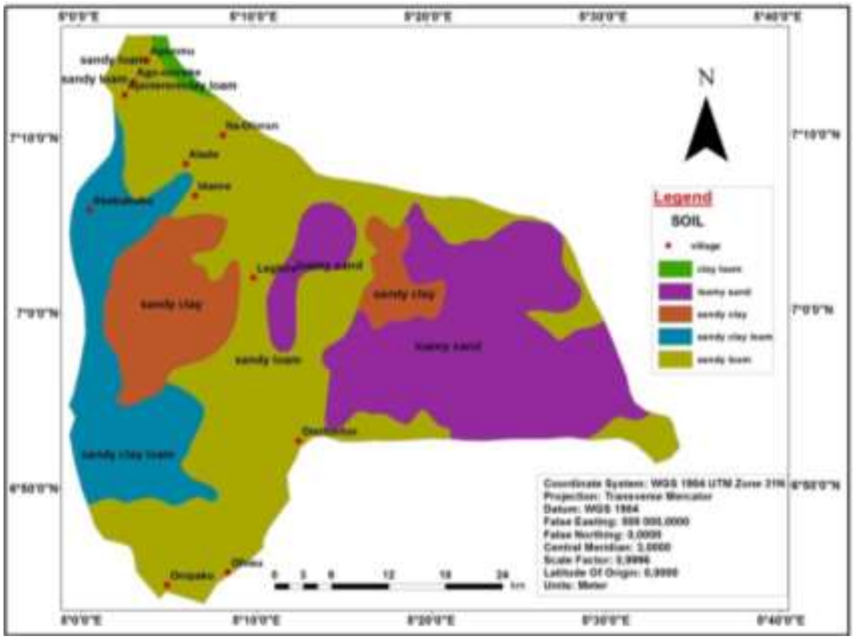

Figure 5. Soil map of Idanre.

Table 4. Proportion of the soil texture in percentage.

Type of soils	Clay (%)	Sand (%)	Silt (%)
Sandy loam	40	60	30
Sandy clay loam	40	60	15
Sandy clay	50	50	10
Clay loam	65	35	35
Loamy sand	20	80	10

rich in iron and potassium will promote best yields especially under good distribution of rainfall.

Slope of the study area

Slope is expressed in percentage and used to identify hilly and low terrain. The result of the slope which was obtained from the DEM (Figure 6) indicates that the slope ranged from 0 to 198%, where the lowest lies between 0 and 8%, and the steepest is between 46 and 198% (Figure 7). The majority of the area is under 46%, which is the area characterized by flat and gently sloping lowlands. Those areas are more favorable for cultivation management. All the fertile soils washed away by rain from the hilly areas are often found in the lowest ground, making those areas more favorable for cultivation. However, areas between 0 and 8% are close to the river and are more subject to flood despite the fact they are fertile. The remaining part of the area above 46% is characterized by mountains and hills, and is therefore not so good for cocoa cultivation, hilly areas being very sensitive to nutrient runoff. As the slope of land increases, the amount of production reduces and the percentage in production increases as the slope decreases. In areas where the slope is steep, it is difficult to manage land and grow cocoa, as it is more time consuming and incurs high agricultural cost. Andersen et al. (2004) confirms that areas where efficient agriculture is not possible are areas where the slope is steep and therefore, constitutes a limiting factor for cultivation. Akinci et al. (2013) recognized slope as one of the spatial elements that reduces machinery and management applications such as drainage and irrigation, thus affecting agricultural production negatively. Soil thickness, fertility and depth are also affected by the increase in slope percentage, thus, hampering on the expected yield. As mentioned by Koulouri and Giourga (2007) erosion occurs more on area with a steep slope that increases the quantity of sediment carried away. To use the agricultural land efficiently and achieve high yield, it is therefore necessary to evaluate and understand the

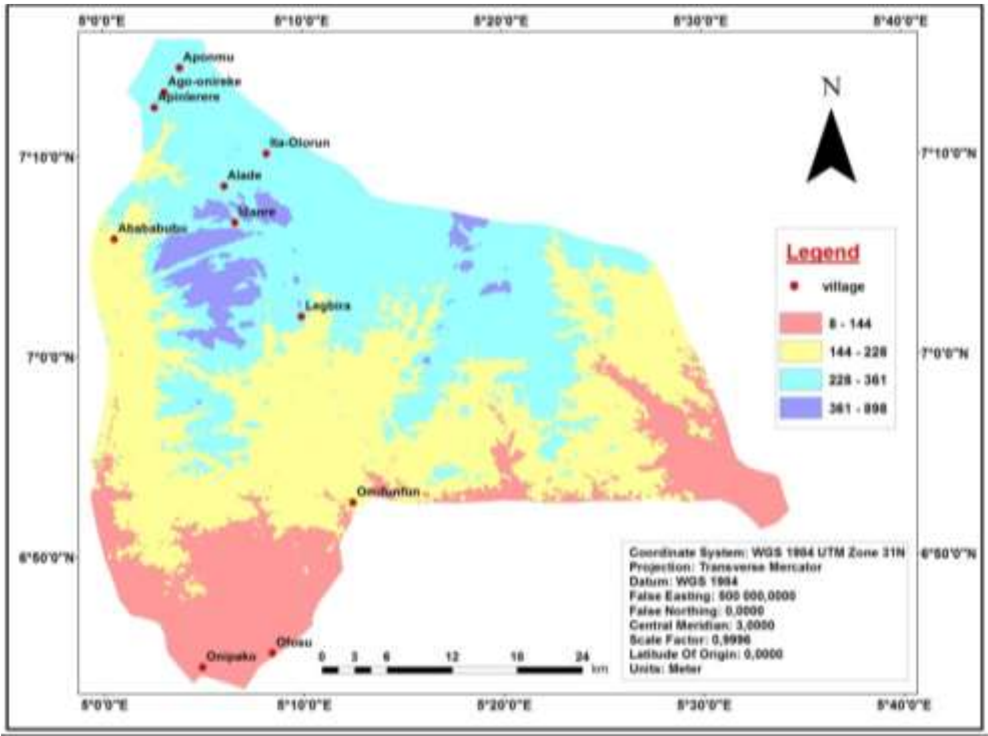

Figure 6. DEM of Idanre.

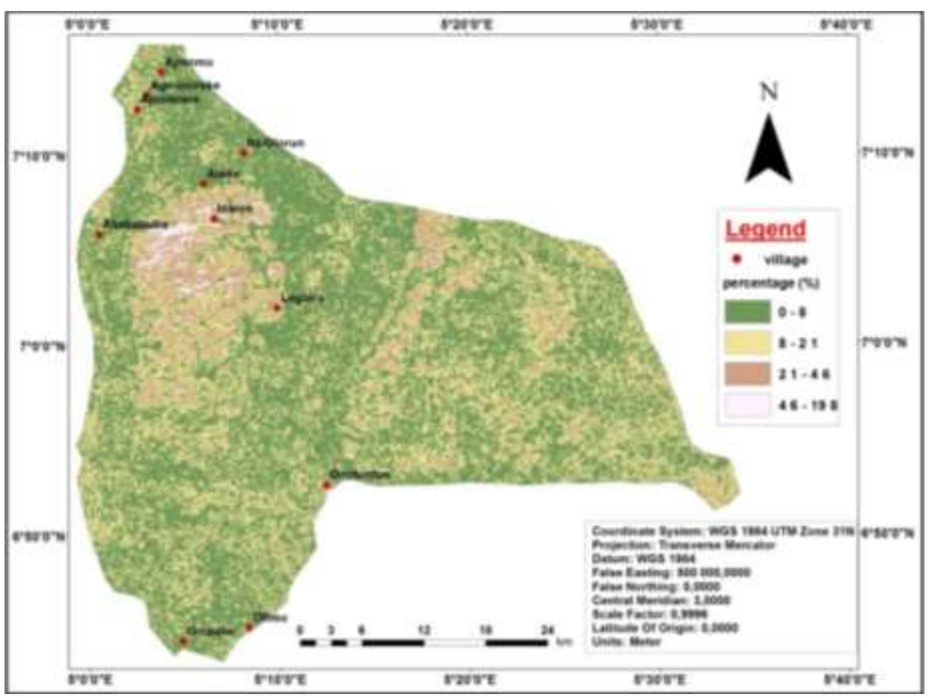

Figure 7. Slope of Idanre.

slope of the area. Slope is an important factor in land management for agricultural practices (Van Asselen and Verburg al., 2012) and a factor that is used to assess the performance and suitability of land for farming,

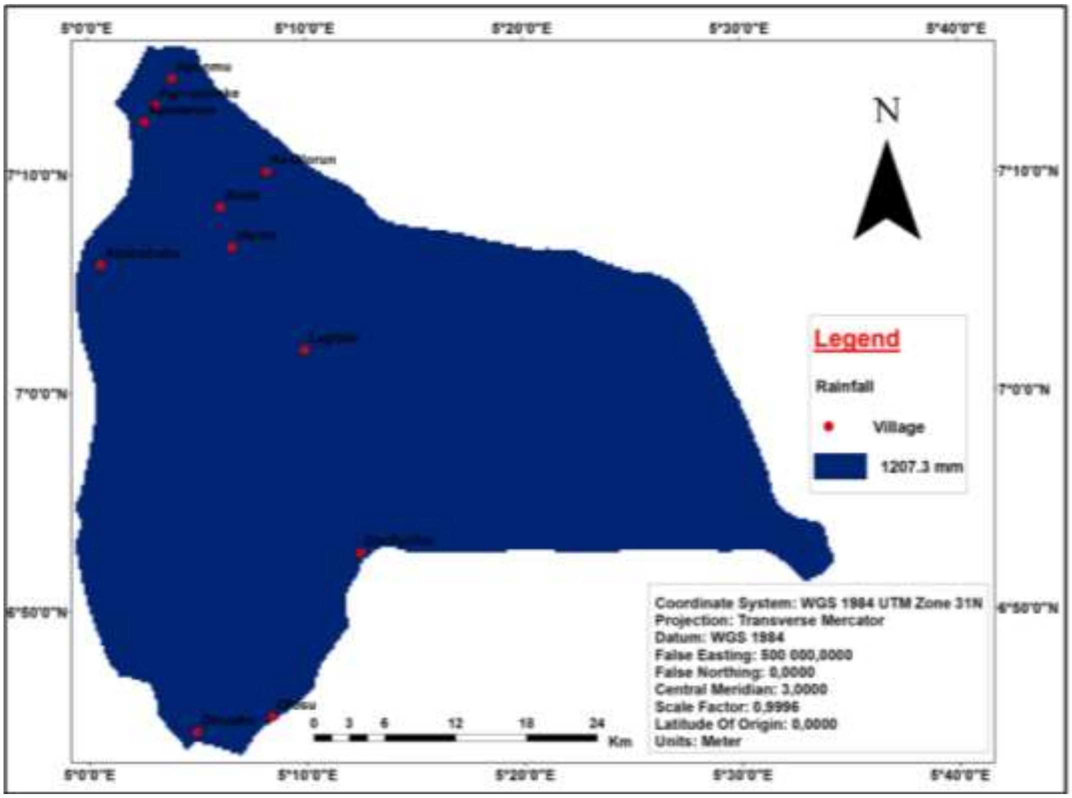

Figure 8. Rainfall map of Idanre.

influencing land use decisions (Buday and Lacko-Bartošová, 2013).

Rainfall

A rainfall condition is of greater impact in ascertaining the crop productivity for agriculture and rainfall interact together. Thus, to improve the crop yield it is necessary to know the average rainfall of the area that should be well distributed over a year in order to have good effect on cocoa yield. The result of the rainfall showed an annual average of 1207.3 mm (Figure 8). Tunde (2011) identified alterations in the climate of the study area as the factor of changes in cocoa yield, cocoa being highly correlated to rainfall. This tends to have negative effects on the cocoa yield and reduce the productivity. Cocoa is very sensitive to drought and as mentioned by Hermann et al. (2010), drought during the establishment phase results in high cocoa seedling mortality. Ojo and Sadiq (2010) identified rainfall as the major factor responsible for cocoa decline, contributing to the reduction of productivity. Amount of rainfall distribution is very critical to cocoa production. Annual rainfall above 2,500 mm will lead to leaching and impoverishment of the soil, and will increase diseases. If the soil physical and chemical properties are suitable and rainfall is not adequate, cocoa production will be affected.

Reclassification of factors

Reclassified LULC

All the features identified in the classified Landsat image which included built up; cultivated area, forest, and rock were reclassified into three classes of suitability (S1, S2, and N). Forest was classified as highly suitable for cocoa, and cultivated area as moderately suitable. Whereas built up and rock were classified as not suitable for cocoa cultivation. The result of the reclassified land use and land cover shows that 72.3% (1420.65885 km^2) of the study area is highly suitable, whereas 19.23% (377.859885 km^2) is moderately suitable and 8.47% (165.0558 km^2) not suitable for cocoa cultivation (Figure 9).

Reclassified soil

Five types of soil were identified in the study area including clay loam, loamy sand, sandy clay, sandy clay loam, and sandy loam (Figure 5). According to the FAO framework the soil texture for cocoa cultivation for a highly suitable area is said to be fine, slightly fine and medium, slightly coarse for a marginally suitable area, and coarse for a not suitable area. Therefore all the soils types were reclassified into three suitability classes (S1,

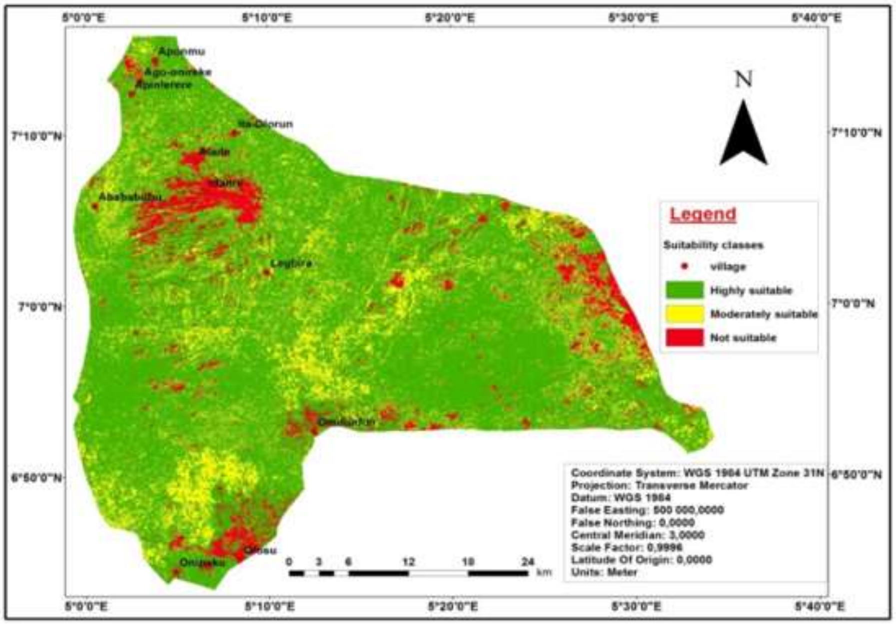

Figure 9. Reclassified LULC.

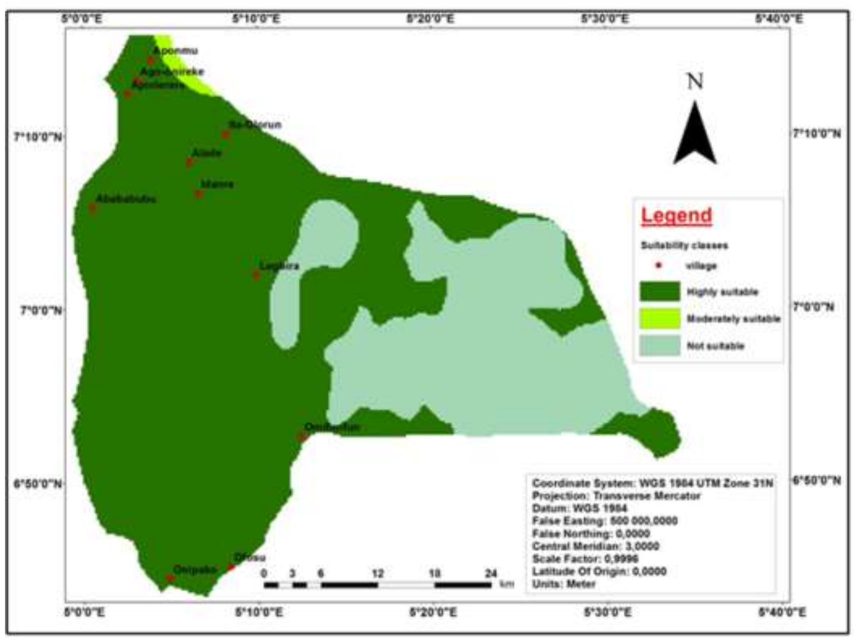

Figure 10. Reclassified soil.

S2 and N). Sandy loam, sandy clay loam, and sandy clay appears to be the most suitable soil for cocoa, while clay loam is moderately suitable, and loamy sand not suitable for cocoa cultivation. The result of the reclassified soil shows that 70.76% (1390.39862 km²) of the study area is highly suitable, 0.62% (12.18269 km²) moderately suitable and 28.62% (562.36869 km²) not suitable for cocoa cultivation (Figure 10).

Reclassified slope

The FAO slope recommended for cocoa cultivation ranges between 0 and 20% classified into 4 classes of

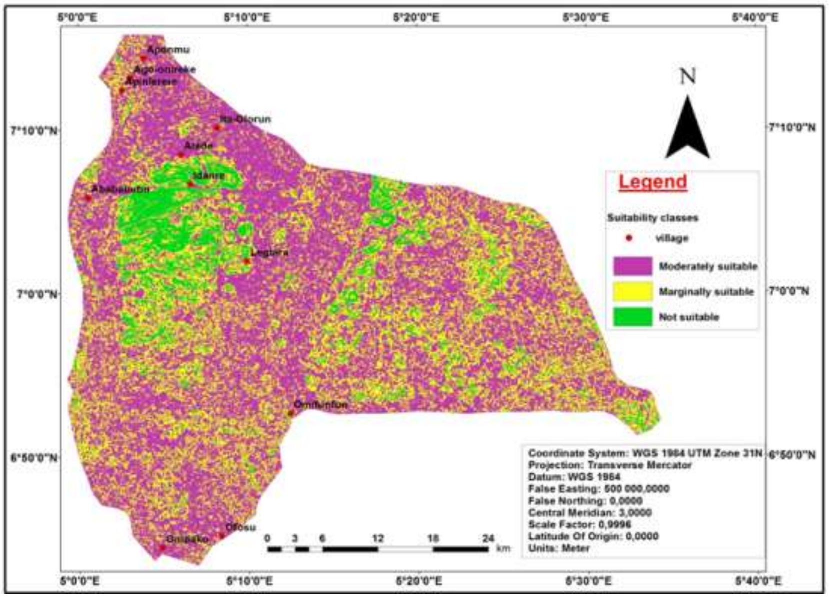

Figure 11. Reclassified slope.

suitability: less than 4% for the highly suitable area, from 4 to 8% for the moderately suitable area, from 8 to 16% for the marginally suitable area, and 16-20 % for the not suitable area. Based on the FAO standard the slope of the study was reclassified into three classes of suitability (S2, S3 and N). The slope ranging between 0 and 8% was classified as moderately suitable, between 8 and 21% marginally suitable, and between 21 and 198% not suitable for cocoa cultivation. The result of the reclassified slope shows that 56.8 % (1116.0916 km²) of the study area is moderately suitable, 35.4% (695.5923 km²) marginally suitable and 7.8% (153.2661 km²) not suitable for cocoa cultivation (Figure 11).

Reclassified rainfall

Rainfall is one of the major factors affecting cocoa cultivation. The average annual rainfall of the study area was 1207.3 mm (Figure 8). According to the FAO standard, the average annual rainfall for cocoa is said to be 1600 to 2500 mm for the highly suitable area, 1400 to 1600 mm moderately suitable area, and 1200 to 4000 mm marginally suitable area. The rainfall of the study area is therefore classified as marginally suitable for cocoa cultivation (Figure 12).

Weighted overlay of the spatial factors and land suitability

Weight was generated through Analytic Hierarchic Process (A.H.P) for all the reclassified factors in order to determine the importance of the effects of each factor relative to other factors on cocoa cultivation and yield. The result of the generated weight attached to each factors shows that soil is the most important factor on which cocoa depends, as it accounts for 59 %, followed by rainfall (23%), cultivated area (11%), and slope (7%) (Table 5). The result of the land suitability analysis for cocoa cultivation shows that 71.34% (1401.79533 km²) of the study area is moderately suitable; while 26.48% (520.31876 km²) is marginally suitable and only 2.18% (42.83591 km²) of the study area is not suitable for cocoa cultivation (Figure 13). The suitability classes of the study are the same as the classes obtained by Kappo et al. (2014). The result reveals that almost all the study area is favorable for cocoa cultivation. This confirms the findings of Ajayi et al. (2010) who identified Idanre as the highest cocoa producing local government in Nigeria. This is due to the capacity of the area to sustain that particular crop. Cocoa is the most cultivated crop in Idanre and the main farming activity that provides cash flow to the population.

Conclusion

This study identified clay loam, loamy sand, sandy clay, sandy clay loam, and sandy loam as the major soil types in the study area. Other land suitability parameters such as rainfall and topography affect the suitability of the land for cocoa cultivation. The integration of the land use and land cover shows the majority of the study area is moderately suitable for cocoa. However, cocoa cultivation faces some challenges and is hampered by some factors such as insufficient rainfall and unsustainable land

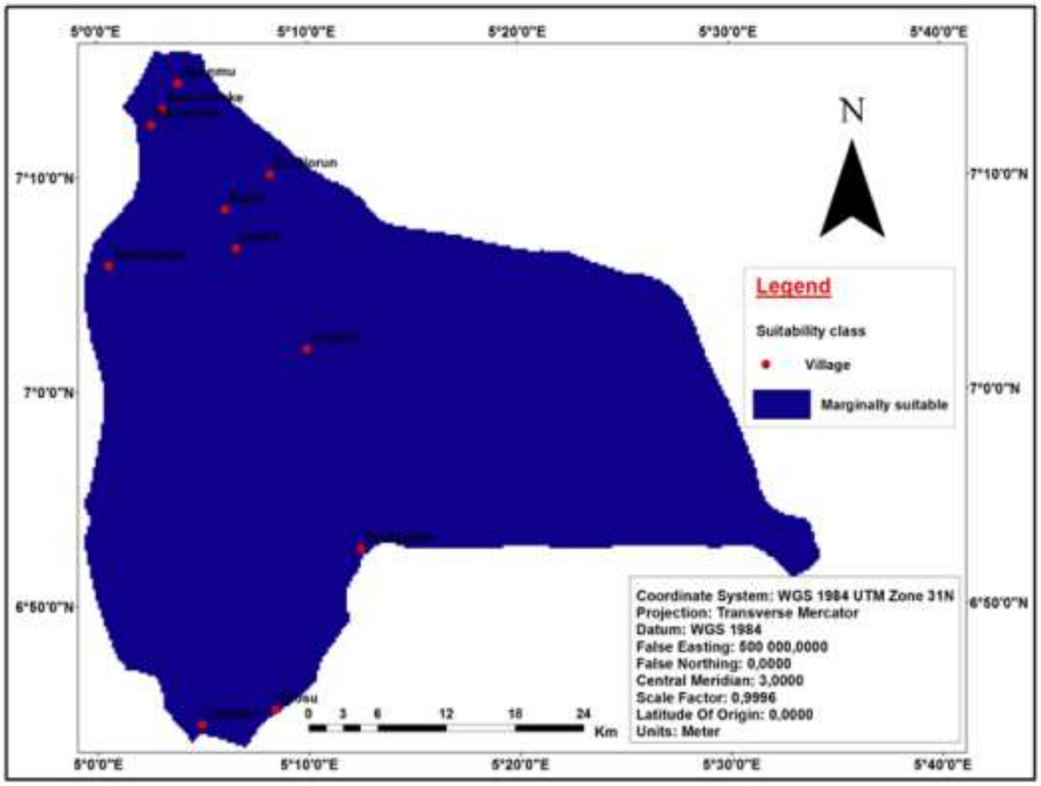

Figure 12. Reclassified rainfall.

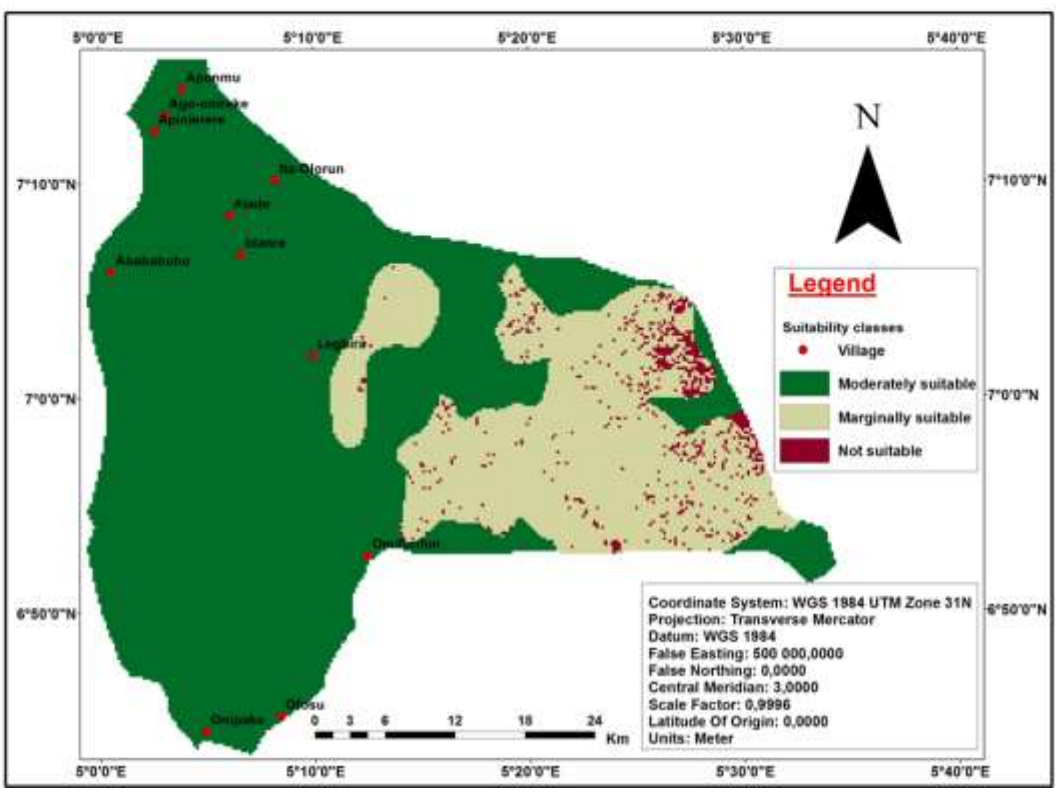

Figure 13. Suitability map for cocoa cultivation in Idanre.

Table 5. Factors and weight for cocoa.

Factor	Cocoa	
	Weight (%)	**Weight (%)**
Soil	0.5856	59
Rainfall	0.2338	23
Land use/land cover	0.1065	11
Slope	0.0741	7
Total	**1**	**100**

management practices, such as unplanned urbanization.

Recommendations

In view of the main limiting factors of good cocoa production and yield being unplanned urbanization that destroyed some fertile areas, and insufficient rainfall, the study recommends that government should have a good urban plan in order to control the use of land by the growing population, and preserve the fertile areas and areas under farming from destruction. The government should also create awareness on rainfall changes and the coping strategies by educating the farmers on sustainable cocoa management program. Farmer should create a cooperative to obtain more support and finance for their cocoa farming. Since cocoa constitutes one of the most exported crops that provide cash flow, the government should invest more on cocoa to sustain the production. However, further studies should be carried out on cocoa production by combining all the factors used in this research, including land use and land cover, rainfall, slope, and soil physical properties, with the socio-economic factor, chemical properties of soil, and temperature to improve the accuracy of the results.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adefila O (2013). Spatial Effect of Cocoa Production on Rural Economy of Idanre-Ifedore Local Government Area, Ondo State Nigeria. Asian Journal of Agriculture and Rural Development 3(393-2016-23983):56.

Afoakwa OE (2014). Cocoa Production and Processing Technology, CRS Press, Taylor and Francis Group, LLC.

Afolayan OS (2016). Soil-Plant Properties Degradation in Aged Cocoa Farms in Southwest Nigeria. Nigerian Journal of Agriculture, Food and Environment 12(4):194-199.

Ajayi IR, Afolabi MO, Ogunbodede EF, Sunday AG (2010). Modeling Rainfall as a Constraining Factor for Cocoa Yield in Ondo State. American Journal of Scientific and Industrial Research 1(2):127-134.

Akinci H, Ozalp AY, Turgut B (2013). Agricultural land use suitability analysis using GIS and AHP technique. Computers and Electronics in Agriculture 97:71-82.

Amin S (2013). Assessment of Different Methods of Soil Suitability Classification for Wheat Cultivation. Journal of Agrobiology 29(2):47-54.

Andersen E, Baldock D, Bennett H, Beaufoy G, Bignal E, Brouwer F, Elbersen B, Eiden G, Godeschalk F, Jones G, McCracken D, Nieuwenhuizen W, van Eupen M, Hennekens S, Zervas G (2004). Developing a High Nature Value farming area indicator. Report to the European Environment Agency, Copenhagen. https://library.wur.nl/WebQuery/wurpubs/fulltext/3918

Audrey L, Brian E, Amélie B, Davis SA, Gagné E, Loudermilk L, Robert M, Scheller FKA, Schmiegelow YF, Wiersma JF (2016). How Landscape Ecology Informs Global Land-Change Science and Policy. BioScience 66(6):458-469.

Buday S, Lacko-Bartošová M (2013) Global challenges for sustainable agriculture and rural development in Slovakia. Journal of Central European Agriculture 14(3):263-278.

Cheruto MC, Matheaus KK, Patrick DK, Patrick K (2016). Assessment of Land Use and Land Cover Change Using GIS and Remote Sensing Techniques: A Case Study of Makueni County, Kenya. Journal of Remote Sensing and GIS 5:4. http://41.89.55.71:8080/xmlui/handle/123456789/3062

Delgado C, Wolosin M, Purvis N (2015). Restoring and protecting agricultural and forest landscapes and increasing agricultural productivity. Working paper for seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. New Climate Economy, London and Washington, DC.

Food and Agriculture Organization (FAO) (1985). Guidelines: Land Evaluation for Irrigated Agriculture. FAO Soils Bulletin 55 Rome.

Food and Agriculture Organization (FAO) (2016). Land Cover Classification System, Software version 3. Rome, 2016.

Gonga J, Hua Z, Chenb W, Liuc Y, Wang J (2018). Urban expansion dynamics and modes in metropolitan Guangzhou, China. Land Use Policy 72:100-109.

Halder JC (2013). Land suitability assessment for crop cultivation by using remote sensing and GIS. Journal of geography and Geology 5:65-74.

Hegazy IR, Kaloop MR (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. International Journal of Sustainable Built Environment 4(1):117-124.

Hermann A, Jürgen P, Valentin DP (2010). Growth and Production of Cacao, in Soils, Plant Growth and Crop Production. In encyclopedia of life support systems, Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford, UK. http://www.eolss.net

International Cocoa Organization (ICCO) (2018). Quaterly Bulletin of Cocoa Statistics XLIV(3). Cocoa year 2017/2018 https://www.icco.org/about-us/icco-news/398-quarterly-bulletin-of-cocoa-statistics-november-2018.html

Jiska A, van V, Maja S, Ken EG (2015). Mineral Nutrition of Cocoa. Plant Production Systems Group, Wageningen University 70 p.

Kappo A, Rilwani ML, Muibi K (2014). Land Suitability Assessment for Cocoa Cultivation in Ife Central Local Government Area, Osun State. International Journal of Scientific Engineering and Research pp. 1-6.

Koulouri M, Giourga C (2007). Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands. Catena 69(3):274-281.

Kuria D, Ngari D, Waithaka E (2011). Using Geographic Information Systems to Determine Land Suitability for Rice Crop Growing In the Tana Delta. Journal of Geography and Regional Planning 4(9):525-532.

McRoberts RE, Walters BF (2012). Statistical inference for remote sensing-based estimates of net deforestation. Remote Sensing of Environment 124:394-401.

Musa MK, Odera PA (2015). Land Use Land Cover Changes and their Effects on Agricultural Land: A Case Study of Kiambu County-Kenya. Kabarak Journal of Research and Innovation 3(1):1-14.

Nuwagaba A, Namateefu LK (2013). Climatic Change, Land Use and Food Security in Uganda: A Survey of Western Uganda. Journal of Earth Sciences and Geotechnical Engineering 3(2):61-72.

Ojo AD, Sadiq I (2010). Effect of climate change on cocoa yield'. Journal of Sustainable Development in Africa. 12(1).

Olaniyi OE, Atalor NO (2018). Land use/land cover dynamics around ecotourism attractions and support facilities in Ikogosi Warm Spring Resorts, Nigeria. Journal of Forestry Research and Management. 15(1):196-220.

Oyinloye RO, Oloukoi J (2012). Spatio-temporal assessment and mapping of the land use land cover dynamics in the central forest belt of southwestern Nigeria. Research Journal of Environmental and Earth Sciences 4(7):720-730.

Perveen F, Nagasawa R, Uddin I, Hossain KMD (2007). Crop-Land Suitability Analysis Using a Multicriteria Evaluation & Gis Approach. 5th International Symposium on Digital Earth. The University of California, Berkeley, USA pp. 1-8.

Poongothai S, Sridhar N, Shourie RA (2014). Change Detection of Land use/ Land Cover of a Watershed using Remote Sensing and GIS. International Journal of Engineering and Advanced Technology 3(6):226-230.

Saaty TL, Vargas LG (1980). Prediction, projection and forecasting. Dordrecht, the Netherlands: Kluwer Academic Publisher.

Sharma MP, Ravindra P, Babu TP, Pal O, Hooda RS (2015). Land Use/Land Cover Change through the Applications of GIS and Remote Sensing in blocks of Mahendragarh district of NCR, Haryana. International Journal of Science, Engineering and Technology Research 4(9).

Shi G, Nan JID, Yao L (2018). Land Use and Cover Change during the Rapid Economic Growth Period from 1990 to 2010: A Case Study of Shanghai. Sustainability 10:426-441.

Tunde AM (2011). Perception of Climate Variability on Agriculture and Food Security by Men and Women Farmers in Idanre L.G.A, Ondo State. Nigeria. Ethiopian Journal of Environmental Studies and Management 4(2):1-14.

Udo RK (2001). Geographical regions of Nigeria. Oxford University Press. Ibadan.

Van Asselen S, Verburg PH (2012). A Land System representation for global assessments and land-use modeling. Global Change Biology 18:3125-3148.

Yadav PK, Kapoor M, Sarma K (2012). Land Use Land Cover Mapping, Change Detection and Conflict Analysis of Nagzira-Navegaon Corridor, Central India Using Geospatial Technology. International Journal of Remote Sensing and GIS 1(2):90-98.

Zuidema PA, Leffelaar PA, Gerritsma W, Mommer L, Anten NPR (2005). A physiological Production Model for Cocoa (Theobroma cacao): Model Presentation, Validation and Application. Agricultural Systems 84:195-225.