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Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research

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

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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.

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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

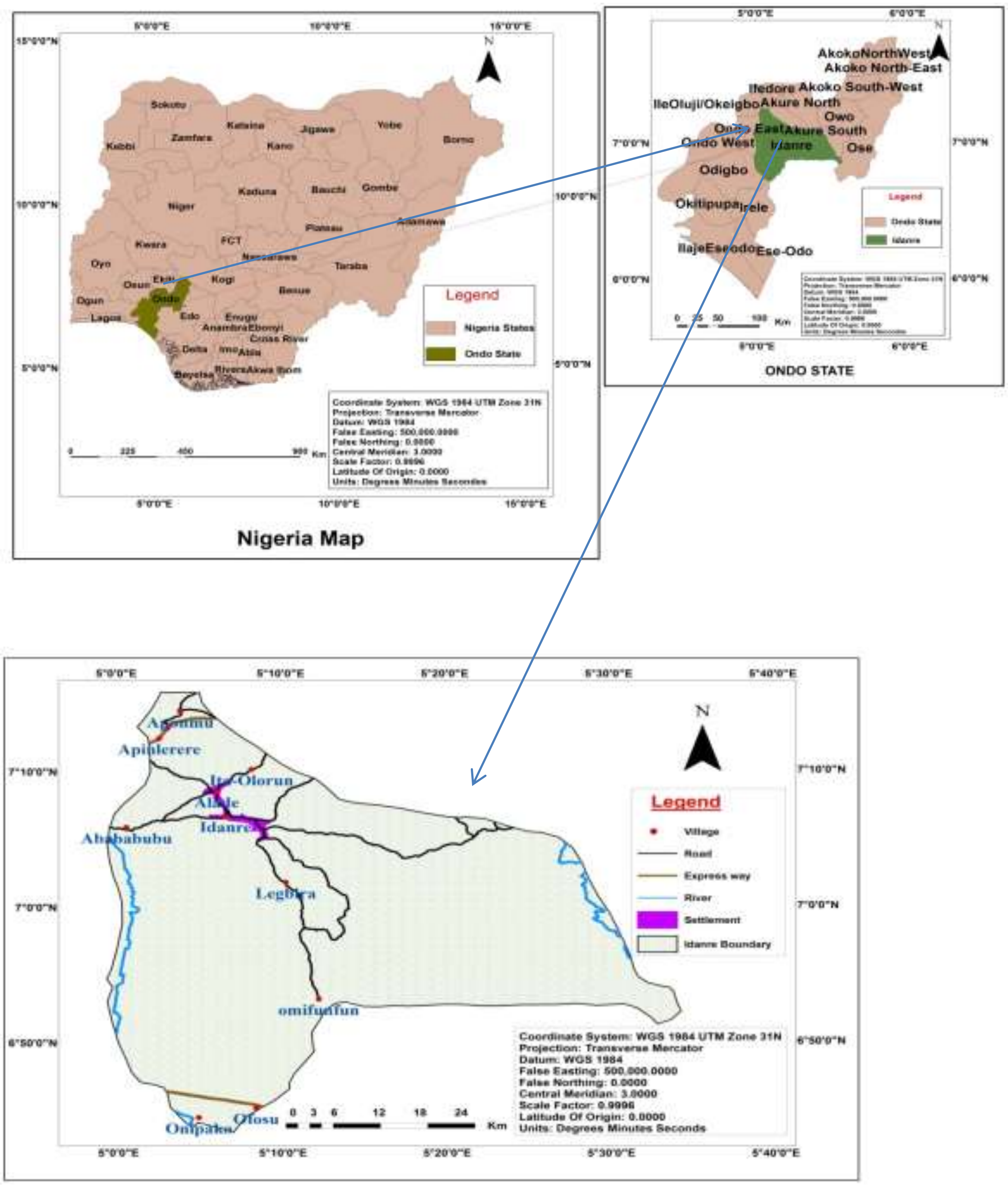

Figure 1. Map of Idanre.

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

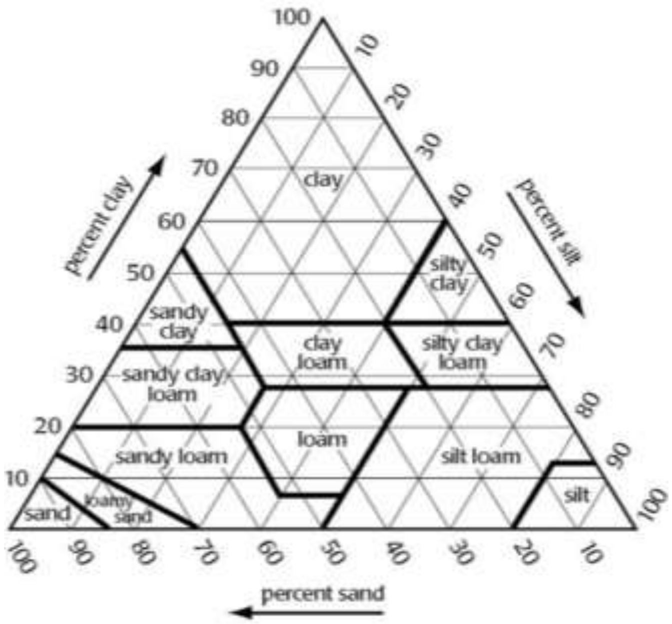

Figure 2. Soil triangle (*Source*: www.nbcsd.org).

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:

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

Where, ΔLULC = 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:

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

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
	S1 (Highly suitable)	Land having no significant limitations to sustained application of a given use.
Orders (suitable)	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 km^2), cultivated area 19% (373.3405 km^2), forest 72% (1414.764 km^2), and rock 3% (58.9485 km^2) (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 km^2) in forest, an increase of 3% (58.9485 km^2) in built up, and an increase of 9% (176.8455 km^2) 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

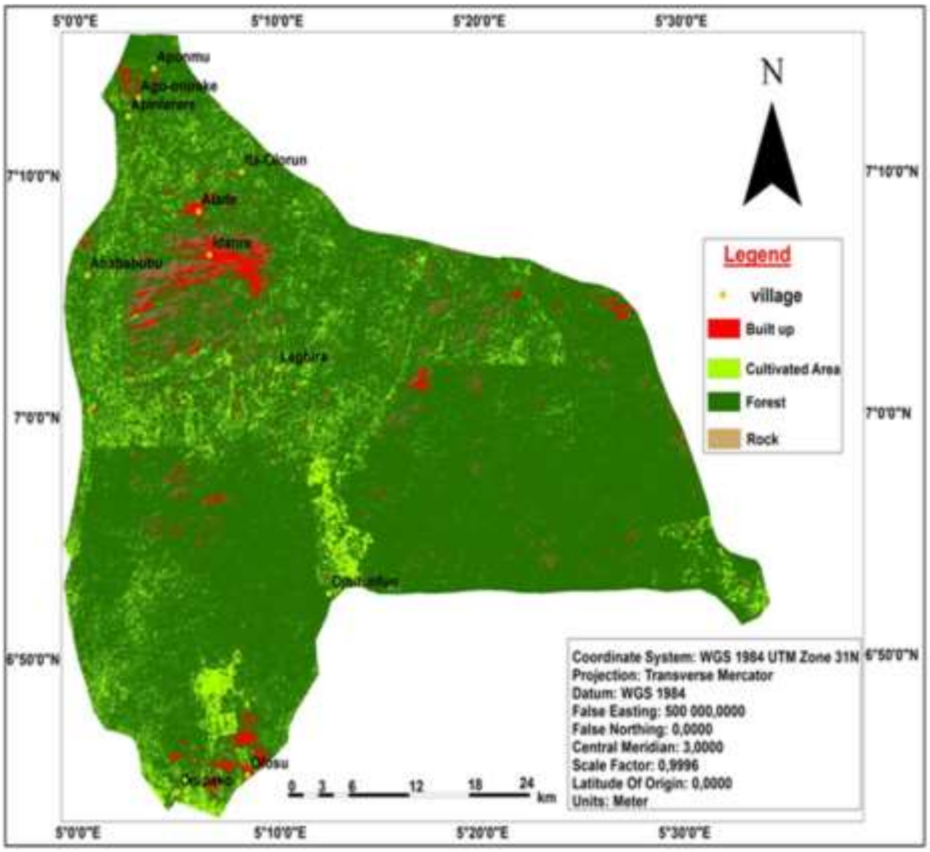

Figure 3. LULC in 2002.

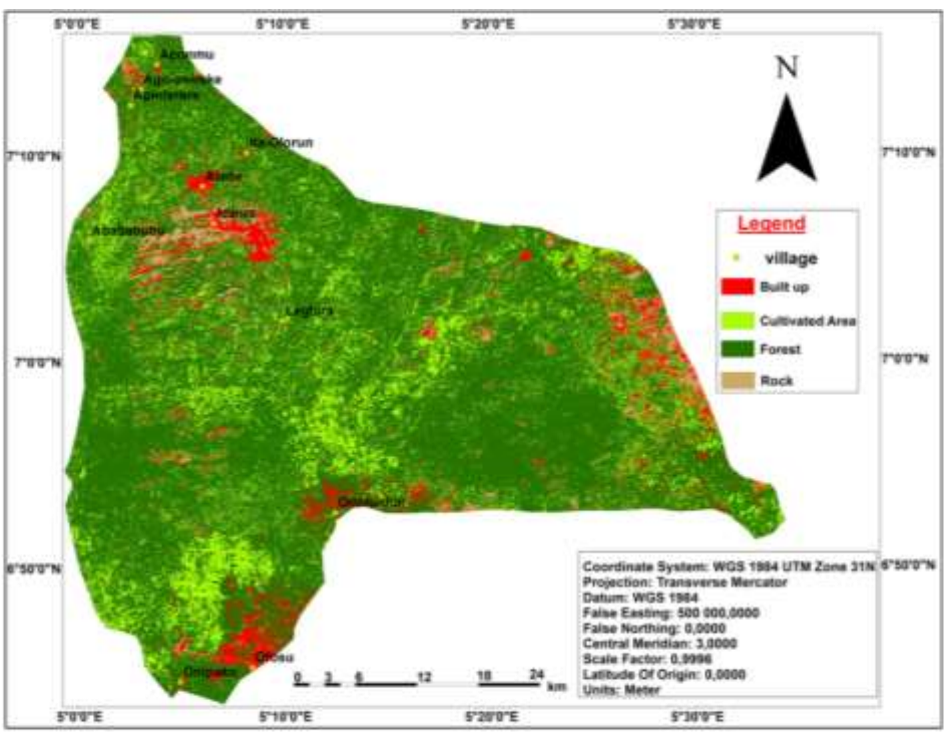

Figure 4. LULC in 2015.

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

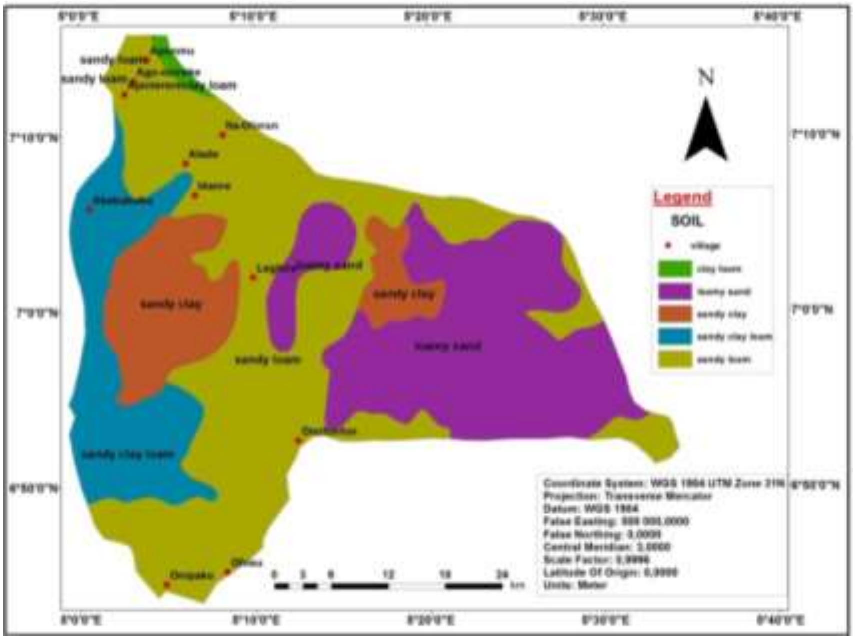

Figure 5. Soil map of Idanre.

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

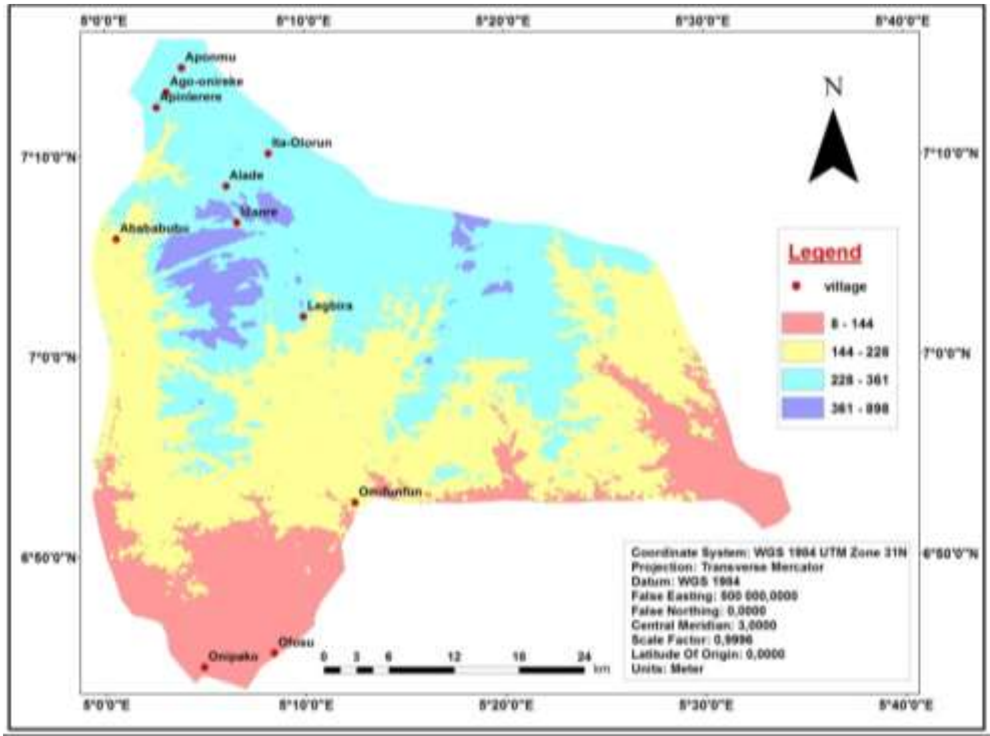

Figure 6. DEM of Idanre.

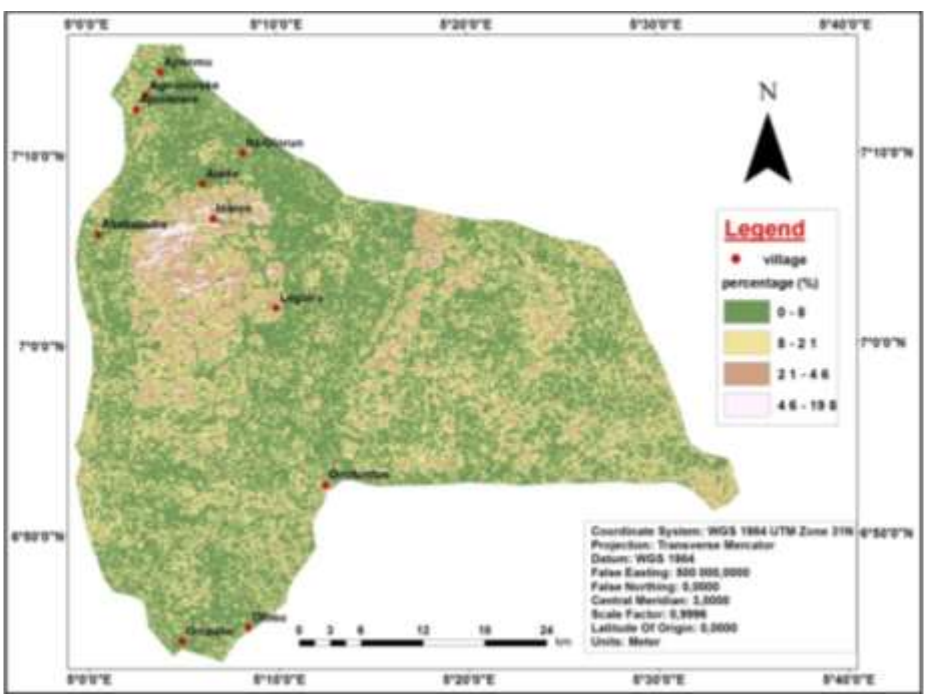

Figure 7. Slope of Idanre.

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,

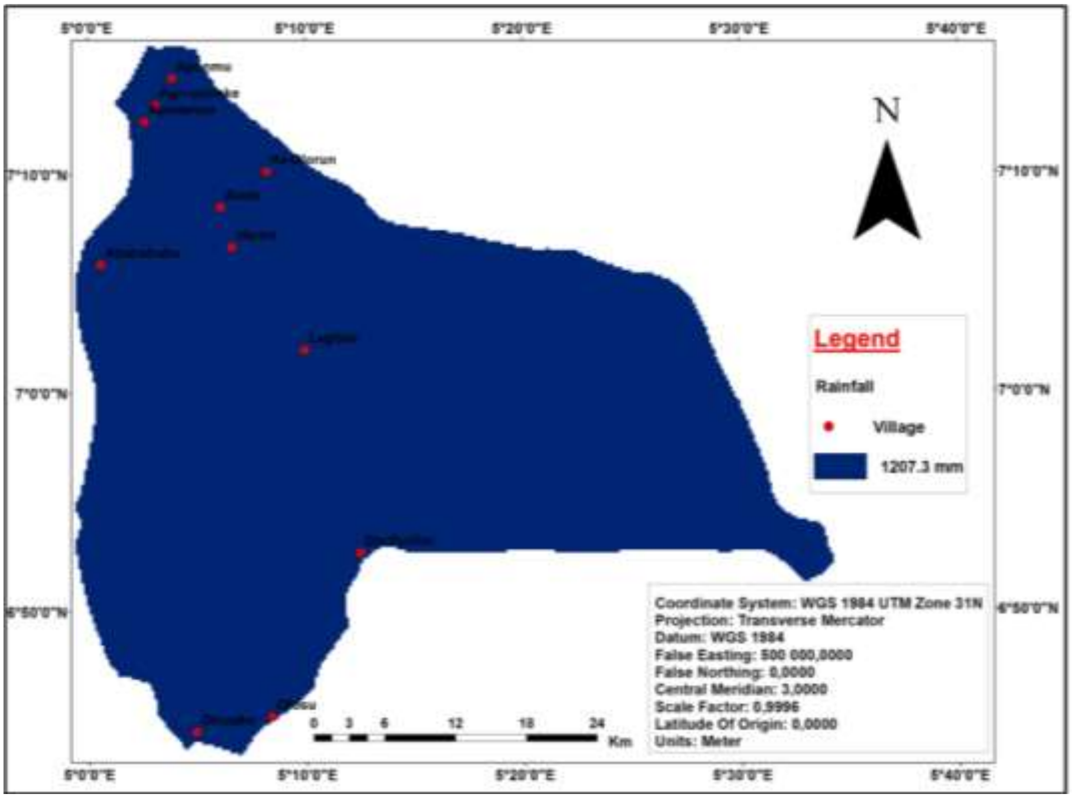

Figure 8. Rainfall map of Idanre.

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 km²) of the study area is highly suitable, whereas 19.23% (377.859885 km²) is moderately suitable and 8.47% (165.0558 km²) 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,

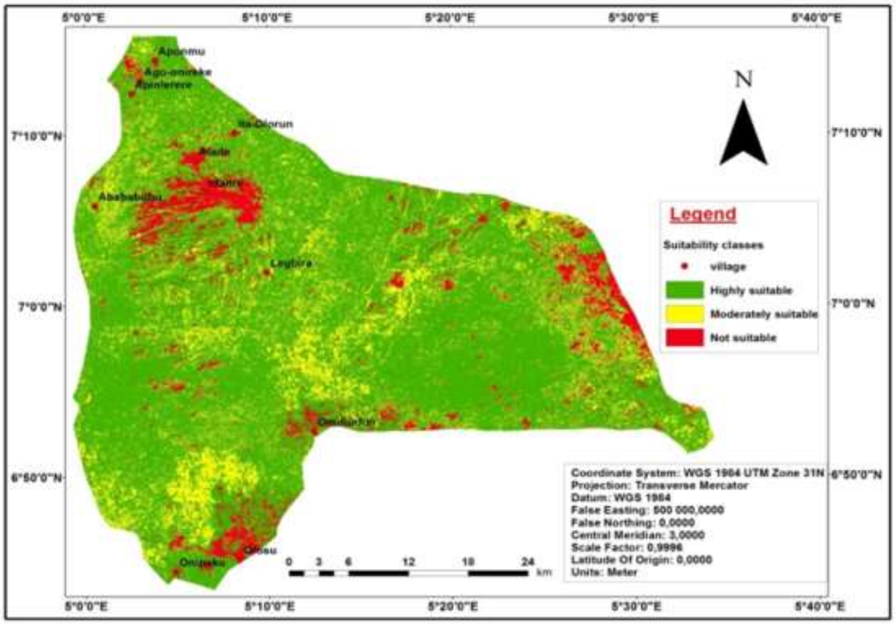

Figure 9. Reclassified LULC.

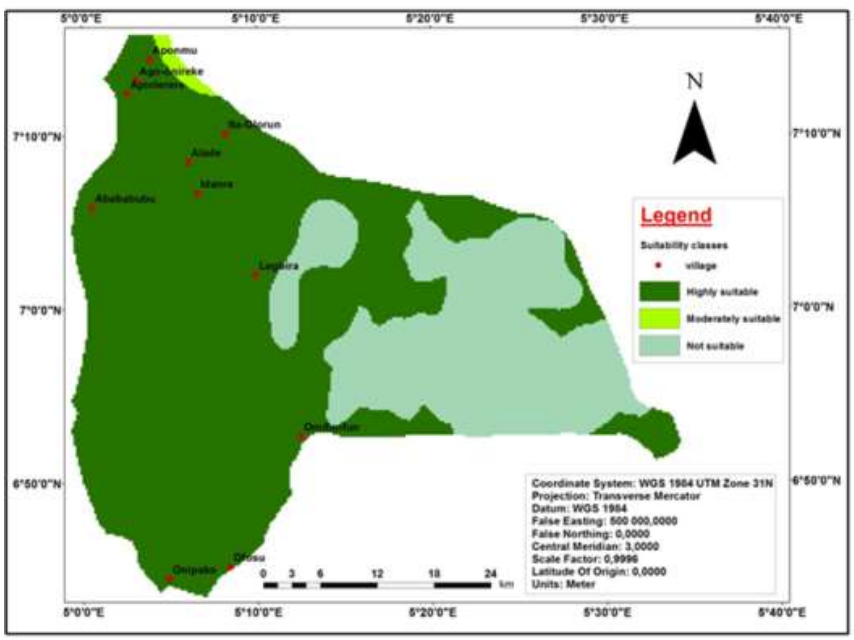

Figure 10. Reclassified soil.

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

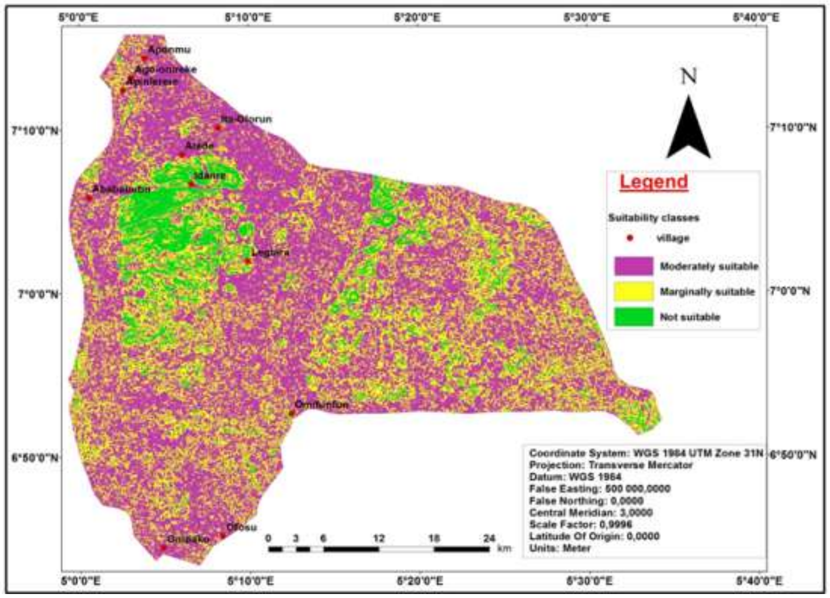

Figure 11. Reclassified slope.

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

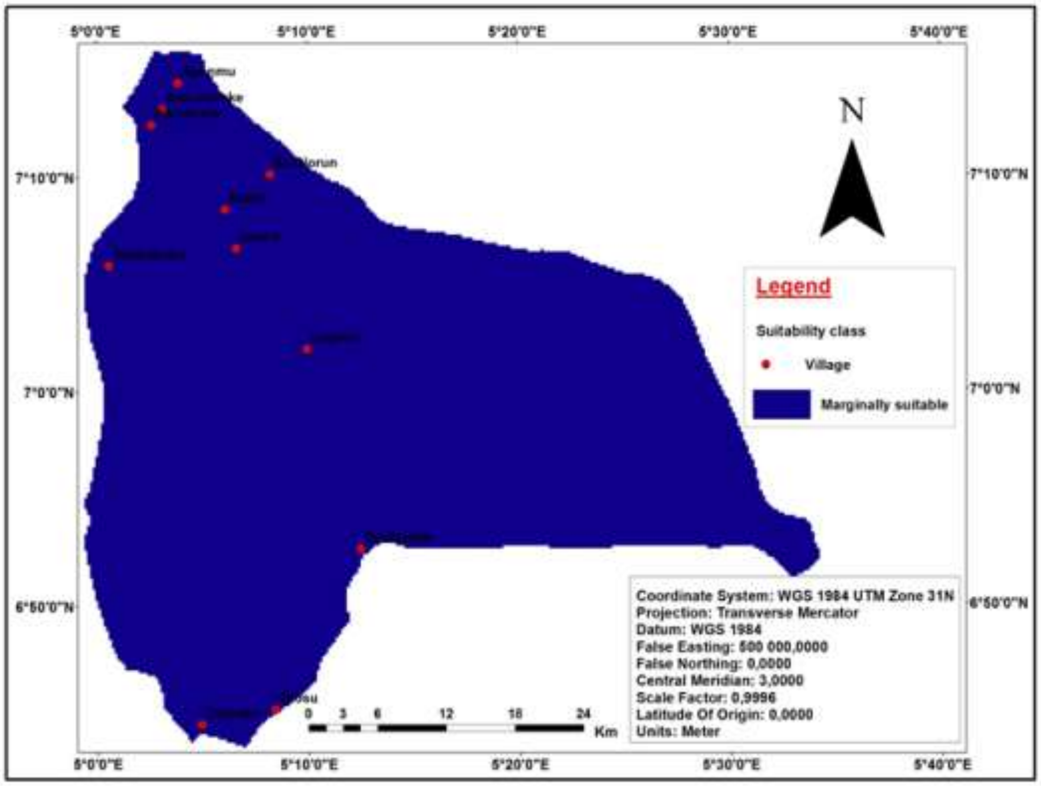

Figure 12. Reclassified rainfall.

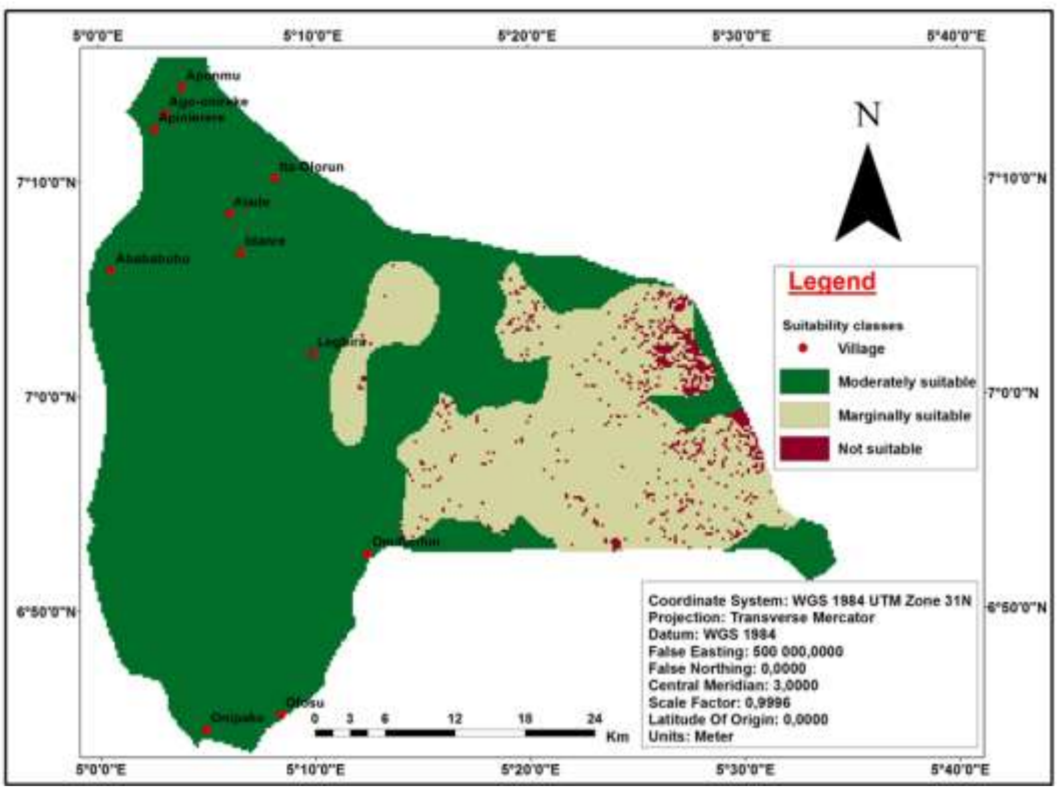

Figure 13. Suitability map for cocoa cultivation in Idanre.

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.

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Full Length Research Paper

Enhancement of tef production through popularization of improved Quncho tef variety at Northwestern Zone of Tigray, Ethiopia

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Tef [*Eragrostis tef (Zucc*.) Trotter] is a cereal crop resilient to adverse climatic conditions. Tef is the most important crop that serves as human food and has a great contribution to food security in Ethiopia, but grain yields are low. Towards enhancing the production and productivity of the tef, the government and non-governmental bodies is therefore promoting the adoption of improved varieties, fertilizers and improved practices. This study was conducted with the aim of enhancing tef production through popularizing the improved Quncho tef variety. The study was executed at three tef growing districts of northwestern Tigray, Ethiopia. A total of 222 farming households who are the safety net program beneficiaries were included in the study. An average grain yield of 1.43 and 1.05 ton/ha was obtained from Quncho and local tef varieties, respectively. This indicates Quncho tef gave 36/% yield advantage over the local tef variety. This will have a significant contribution to the efforts towards improving food security of the farm households. Moreover, Quncho tef were selected by the farmers in attributes like, tillering ability, spike length, biomass yield, seed color, market preference and grain yield as compared to the local one. Therefore, it is recommended that, the agriculture and rural development office of the respective districts and other stakeholders should further scaled out Quncho tef variety to large number farmers of the study areas.

Key words: Farmers perception, popularization, Quncho tef, *Eragrostis* tef, Tigray, Ethiopia.

INTRODUCTION

Tef [Eragrostis tef (Zucc) Trotter] is a cereal crop that belongs to the family Poaceae. Tef is indigenous to Ethiopia (Seyfu, 1991; National Research Council, 1996). According to Ponti (1978) the history of tef cultivation goes back to 6000 years. Tef is grown under diverse agro-climatic zones. It can thrive well in both waterlogged as well as drought condition (Assefa et al., 2010). Tef in Ethiopia is cultivated in about 3.01 million hectare and accounts for 29.5% of the area allocated for cereals and 19.7% of gross cereal production (CSA, 2017).

Tef is primarily grown in Ethiopia as human food. However, its straw is highly valuable which is highly preferable by cattle and its price was higher than the straw of other cereals (Ketema, 1997).

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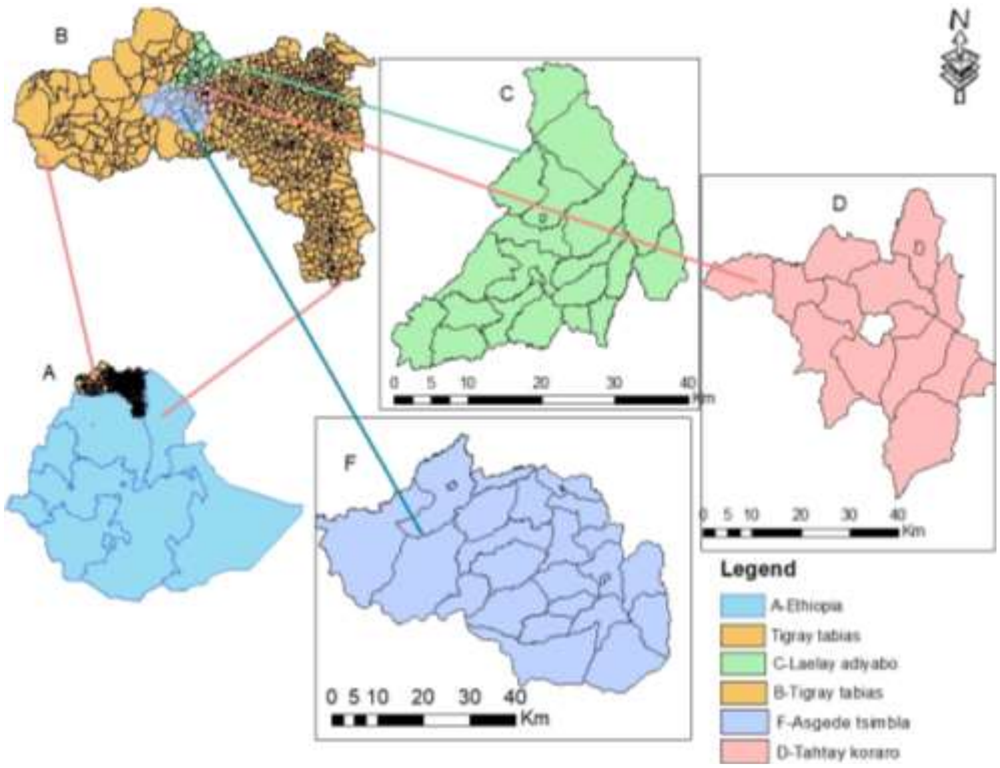

Figure 1. Map of the study area.

Tef is Ethiopia's most important staple crop. Tef has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of tef is second followed by coffee (Minten et al., 2013).

It would seem that because of its superior nutritional qualities, tef would be available to all persons in Ethiopia to make Enjera. Tef with 11% of protein is an excellent source of essential amino acids, especially lysine (the amino acid that is most often deficient in grains) (Ayalew et al., 2011). Tef grain is rich in iron, calcium, and fiber and the grains are low on the glycemic index, which makes them suitable for people and the grain is also gluten-free (FAO, 2015).

However, despite its importance in Ethiopia, tef yields are low. In the production year of 2016/2017, the average tef grain yield 1.66 tons per hectare is low compared to other cereals, such as maize (3.67 t/ha), sorghum and wheat (2.52 and 2.67 t/ha) (CSA, 2017). This low yield of tef is mainly attributed to lodging, moisture stress, shattering, and poor pre- and post-harvest agronomic management and low modern inputs use (Assefa et al., 2011; Fufa et al., 2011).

However farmers using improved cultivars and management practices, can obtain yields up to 2.5 t/ha (Tefera and Belay, 2006), while the yield potential of tef under optimal management can give up to 4.6 t/ha (Teklu and Tefera, 2005).

Tigray specifically northwestern zone is among the potential tef producing areas. But, due to lack of improved technologies and management practices, tef production remained low. To improve tef production in the area, Quncho tef variety which was released in 2006 (MoARD, 2008) was introduced via Shire-Maytsebri Agricultural Research Center in collaboration with different research centers and projects. Thus, the study was aimed at boosting production and productivity of tef through popularization of Quncho tef variety and to collect the farmers perception towards the variety.

METHODS AND APPROACHES

Location of the study area

Quncho tef variety popularization was conducted at three potential tef producing districts of Northwestern Tigray, Ethiopia. A total of seven Kebelles/villages were included in the study based on their potential for growing tef. The study was executed in 2012/13 at Tahtay Koraro, Asgede Tsimbla and Laelay Adyabo districts. Farming system of the study area is mixed farming, mostly crop and livestock production.

Asgede Tsimbla is found at 13° 73'N to 14o 21'N and 37° 59'E to 38° 31'E. The district has 25 to 35°C of temperature and 500 to 900 mm annual rainfall. Laelay Adyabo district is located at 14° 08 N to 14° 69 N and 37° 89'E to 38° 46'E and annual rainfall is 605 to 1370 mm. While Tahtay Koraro district is found at 13° 9N to14° 27N and 38° 05'E to 38° 45'E and annual rainfall ranged from 800 to 1000 mm (Figure 1).

Figure 2. Quncho tef variety performance at farmer's field at Laelay Adyabo, 2012/13 production season.
Sources: Photo recorded with the researchers during the field day (November, 2013)

Beneficiaries selection and implementation procedures

Beneficiary farmers were selected based on the criteria and objectives of the operational research for technology dissemination project and interest of farmers to participate in the demonstration trials. In addition, the safety net program beneficiaries and disadvantaged households (youths and women headed household) were the main focus of the project. The participating farmers were selected by office of agriculture and rural development of respective districts (Figure 2). A total of 222 farming households (24 female and 198 male) were selected from the three districts for the intervention of Quncho tef variety. The major criteria for selection of the respondents were; their interest to join the program and their food security status. All the target groups were recipients of the Productive Safety Net Program.

Each farmer was allocated the plot size ranged from 0.25 to 0.5 ha. 3 to 8 kg of Quncho seed were offered to each of the respondents by Operational Research Technology Dissemination Project. Farmers, experts and development agents were trained about the improved varieties and improved agricultural practices such as seed rate, fertilizer rate, planting methods (row planting) and crop protection. All the technical implementation and backstopping was managed by researchers, district experts and development agents of the Kebelles. The host farmers were expected to apply all necessary management practices as the recommendations.

Methods of data collection and analysis

Both primary and secondary data were collected. Primarily data like qualitative and quantitative data were collected quantitative data (grain yield) were collected using quadrant from the plot area of 1 m*1 m and qualitative data were collected from the beneficiaries using the checklist. The scales of poor, same and good were used for the parameters including tolerance to insect and diseases, spike length, tillering ability, stand ability (lodging), plant height, drought tolerance, seed color, marketability, straw palatability, biomass yield and grain yield were used to collect the qualitative data from the farmers. Secondary data were collected from different relevant published and unpublished sources. The collected quantitative data was analyzed using descriptive statistics such as mean and percentages.

RESULTS AND DISCUSSION

Grain yield of Quncho tef variety

Production comparison between Quncho and local tef varieties were computed. The result obtained from the two tef varieties is presented in Table 1. As shown in Table 1, an average grain yield of 1.43 and 1.05 ton/ha were obtained from the improved tef (Quncho) and local tef variety, respectively. The result shows, Quncho tef variety was given 36% yield increment over the local tef variety. In line with this, the report of Kebebew et al. (2011) shows Quncho tef gave an average on-farm grain yield of 1.27 ton/ha. But, the on-station research result of Quncho tef variety shows the variety gave an average grain yield of 2.46 ton/ha (Kebebew et al., 2011). The higher grain yield of the Quncho tef variety is attributed due to less lodging, better tillering and the longer spike length of the variety.

In Ethiopia tef is cash crop and economically superior commodity for producers (FAO, 2015). Tef commands a market price of 2 to 3 times higher than maize (Abraham, 2015). So the higher grain yield, obtained from Quncho tef variety in the study area has higher contributions to improve income and food security of the household.

Farmers perception on attributes of Quncho tef variety

The perception and insight of farmers' on the overall performance of the improved tef variety as compared to the local variety were assessed. The attributes that was used to survey the farmers perception; tolerance to insect and diseases, spike length, tillering ability, stand ability (lodging), plant height, drought tolerance, seed color,

Table 1. Grain yield of Quncho versus the local tef variety in the stud area.

SN	Woredas	Kebelles	Grain Yield of Quncho tef (quintal/ha)	Grain yield of local (ton/ha)	Yield increment over the local variety in (%)
1	Tahtay Koraro	Maidmu	1.5	1.2	25
		Lemlem	1.4	1.0	40
		Adigdad	1.57	1.22	28.5
2	Laelay Adyabo	Hibret	1.4	0.95	47
		Adiabagie	13	0.8	62.5
3	Asgede Tsimbla	Lemlem	1.42	1.15	23.5
	Mean		1.43	1.05	36.19

Sources: Complied from own data, (2012/13).

Table 2. Farmers' perception on attributes of Quncho tef variety versus local variety.

S/N	Parameter	Kebelles and perception levels								
		Adigdad			Belles			Lemlem		
		Poor (%)	Same (%)	Good (%)	Poor (%)	Same (%)	Good (%)	Poor (%)	Same (%)	Good (%)
1	Tolerance to insects and disease	28	29	43	33	50	17	17	33	50
2	Biomass yield		14	86		17	83		17	83
3	Tillering		29	71			100			100
4	Stand ability		29	71		17	83			100
5	Plant height		15	85		17	83		17	83
6	Spike length			100			100			100
7	Drought tolerance	71	29		67	33		67	33	
8	Grain yield			100			100			100
9	Seed color			100			100			100
10	Market preference			100			100			100
11	Straw palatability	28	29	43	17	33	50	33	17	50

Sources: Complied from own data, (2013/14).

marketability, straw palatability, biomass yield and grain yield; along with the scales of poor, same and good. The farmers perception result shows that, the participant farmers perceive the improved Quncho tef variety as favour in its tillering ability, spike length, biomass yield, seed color, market preference and grain yield (Table 2). Similar to this study, the finding of Belay et al. (2008) also indicate that Quncho fits the most important farmers' selection criteria driven by market, seed colour and yield. On the other side, the farmers in the area criticized negatively the improved variety in the attributes like less drought tolerance and less straw palatability as compared to the local tef variety. But less straw palatability does not mean the animals are not feeding the straw but it means that they prefer the local tef straw than the improved one if you gave them aside. The straw of tef in the area is stored and serves as a very important source of animal feed, especially during the dry season.

CONCLUSION AND RECOMMENDATION

The study concludes that the Quncho tef showed higher grain yield and better perception by the farmers compared to the local tef cultivars. Quncho tef variety scored yield advantage of 36% over the local tef. This shows that the farmers who planted Quncho tef variety have high grain yields than the planted local varieties. Thus, Quncho tef is one of the alternatives that could help in enhancing production and productivity of tef and this play a vital role in improving household food security. Hence, the study recommended that:

1. The agriculture and rural development offices of the districts and other stakeholders should further disseminate the Quncho variety to large number of farmers of the similar agro ecologies.
2. Ensure sustainable seed supply both in quality and

quantity of Quncho tef variety.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effect of fermentation on sorghum and cowpea flour blends

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This study was designed to investigate the suitable proportions of cowpea that can be used to improve the nutrient content of sorghum and also to ascertain the effect of fermentation on the sample blends. The raw and fermented sample blends were analyzed for microbial load, proximate composition, mineral and anti-nutrient contents. The microorganisms isolated were *Staphylococcus aureus*, *Bacillus cereus*, *B. polymyxa*, *B. licheniformis*, *Lactobacillus fermentum*, *L. acidiophilus*, *L. plantarum Streptococcus lactis*, *Aspergillusf lavus, A. fumigatus, A. niger, Mucor mucedo* and *Rhizopus nigricans*. Moisture content of unfermented sample blends ranged between 0.75 and 1.07% while that of fermented blends ranged between 26.96 and 42.65% respectively. Unsupplemented cowpea recorded the highest level of ash content before and after fermentation but crude protein increased after fermentation. Unsuplemented cowpea recorded the highest level of protein content. Cowpea: sorghum (7:3) also had a significant amount of protein when compared with sorghum: cowpea (8:2). Carbohydrate content reduced after fermentation while anti-nutrient content reduced significantly after fermentation process. There was significant increase in protein content of sorghum supplemented with cowpea, and a drastic reduction in the anti-nutrient content of all the fermented sample blends. Therefore, it can be concluded that sorghum supplemented with cowpea, then fermented for 72 h could be recommended for improving the protein quality of sorghum.

Key words: Sorghum, fermentation, anti-nutrient, *Lactobacillus fermentum*, cowpea.

INTRODUCTION

Sorghum (*Sorghum bicolor*) is a staple cereal based food that has been reported to be a major source of energy in most African's diet (Elkhier and Hamid, 2008). Smith and Frederiksen (2000) and FAO (2005) also documented that sorghum is the 5th most important grain crop after wheat, maize, rice and barley which belongs to a member of the family Poaceae. It is a drought tolerant crop that provides a good source of energy and antioxidant (Taylor et al., 2006; Duodu et al., 2003). Sorghum thrives on a wide range of soils from light loams to heavy clays but

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grows well on light sandy soils (Kimber, 2000), tolerates a range of soil acidity from pH 5.0-8.5 and has a moderate tolerance to salinity (Cothren et al., 2000). Sorghum is composed of mainly starch, about 75-79% of grain weight, comprises of 70-80 amylopectin and 20-30% amylose (Waniska et al., 2004). The pericarp and germ of sorghum grains are rich in minerals such as iron, zinc, potassium, phosphorus, dietary fibre, B vitamins and essential fatty acids such as linoleic acid (49%), oleic (31%), palmitic (14%), linolenic (2.7%) and stearic (2.1%) (FAO, 1995; USDA, 2014) which is sometimes lost during dry and wet milling processes (Taylor, 2003).

Sorghum is used in the production of different food varieties such as: bread, porridge, pancakes, muffins, dumplings and breakfast cereals like ogi (Taylor, 2003). It contains more fat than wheat and rice but slightly less than corn. Sorghum is a very important food crop because it is gluten-free which makes it an excellent replacement for people that are allergic to gluten intake (Farmcrowdy, 2017).

Cowpea (*Vigna unguiculata* [L] Walp) has been reported to be the most important food legume in the dry savanna of tropical Africa (AATF, 2005). It is consumed by millions of people in the tropics, especially Africa (AATF, 2005). Cowpea is very rich in protein and contains almost as much energy by weight as cereal grains (USDA, 2014). This has however made it a good compliment to fortify weaning foods such as sorghum. The technique employed in traditional weaning food formulations include the use of composite foods made from cereal and legumes such as cowpea (Sefa-Dedeh et al., 2001). It is also used in the preparation of various foods such as “akara” (a fried cowpea paste), “moi-moi” (a steamed cowpea paste) and “kpejigaou” (a griddled cowpea paste) (Phillips et al., 2003; Amonsou et al., 2008). Cowpea contains an average of 24 g protein/100 g and 7 g lysine/100 g protein (Philips et al., 2003). According to FAOSTAT (2015), Nigeria is the World’s largest producer pf cowpeas followed by Niger.

The protein inherent to cowpeas is located in the cotyledons while the minerals are concentrated on the seed coat (Adebooye and Singh, 2007). Cowpeas are majorly cultivated for human consumption in sub-saharan Africa countries, but it can also be used as animal feed, and raw material for processing green manure used to improve soil fertility (Singh et al., 2003, 2011). The fresh green seeds can be roasted as snacks for human consumption and it can also be used to make soups and a variety of delicacies. The dried seeds can also be used to prepare soup such as “gbegiri” (Onyenekwe et al., 2000). Cowpea is a nitrogen fixing plant which makes the soil more conducive for the cultivation of vegetables and other staple foods (Singh et al., 2003). However, despite the high content of cowpea, it contains some indigestible sugars such as reffinose and stachyose (Onyenekwe et al., 2000) which produces flatulence when consumed. Soaking and blanching has been documented to reduce the levels of these indigestible sugars that inhibits iron and calcium absorption (Hotz and Gibson, 2007; Lestienne et al., 2005). However, fermentation have been documented to improve protein digestibility and food quality in terms of increase in amino acids and vitamins production. Hotz and Gibson (2007) also reported that fermentation improves food safety and confers microbial stability in the fermented food product. Therefore, the objective of this study was to evaluate the effect of fermentation on the proximate composition, mineral content, anti-nutrient contents, physicochemical properties and microbial characteristics of sorghum-cowpea flour blends as well as the general acceptability through the development of a fortified food product.

MATERIALS AND METHODS

Source of materials

Dry sorghum (*S. bicolor*) and cowpea (*V. unguiculata* [L] Walp) grains were purchased from Oja-oba, a local market in Akure, Ondo state, Nigeria. The samples were transported to the laboratory in clean low density polythene bags.

Preparation of samples

Grits and stones were sorted to remove extraneous materials, after which the sorghum-cowpea samples were divided into four (4) portions, coded A, B, C and D. Portions A and B were 500 g of whole cowpea and sorghum respectively, portion C was a ratio of cowpea and sorghum (7:3), while portion D was a ratio of sorghum and cowpea (8:2). Each of the samples was mixed with 100 ml distilled water inside a 250 ml clean plastic container labeled A-D. These containers were taped at the edges and subjected to spontaneous fermentation for 72 h at room temperature. At the end of fermentation process, the samples were dried in an hot air-oven at 65°C for 24 h and then packaged in low density polythene pouches and stored at 8°C prior to further analyses.

Proximate composition

The moisture, crude protein (Marcokjeldahl method), ash, crude fat, crude fibre, carbohydrate, mineral contents of samples were analyzed before and after 72 h of fermentation using the method described by the Association of Official Analytical Chemists (AOAC, 2012). The total carbohydrate content was calculated by difference method (subtracting the sum of % moisture, crude protein, crude fat and ash from 100%).

Mineral contents

5 g of sample were heated in a muffle furnace until white-grey ash powder was obtained. The ash powder was allowed to cool. 20 ml of distilled water and 10 ml of diluted hydrochloric acid was added to the ash powder. The mixtures were analyzed for heavy metals such as: potassium (K), sodium (Na), magnesium (Mg) and lead (Pb) using atomic absorption spectrophotometer; Bulk Scientific

Model VGB 210 System (2008) edition 6 (AOAC, 2012).

Anti-nutrient contents

Tannin

0.2 g of finely ground sample was weighed into a 50 ml sample bottle, 10 ml of 70% aqueous acetone was added to it and mixed thoroughly. The bottles were kept in ice bath shaker and shaken for 2 h at 30°C. Each solution was then centrifuged and the supernatant stored in ice. 0.2 ml of the solution was pipetted into a test tube and 0.8 ml of distilled water was added. Standard tannin acid solutions were prepared from a 0.5 mg/ml of the stock and the solution made up to 1 ml with distilled water. 0.5 ml of Folin Ciocaeteau reagent was added to both sample bottles and standardized by pipetting 2.5 ml of 20% Na_2CO_3. The bottles were vortexed and incubated for 40 min at room temperature after which its absorbance was read at 725 nm using AJ- IC03 spectrophotometer against a reagent blank concentration of the same solution from a standard tannic acid curve that was prepared (AOAC, 2012).

Tannin acid 1 ml extract = $\frac{R \, x \, 100}{Ml \, of \, sample \, used}$

Where, R = result read from the standard curve.

Oxalate

One gram sample was weighed into 1000 ml conical flask. 0.75 M H_2SO_4 was added and stirred intermittently with a magnetic stirrer for 1 h. The mixture was filtered using Whatman No. 1 filter paper. A 25 ml of sample filtrate (extract) was collected and titrated hot (80-90°C) against 0.1 $MKMnO_4$ solution to the point when pink colour appeared that persisted for at least 30 seconds (AOAC, 2012)

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Phytate

4 g of sample was soaked in 100 ml of 2% HCl for 3 h and filtered using Whatman No. 1 filter paper. 25 ml of the filtrate was placed in 100 ml conical flask and 5 cm^3 of 0.03% of ammonium thiocynate solution (NH_4SCN) was added as an indicator. 50 ml of distilled water was added to the solution and titrated against 0.00566 g per milliter of standard iron (iii) chloride solution which contains 0.00195 g of iron per milliliter until a brownish yellow colouration appears and lasted up to 5 min. Phytate content in mg/100 g was calculated (AOAC, 2012).

Iron equivalent = litre value x 1.95
Phytic acid = litre value x 1.95 x 1.19 x 3.55 mg/phytic acid.

Saponin

0.5 g of sample was weighed into a 20 ml test tube and 10 ml of 80% ethanol was added. The mixture was shaken on a shaker for 5 h to ensure uniform mixing and filtered through a Whatman No. 1 filter paper into a 100 ml beaker. 20 ml of 40% saturated solution of Magnesium carbonate added was added to the filtrate. The mixture was saturated with $MgCO_3$ and filtered again through a Whatman No 1 filter paper to obtain a clear colourless solution. 1 ml of the colourless solution was pipetted into 50 ml volumetric flask and 2 ml of 5% FeCl3 solution was added. The mixture was allowed to stand for 30 min for a blood red colour to develop. 0-10 ppm standard saponin solutions was prepared from saponin stock solution. The standard solutions were treated similarly with 2 ml of 5% FeCl solution. The absorbances of the sample as well as standard saponin solutions were read after colour development on a Spectronic 2lD Spectrophotometer at a wavelength of 380 nm (AOAC, 2012).

Physico-chemical properties

The method described by AOAC (2012) was used to determine the pH and titratable acidity of the fermenting medium. Samples were taken every 24 h during the fermentation period using the method described by Fayemi and Ojokoh (2014). The pH of the samples was determined using an Orion pH meter (Model 310, Orion Research Inc, Beverly, MA) equipped with glass electrode. The titratable acidity (TTA) was determined by titrating 10 ml of thoroughly mixed sample against 0.1 M NaOH, using phenolphthalein as an indicator. Values obtained were expressed as % lactic acid. All analyses were carried out in triplicate.

Microbial characteristics

The microbial profile of the raw (control) and fermenting blend samples were determined at 24 hr interval. The changes in microbial population (cfu/g) of the total aerobic bacteria was determined using nutrient agar (NA) (Merck, Darmstadt, Germany) while De Man, Rogosa and Sharpe (MRS), (Merck) and M17 agar media (Oxoid, Basingstoke, Hampshire, England, UK) was used for the isolation of lactic acid bacteria (LAB). Four different colonies were randomly picked using visual assessment from the highest dilution factor of MRS and M17 agar plates to determine the dominant bacteria during the fermentation of the blends. All the samples were analyzed by homogenizing 1g of the fermenting blend with 9 ml sterile 0.1% buffered peptone water (BPW) (Merck) followed by appropriate dilutions, spread plating and incubation at the required temperatures. The NA agar plate were incubated at 37°C for 24 h while MRS agar plates were incubated anaerobically using anaerobic jar together with anaerocult system (Merck) at 37°C for 48 h. Colonies were selected randomly, purified and subjected to various biochemical tests such as: motility, spore staining, citrate, catalase, coagulase, etc. and sugar fermentation tests which includes: glucose, lactose, mannitol, etc according to the method employed by Ojokoh et al. (2015).

Statistical analyses

Analysis of variance (ANOVA) was performed on the data at $p \leq 0.05$ using MINITAB statistical software (Minitab® Release 14.13, Minitab Inc., USA). Significant means were separated using the least significant difference (LSD) at $p \leq 0.05$.

RESULTS

Proximate composition

The proximate composition of fermented and unfermented sorghum and cowpea flour blends is shown in Table 1. Moisture contents of sorghum and cowpea samples before fermentation (control) was 0.75 and 0.83%

Table 1. Proximate composition of fermented and unfermented sorghum and cowpea flour blend samples.

Sample	Component (%)											
	Moisture		Ash		C .Protein		C. Fat		C. Fibre		Carbohydrate	
	Raw	Fermented	Raw	Fermented	Raw	Fermented	Raw	Fermented	Raw	Fermented	Raw	Fermented
Cowpea	0.83±0.06[a]	42.65±0.5[c]	1.89±0.3[d]	0.82±0.01[c]	22.63±0.57[d]	28.61±0.59[d]	2.07±0.02[d]	0.93±0.01[c]	1.09±0.01[a]	0.75±0.01[a]	72.57±0.43[a]	28.18±0.82[a]
Sorghum	0.75±0.14[a]	28.57±0.5[a]	1.06±0.04[a]	0.57±0.05[a]	4.12±0.07[a]	7.20±0.01[a]	1.11±0.08[b]	0.43±0.01[a]	4.90±0.04[d]	2.05±0.04[d]	89.26±0.83[c]	61.85±0.14[d]
Cowpea:sorghum (7:3)	1.07±0.03[a]	39.94±0.[b]	1.69±0.02[c]	0.67±0.03[b]	19.80±0.30[c]	22.12±0.18[c]	1.77±0.05[c]	0.63±0.02[b]	2.05±0.01[b]	0.89±0.01[b]	74.52±0.47[a]	36.49±0.01[b]
Sorghum: cowpea (8:2)	1.03±0.07[a]	26.96±0.2[a]	1.36±0.05[b]	0.50±0.01[a]	10.07±0.13[b]	13.62±0.58[b]	0.88±0.04[a]	0.41±0.01[a]	3.43±0.03[c]	1.27±0.03[c]	83.75±0.25[b]	59.18±0.82[c]

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P<0.05).

respectively. Unfermented samples had significant low moisture content (p≤0 .05) compared to fermented blends of sorghum and cowpea. After fermentation, the sample blends had moisture content ranging from 26.96 to 39.94% (Table 1). However, the moisture content of all the samples were significantly different (p≤0 .05) from each other. Therefore, it can be deduced from this results that moisture contents of fermented sorghum and cowpea blends were significantly higher than the unfermented samples. This observation could be attributed to the effect of soaking the samples during fermentation and the temperature of the fermenting medium. This observation is contrary to the report of Wakil and Kazeem (2012) whereby moisture content of cowpea-sorghum blends decreased with increased fermentation time. Ojokoh et al. (2014) also observed lower moisture content during the fermentation of cowpea-bread fruit blends (10.91-10.77%).

Crude protein content of unfermented sorghum and cowpea samples were 4.12 and 22.63% respectively. Increasing the proportion of cowpea significantly (p≤0 .05) increased the protein content of the fermented sorghum and cowpea blends. The protein content of fermented sorghum and cowpea blends ranged from 13.62 to 22.12% (Table 1). Fermentation significantly (p≤0.05) increased the protein content of sorghum and cowpea blends compared to the raw samples. Ojokoh et al. (2014) reported a similar observation during the fermentation of bread-fruit-cowpea blends in which the protein content ranged from 7.25 to 24.14%.(Sefa-Dedeh et al. 2001) also documented that fortifying cereals with cowpea improves the protein content of the cereal diet. Bello et al. (2018) reported that food products of plant origin capable of providing more than 12% of its calorific value from protein are considered as good source of protein. Increase in protein content may be due to the increased growth and microbial proliferation in the form of single cell protein and the structural proteins that are intergral part of the microbial cell (Tortora et al., 2002; Wakil and Kazeem, 2012). Cowpea-sorghum blend (7:3) had the highest protein content (22.12%). Earlier works have also documented that protein quality is improved in cereal-cowpea blends due to the synergistic combination effect of lysine by cowpea and methionine by cereals (Bressani, 1993; Wakil and Kazeem, 2012; Momanyi et al., 2019).

The total ash contents of the raw unfermented sorghum and cowpea samples were 1.06 to 1.89% respectively. However, the ash content decreased significantly after the fermentation of sorghum and cowpea blends. Ash content ranging from 0.505 to 0.67% was observed after the fermentation of sorghum and cowpea blends. There was no significant (p≤0 .05) in the ash content of fermented sorghum (0.57%) and fermented sorghum-cowpea (8:2) blends (0.50%). This observation is in contrast with the report of Ojokoh et al. (2014) in which ash content increased as the amount of cowpea increases during the fermentation cowpea-breadfruit blends. The ash content ranged from 2.42 to 3.61%. The total ash content of fermented sorghum (0.57%) and sorghum-cowpea blends (8:2) (0.50%) were not significantly (p≤0 .05) different. The decrease in ash content as observed in this study could be attributed to the general activities of the fermenting microorganisms whose enzymatic activities has been broken down into absorbable forms. Crude fat of raw unfermented sample blends ranged from 0.88 to 2.07%. The fat content of raw cowpea was significantly (p≤0 .05) higher (2.07%) compared to the blend samples of cowpea and sorghum (7:3) (1.77%). As fermentation increases, the fat content of sorghum and cowpea (8:2) blends decreases (0.41%)

Table 2. Mineral composition of sorghum and cowpea blend samples.

Sample	Minerals (mg/100 g)							
	K		Na		Mg		Pb	
	Raw	Fermented	Raw	Fermented	Raw	Fermented	Raw	Fermented
Cowpea	320.00±2.0[a]	287.50±3.5[a]	23.50±1.0[a]	11.00±1.0[a]	259.00±5.0[a]	210.50±0.0[b]	0.10±0.0	0.00±0.0
Sorghum	448.00±2.0[c]	390.50±1.5[b]	30.50±1.0[b]	20.50±1.0[b]	290.00±2.0[c]	221.50±1.0[c]	0.12±0.0	0.00±0.0
Cowpea:sorghum (7:3)	434.00±1.0[b]	403.50±1.5[c]	39.50±1.0[c]	25.00±1.0[c]	270.50±1.0[b]	163.50±1.0[a]	0.14±0.0	0.00±0.0
Sorghum: cowpea (8:2)	444.00±2.0[c]	395.50±3.5[bc]	40.00±2.0[c]	30.00±1.0[d]	321.50±1.0[d]	219.00±1.0[c]	0.19±0.0	0.00±0.0

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P<0.05).

significantly (p≤0.05). No significant difference was observed in the fat content of fermented sorghum and sorghum-cowpea (8:2) (0.43 and 0.41%) respectively. Low percentage of crude fat observed in this study signifies prolong storage of the food blends. High fat content in foods causes rancidity which could impact unpleasant odor in the food (Ikram et al., 2010). The result of this work is contradictory to the earlier report of Ojokoh et al. (2014) who observed a significant increase in the proportion of fermented cowpea-breadfruit blends (3.05 to 4.72%). The crude fibre content of unfermented sorghum and cowpea blends ranged from 2.05 to 3.43% compared to 1.09% for cowpea and 4.90% for sorghum. Crude fibre content of fermented sample blends were significantly different at (p≤0 .05). Fermented sorghum and sorghum-cowpea blends (8:2) had a higher fibre content (2.05 and 1.27%) respectively than fermented cowpea and cowpea-sorghum blends (7:3), 0.75 and 0.89% respectively. This report disagrees with the findings of Ojokoh et al. (2014) who observed a significant increase in ash content during the fermentation of cowpea-cereal blends.

Carbohydrate content of unfermented sorghum-cowpea blends ranged from 74.52-83.75% compared to 89.26% for sorghum and 72.57% for cowpea. Increased proportion of sorghum contributed to a significant (p≤0 .05) increase in carbohydrate content. Fermentation significantly decreased (p≤0 .05) the carbohydrate content of fermented cowpea and 7:3 cowpea-sorghum blends. However, fermented sorghum had the highest carbohydrate content (61.85%). The increase in carbohydrate content with increasing sorghum proportion could be attributed to the high carbohydrate (starch) content of sorghum (Table 1). Ariahu et al. (1999) had earlier documented carbohydrate values of 62.6% and 61.2% for non-germinated and non-fermented soy-breadfruit formulation blends. Low carbohydrate content of fermented cowpea and cowpea-sorghum blends (7:3) (28.18% and 36.49%) respectively could be attributed the low carbohydrate content of cowpea compared to sorghum, utilization of fermentable sugars by the fermenting microorganisms and other metabolic activities (Ojokoh et al., 2013, 2014).

Mineral composition

Table 2 shows the mineral compositions (100/mg) of unfermented sorghum, cowpea, cowpea-sorghum blends (7:3) and sorghum-cowpea blends (8:2). The potassium (K) compositions of raw unfermented cowpea, sorghum, cowpea-sorghum (7:3) and sorghum-cowpea (8:2) blends were 320, 448, 434 and 444% respectively while that of fermented sample blends were 287.50, 390.50, 403.50 and 395.50% respectively. The sodium (Na) compositions of raw unfermented blends were 23.50, 30.50, 39.50 and 30.00% respectively while that of fermented samples was 11.00, 20.50, 25.00 and 30.00% respectively. However, the magnesium (Mg) compositions of raw unfermented blends were 259.00, 290.00, 270.50 and 321.50% respectively while that of fermented samples was 210.50, 221.50, 163.50 and 219.00% respectively. In addition, the lead (Pb) compositions of raw unfermented blends were 0.10, 0.12, 0.14 and 0.19%, respectively while that of fermented samples were all 0.00%. FAO (2001) documented that minerals such as potassium (K), sodium (Na) and magnesium (Mg) are low in cereals but the addition of legumes such as cowpea can improve these mineral contents. Potassium serves as an intracellular cation that binds to protein and sodium and therefore influences osmotic pressure and normal

Table 3. Anti-nutrients composition of sorghum and cowpea blend samples.

Sample	Anti-nutrients (mg/g)							
	Tannin		Saponin		Oxalate		Phytate	
	Raw	Fermented	Raw	Fermented	Raw	Fermented	Raw	Fermented
Cowpea	0.94±0.01[b]	0.78±0.02[d]	6.63±0.09[a]	2.68±0.0[b]	2.42±0.01[c]	1.30±0.04[d]	19.73±0.0[a]	13.16±0.01[a]
Sorghum	0.86±0.01[a]	0.22±0.01[a]	7.08±0.05[a]	1.76±0.1[a]	1.16±0.01[a]	1.04±0.01[c]	19.37±0.1[a]	17.28±0.02[d]
Cowpea:sorghum (7:3)	0.99±0.02[c]	0.43±0.03[b]	13.08±0.5[c]	6.17±0.3[c]	1.72±0.02[b]	0.71±0.01[b]	25.88±0.3[b]	13.98±0.02[b]
Sorghum: cowpea (8:2)	0.98±0.01[bc]	0.58±0.02[c]	9.02±0.22[b]	3.37±0.0[b]	2.93±0.03[d]	0.44±0.01[a]	29.66±0.8[c]	15.63±0.02[c]

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same colunm are not significantly different (P<0.05).

pH equilibrium of the body (Oyarekua, 2010). Sodium is a major cation of body fluid cells and the values obtained in this study falls within the recommended potassium/ sodium values equired for complimentary food formulations for ages 6 to 23 months old. Magnesium is needful for the normal functioning of nerve and muscle cells, maintains a healthy immune system and helps to make the bone strong. However, 0% values were obtained for all the sample blends which implies that these formulations can be consumed without causing any adverse effects that accompanies the consumption of lead contaminated foods such as abdominal pain, seizure, cancer or even death.

Anti-nutrient composition

Tannin contents of unfermented and fermented sorghum-cowpea blends ranged from 0.865 to 0.99 mg/100 and 0.22 to 0.7 mg/100 respectively. Tannin content was highest in fermented cowpea (0.78 mg/100) compared to tannin content in fermented in sorghum, cowpea-sorghum (7:3) and cowpea-sorghum (8:2) blends (0.22, 0.43 and 0.58 mg/100 respectively). Saponin content in raw unfermented cowpea and sorghum samples were not significantly (P<0.05) different giving a yield of 6.63 and 7.08 mg/100 respectively (Table 3). However, values for fermented cowpea, sorghum, cowpea-sorghum (7:3) and sorghum-cowpea (8:2) were 2.68, 1.76, 6.17 and 3.37 mg/100 respectively. The values were significantly different at P<0.05.Oxalate content of unfermented sample blends ranged from 1.16 to 2.93 mg/100 which were significantly different at P<0.05. However, the phytate values of fermented cowpea, sorghum, cowpea-sorghum (7:3) and sorghum-cowpea (8:2) are 1.30, 1.04, 1.72 and 2.93 mg/100 respectively which were significantly different at P<0.05. This report does not agree with the findings of Ojokoh et al. (2014) who reported lower phytate values of 0.59 to 0.93 mg/100 for unfermented breadfruit-cowpea blends and recorded values that ranged between 0.24 to 0.58 mg/100 for fermented sample blends. Ariahu et al. (1999) documented similar phytate values of 1.76 and 1.17 mg/100 for nongerminated-nonfermented soy breadfruit seeds and nongerminated-fermented soy breadfruit seeds blends. Onweluzo and Nnamuchi (2009) also reported high phytate values of143.3, 125 and 80.13 mg/100 for parboiled, boiled and African fermented breadfruit flour. Ojokoh et al. (2013) has previously reported that the fermenting lactic acid bacteria possesses phytase enzyme that breaks down phytate.

Physico-chemical properties

pH and titratable acidity

The pH of fermenting medium decrease with increase in titratable acidity of the fermented blend samples. The variation in the pH of sample blends may be due to variations in the composition of sample blends supplementation (Figure 1). However, increase in titratable acidity could be attributed to the dominance of the environment by lactic acid bacteria which utilizes the fermentable sugars leading to the acidification of the fermenting medium (Figure 2). Similar decrease in pH and increase in titratable acidity (TTA) had earlier been reported by Ojokoh et al. (2013) during the spontaneous fermentation of breadfruit-cowpea blends, Ariahu et al. (1999) during the fermentation of nongerminated and germinated soy-breadfruit blends. High acidity in fermented food products confers microbial stability on the food which helps to reduce the incidence of diarrhea among consumers.

Microbial characteristics

Table 4 shows that a total of eight (8) bacteria was isolated and identified in the sample blends. Figures 3 to 5 presents the changes in bacterial, fungal and lactic acid loads during the fermentation processes. *S. aureus* and *B. cereus* were isolated from the raw sample at the early stage of fermentation of the blends followed by a gradual disappearance towards the end of the fermentation process. Ilango and Antony (2014) reported similar

Table 4. Biochemical characteristics of all bacterial isolate during fermentation of sorghum and cowpea blend samples.

Tests	IS01	IS02	IS03	IS04	IS05	IS06	IS07	IS08
Gram rxn	+	+	+	+	+	+	+	+
Shape	Cocci	Rod	Rod	Rod	Rod	Rod	Rod	Cocci
Motility	-	+	+	+	-	-	-	-
Spore formation	-	+	+	+	-	-	-	-
Citrate	-	+	+	+	-	-	+	-
Catalase	+	+	-	-	-	-	-	-
Coagulase	+	-	-	+	-	-	-	-
MR/VP	-	-	+	-	-	+	+	-
Glucose	+	+	+	+	-	+	-	-
Lactose	+	+	+	+	+	+	+	-
Mannitol	+	+	+	-	+	-	-	-
Sucrose	-	-	+	+	-	-	-	-
Galactose	-	+	+	+	-	-	-	-
Suspected organisms	*Staphylococcus aureus*	*Bacillus cereus*	*B. polymyxa*	*B. licheniformis*	*Lactobacillus fermentum*	*Lactobacillus acidiophilus*	*Lactobacillus plantarum*	*Streptomyces lactis*

+=Positive; -=negative.

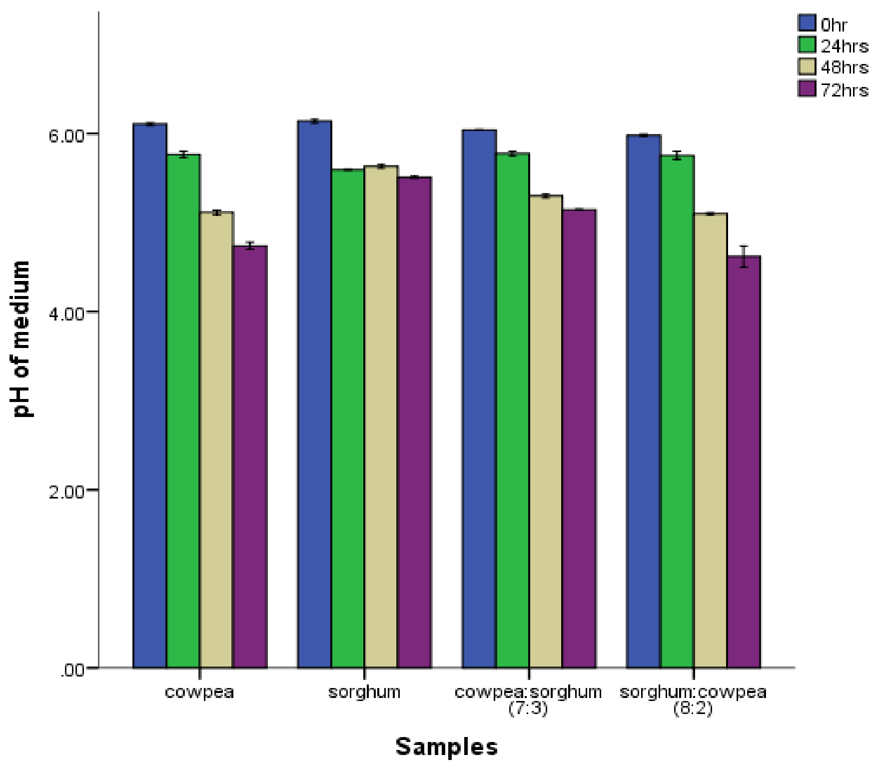

Figure 1. pH variation during fermentation of sorghum and cowpea blend samples.

findings during the fermentation of "koozh", an Indian fermented millet beverage. This implies that these organisms are microbial flora of the raw samples or might have been introduced as a result of inadequate precautionary measures during the processing such as the utensils, water, the environment or even the

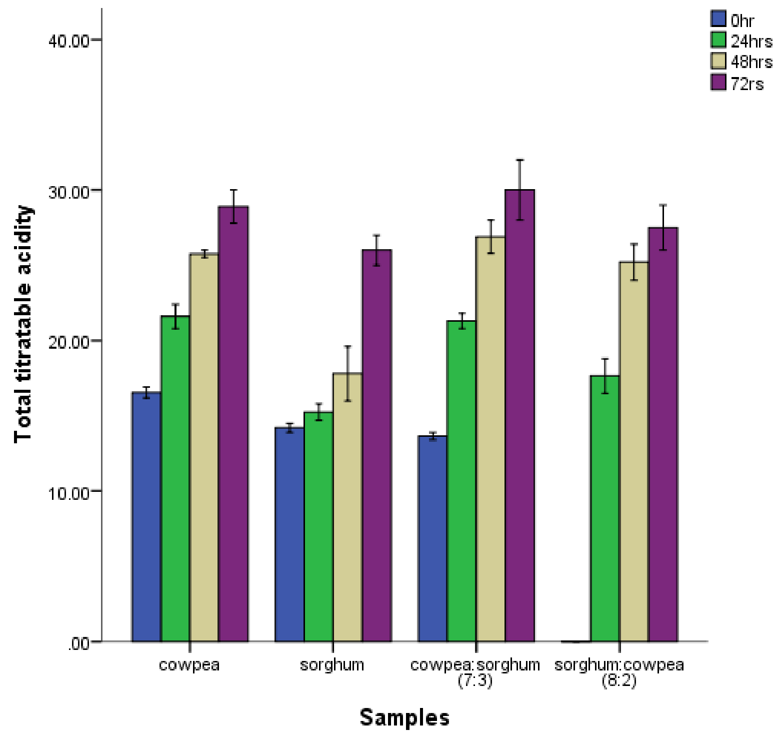

Figure 2. Total titratable acidity variation during fermentation of sorghum and cowpea blend samples.

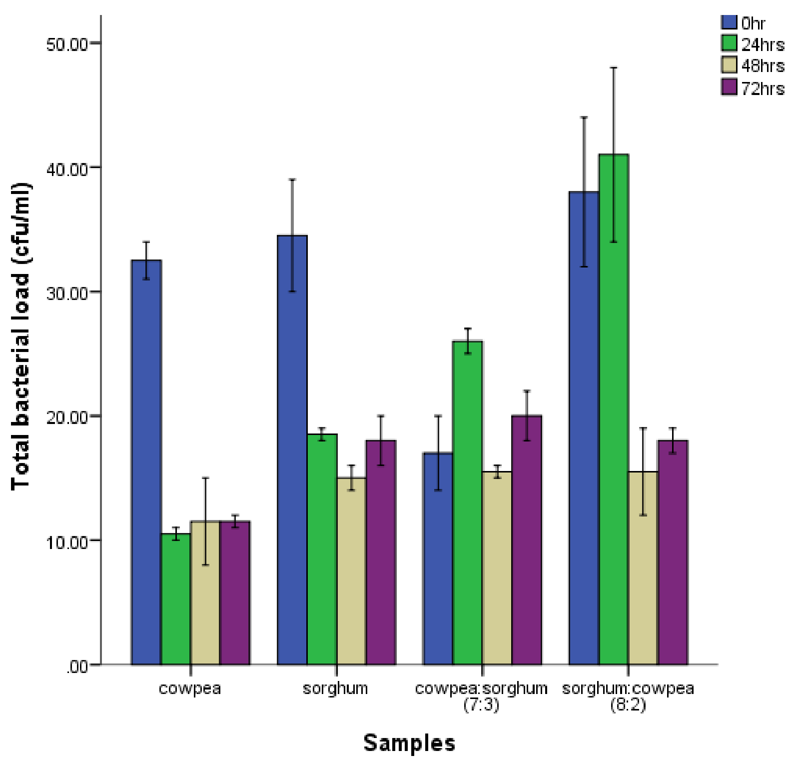

Figure 3. Changes in bacterial load during fermentation of sorghum and cowpea blend samples.

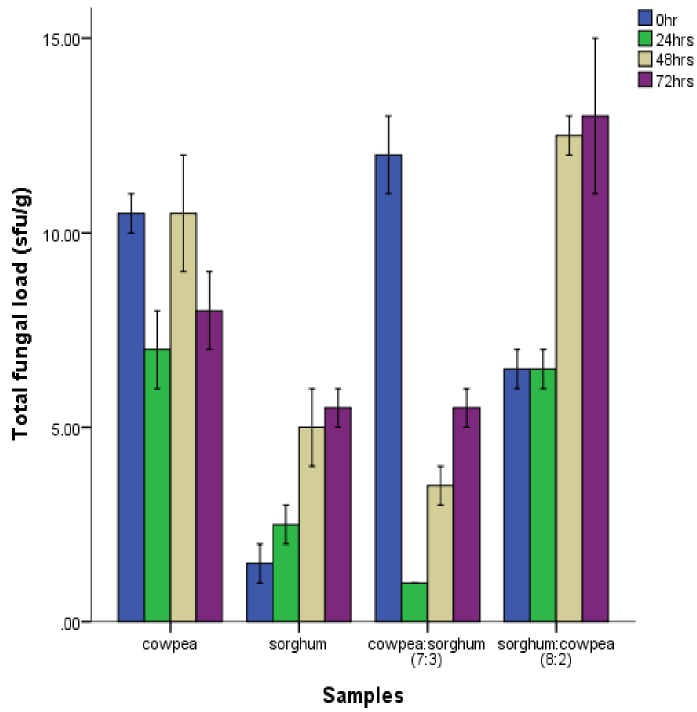

Figure 4. Changes in fungal load during fermentation of sorghum and cowpea blend samples.

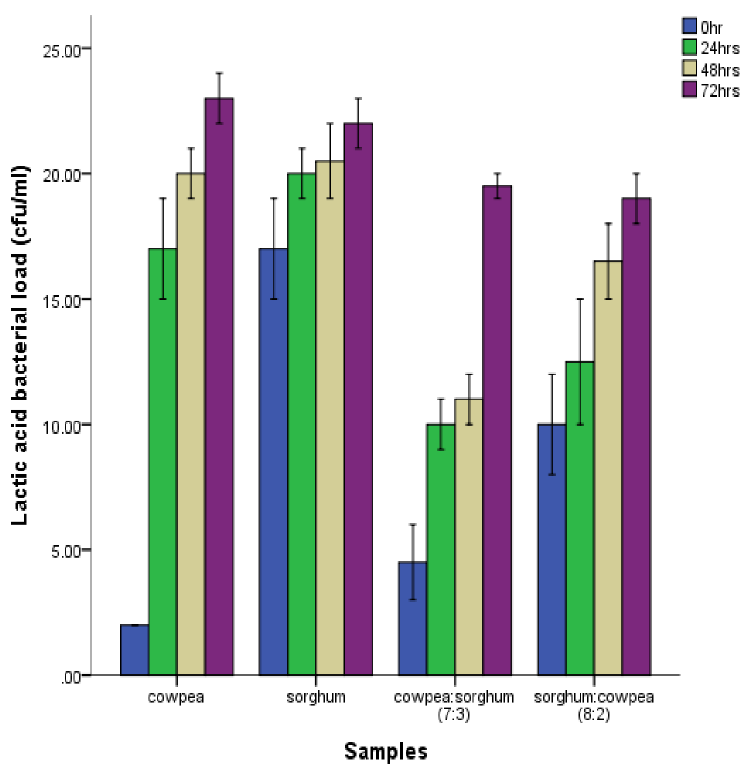

Figure 5. Changes in lactic acid bacterial load during fermentation of sorghum and cowpea blend samples.

producers.

B. polymyxa and *B. licheniformis*, *L. fermentum, L. acidophilus, L. plantarum* and *Streptococcus lactis* were isolated towards the end of the fermentation process. Several studies have documented that fermenting cereals helps to alter pH levels which do not favor the growth of pathogenic microorganisms due to the production of antimicrobial compounds such as succinic acid, acetic acid, hydrogen peroxide produced by lactic acid bacteria during the fermentation process (Steinkraus, 2002; Hernandez-Ledesma et al., 2004; Odumodu and Inyang, 2006; Ojokoh et al., 2014; Oliveira et al., 2014).

Conclusion

The findings obtained from this study revealed that there is a significant increase in protein content of sorghum supplemented with cowpea and a drastic reduction in the anti-nutrient contents of all the fermented sample blends. Lactic acid bacteria were the dominant microorganisms during the fermentation process. Therefore, sorghum fortified with cowpea, fermented for 72 h can be recommended for improving the quality of the protein quality of sorghum. In addition, this food blend may be recommended as desirable for solving the problem of protein deficiency among the populace especially infants in developing countries.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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