Soil suitability evaluation for production of improved Cassava (*Manihot esculenta*) varieties in Kwara State, Nigeria: A GIS-Based and Multi-Criteria analysis

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Abstract

A study was carried out to determine the adaptability of improved cassava varieties in various locations in the eastern part of Kwara State, Nigeria. Four improved cassava varieties and one local variety were investigated in the University of Ilorin (Unilorin) farm and at the Offa area of Kwara State. Physico-chemical properties were used to calculate soil suitability index using Multi-Criteria Analysis (MCA). Soil suitability and productivity index were interpolated over the Eastern part of Kwara State using a kriging method in SUFER 8.01, GIS software. The results showed that whereas Unilorin had better physical soil properties, the Offa area, on the other hand, showed better chemical soil properties. Soil suitability for cassava production was better in Offa (57.2%) than in Unilorin (37.6%). The spatial analysis showed increasing soil suitability from the northern to the southern regions with the highest suitability in Oyun, Offa and Irepodun districts. The improved cassava varieties produced an average yield of 19-20 tons/ha compared to 5.3-6.5 tons/ha of the local variety. The spatial analysis showed decreasing cassava productivity from the western to the eastern regions with the highest productivity in the Asa, Oyun, Offa and Ilorin districts. It is recommended that the cultivation of these improved cassava varieties be accompanied with good soil fertility management practices like organic fertilizer application combined with inorganic fertilizer microdosing technology in the Eastern Districts of the Kwara State, especially at Moro, Edu, Ifelodun and Isin districts.

Introduction

Agriculture is key to achieving the sustainable development goals (SDGs) 1 (to end extreme poverty in all forms) and 2 (to end hunger, achieve food security and improved nutrition and promote sustainable agriculture) (UNDP, 2015). Food insecurity can be eradicated by sustainable agricultural practices and precision farming. This means that crops and soils irrespective of climatic variations should be provided with favourable conditions for optimum health and productivity. This optimum condition has been defined by Troeh et al. (2003) as agricultural systems adapted to a particular area so that plant and animal products do not decline over time but remain reasonably stable irrespective of change in climate. Although Nigeria produces large quantities of petroleum, it suffers food insecurity like many other African countries. Plant breeding and crop improvement constitute efficient ways of combating food insecurity. Soil scientists, on the other hand, provide information on suitable areas for optimum crop production. Moreover, using improved crop varieties has been identified as one of the Climate Smart Agriculture (CSA) practices with high potential to achieve the "Zero Hunger" objective in the world (Kpadonou et al., 2019a; FAO 2013). Cassava (*Manihot esculenta*) has many benefits such as providing income to smallholder farmers, serves as famine reserve crop, source of industrial raw materials for the production

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of starch, plywood, alcohol, and animal feed. The leaves and shoots, which are relatively high in protein, are often eaten in Asian and African countries (Dixon et al., 2003). Dorosh et al. (2007) and PIND (2011) reported that cassava is a vital and staple crop for food security and poverty reduction in Africa and Asia. They further reported that cassava provides over 15% of daily calorie intake in Africa. However, cassava production, despite all the technical and financial efforts, has not yet met the demand across the continent (Ande et al., 2011). In Nigeria, Amao and Awoyemi (2008) attributed the low level of adoption of improved cassava varieties at farm scale to the fact that farmers are generally unaware of their availability and the recommended conditions under which they should be cultivated. The problem can be addressed by using technologies of Geographic Information System (GIS) to identify suitable local areas for cassava production. Acton and Gregorich (1995) pointed out that soil quality assessment is important in determining sustainability of land management systems.

Several studies have analysed the suitability of Nigerian soils for the cultivation of various crops. Joshua et al. (2013) applied a GIS and a multi-criteria decision analysis (MCDA) to identify suitable areas for agricultural production irrespective of crop type in the Greater Karu Urban Area, Nasarawa State. These authors concluded that suitability varies from moderate to high across the area studied. Maniyunda and Gwari (2014) studied maize and groundnut in the sub-humid environment of Nigeria and concluded that none of the Haplustalfs they evaluated was highly suitable for cultivation of these crops. Similar conclusions were made by Ahukaemere et al. (2015) on the same crops in Owerri, Southeastern Nigeria. Abegunde et al. (2015) found low to medium soil suitability levels for maize production in the Oyo State. Similar conclusions were arrived at for oil palm and plantain production in the Etung local Government area by Ajiboye and Olaniyan (2016). However, few soil suitability studies have focused on cassava in Nigeria (Ande et al., 2011; Gbadegesin et al., 2011; Oniya et al., 2013; Abua, 2015) and none in Kwara State. Therefore, this study aimed to evaluate soil suitability levels for the production of selected improved cassava varieties in the Kwara State using GIS and multi-criteria analysis. The specific objectives were to:

(i) Determine variability of physico-chemical properties of soils in the study areas
(ii) Evaluate soil suitability and cassava productivity levels in the study areas
(iii) Identify agro-climatic zones suitable for cultivation of improved cassava varieties

Materials and methods

Description of the study sites

The study was carried out in the Southern Guinea Savannah zone of Ilorin, Kwara State, Nigeria. The field experiments were conducted at two sites (Fig.1). One site (8^o 27' 21" N and 4^o 39' 33" E) was located at the University of Ilorin (Unilorin), Teaching and Research Farm, about 8 km east of the Ilorin Township. The second study site was located at Offa (8^o 12' 14" N and 4^o 42' 36" E) along the Oshogbo Ikirun road. The Federal Bureau of Statistics, Nigeria (2011) estimated the population of both Ilorin and Offa to be between 1.11 and 1.50 million people. The average annual rainfall of Ilorin during 1980-2015 was about 1200-1500 mm with average

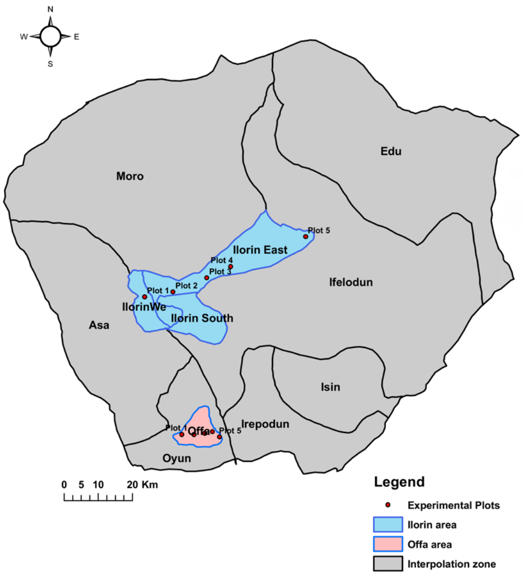

Fig 1. Studied Areas

minimal temperature of 21 °C and maximum temperature of 35 °C (Olubanjo, 2019). The soils of Ilorin are predominantly derived from ferruginous and crystalline acidic rocks and are predominantly Alfisols (Olaniyan, 2001). The soils are dominated with kaolinite, oxides and hydroxides of aluminium and iron.

Data collection and research field management

Experimental field design and management

The planting materials were stem cuttings (*manivas*), each 0.15 m long and with five viable buds. All the cuttings planted were healthy and looked viable. For optimum density, a planting distance of 1 m x 0.75 m was used to achieve about 14,000 to 15,000 plants per hectare per variety, because the improved varieties were mostly non-branching types of cassava. Flat to gently sloping fields were used for the study at the two sites. At each site, a rectangular layout was used, and the rows were in the east-west direction for efficient use of light for photosynthesis. The ridges had a spacing of 1 m between their tops to promote deep rooting.

Field experiments were carried out after land preparation which involved removal of stubbles and debris and tractor ploughing with ridges of 20-30 cm deep. Cassava varieties (four improved and one local) were planted on 15th July 2015 and harvested in April 2016. The cumulative rainfall amount during the period of the experiment was about 1600 mm and the mean temperature was 26 °C. September 2015 was the wettest month when about 600 mm rainfall was recorded (Fig. 2). At each study site, each cassava variety was planted on two hectares (2 ha), monitored by the farmers, to serve as demonstration fields for the West Africa Agricultural Productivity Programme (WAAPP). An experimental unit of size 25 m x 25 m was delineated in each hectare at each site for data collection. Thus, each site had two of such experimental units. Figure 3 gives an overview of the experimental framework.

The four improved varieties used in the study were Tropical Manihot System (TMS) 419, 623, 326 and 1632. These varieties were developed and distributed by the Agricultural Research Council of Nigeria (ARCN) and the West Africa Agricultural

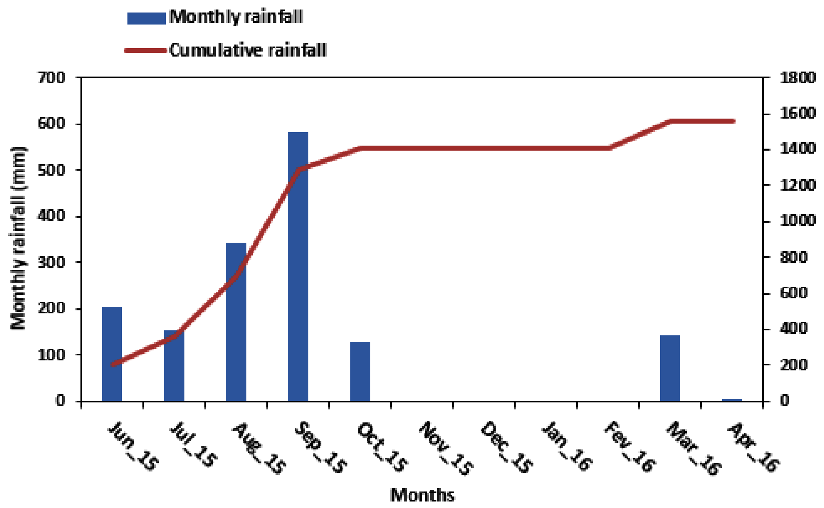

Fig 2. Rainfall distribution during the experiment

Productivity Programme (WAAPP) under the World Bank Project for West African Countries for Sustainable Agriculture and Poverty Alleviation. The improved varieties are resistant to stress (i.e. they withstand low rainfall and are resilient to climatic stress). They are also known to grow tall with good yields when properly managed from the beginning such as removing excess branches. The local variety, called "Oko iyawo" reported to be the best among local varieties, was obtained from farmers.

Weeding was done three times before harvesting. A pre-emergence herbicide (atrazine) was applied as an initial weed control within 2-3 days after planting while glyphosate (*round up and force up*) was applied as post-emergence for the second and the third weed control.

Soil sampling and laboratory analysis

From each experimental unit, top soil (0-30 cm) samples were taken from ten different spots and bulked together to form a composite sample for each 2 ha plot. The soil samples were put into polyethylene bags, labelled and transported to the laboratory and subsequently analyzed for chemical and physical properties.

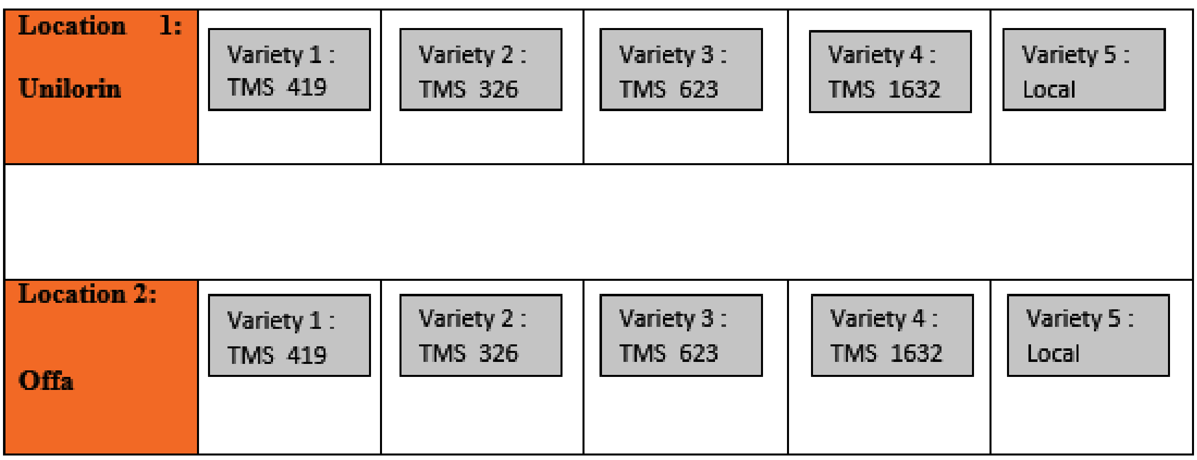

Fig 3. Experimental framework

They were air-dried, crushed, and passed through a 2 mm mesh sieve. The laboratory analyses were carried out at the Faculty of Agriculture, Central Research Laboratory, University of Ilorin, Nigeria. Soil pH was determined in a 1:2 soil/water ratio with glass electrode (Peech, 1965). Electrical Conductivity (EC) was measured with an EC meter in a saturated paste extracted as described by (Peech, 1965). Soil Organic Carbon (SOC) was determined by the method described by Walkley and Black (1934). Total nitrogen was determined according to the Kjedahl method. Available phosphorus was determined by using the Bray No.1 method (Bray and Kurtz, 1945) and read with the spectrophotometer. Exchangeable bases, calcium (Ca), magnesium (Mg), potassium (K) and Sodium (Na) were analyzed after extraction with 1 mol ammonium acetate at pH 7.0. Cation Exchangeable Capacity (CEC) was determined according to the method of Rhodes (1982). Particle size distribution was determined using the hydrometer method (Bouyoucos, 1962). Bulk density was determined by using the core method described by Blake and Hartge (1965). Tuber yield was measured per plot at the end of the growing season.

Data analysis and mapping

Soil suitability assessment for cassava production was based on physical and chemical soil properties compared with critical values required for optimum production of the crop (Howler, 1996; 2002). These critical values (Table 1), were used by Ande et al. (2008) and Abua (2015) for cassava production and soil suitability analysis in Nigeria.

Multi-Criteria Analysis (MCA), a very useful tool (Carriço et al., 2014), was used to determine the suitability levels of each soil. Multi-Criteria Decision Making (MCDM) can be considered as a process that combines and transforms several information including geographical data called inputs into a "decision variable", called output (Drobne and Lisec, 2009). In MCDM, each input is given a weight to represent its optimum importance (DCLG, 2009; Chow and Sadler, 2010) according to their role in the production system (Al-Mashreki, 2011). This mode of assigning weights is widely used to assess the suitability of technologies and practices for agricultural production (Diouf et al., 2014) and energy (Carriço et al., 2014). The method demands less data (Cinelli et al., 2014) and is most suitable for land and real estate management (Guarini et al., 2018). In this study, the input data were the physical and chemical soil properties analysed in the laboratory.

Soil data used as criteria in the MCA were compared to critical values (CV) defined by Howler (1996; 2002) for the optimum growth of cassava. The criteria (soil properties) were categorized into three groups and each group carried a point (weight) (Fig. 4) according to their importance in cassava production. The physico-chemical soil data obtained from laboratory analysis (Ld) were used to calculate the proportion (%) carried by each criterion relative to the mean of the critical

TABLE 1

Critical levels of properties required for cassava production

Properties	**pH**	**EC**	**Org. C**	**N**	**P**	**Ca**	**Mg**	**K**	**Na**	**BD***
		dS m^{-1}	g kg^{-1}		mg kg^{-1}	cmol kg^{-1}				Mg m^{-3}
CV**	4.6-7.0	2-4	20-40	1.5-2.0	10-14	1-4	0.4-1.0	0.2-0.4	0.2-0.8	1.0-1.4

*BD = Bulk Density. **CV = Critical Values

values by using equation 1. These proportions were called normalized scores (NS).

The normalized scores for each criterion were used to calculate the weighted scores

$$\mathbf{NS} = \frac{Ld}{cv} * \mathbf{100} \qquad (1)$$

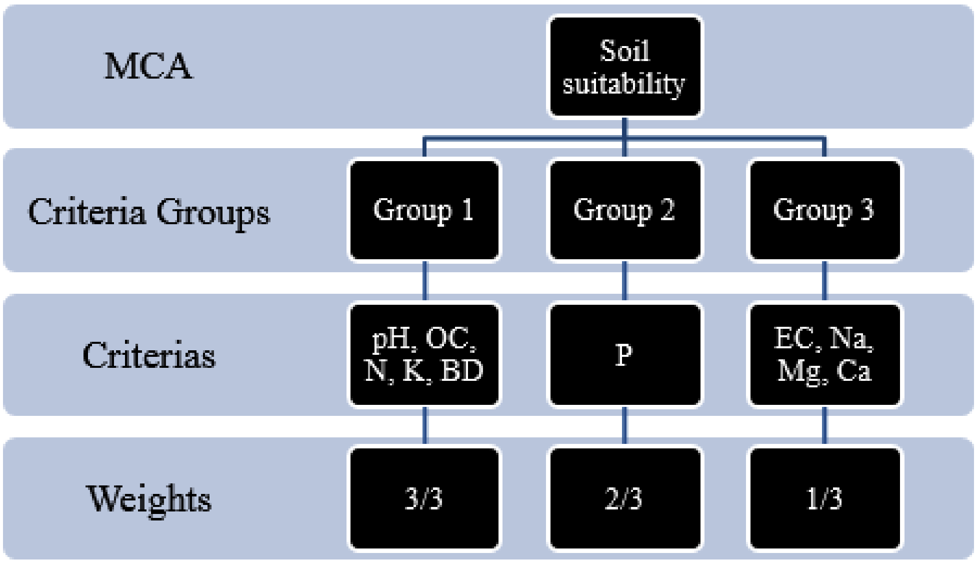

Fig 4. Weight of criteria for the Multi-Criteria Analysis

(WS) (Fig. 4) following their importance in cassava production system using equation (2). For example, the parameters of Group I (pH, organic carbon, N, K and soil texture) carried the weight (W) of three over three (3/3) because they played a crucial role in cassava growth and development (Howler 2002). Moreover, Gbadegesin et al. (2011) and Oshunsanya et al. (2018) pointed out these soil properties to be highly correlated with cassava production in Nigeria.

$$WS_i = NS_i * W_i \qquad (2)$$

Where W_i and NS_i are the weight and the normalized score of the i^{th} soil parameter considered.

The *WS* were converted into Soil Suitability Index (SSI) for each plot using equation (3)

Where WS_i is the suitability index of the i^{th} soil parameter and WS_{imax} the maximal suitability

$$SSI = \frac{\sum_n^i WS_i}{\sum_n^i WS_{imax}} * 100 \qquad (3)$$

index that same i^{th} parameter is supposed to have (100%).

The productivity of the improved cassava varieties called Yield Increasing Index (YI) is the yield difference between the yield of the improved varieties (Yi) and that of the local variety (YL) which is calculated using equation (4). YI gives the proportion (percentage) by which the improved varieties would give more or less yields than the local variety.

Values calculated for soil suitability index (SSI) and productivity of the improved cassava

$$YI = \left(\frac{(Y_i - Y_L)}{Y_L}\right) * 100 \qquad (4)$$

varieties (YI), were spatially interpolated over the Eastern regions of Kwara State using kriging method with SUFER V. 8.0. Kriging is a geostatistical method that uses a stochastic approach to predict values for unvisited locations using information available from visited locations. The method conforms to the first law of geography which states that “everything is related to everything else, but things that are closer to each other are more related than others that are distance apart" (Toble, 1970). Meng et al. (2013) compared seven GIS interpolation methods and concluded that the regression kriging method has the potential to significantly improve the accuracy of geo-spatial prediction. The kriging method, classified as an exact interpolator by Sajid et al. (2013), is one of the most popular geostatistical methods applied in many fields (Yang et al., 2004). The principle behind the method can be described using equation 5.

Where Z_A is the predicted value of grid node A, n is the total number of observed values, Z_i

$$Z_A = \sum_{i=1}^{n} W_i * Z_i \qquad (5)$$

is the observed value at location *i* with weight W_i.

In this study, a total of twenty observed values at different points at the two sites were used as input in the interpolation. There are two different groups of kriging options in the SUFER software namely point and block kriging. Point kriging which estimates values of given points at grid nodes was applied in this study rather than block kriging. Block kriging method averages the estimated values of rectangular blocks centered on grid nodes (Hengl et al., 2007).

Results and discussion

Physico-chemical properties of soils

Tables 2 and 3 show physico-chemical properties of the soils from the two study sites. At the Unilorin site, soil pH ranged from 6.71 to 6.75 with a mean of 6.73. When soil pH is maintained at an optimum level, plant nutrient availability would be optimized, solubility of toxic elements minimized, and beneficial soil organisms would be most active thereby promoting good yield. The EC ranged from 0.82 to 0.85 dS m^{-1} with a mean value of 0.84 dS m^{-1}. Organic carbon content ranged from 0.52 to 0.55% with a mean value of 0.53% which was very low and could have been due to intensive farming activities with very little or no organic matter addition. The levels of macronutrients were also low; total nitrogen (N) content ranged from 0.05 to 0.07 g kg^{-1}, available phosphorus (P) content from 6.01 to 7.02 mg kg^{-1}, and potassium (K) content ranged from 0.05 to 0.08 cmol kg^{-1}. Thus, the soils at the Unilorin site were low in fertility. The levels of the other extractable bases were 2.19 – 2.22 cmol kg^{-1} for Ca, 1.25-1.27 cmol kg^{-1} for Mg and 0.17 – 0.18 cmol kg^{-1} for Na. Relative to the critical levels required for cassava production, the Ca levels were moderate, the Mg levels high and the Na levels low. Furthermore, CEC which ranged from 1.23 to 1.25 cmol kg^{-1}, confirmed the poor fertility status of the soils. In general, the Unilorin soils had poor chemical properties. On the other hand, the Unilorin soils had more suitable physical properties. The texture of the soils (predominantly sandy loam) and their moderate levels of bulk density (1.05 to 1.48 Mg m^{-3}) would be favourable for root and tuber growth.

The pH of the soils from the Offa site ranged from 4.80 to 6.76 with a mean of 5.81. Thus, apart from Plot 3, the pH of the soils from Offa ranged from strongly acidic to moderately acidic which could adversely affect soil productivity. The EC of the soils ranged from 0.61 to 0.68 dS m^{-1} with a mean of 0.65 dS m^{-1}. The organic carbon content of the soils ranged from 0.48 to 0.52% with a mean of 0.50%. The total N content of the soils ranged from 0.46 to 0.65 g kg^{-1} with a mean of 0.56 g kg^{-1}. The available P content of the soils

TABLE 2
Properties of soils at Unilorin

Plots	pH	EC	Org. C	N	P	Ca	Mg	K	Na	CEC	Sand	Silt	Clay	BD*
		dS m^{-1}	g kg^{-1}		mg kg^{-1}	-----------------cmol kg^{-1}--------------------					---------- % ---------			Mg m^{-3}
1	6.72	0.83	0.53	0.05	6.02	2.22	1.26	0.06	0.17	1.24	69.8	4.0	26.2	1.05
2	6.75	0.85	0.52	0.06	6.04	2.21	1.27	0.08	0.18	1.25	68.8	5.0	26.2	1.42
3	6.71	0.84	0.55	0.05	6.01	2.22	1.25	0.05	0.19	1.24	73.0	3.5	23.5	1.48
4	6.74	0.84	0.54	0.07	7.02	2.21	1.26	0.06	0.18	1.23	73.0	6.4	20.6	1.34
5	6.75	0.82	0.52	0.06	6.02	2.19	1.27	0.07	0.17	1.24	72.0	4.7	23.3	1.05

TABLE 3
Properties of soils at Offa

Plots	pH	EC	Org. C	N	P	Ca	Mg	K	Na	CEC	Sand	Silt	Clay	BD*
		dS m^{-1}	g kg^{-1}		mg kg^{-1}	-----------------cmol kg^{-1}--------------------					---------- % ---------			Mg m^{-3}
1	5.87	0.86	0.63	0.84	8.03	3.40	2.30	2.04	0.18	1.27	80.8	3.0	16.2	1.31
2	5.82	0.88	0.58	0.94	8.05	3.41	3.21	2.02	0.16	1.25	82.6	7.0	10.4	1.33
3	6.76	0.85	0.59	1.02	9.00	3.39	2.32	2.00	0.17	1.28	75.4	4.0	20.6	1.20
4	4.80	0.87	0.64	0.93	10.10	3.38	2.31	2.00	0.18	1.27	78.0	3.6	18.4	1.22
5	5.79	0.86	0.64	1.01	7.96	3.40	2.31	2.03	0.17	1.29	79.9	4.9	15.2	1.19

ranged from 6.04 to 7.06 mg kg^{-1} with a mean of 6.55 mg kg^{-1}. The levels of the exchangeable bases were 3.39-3.42 cmol kg^{-1} for Ca (mean of 3.39 cmol kg^{-1}), 1.23 to 1.25 cmol kg^{-1} for Mg (mean of 1.24 cmol kg^{-1}), 0.04 to 0.07 cmol kg^{-1} for K (mean of 0.06 cmol.kg^{-1}), and 0.16 to 0.18 cmol kg^{-1} for Na (mean of 0.17 cmol.kg^{-1}). The CEC of the soils ranged from 1.25 to 1.29 cmol kg^{-1} with a mean of 1.28 cmol kg^{-1}. The soils from Offa were coarse textured, with > 75% sand content. The high sand content of the soils partly explains why they had very low CEC. Furthermore, the soils could be prone to leaching of nutrients.

Soil suitability level

Although the soils from Offa were moderately to strongly acidic and were coarse textured (predominantly loamy sand), their properties relative to the critical values make them generally suitable for cassava production. Based on the MCA, the soils from Offa were more suitable (average suitability level of 57.2%) than those from Unilorin (average suitability level of 37.6%) for the production of cassava (Table 4). The superior suitability levels of the soils from Offa could be due to their relatively more favourable chemical properties compared to those from Unilorin.

Spatial analysis showed a trend of increasing soil suitability index from the north to the south, i.e. soils of the north were less suitable

TABLE 4
Soil suitability levels

Plots	**1**	**2**	**3**	**4**	**5**	**Means**
Unilorin	36.5%	38.6%	37.5%	38.5%	36.9%	37.6%
Offa	56.7%	57.1%	58.6%	56.6%	57.3%	57.2%

than those in the south. Three different zones were observed (Fig. 5):

(1) Areas with a relatively low (30-40%) soil suitability level: Northern Asa, Moro District, Edu District, Ilorin West, Ilorin East and the Northern part of Ifelodun.

(2) Areas with a moderate suitability level (40-50%): Southern Asa, South Illorin, a large part of Ifelodun and the Northern part of the Isin District.

(3) Areas with high soil suitability level (50-70%): Oyun District of Offa: Irepodun and the Southern part of the Isin District.

In general, the soil suitability level for cassava production in Kwara State was moderate with an average of 47.4%. This level of suitability was higher than the level (21.43%) reported by Abua (2015) in the Cross River State of Nigeria. The difference might be due to the Multi-Criteria Analysis (MCA) used in our study rather than the differences in soil properties relative to the critical values used in the study of Abua (2015). Obviously, all soil properties do not have the same influence on cassava production. As stated by Gbadegesin et al. (2011) and Oshunsanya et al. (2018), soil pH, organic C, N, K and bulk density are more correlated with high yield of cassava in Nigeria. These soil properties were therefore categorized into group I in the MCA process in our study and might have resulted in raising the suitability levels. Technically, this level of soil suitability cannot effectively sustain cassava production without good soil fertility management practices. A moderate soil suitability level had been reported also for cocoa production in the same area of Kwara State by Ibiremo et al. (2015).

Cassava yields

For the improved varieties, a yield of 26 ton/ha of tubers (with a mean of 20 tons/ha) was obtained at Unilorin while a yield of 24.5 ton/ha (with a mean of 19 tons/ha) was obtained at Offa (Table 5). The local variety yielded 6.5 ton/ha at Unilorin and 5.3 ton/ha at Offa. On the average, the soils from Unilorin yielded one ton/ha of cassava more than the soils from Offa. The TMS 419 variety had the highest yield while the local variety had the lowest yield at both study sites. Thus, the improved varieties produced much higher yields than the local variety as had also been reported by Parkes et al. (2012).

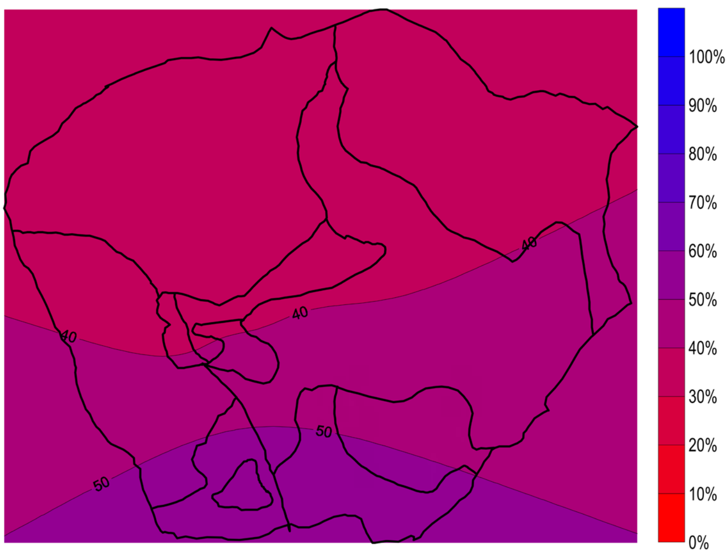

Fig 5. Average soil suitability levels at study sites

TABLE 5
Cassava yields at study sites (tons/ha)

Varieties	Unilorin	Offa
TMS 419	26.0	24.5
TMS 326	25.0	24.0
TMS 623	24.0	23.5
TMS 1632	25.0	22.5
Local Variety	6.5	5.3

Productivity index which is the yield of the improved cassava varieties compared to that of the local variety showed that the soils from Offa gave better results (345%) than the soils from Unilorin (284%). This result might primarily be due to the more favourable chemical properties of the soils at Offa. Spatial analysis of the productivity index showed a decreasing trend across the study area from the Western to Eastern Districts with four distinct zones (Fig. 6). The zones are:
(1) the Asa District, the Central part of Moro, the three Districts of Ilorin except the Eastern part of Ilorin East, the Oyun and the Offa Districts showed the highest productivity level (200-350%) i.e. the yield of the improved varieties in this region was triple that of the local variety. It would therefore be advisable to start the promotion of these improved varieties in this region.
(2) Eastern Moro, part of Eastern Ilorin, Ifelodun-West and Irepodun-West showed moderate productivity (100-200¬%) i.e. yield of the improved varieties was double that of the local variety in this region. Thus, this region would be suitable for production of the improved cassava varieties.
(3) Western Edu, Western part of Ifelodun, Western part of Isin and the Central part of Irepodun showed fairly moderate productivity (0-100%) i.e. the yield of the improved cassava varieties relative to that of the local variety ranged from similar levels (0%) to higher levels up to a maximum of 100% in this zone.
(4) The western parts of the Moro, Ifelodun, Isin and Irepodun Districts showed the lowest productivity level (i.e. less than 0%). To promote the production of improved cassava

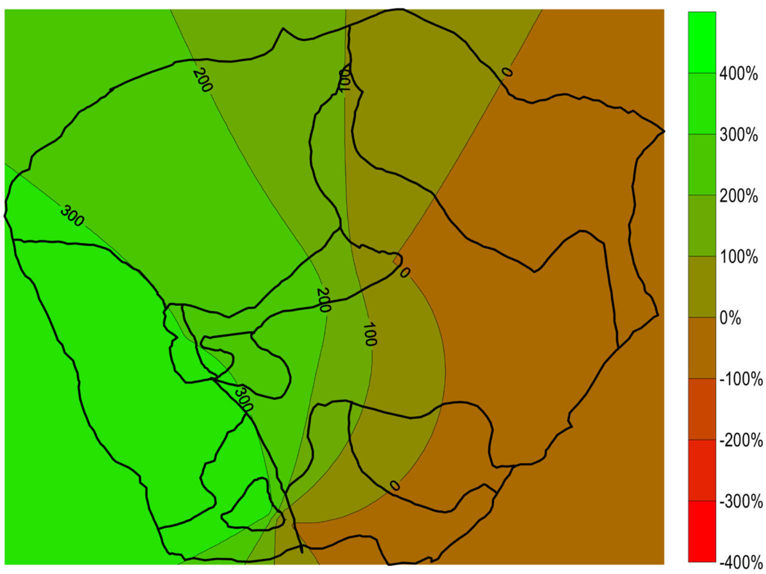

Fig 6. Average productivity of improved cassava varieties

varieties in this region would require supply of adequate amounts of fertilizers combined with other soil fertility management practices. In general, the yield of the improved cassava varieties increased by 100-350% relative to that of the local variety across the Kwara State. We therefore recommend the promotion of these improved varieties, especially TMS 419 for cultivation in the Kwara State.

Soil suitability index versus cassava productivity index

The yield of cassava was slightly higher at Unilorin than at Offa (Table 5) probably due to more favourable soil texture for root and tuber development at the former site. However, comparing the combined effects of the other soil properties with the productivity index, an opposite trend was observed. Taking all the soil parameters into consideration, the soils at Offa were more suitable for cassava production (57.2%) than those at Unilorin (37.6%) (Table 4). Consequently, the productivity index was also better at Offa (345%) than at Unilorin (284%). Furthermore, the improved cassava varieties performed much better than the local variety at Offa than at Unilorin because of the generally more favourable soil chemical properties at the former site. However, the soils at Offa would have to be limed and their organic matter content improved to achieve higher yield of cassava. Ande et al. (2008) reported that cassava produced maximally on light to medium textured and fertile soils. In addition, promotion of the production of the improved cassava varieties should be accompanied with good soil fertility management practices such as application of organic matter for instance compost, biochar, or cow dung (Tovihoudji et al., 2015) and adequate amount of requisite fertilizers (e.g. micro-dose fertilization technique) (Kpadonou et al., 2019b) among others.

The improved cassava varieties performed far better than the local variety even though the soils (plots) received the same treatments. It could be concluded that the more suitable the soil, the better the improved varieties performed.

Conclusion and Recommendations

Suitable levels of pH, organic carbon, nitrogen, phosphorus and CEC were critical in improving the production of cassava in Kwara state. Soil suitability generally decreased from the north to the south of the study area while the improved cassava varieties showed decreasing productivity from the Western to the Eastern Districts. The study also showed that the improved cassava varieties adapted well to the study area indicating that their production would be good for achieving food security. We, therefore, recommend the promotion of these improved cassava varieties for cultivation. However, application of organic and inorganic fertilizers to improve soil nutrient levels and correct soil deficiencies would be vital for the production of these improved cassava varieties. These soil management measures are needed more in the Moro, Edu, Irepodun and Isin districts for better response. Future research could further assess the suitability levels by considering other factors like land use type, soil types, climatic factors such as temperature, rainfall, relative humidity, and landform related factors such as slope, topography and erosivity. Another study could examine socio-economic conditions and compare suitability results with those of land use and land cover of the area.

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