Maize and Cassava Based Systems: Implications of Continuous Cropping on Chemical Properties of a *Ferric Acrisol/dystic Fluvisol*

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Abstract

Cassava and maize are important staple foods in several tropical countries including Ghana and are largely cultivated on subsistence bases. This study assessed and compared the effect of continuous cassava-based (CB) and maize-based (MB) cropping systems on some selected soil chemical properties, after seven years continuous cropping. The study was superimposed on two cropping systems on four fields. Similar pH, C, SOM, exchangeable K, CEC and available. K values among the cassava based cropping systems within both 0-20 cm and 20-50 cm depth of soil profiles possibly suggests minimum influence or impact of cropping on these parameters. Repeated mechanized activities on cassava-based system 2 (CB2), may have resulted in significantly lower levels of N relative to that of cassava-based system 1 (CB1) within 0-20 cm depth of profile. Thus, the probable decrease in mechanical activities with increased depth (20-50 cm) may have resulted in comparable N levels for both CB1 and CB2. Increased frequency of legume cultivation contributed significantly to a higher buildup of Ca and avail. P within the 20-50 cm soil depth where physical activity is minimal for CB2 compared to CB1. Integration of legume rotation, short fallows and fertilization demonstrate the higher potential of integrated soil fertility management to sustainably improve soil fertility over natural fallowing which requires longer duration to restore fertility

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Keywords: Chemical Properties, Continuous Cropping, Legume-based, Maize-based.

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Résumé

Le manioc et le maïs sont des aliments de base importants dans plusieurs pays tropicaux, y compris le Ghana et sont largement cultivés sur des bases de subsistance. Cette étude a évalué et comparé l'effet des systèmes continus de manioc (CB) et de maïs (MB) sur certaines propriétés chimiques du sol sélectionnées, après sept années de culture continue. L'étude a *été superposée sur deux systèmes de culture sur quatre champs. PH, C, SOM, K échangeables, CEC et les valeurs de K disponibles parmi les systèmes de culture à base de manioc à la profondeur des profils de sol de 0-20 cm et 20 à 50 cm suggèrent éventuellement une influence ou l'impact minimum de la culture sur ces paramètres. Les activités mécanisées répétées sur le système basé sur le manioc 2 (CB2) ont entraîné des niveaux nettement inférieurs de N par rapport à celui du système 1 (CB1) basé sur le manioc dans une profondeur de profil de 0 à 20 cm. Ainsi, la diminution probable des activités mécaniques avec une profondeur accrue (20-50 cm) peut avoir entraîné des niveaux de N comparables pour CB1 et CB2. La fréquence accrue de cultivation des légumineuses a contribué de manière significative à une accumulation plus élevée de Ca et de P disponible dans la profondeur du sol de 20 à 50 cm où l'activité physique est minimale pour CB2 par rapport à CB1. L'intégration de la rotation des légumineuses, les jachères courtes et la fécondation prouvent que le plus grand potentiel de la gestion intégrée de la fertilité des sols pour améliorer durablement la fertilité des sols sur les jachères naturelles, ce qui nécessite une durée plus longue pour rétablir la fertilité.*

Mots-clés: Propriétés chimiques, culture continue, légumineuses de base, maïs de based.

Introduction

Poverty, hunger and food security are issues of global concern due to their direct linkage to human existence. Farmers whose production are small scale in nature depend on the soil nutrient's resource base in sub-Saharan Africa. Cassava and maize are important staple foods in several tropical countries including Ghana and are largely cultivated on subsistence bases. In a greater part of the tropics, however, population growth and technological changes have resulted in increased intensity of farming either by reducing the length of the fallow period or by clearing large areas of land for continuous cropping. Such changes have led to "soil nutrient mining" and accelerated soil erosion (Juo and Franzluebbers, 2003). These affect soil physical and chemical properties by increasing soil bulk density and reducing both macro-porosity and macro-aggregates, resulting in less water and nutrient availability (Qin *et al.*, 2007).

Poor agricultural practices coupled with the adverse effects of climate change poses a major threat to food security. Sound agricultural practices could, however, mitigate or reduce these challenges and ensure sustained food production. The use of leguminous plants in cropping systems as cover crops, live-mulch, or food crops through alley farming, planted fallows or multiple cropping systems has been recognized to contribute significantly to the maintenance of soil physical and chemical properties. In a study, rotation of cowpea with maize and cassava resulted in a general improvement in soil fertility (Adjei-Nsia and Sakyi-Dawson, 2012).

To ensure sustainable and cost effective food crops production, it is vital to explore and promote practices that ensure minimal impact on soils. This study assessed the impacts of continious cropping of cassava and maize for seven years on selected soil chemical properties. Specifically, the objectives of the study were to comparatively assess soil chemical properties of cassava and maize cropped soils and determine changes in these properties within the seven year period.

Materials and Methods

Site Description

This study was conducted on the Grains and Legumes Development Board (GLDB) foundation seed production fields at Afraku, in the Ejisu-Juaben District in the Ashanti Region of Ghana. The location lies on longitude 06°, 43' W and latitude 01°, and 36° N at altitude of 278 m above sea level. The mean annual rainfall is 1,600 mm and the mean air temperature ranges between 24 and 27° C with mean relative humidity which ranges between 40 and 85%. The soils in the area belong to the Bomso-Ofin Association (Ghana Soil Classification) or *Ferric Acrisol/Dystic Fluvisol* (FAO/UNESCO Soil Classification, 1976).

Experimental Procedure

The current study was superimposed on two cassava and maize cropped fields subjected to different cropping treatment schedules replicated three times and arranged in a completely randomized design. The treatments comprised (i) four acre cassava-based system with five years continuous production followed by one year bush fallow and one year cowpea production (CB1); (ii) five acre cassava-based system with two years continuous production, followed by one year fallow and two years of legume production (CB2); (iii) five acre maize-based system with alternated 4 months maize production and 8 months bush fallow for continuous seven years period (MB1) and (iv) four acre maize-based system alternated 6 months maize production with 6 months cowpea production for seven continuous years (MB2). Land preparation was done mechanically by slashing, ploughing and harrowing every cropping season. Breeder seeds of *Obatanpa* maize, an open pollinated variety with maturity period of 105-110 days, were obtained from Crops Research Institute. A breeder seed of *asetenapa*, a cowpea variety which matures between 62-65 days was also obtained from Crops Research Institute. All the maize fields were fertilized during the cropping period with NPK 15:15:15 at the rate of 250 kg/ha product two weeks after planting (WAP) and sulphate of ammonia at the rate of 125 kg/ha product four WAP. The cassava and legume fields were not fertilized.

Soil Sampling and Laboratory Analysis

Initial soil parameters were determined before the imposition of the treatments as shown in Table 1. At the seventh year of cropping soil samples were collected from treatment plots along transects across each plot at 50 m interval sampling points using an auger. A minimum of four sampling points were located on each field. At each sampling point, three core soil samples spaced 50 m apart were collected on a line perpendicular to the transect at two soil depths, 0-20 cm and 20-50 cm. These were thoroughly mixed and 32 sub-samples were collected for each depth of profile and transported in sealed poly bags to the Council for Scientific and Industrial Research-Soil Research Institute laboratory for analysis.

Kjeldahl digestion method was used to determine total nitrogen (N). Subsamples were subsequently air-dried at room temperature (~20-25 °C) to a constant weight and passed through a 2-mm sieve (#10 US standard Testing Sieve). Soil pH was measured in a 1:2 soil solution (0.01 M $CaCl_2$; Kalra and Maynard, 1991) with a digital pH meter (Model PHH-200, Omega Eng. Inc., Stamford CT). Phosphorus (P) was determined by the Bray and Kurtz No.1 method for acidic soils. Cation exchange capacity (CEC) was determined by the manual leaching method using vacuum extraction, potassium (K) by the atomic absorption spectrophotometry, and calcium (Ca) and magnesium (Mg) by the ethylenediaminetetra acetic acid (EDTA) titration method (Kalra and Maynard, 1991). Soil organic matter

(SOM) content was measured followed by reacting 0.5 g of soil with 10 ml of 1M $K_2Cr_2O_7$ in the presence of concentrated H_2SO_4 (98%). After reaction, excess dichromate was quantified calorimetrically and used to assess how much reacted with the soil Carbon (C) (Skjemstad and Baldock, 2007).

Statistical Analyses

The Student's t-test analysis was used to compare data on soil chemical properties within and between cropping systems.

The levels of these soil chemical properties were compared to the benchmark data recorded after the field was bulldozed for food crop productions in 1998 (Table 1).

The initial soil property levels were also used to calculate the percentage changes by using the formula a-b/b*100. Where a, is the initial soil chemical properties determined in 1998, and b the current soil chemical properties.

Results

Soil Chemical Characteristics among Cassava and Maize-Based Cropping Systems

Soil pH, C, SOM, exchangeable K, CEC and avail. K after 7 years of cropping were similar among the cassava based cropping systems within both 0-20 cm and 20-50 cm depth of soil profiles. The ranges of soil properties were pH (5.54-5.84), C: 1.08-1.33%, SOM: 1.86-2.28 %, exch. K: 0.94-0.93 cmol kg^{-1}, CEC: 8.80-7.35 cmol kg^{-1}, and avail. K: 135.9-123.4 cmol kg^{-1}. Nitrogen was also comparable within 20-50 cm depth of profile for both cropping systems but was higher for CB1 than CB2 within 0-20 cm depth of profile.Whiles Mg was significantly higher within both depths of profiles for CB1 than CB2, higher levels of Ca and avail. P were only observed within 20-50 cm depth (Table 2).

Among the maize-based cropping systems, soil pH, C, SOM, N, Mg, exchangeable K and P were similar within both 0-20 cm and 20-50 cm depth of soil profiles over the seven year cropping period. The ranges were: soil pH: 5.53-5.54, C: 1.27-1.33%, SOM: 2.19-2.29%, N: 0.15-0.16%, exch. K: 0.71-0.82 cmol kg^{-1} and P: 5.15-5.46 mg kg^{-1}. However, Ca, CEC and Mg were higher for MB2 than MB1 for both depth of profiles (Table 3).

Soil Chemical Characteristics between Cassava and Maize-Based Cropping Systems

Soil pH was significantly higher for CB1 than MB1 within 0-20 cm soil depth but otherwise in the 20-50 cm depth. Consistently higher Mg values were obtained for CB1 than MB1 in contrast to avail. P which was higher for MB1 than CB1 within both soil depths. Significantly higher Ca levels were however, only observed within the 20-50 cm depth. Soil C, N, SOM and avail. K, did not vary significantly ($p < 0.05$) between CB1 and MB1 for both depths of profiles (Table 4).

Both exchangeable and avail. K were higher for CB1 than MB2 with both soil depths but vice versa for avail. P. CEC was however, higher for MB2 than CB1 only within the 20-50 cm soil depth (Table 5).

Soil Ca was significantly higher ($p < 0.05$) for CB2 (4.90 me/100 g) than MB1 (4.30 cmol kg^{-1}) within 0-20 cm depth but vice versa with increased soil depth (20-50 cm) (Table 6). CEC was higher for CB2 (7.35 cmol kg^{-1}) than MB1 (6.55 cmol kg^{-1}) within 0-20 cm depth in contrast to pH and Mg which were higher for CB2 within 20-50cm depth of profile. Exchangeable K and avail. P were also significanlty ($p < 0.05$) higher for MB1 than CB2 within 20-50 cm depth (Table 6). While Ca was significantly ($p < 0.05$) higher for MB2 than CB2 within both depth of profiles, avail. K was higher for MB2 just within 20-50 cm depth. Also, avail. P was higher for MB2 (5.15 mg kg^{-1}) than CB2 (3.22 mg kg^{-1}) in contrast to exchangeable K and CEC which were significantly ($p<0.05$) low in MB2 within the 0-20 cm depth of profile (Table 7).

Percentage Changes in Soil Chemical Properties in Cassava and Maize-Based Cropping Systems

Noticeable changes in soil chemical properties were observed for most soil parameters within the 0-20 cm soil depth for both cassava and maize-based cropping systems. Calcium, exch. K, Mg, CEC, avail. P and avail. K recorded over 100% increases in both cassava (CB) and maize (CB) based systems. However, C, SOM and N recorded increases below 100%. (Table 8). Similar trends were observed within the 20-50 cm soil depth with C, SOM and N again recording less than 100% increments (Table 8).

Discussion

Soil Chemical Characteristics among Cassava and Maize-Based Cropping Systems

*Similar p*H, C, SOM, exchangeable K, CEC and avail. K values among the cassava based cropping systems within both 0-20 cm and 20-50 cm depth of soil profiles possibly suggests minimum influence or impact of cropping on these parameters. However, repeated mechanized activities on CB2, may have resulted in significantly lower levels of N relative to that of CB1 within 0-20 cm depth of profile (Agbede *et al.,* 2009). Thus, the probable decrease in mechanical activities with increased depth (20-50 cm) may have resulted in comparable nitrogen levels for both CB1 and CB2. Also, the increased frequency of legume cultivation could have contributed significantly to a higher buildup of Ca and avail. P within the 20-50 cm soil depth where physical activity is minimal for CB2 compared to CB1 (Wild, 1993; Adjei-Nsiah and Sakyi-Dawson, 2012). This complements the results of a study that indicated that frequent legume crop rotation over a period of time contributes to the improvement in soil fertility (Bado *et al*., 2011).

Similarly, soil pH, C, SOM, N, Mg, exchangeable K and P were comparable among maize-based cropping systems (MB1 and MB2) within both depths of soil profiles over the seven year cropping period. However, higher Ca, CEC and Mg for MB2 than MB1 for both depth of profiles demonstrate the higher potential of crop rotation to improve soil fertility over natural fallowing which requires longer duration to restore fertility. CEC of a soil represents the total amount of exchangeable cations that the soil can adsorb. Calcium and Magnesium are among the essential cations used by plants in the largest amounts. The higher CEC, Ca and Mg levels for MB2 could translate to maize yield increases (Major *et al*., 2010). Results of this study suggests that sustained yield of maize for years could be achieved through equal duration of cropping and rotation with cowpea rather than shorter cropping duration followed by longer natural fallow periods.

Soil Chemical Characteristics as Affected By Cassava and Maize-Based Cropping Systems

The lack of significant differences in soil C, N, SOM and avail. K, between CB1 and MB1 could imply that the inclusion of fallows and/or legume crops cultivation in both systems could have similar effects on these nutrients as reported (Biederbeck *et al.,* 1994) The soil under MB1 was more acidic than CB1 within 0-20 cm soil depth probably due to soil fertility management practices like top dressing of maize with sulphate of ammonia. A study has shown that most N-containing inorganic fertilizers, unless specially treated tend to acidify soils (Gazey and Ryan, 2015). This is mainly due to the impact of certain carriers that supply ammonia or result in its production when added to the soil. Upon oxidation, the ammonia compounds release H^+ ions which are potential sources of soil acidity.

Higher Mg values were obtained for CB1 compared to MB1 and the reverse of higher avail. P for MB1 than CB1 within both soil depths contrasts the report that cassava take-up Ca, Mg and exchangeable K in greater quantities than maize (Howeler, 1991). This however, could suggest that either the levels of demand of these nutrients by the plants may vary depending on the management practices. Also, the zone of nutrients uptake resulted in the lower Ca levels observed within the 20-50 cm depth for MB1 than CB1. The cassava root tubers were located within the 20-50 cm soil depth and most probably resulting in higher uptake of Ca. Hence, soil Ca was also higher ($p < 0.05$) for CB2 than MB1 (4.30 cmol kg^{-1} within 0-20 cm depth but vice versa with increased soil depth 20-50 cm). Also, higher Ca for MB2 compared to CB2 within the 0-50 cm depth suggests that cropping of maize followed immediately by legumes at shorter intervals has a higher potential to maintain Ca than prolonged cropping of cassava followed by a combination of fallows and legume cultivation. Generally, the study results indicated that the cassava based systems enhanced CEC better than maize based systems attributable to the potential of fallows to restore soil fertility. For example, a study reported that soils under fallows enhanced the amounts of C, N, SOM and K than those without fallows (Vanlauwe *et al*., 1999). However, increased population, scarcity of land coupled with increased food demands is a major obstacle to the practice of fallowing the benefits of it nothwithstanding.

The lower exchangeable K in the MB2 system could be attributed to fast growth of maize which requires high utilization of K and is often lost through frequent harvesting of maize compared to cassava. Conversly, differences in nutrient uptake possibly resulted in higher levels of avail. P for MB2 compared to CB1. For instance, maize utilizes more N compared to P (Masters *et al.,* 2016). Thus, the depth of nutrient uptake by maize coupled with the probable less utilization of P could account for the significanlty ($p < 0.05$) higher exchangeable K and avail. P for MB1 than CB2 within 20-50 cm depth.

Percentage Changes in Soil Chemical Properties in Cassava and Maize-Based Cropping Systems

The cropping systems did not negatively affect the soil nutrients determined. With exception of C, SOM and N, all the other soil nutrients recorded over 100% positive changes. The over 100% increases for both cassava (CB) and maize (CB) based systems within the 0-20 cm soil depth for Ca, exch. K, CEC, avail. P and avail. K contrasts a similar study on cassava and maize which reported

Table 1. Data on some initial soil chemical properties at the study site after bulldozing.

Series	Depth (cm)	pH 1:1 H_2O	Org C %	N %	SOM %	Ca cmol kg^{-1}	Mg cmol kg^{-1}	K cmol kg^{-1}	CEC cmol kg^{-1}	P Mg kg^{-1}	K cmol kg^{-1}
Bomso	0-20	4.6	1.8	0.2	3.1	3.4	0.6	0.1	4.6	0.4	62
	20-50	4.5	1.2	0.1	2.1	1.9	0.5	0.1	3.6	trace	57

Source: Modified from Dwomo and Kyei (1998)

Table 2. Soil chemical properties as affected by cassava-based cropping systems after seven years of cultivation

Depth / Properties	*Cropping System*		*P-Values*
	CB1	*CB2*	
0-20 cm			
pH (H$_2$O)	5.84 ±0.14	5.54 ± 0.28	0.06^{ns}
C %	1.08 ± 0.44	1.33 ± 0.30	0.20^{ns}
SOM %	1.86 ± 0.76	2.28 ± 0.52	0.20^{ns}
N %	0.19 ± 0.04	0.14 ± 0.02	0.04**
Ca cmol kg^{-1}	5.78 ±0.13	4.90 ± 0.07	1.19^{ns}
Mg cmol kg^{-1}	1.74 ± 0.13	1.22 ± 0.07	0.00***
Exch.K cmol kg^{-1}	0.94 ± 0.16	0.93 ± 0.12	0.44^{ns}
CEC cmol kg^{-1}	8.80 ± 0.24	7.35 ± 0.21	5.13^{ns}
Avail. P mg kg^{-1}	2.35 ± 0.73	3.22 ± 0.88	0.09^{ns}
Avail. K cmol kg^{-1}	135.93 ±34.59	123.44 ± 20.16	0.29^{ns}
20-50 cm			
pH (H$_2$O)	5.24 ± 0.12	5.16 ± 0.26	0.30^{ns}
C %	0.58 ± 0.12	0.63 ± 0.11	0.26^{ns}
SOM %	0.99 ± 0.20	1.09 ± 0.19	0.24^{ns}
N %	0.07 ± 0.01	0.09 ± 0.02	0.11^{ns}
Ca cmol kg^{-1}	2.30 ± 0.08	2.52 ± 0.08	0.00***
Mg cmol kg^{-1}	0.89 ± 0.06	1.00 ± 0.08	0.03**
Exch.K cmol kg^{-1}	0.46 ± 0.12	0.38 ± 0.03	0.13^{ns}
CEC cmol kg^{-1}	4.11 ± 0.22	4.44 ± 0.35	0.09^{ns}
Avail. P mg kg^{-1}	0.86 ± 0.24	1.41 ± 0.24	0.01***
Avail. K cmol kg^{-1}	69.54 ±16.89	70.75 ±15.93	0.46^{ns}

, * is significant at 0.01 and 0.001 probability levels respectively, Values are means ± standard error, ns = not significant

Table 3. Soil chemical properties as affected by maize-based cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*		*P-Values*
	MB1	*MB2*	
0-20 cm			
pH (H_2O)	5.53 ± 0.13	5.53 ± 0.40	0.50^{ns}
C %	1.33 ± 0.25	1.27 ± 0.33	0.39^{ns}
SOM %	2.29 ± 0.43	2.19 ± 0.58	0.40^{ns}
N %	0.16 ± 0.03	0.15 ± 0.03	0.46^{ns}
Ca cmol kg^{-1}	4.30 ± 0.14	5.04 ± 0.07	3.30^{ns}
Mg cmol kg^{-1}	1.22 ± 0.08	0.79 ± 0.05	3.45^{ns}
Exch.K cmol kg^{-1}	0.82 ± 0.14	0.71 ± 0.18	0.19^{ns}
CEC cmol kg^{-1}	6.55 ± 0.09	6.95 ± 0.16	0.00***
Avail. P mg kg^{-1}	5.46 ± 3.07	5.15 ± 1.58	0.43^{ns}
Avail.K cmol kg^{-1}	115.19 ±35.51	95.45 ± 27.01	0.21^{ns}
20-50 cm			
pH (H_2O)	5.53 ± 0.13	5.53 ± 0.41	0.50^{ns}
C %	0.66 ± 0.15	0.49 ± 0.11	0.07^{ns}
SOM %	1.13 ± 0.26	0.84 ± 0.20	0.07^{ns}
N %	0.09 ± 0.02	0.09 ± 0.02	0.36^{ns}
Ca cmol kg^{-1}	2.62 ± 0.08	2.78 ± 0.08	0.01***
Mg cmol kg^{-1}	0.79 ± 0.05	0.90 ± 0.07	0.02**
Exch.K cmol kg^{-1}	0.45 ± 0.04	0.44 ± 0.20	0.39^{ns}
CEC cmol kg^{-1}	4.21 ± 0.67	4.65 ± 0.53	0.09^{ns}
Avail. P mg kg^{-1}	2.17 ± 0.24	1.82 ± 0.51	0.14^{ns}
Avail.K cmol kg^{-1}	115.19 ± 28.81	95.45 ± 10.70	0.30^{ns}

, * is significant at 0.01 and 0.001 probability levels respectively, ^{ns} not significant at 0.01, Values are means ± standard error

Table 4. Comparison of selected soil chemical properties between CB1 and MB1 cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*		*P-Values*
	CB1	*MB1*	
0-20 cm			
pH (H$_2$O)	5.84 ± 0.14	5.53 ± 0.13	0.01***
C %	1.08 ± 0.44	1.33 ± 0.25	0.19^{ns}
SOM %	1.86 ± 0.76	2.29 ± 0.43	0.18^{ns}
N %	0.19 ± 0.04	0.16 ± 0.03	0.13^{ns}
Ca cmol kg^{-1}	5.78 ± 0.13	4.30 ± 0.14	2.20^{ns}
Mg cmol kg^{-1}	1.74 ± 0.13	1.22 ± 0.08	0.00***
Exch.K cmol kg^{-1}	0.94 ± 0.16	0.82 ± 0.14	0.14^{ns}
CEC cmol kg^{-1}	8.80 ± 0.24	6.55 ± 0.09	1.04^{ns}
Avail. P mg kg^{-1}	2.35 ± 0.73	5.46 ± 3.07	0.05*
Avail.K cmol kg^{-1}	135.93 ± 34.59	115.19 ± 35.51	0.23^{ns}
20-50 cm			
2pH (H$_2$O)	5.24 ± 0.12	5.53 ± 0.13	0.01***
C %	0.58 ± 0.12	0.66 ± 0.15	0.23^{ns}
SOM %	0.99 ± 0.20	1.13 ± 0.26	0.21^{ns}
N %	0.07 ± 0.01	0.09 ± 0.02	0.07^{ns}
Ca cmol kg^{-1}	2.30 ± 0.08	2.62 ± 0.08	0.00***
Mg cmol kg^{-1}	0.89 ± 0.06	0.79 ± 0.05	0.02**
Exch.K cmol kg^{-1}	0.46 ± 0.12	0.45 ± 0.04	0.46^{ns}
CEC cmol kg^{-1}	4.11 ± 0.22	4.21 ± 0.67	0.23^{ns}
Avail. P mg kg^{-1}	0.86 ± 0.24	2.17 ± 0.24	0.00***
Avail.K cmol kg^{-1}	69.54 ± 16.89	115.19 ± 28.81	0.07^{ns}

*, **, *** is significant at 0.01 and 0.001 probability levels respectively, Values are means ± standard error, ns = not significant

Table 5. Comparison of selected soil chemical properties between CB1 and MB2 cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*		*Ho: μ_1-μ_2=0*
	CB1	*MB2*	
0-20 cm			
pH (H_2O)	5.84 ± 0.14	5.53 ± 0.40	0.10^{ns}
C %	1.08 ± 0.44	1.27 ± 0.33	0.27^{ns}
SOM %	1.86 ± 0.76	2.19 ± 0.58	0.26^{ns}
N %	0.19 ± 0.04	0.15 ± 0.03	0.11^{ns}
Ca cmol kg^{-1}	5.78 ± 0.13	5.04 ± 0.07	2.79^{ns}
Mg cmol kg^{-1}	1.74 ± 0.13	0.79 ± 0.05	5.16^{ns}
Exch.K cmol kg^{-1}	0.94 ± 0.16	0.71 ± 0.18	0.05*
CEC cmol kg^{-1}	8.80 ± 0.24	6.95 ± 0.16	6.84^{ns}
Avail. P mg kg^{-1}	2.35± 0.73	5.15 ± 1.58	0.01***
Avail.K cmol kg^{-1}	135.93 ± 34.59	95.45 ± 27.01	0.07^{ns}
20-50 cm			
pH (H_2O)	5.24 ± 0.12	5.53 ± 0.41	0.11^{ns}
C %	0.58 ± 0.12	0.49 ± 0.11	0.17^{ns}
SOM %	0.99 ± 0.20	0.84 ± 0.20	0.18^{ns}
N %	0.07 ± 0.01	0.09 ± 0.02	0.11^{ns}
Ca cmol kg^{-1}	2.30 ± 0.08	2.78 ± 0.08	6.99^{ns}
Mg cmol kg^{-1}	0.89 ± 0.06	0.90 ± 0.07	0.36^{ns}
Exch.K cmol kg^{-1}	0.46 ± 0.12	0.44 ± 0.20	0.39^{ns}
CEC cmol kg^{-1}	4.11 ± 0.22	4.65 ± 0.53	0.05*
Avail. P mg kg^{-1}	0.86 ± 0.24	1.82 ± 0.51	0.01***
Avail.K cmol kg^{-1}	69.54 ± 16.89	95.45 ± 10.70	0.05*

*, **, *** are significant at 0.01 and 0.001 probability levels respectively, Values are means ± standard error, ns = not significant

Table 6. Comparison of selected soil chemical properties between CB2 and MB1 cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*		*P-Values*
	CB2	*MB1*	
0-20 cm			
pH (H_2O)	5.54 ± 0.28	5.53 ± 0.13	0.47^{ns}
C %	1.33 ± 0.30	1.33 ± 0.25	0.50^{ns}
SOM %	2.28 ± 0.52	2.29 ± 0.43	0.50^{ns}
N %	0.14 ± 0.02	0.16 ± 0.03	0.21^{ns}
Ca cmol kg^{-1}	4.90 ± 0.07	4.30 ± 0.14	0.00***
Mg cmol kg^{-1}	1.22 ± 0.07	1.22 ± 0.08	0.26^{ns}
Exch.K cmol kg^{-1}	0.93 ± 0.12	0.82 ± 0.14	0.14^{ns}
CEC cmol kg^{-1}	7.35 ± 0.21	6.55 ± 0.09	0.00***
Avail. P mg kg^{-1}	3.22 ± 0.88	5.46 ± 3.07	0.11^{ns}
Avail.K cmol kg^{-1}	123.44 ± 20.16	115.19 ± 35.51	0.35^{ns}
20-50 cm			
pH (H_2O)	5.16 ± 0.26	5.53 ± 0.13	0.02**
C %	0.63 ± 0.11	0.66 ± 0.15	0.41^{ns}
SOM %	1.09 ± 0.19	1.13 ± 0.26	0.40^{ns}
N %	0.09 ± 0.02	0.09 ± 0.02	0.36^{ns}
Ca cmol kg^{-1}	2.52 ± 0.08	2.62 ± 0.08	0.05*
Mg cmol kg^{-1}	1.00 ± 0.08	0.79 ± 0.05	0.00***
Exch.K cmol kg^{-1}	0.38 ± 0.03	0.45 ± 0.04	0.02***
CEC cmol kg^{-1}	4.44 ± 0.35	4.21 ± 0.67	0.16^{ns}
Avail. P mg kg^{-1}	1.41 ± 0.24	2.17 ± 0.24	0.00***
Avail.K cmol kg^{-1}	70.75 ± 15.93	115.19 ± 28.81	0.08^{ns}

*, **, *** are significant at 0.01 and 0.001 probability levels respectively, Values are means ± standard error, ns = not significant

Table 7. Comparison of selected soil chemical properties between CB2 and MB2 cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*		*P-Values*
	CB2	*MB2*	
0-20 cm			
pH (H_2O)	5.54 ± 0.28	5.53 ± 0.40	0.48^{ns}
C %	1.33 ± 0.30	1.27 ± 0.33	0.39^{ns}
SOM %	2.28 ± 0.52	2.19 ± 0.58	0.41^{ns}
N %	0.14 ± 0.02	0.15 ± 0.03	0.25^{ns}
Ca cmol kg^{-1}	4.90 ± 0.07	5.04 ± 0.07	0.02**
Mg cmol kg^{-1}	1.22 ± 0.07	0.79 ± 0.05	6.79^{ns}
Exch.K cmol kg^{-1}	0.93 ± 0.12	0.71 ± 0.18	0.05*
CEC cmol kg^{-1}	7.35 ± 0.21	6.95 ± 0.16	0.01***
Avail. P mg kg^{-1}	3.22 ±0.88	5.15 ± 1.58	0.04***
Avail.K cmol kg^{-1}	123.44 ± 20.16	95.45 ± 27.01	0.08^{ns}
20-50 cm			
pH (H_2O)	5.16 ± 0.26	5.53 ± 0.41	0.09^{ns}
C %	0.63 ± 0.11	0.49 ± 0.11	0.06^{ns}
SOM %	1.09 ± 0.19	0.84 ± 0.20	0.06^{ns}
N %	0.09 ± 0.02	0.09 ± 0.02	0.50^{ns}
Ca cmol kg^{-1}	2.52 ± 0.08	2.78 ± 0.08	0.00***
Mg cmol kg^{-1}	1.00 ± 0.08	0.90 ± 0.07	0.06^{ns}
Exch.K cmol kg^{-1}	0.38 ± 0.03	0.44 ± 0.20	0.16^{ns}
CEC cmol kg^{-1}	4.44 ± 0.35	4.65 ± 0.53	0.26^{ns}
Avail. mg kg^{-1}	1.41 ±0.24	1.82 ± 0.51	0.10^{ns}
Avail.K cmol kg^{-1}	70.75 ± 15.93	95.45 ± 10.70	0.05*

*, **, *** are significant at 0.01 and 0.001 probability levels respectively, Values are means ± standard error, ns = not significant

Table 8. Changes in soil chemical properties for CB and MB cropping systems after seven years of continuous cropping

Depth / Properties	*Cropping System*	
	CB	*MB*
0-20 cm		
pH (H_2O)	119.20	119.29
C %	74.61	71.03
SOM %	74.79	71.45
N %	70.01	75.04
Ca cmol kg^{-1}	141.74	147.34
Mg cmol kg^{-1}	202.19	131.05
Exch.K cmol kg^{-1}	929.16	709.28
CEC cmol kg^{-1}	155.58	149.14
Avail. P mg kg^{-1}	803.05	1282.44
Avail.K cmol kg^{-1}	125.17	100.76
20-50 cm		
pH (H_2O)	113.93	121.86
C %	53.12	41.37
SOM %	53.01	40.97
N %	90.03	90.01
Ca cmol kg^{-1}	132.23	145.60
Mg cmol kg^{-1}	199.61	179.71
Exch.K cmol kg^{-1}	379.64	439.65
CEC cmol kg^{-1}	122.82	128.56
Avail. P mg kg^{-1}	Nd	Nd
Avail. K cmol kg^{-1}	111.58	109.27

Nd is not determined

that the removal of stem and root tubers, coupled with slow initial growth resulted in the extraction and subsequent decreases in P and K percentages (Imas and John, 2013; Hulugalle *et al*., 2007). The increase of C levels in MB system contrasts a reported loss of 371 kg C in an 8 year continuous maize cultivation mainly attributed to increased mineralization during crop establishment and tending (Tian *et al*., 2001). Thus it could be said that the growth of cassava on the field for more than one cropping season results in less soil disturbance and reduced C mineralization in the CB system.

Harvested produce has been identified as the major avenue of nutrient removal from the soil in many systems (Pettygrove and Bay, 2009). Increases in the soil nutrients levels could be attributed to the legume rotations, fallows and the fertilization which emphasizes the importance of integrated soil fertility management in sustainable agriculture.

Conclusion

Most soil chemical properties within and between both cassava and maize based systems were similar seven years after cropping. Variations in soil properties between cassava and maize based systems were mostly associated with soil depth. The similar soil properties for both systems highlights the positive interaction and additional benefits accrued by fallowing, legume rotation and fertilizer application. This emphasizes the importance of integrated crop and nutrient management systems to maintenance and improvement of the quality and productive capacity of soils.

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