Assessing the influence of land-use change on the variability of soil chemical properties in semi-arid zone of Ghana

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ABSTRACT

The study aimed at providing basis to consider spatial variability in soil fertility to inform effective decision making in mineral fertilizer recommendations. The study area was classified into six land-use categories using a rural rapid appraisal technique with the aid of the farmers in the community, and by remote sensing satellite imagery (Quick bird). Land-use categories varied significantly in their nutrient, organic carbon content, and stock with coefficient of determination ranging from 0.14 to 0.46. This is reflected in decline in soil nutrient, organic carbon content, and stock with increasing number of years the land was put under cultivation except for permanently cultivated fields. Permanantly cultivated fields were located in the homestead and benefited from nutrient imports from the bush fields. The two farm types also differed significantly with respect to soil nutrients, organic carbon and stock. Soil organic carbon content was 8.2 and 4.5 g kg^{-1} for the homestead and bushfields, respectively. Soil organic carbon stock estimated for the two farm types were 125 and 74 t ha^{-1} for the homestead and bush fields, respectively. The study shows a distinct zone of nutrient enhancement within the homestead and bushfields that should be sampled separately when sampling the zone for fertilizer recommendations.

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Introduction

Land-use activities such as agriculture, mining, and settlement generate economic benefits for the sustenance of man. However, changes in land use, reflecting in changes in land cover have inevitably a detrimental effect on the productivity of the soil. The extent to which this occurs depends on the land-use type and management practices, soil/land characteristics, and the intensity of the land-use activity. In many parts of the world, particularly in the tropics, soil productivity (quality) is threatened by environmental degradation associated with increasing land-use and land-cover change (Vitousek *et al*., 1997; Smalberger *et al.*, 2006). Oygard, Vedeld & Aune (1999) reported plant nutrient supply and soil fertility decline as major biophysical causes of declining per capita food production in semi-arid areas. Land-use changes and hillslope position rapidly diminish soil quality, particularly soil chemical properties (Mojiri, Kazemi & Amirossadat, 2011). Aghasi, Jalalian & Hornajoo, (2011) also reported that land-use change may lead to lower soil quality (organic carbon), and increase soil degradation with undesirable consequences. Other studies have also investigated the impact of land-use change on land quality (Glantz, 1998; Braimoh & Vlek, 2004). Ghartey *et al.* (2012), in their study on the assessment of soil variability in the coastal savanna of Ghana, indicated that land-use types significantly varied in terms of organic carbon and total nitrogen (N). Availability of published studies on the impact of land use/cover change on soil properties for Ghana is rather limited (Dowuona, Atsivor & Adiku, 2000; Ghartey *et al*. 2012). The study will, thus, serve to bridge that gap.

In Ghana, conversion of land under natural vegetation to agricultural land over the last two decades has been on the increase (Abatania & Albert 1993). The area of closed forest is estimated to be declining at an annual rate of 0.4 per cent and for the savanna woodland at 0.5 per cent (Forestry Department of Ghana, 1998). The expansion of agricultural land is mainly a response to increasing demand for food as a result of increasing population growth. Soils in the study area are described as fragile, easily degradable and are deteriorating at an alarming rate (Vlek, Kuhne & Denich, 1997). This is supported by findings of Braimoh & Vlek (2004), which showed that soil fertility in northern Ghana has been on the decline for the last two decades. The causes are believed to be mainly due to land management practices such as continuous cropping, mono-cropping, burning of standing vegetation and overgrazing among others.

Declining soil fertility is a major concern for communities in the savanna and transitional zones of Ghana (Abatania & Albert, 1993). To counteract this and increase fertility of the soil, animal manure is applied to fields in the homestead. Additionally, crop residues are carried from fields located in the bush for fodder and beddings for animals, which eventually end up in fields located in the settlement. Grazing may also mine nutrients from the bush fields to the homestead if livestock are kept overnight at the homestead (Wopereis *et al*., 2006). This may results in the creation of nutrient gradient between fields located within the settlement (homestead), and those located outside of the settlement (bush fields) (Zingore *et al.*, 2007).

The conversion and modification of land-cover through land-use activities, and the intensity with which these activities are carried out have the potential to interrupt the ecological services provided by the soil ecosystem. These include its ability to support soil micro-organisms, capability to store soil organic matter and recycle soil nutrients (Monreal *et al.,* 1998). The study seeks to provide a scientific basis to discourage the current practice of 'blanket' fertilizer recommendation to farmers (Wopereis *et al*., 2006). The objectives of the study were to assess the impact of land-use categories, management systems (farm types) on soil chemical properties, organic carbon content and stock in Pungu community in the semi-arid zone of Ghana.

Materials and method

Description of study area and farm management systems

The study was conducted at Pungu, a com-

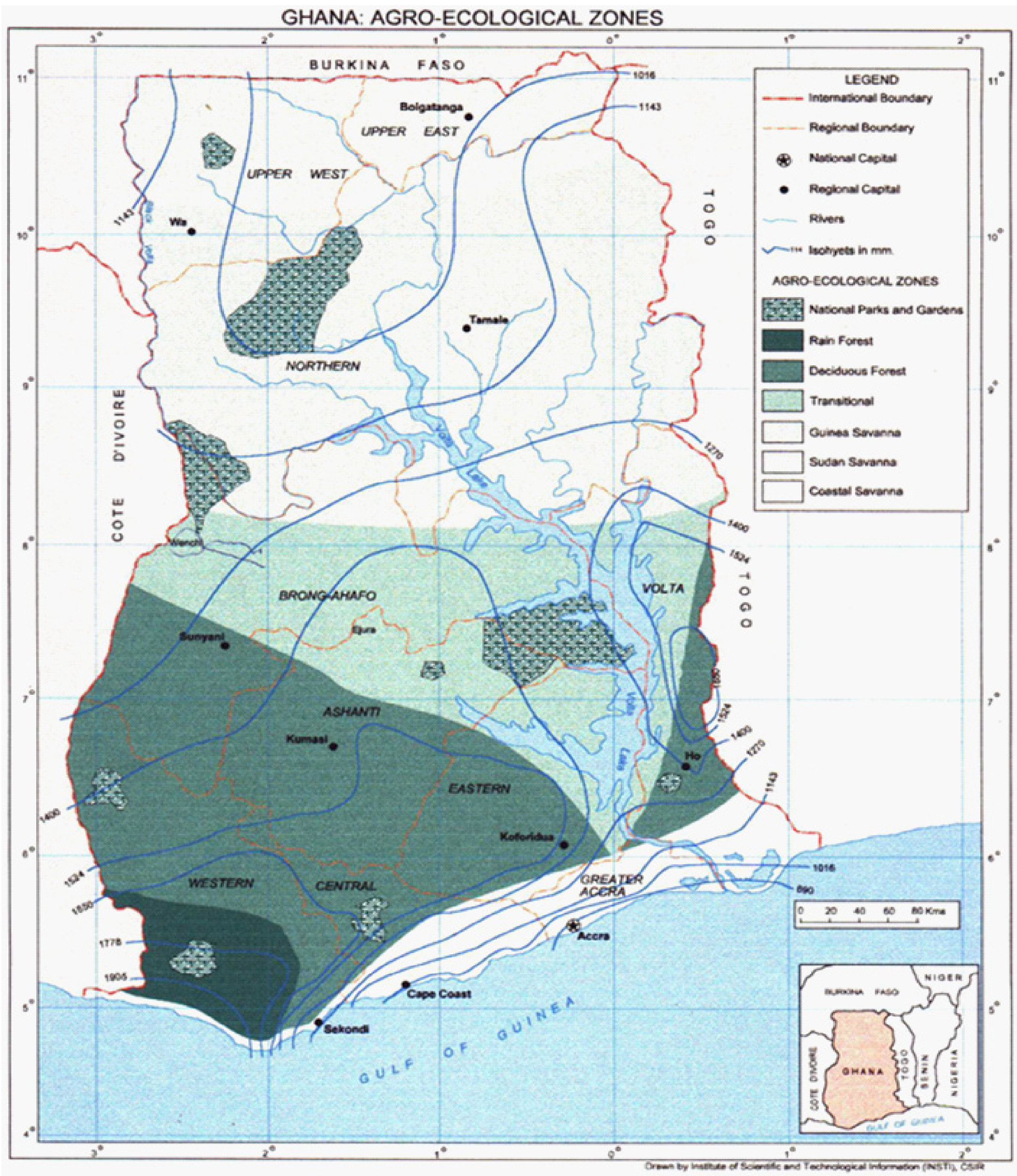

Fig 1. Study area located within the Volta basin of West Africa.

munity located in the Upper East Region of Ghana (Fig. 1). It lies in the transition zone of Guinea and Sudan savanna agro-ecological zones, and is characterised by grassland with scattered trees and shrubs. The Region is characterized by a uni-modal rainfall pattern with an annual average rainfall of 950 mm. The rainy season begins in May and ends in September/October, with some variation from year to year. The dominant soil type in the study area is Eutric Gleyic Regosol developed over voltaian sandstone (Overseas Development Institute, 1999).

There are two types of farm types, namely homestead/compound (fields close to the settlements) and bush-fields (fields located outside the settlements) which differ in soil fertility management practices. In the homestead, cereals are intercropped mainly with legumes and, in some instances, vegetables. The main crops cultivated in the area are sorghum and millet while the legumes cultivated are ground-nuts (*Arachis hypogaea* L.), bambara groundnuts (*Vigna subterranea*) and cowpea (*Vigna uniguiculata*). In the bush-farms, sole cropping is practiced (sole groundnuts or cowpea). Cereal cultivation in the bush-fields is quite limited due to the inability of farmers to apply fertilizers which are needed for reasonable yield. The main source of replenishing nutrient uptake by plants is through application of animal manure.

Sampling design

The study area was stratified into different land-use categories based on their land-use histories (number of years they were under continuous cultivation and under fallow). This was achieved through a participatory rural appraisal approach with the aid of a quick bird image (2.4 m × 2.4 m resolution). Ten farmers from the communities were selected with the aid of an agricultural extension staff to identify and map the various land-use categories. The farmers were divided into two groups on the basis of sex, and each group was asked to sketch a land-use/cover map. Each land-use category had fields with similar land-use history. Fields not cultivated consecutively for 15 years were taken as old fallow (Table 1). Subse-

Table 1

Description of Land-use Change Categories

Type	*Description**
Old fallow	A previous cropland which had not been cultivated for the past 15 years
Medium fallow	Cropland that reverted to natural vegetation in the past 4 years after being under continuous cultivation for 5 years.
Recent fallow	Cropland that reverted to natural vegetation in the past 2 years after being under continuous cultivation for 5 years.
Recent cropland	Six years fallow land converted to cropland in the past 1 or 2 years.
Old crop land	Six years fallow land converted to cropland in the past 5 to 6 years.
Permanently cultivated	Land under continuous cultivation for more than 15 years.

*Land-use history is similar for fields in same land-use category quent to this classification, the six categories of land-use were reclassified into farm types (homestead or bush fields). Permanently cultivated fields were with the homestead field category, whilst the remaining five land use categories were classified as bush fields.

Four fields (each of which is 1 ha in size) were identified for each land-use category for soil sampling. With the aid of the quick bird imagery and the sketches from the two groups, a land use map was drawn. All selected fields were located in the mid-slope position with a mean slope of 6.7 per cent. Location of fields relative to each other were by chance. Three mini-pits (70 cm in depth and 30 cm in diameter) were dug diagonally on each of the fields in each category of land-use, and soil type determined based on soil profile descriptions. Four fields classified as Eutric Gleyic Regosol were then selected for sampling from each category of land use.

Response of sorghum to N fertilizer application

Two N fertilizer trials were conducted in the homestead and bush fields with four levels (0, 40, 80 and 120 kg N ha^{-1}) of N applied in the form of urea. Grain yield data collected from this trial was used to draw a fertilizer response curve for the two farm types. Details of this experiment are available in MacCarthy *et al.* (2010).

Soil sampling and analysis

Soil sampling was done in the second week of June, 2005. Samples were collected along two transects that run diagonally on each of the four fields in each of the six land-use categories. A total of 30 soil samples were collected from each category. Soil samples were taken from the topsoil (0 - 15 cm depth) of each of the land-use category. The elevation of each sampling point was determined using a hand held Global Positioning System (GPS). The slope for each sampling point was derived from a digital elevation model. The soil samples were air dried, sieved through a 2-mm seive and, subsequently, analysed for soil organic carbon (Walkley &Black, 1934), total N (Kjeldahl) (Bremner, 1996) available P (Bray 1 P) (Bray & Kurtz, 1945), available K (0.5 *M* ammonium acetate), exchangeable acidity (1*M* KCl), exchangeable bases (K, Na, Ca and Mg) by 1*M* NH4-acetate method CEC (summation of exchanagble cations - index cation method) (Helmke & Sparks, 1996), *p*H (1:2.5 CaCl2) (Thomas, 1996) and base saturation.

Estimation of soil carbon stock

Soil carbon stock was calculated following (Li *et al*., 2012); SOCst (t ha^{-1})= BD (g cm^{-3}) × SOC (g kg^{-1}) × D (cm). Where SOCst is soil organic carbon stock, BD is bulk density, SOC is soil organic carbon and D is depth of sampling. Bulk density used in estimating carbon stock was estimated using the emperical relationship (Wu *et al.,* 2003) between organic carbon and bulk density; BD = -0.1229 ln(SOC) + 1.2901 (for SOC < 6 %).

Data analysis

Analysis of variance (ANOVA) was performed using the general linear model (GLM) procedure. Statistics applied included, descriptive statistics and Pearson's product moments correlation. Data sets were first tested for normal distribution using Kolmogorov – Simirnov test statistics, and those failing the test were log-, square-, root- or reciprocal-transformed to normality. Linear regression was used to show the strength of the functional relationship between organic carbon and selected soil properties in two management systems (homestead and bush fields). Tukey's mean separation procedure was used to differentiate between land-use categories and management systems (farm types).

Results

General description of soil

Soils in the study area are generally moderately acidic with a mean *p*H value of 5.7 ± 0.56 (Table 2). SOC contents of the soils were low and are generally very poor with very low levels of total N, available P and K. The soil CECs were also low. The soil chemical properties were generally highly variable, with CVs above 50 per cent except for soil *p*H and base saturation. Mean SOCst surveyed was 83 t ha^{-1} with a CV of 60.

Impact of land-use categories and farm types on soil chemical properties

The impact of land-use categories on soil chemical attributes are represented by their respective coefficient of determination (Table 2). The coefficient of determination indicating the influence of land-use categories on soil attributes range from 0.14 to 0.46. The impact was in decreasing order: *p*H > Mg = CEC > Ca > available P > available K > SOC > SOC_{st} > exchangeable K > exchangeable Na > total N > base saturation > exchangeable acidity > C:N. Differences in soil chemical attributes as a result of the different land-use categories are presented in Table 3. Soils under permanent cultivation had higher levels of SOC, SOC_{st}, total N, CEC, available P and K compared to the

Table 2

Summary Statistics of Soil Attributes of the Study Area

Soil attribute	*Min*	*Max*	*Mean*	*Sd**	*Cva (%)*	*R^2*
*p*H	4.7	8.2	5.7	0.56	10	0.46
SOC (g kg^{-1})	0.4	21.8	5.7	4.00	70	0.35
SOCst (t ha^{-1})	10	298	83	50	60	0.31
Total Soil N (g kg^{-1})	0.1	2.3	0.6	0.3	50	0.30
C-N ratio	2.7	19.0	8.8	3.6	41	0.14
Ca (cmol (+) kg^{-1})	0.4	17.8	2.6	2.0	77	0.41
Mg (cmol (+) kg^{-1})	0.2	4.0	0.8	0.7	81	0.44
Exchangeable K (cmol (+) kg^{-1})	0.06	3.01	0.2	0.26	110	0.26
Exchangeable Na (cmol (+) kg^{-1})	0.02	1.48	0.1	0.11	97	0.24
Exchangeable acidity (cmol (+) kg^{-1})	0.05	1.3	0.2	0.13	75	0.20
CEC (cmol (+) kg^{-1})	0.5	23.2	4.0	2.8	72	0.44
Available P (mg kg^{-1} Bray 1)	0.4	140.0	9.3	10.6	97	0.37
Available K (mg kg^{-1})	33	593	109	95.6	88	0.36
Base saturation (%)	70	99	94	4.9	5	0.24

Cv = Coefficient of variation; Sd = *Standard deviation; R^2 = Coefficient of determination.

TABLE 3

Statistics for Soil Chemical Properties of the Land-use Categories of the Study Area.

Land use history	p*H*	*SOC* *(g kg⁻¹)*	*SOCst* *(t ha⁻¹)*	*Total soil N* *(g kg⁻¹)*	*CEC* *(Cmol(+) kg⁻¹)*	*Avail. P* *(mg kg⁻¹)*	*Avail. K* *(mg kg⁻¹)*	*Ca* *(cmol (+) kg⁻¹)*	*Mg* *(cmol (+) kg⁻¹)*	*Exch Na* *(cmol (+) kg⁻¹)*	*Exch K* *(cmol (+) kg⁻¹)*	*Exch acidity* *(cmol(+) kg⁻¹)*	*BS* *(%)*
Old fallow [1]	5.2 (6)*	6.3 (25)	100 (23)	0.6 (28)	3.2 (27)	1.8 (60)	100.7 (56)	2.0 (32)	0.7 (51)	0.12 (54)	0.19 (40)	0.23 (62)	92.0 (6)
Medium fallow [2]	5.6 (6)	3.2 (88)	54 (76)	0.4 (50)	2.9 (36)	4.1 (81)	70.7 (28)	1.9 (42)	0.5 (52)	0.09 (44)	0.20 (36)	0.17 (56)	93.3 (5)
Recent fallow [3]	5.3 (6)	3.6 (31)	61 (27)	0.5 (30)	2.5 (30)	3.8 (15)	71.7 (28)	1.6 (32)	0.5 (50)	0.09 (67)	0.16 (35)	0.16 (63)	93.5 (4)
Recent cropland [4]	5.6 (4)	6.1 (51)	91 (45)	0.7 (36)	3.2 (50)	3.0 (52)	77.7 (30)	2.1 (51)	0.7 (55)	0.10 (42)	0.20 (49)	0.17 (48)	93.9 (4)
Old cropland [5]	5.5 (5)	3.8 (34)	65 (32)	0.4 (31)	2.4 (26)	3.4 (92)	59.0 (50)	1.6 (33)	0.5 (36)	0.08 (38)	0.13 (39)	0.18 (58)	91.7 (7)
Permanent	6.4	8.0	125	0.8	7.2	28.1	204.3	5.0	1.4	0.16	0.56	0.1	98.0
Cultivation [6]	(12)	(76)	(63)	(49)	(64)	(103)	(64)	(67)	(64)	(54)	(92)	(37)	(2)
ANOVA	0.00[a] 36.7[b]	0.00[a] 23.0[b]	0.00[a] 21.3	0.00[a] 18.0[b]	0.00[a] 34.0[b]	0.00[a] 25.1[b]	0.00[a] 22.9[b]	0.00[a] 30[b]	0.00[a] 34.0[b]	0.00[a] 30.1[b]	0.00[a] 29.9[b]	0.00[a] 30.0[b]	0.00[a] 13.2[b]
Tukey HSD mean seperation ($P = 0.05$)	3#4, 3#6 4#6, 1#4 1#6, 6#5 6#2, 1#5 1#2,	3#4, 3#6 3#1, 4#5 4#2, 6#1 6#5, 6#2 1#5, 1#2	3#4, 3#6 3#1, 4#5 4#2, 6#1 6#5, 6#2 1#5, 1#2	3#6, 4#6 4#5, 6#1 6#5, 6#2 1#5, 1#2	3#6, 4#6 6#1, 6#5 6#2,	3#6, 4#6 6#1, 6#5 6#2,	3#6, 4#6 6#1, 6#5 6#2,	3#4, 4#6 6#1, 6#5 6#2,	3#4, 4#6 6#1, 6#5 6#2,	3#4, 4#6 6#1, 6#5 6#2,	3#4, 4#6 6#1, 6#5 6#2,	3#4, 4#6, 6#2, 6#5, 6#2	3#4, 4#6 6#1, 6#5 6#2,

[a]; probability, [b] = F-statistics, # = significantly different; $P < 0.05$, SOC = Soil organic carbon, Avail. = Available, ( )* coefficient of variation in parenthesis

other land-use categories. Soil carbon stock (15 cm deep) sampled ranged from 54 to 125 t ha^{-1}for the various land-use categories and were significantly different among land-use categories. Total soil N levels were very low and variable with the variability being highest on permanently cultivated fields (CV = 49 %).

Land-use categories did differ among themselves with respect to CEC, available P and K. The total N level in old fallow lands was significantly higher than that in old cropland and medium fallow. The mean value of total soil N measured for all the land use categories were in decreasing order: permanent cultivation > new cropland > old fallow > new fallow > old cropland > medium fallow. In general, decreasing trends were observed in the values of soil nutrients with increasing intensity of cultivation except for those on permanently cultivated fields.

Difference between farm types (homestead and bushfields), differences in soil nutrients, SOC and SOC_{st} for the farm types are shown in Table 4. Homestead fields had higher contents of SOC, SOC_{st}, total N, available K and P than the bush fields. Mean CEC of the soil was also higher in the homestead fields than in the bush fields. Twice as much organic carbon were measured in the homestead compared to that in the bush fields. Mean values of available P were 28.1 and 3.2 mg kg^{-1} in the homestead and bush fields, respectively. Thus, available soil P in the homestead was more than eight-folds higher than that of the bush fields (Table 4). Variability in soil properties in the two farm types were between moderate to very high (between 37% and 97%) except for *p*H. Properties were more variable in the homestead fields than in the bush fields.

The correlations among soil attributes from the bush fields were lower in magnitude than those of the homestead fields.

TABLE 4

Soil Chemical Attributes of Two Farm Types at the Study Area (Pungu)

Soil attribute	*Min*	*Max*	*Mean*	*Cv*	*Min*	*Max*	*Mean*	*Cv*	*T-test*
	Homestead fields				*Bush fields*				
*p*H	5.2	8.2	6.4	12	4.7	6.3	5.4	6	-7.60*
SOC (g kg^{-1})	4.0	21.8	8.2	72	0.5	13.3	4.5	54	-6.20*
SOCst(t ha^{-1})	30	298	125	63	10	194	75	48	-6.01*
Total Soil N (g kg^{-1})	0.3	2.3	0.9	49	0.1	1.4	0.5	40	-4.88*
Ca (cmol (+) kg^{-1})	1.4	17.7	5.0	67	0.1	5.6	1.8	41	-11.72*
Mg (cmol(+) kg^{-1})	0.3	3.8	1.4	64	0.2	1.8	0.6	54	-10.11*
K (cmol(+) kg^{-1})	0.2	3.0	0.6	92	0.1	0.5	0.2	43	-9.98*
Na (cmol(+) kg^{-1})	0.08	0.6	0.16	54	0.02	0.04	0.01	52	-4.32*
Exchangeable acidity	0.05	0.2	0.10	37	0.05	0.63	0.2	61	-5.74*
CEC (cmol(+) kg^{-1})	2.7	23.0	7.2	63	0.5	8.0	2.8	37	-5.98*
BS (%)	92.6	99.8	98.0	2	70.3	99.0	92.9	47	-6.47*
Available P (mg kg^{-1})	4.8	91.7	28.1	90	0.1	18.9	3.2	72	-11.84*
Available K (mg kg^{-1})	32.9	559.7	204.3	60	123	398.2	75.9	5	-6.14*

Bs = Base saturation; Cv = Coefficient of variation, There was a significant correlation ($r = 0.50$) between soil organic carbon and P in the homestead field soils, while relationship in the bush field soils was not significant. Soil *p*H correlated significantly with all soil attributes in the homesteads. In the bush field soils, it related to all soil attributes except for SOC and Ca. The relationship between soil properties were significantly different between the two farm types. This is evident from the weaker correlation (Fig. 2) between SOC and CEC, total N and available P in the bush fields soils as compared to those in the homestead fields. In the bush field soils, available P showed a consistent lack of correlation with all soil attributes except *p*H.

Discussion

Results from the study indicated that the soils in the study area are generally poor in soil nutrients, SOC and carbon storage. This is in agreement with similar studies carried out by Braimoh & Vlek (2004). The low fertility status may be related to low soil productivity in the area (MacCarthy *et al*., 2010). It can also significantly affect the responsiveness of the soil to mineral fertilization as reported by Rusinamhodzi *et al.* (2013). The high coefficient of determinations for the soil parameters indicated the significance of the impact of land use categories on soil nutrient, and organic carbon status and carbon stock. This is underlined by the high explanatory power of land-use categories on the variations in soil attributes (Table 2). Percentage base saturation of the soils was the least influenced by land-use categories with a coefficient of determination of 0.24. Soil *p*H showed the highest impact with a coefficient of determination value of 0.46, CEC and SOC contents with the values, 0.44 and 0.35, respectively. Except for the fields under continuous culti-

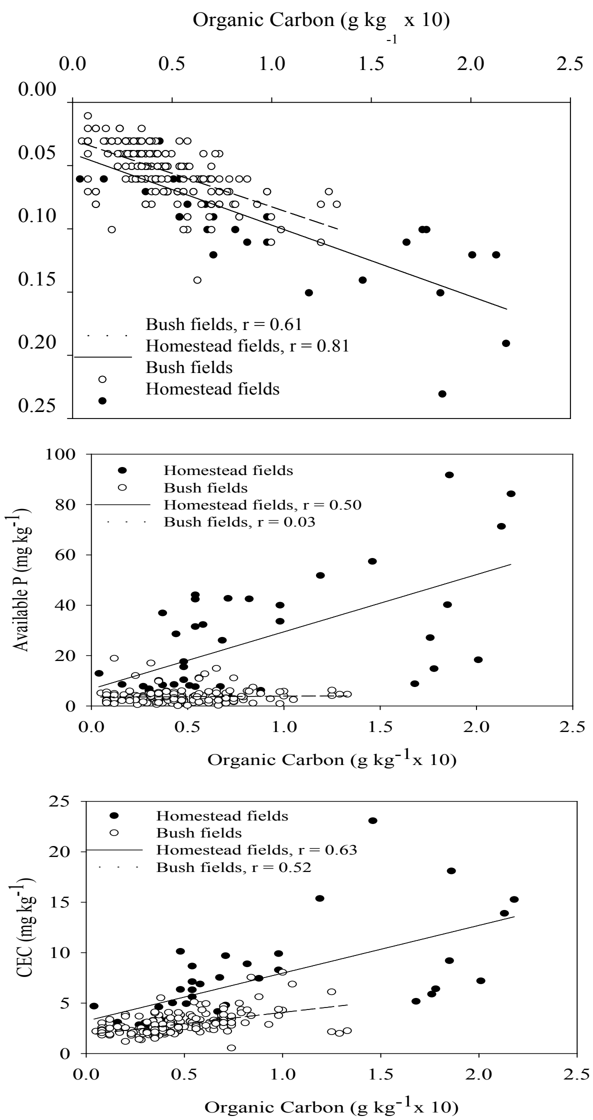

Fig. 2. Functional relationship between soil organic matter and total N, available P and CEC in different management zones.

vation in the homestead, there was a negative correlation between number of years that fields were cultivated and soil nutrient and organic carbon status.

A plot of the response of sorghum to mineral fertilization in the study area clearly separates the homestead from the bush fields based on their productivity (Fig. 3). For the same amount of N fertilizer applied, higher returns were made in the homestead than on the bush fields. Similar results were reported by Zingore *et al.* (2007), where yield response differed between two types of fields base on their nutrient and organic carbon content as well as between clayey and sandy soils. The differences were attributed to differences in inherent soil fertility (soil organic carbon). This can be alluded to for the study as presence of organic carbon is known to be critical for crop production, particularly in the tropics where investments in external inputs are meager. The homestead fields are products of the deposition of nutrients through crop residue additions, household waste and animal manure. The bush fields, on the contrary, lose all these nutrients to the homestead fields. This accounts for the differences between the two types of fields.

Soil organic carbon, carbon stock, CEC, available P and K were more variable in the homestead fields than in the bush fields, because applied organic resources are not readily available in the right quantities and, hence, allocation to fields are un even (Mapfumo, Filler & Mimeo, 2001). The higher CEC of the soils in the homestead fields

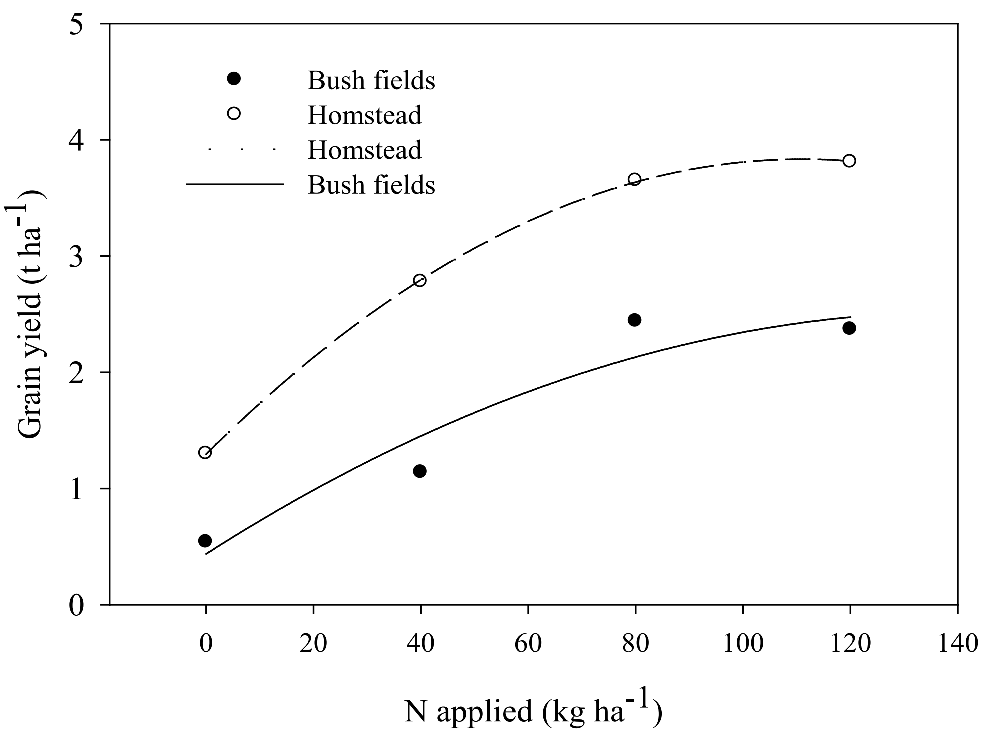

Fig. 3. Response of sorghum to mineral N fertilization on two farm types (homestead and bush fields).

can be attributed to the contribution of soil organic matter, which is the prime contributing factor to CEC (Mapfumo, Giller & Mimeo, 2001; Vanlauwe & Giller, 2006) in sandy soils. In the study, SOC levels for both homestead and the bush fields were 8.2 and 4.5 g kg^{-1}, respectively, and well below values reported for other studies. For instance, Wopereis *et al*. (2006) reported 13.4 and 6.3 g kg^{-1} of SOC for the homestead and bush fields, respectively, for a farming community in the Guinea savanna zone in Togo. Consequently, SOC_{st} estimated for the homestead and bush fields were 125 and 74 t C ha^{-1} respectively. Soil carbon stocks were significantly different between the farm types. Differences in carbon stocks among land use categories were also significant.

Given that animal manure and crop residues which are the main source of organic carbon are not readily available in required quantities, the importance of inorganic fertilizers in this area cannot be over emphasised. The use of mineral fertilizers is critical to obtain adequate crop yields. Efforts to increase soil organic matter content is also necessary to minimise loss of nutrients through leaching, a phenomenon that is characteristic of sandy soils (71 %) (Kpongor, 2007) and, thus, maximise the efficiency of fertilizer use (MacCarthy *et al*., 2010).

Since SOC levels are generally low, available P is equally low as it is the main source of P on highly weathered soils. Similar trends were reported by Breman, Fofana & Mando (2005) in their synthesis of three other studies in sub-Saharan Africa. Additionally, P can be lost from the bush fields to the homestead through over-grazing in the bush fields. P nutrition of crops in this environment is critical for adequate crop yield (Gijsman *et al*., 1996), hence, needed to be supplied through inorganic fertilizers. This implies that optimum crop (cereals) production in the bush fields in particular cannot be attained without the use of inorganic fertilizer (MacCarthy *et al.,* 2010) as the soil attributes levels are generally below critical values required for optimum production (Landon, 1991).The high variability in available P and K can be linked to the uneven allocation of organic resources and burning of these resources, which are not uniform over the study area surveyed. High variability in available P was also reported by Abekoe & Tiessen (1998) for northern Ghana.

Conclusions

The nutrient, organic carbon content and carbon stock of the soils are well below critical values required for optimum crop production, hence, there is the need for fertilizer input to improve crop yield. Land-use intensity impacted negatively on mineral soil nutrient and soil carbon content and-stocks. Differences in farm types in terms of soil nutrient and organic carbon content and stock were also established. To reverse the continuous decline in soil nutrients observed in the study, soil management practices that help to conserve soil organic matter and other nutrients need to be encouraged. When locating sites in the study zone for fertility trials, the homestead and bush fields should be taken into consideration.

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