

Full Length Research Paper

Farmer's perception of soil and watershed degradation and the assessment of soil nutrients status under agroforestry systems in the Western Highlands of Cameroon: Case of Ako sub division

Njini Loveline Munjeb*, Yerima Bernard Palmer Kfuban and Avana Tientcheu Marie Louise

Department of Forestry, Department of Soil Sciences, Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang, P. O. Box. 222 Dschang, Cameroon.

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The objective of this study was to assess farmers' perception regarding the activities which degrade the soil and watershed and to analyze soil nutrients status under different agroforestry systems. The aim of the study was to identify and promote locally-known agroforestry-based practices for soil and watershed conservation in the savannah highland area of Cameroon. Semi-structured questionnaires were administered to 120 farmers purposively selected from 10 villages in the Ako sub division characterized by favorable environmental conditions for agricultural production and the presence of agroforestry systems. The 10 villages were classified following a stratified sampling based on the degree of degradation of the soil and the watershed. Ako sub division was chosen because it is a priority zone for agricultural production and some of the practices are unsustainable leading to soil and watershed degradation. Soil samples were collected from each of the agroforestry systems found in the villages sampled and were analyzed for soil nutrients status. The soil nutrients that were analyzed are: Organic matter by the wet oxidation method; exchangeable cations; cation exchange capacity; total nitrogen by Kjeldahl method; available phosphorus by Bray II method and carbon to nitrogen ratio. The results showed that farmers perceived poor farming methods (33.10%) and deforestation (29.58%) as the main activities degrading the soil and the watershed. The standard values developed were used to compare the level of soil nutrients in each agroforestry system. The results of the soil analysis under each agroforestry system in Ako indicated that, soils were highly deficient in phosphorus in all the systems. The values were very low in all the systems ranging from 0.21 in palm agroforestry system to 0.46 in cocoa agroforestry system. Based on the level of organic matter and cation exchange capacity observed in the different farms, the agroforestry systems that should be promoted are: Coffee agroforestry systems, and cocoa agroforestry systems.

Key words: Cocoa and coffee-based agroforestry systems, soil properties, watershed, farmers' opinion.

INTRODUCTION

Watershed degradation marks the deterioration in hydrological behavior of river systems, which reduces the

health and potential of land and water there by causing a water flow of inferior quality, quantity and timing. These

processes, predominantly human induced, have been a major source of conflict among various land and water users (Leslie, 2014). In the case of soil erosion associated with inappropriate land management practices, lack of effective planning and implementation for soil conservation are responsible for accelerating degradation (Wollega, 2017). Intense land cultivation, uncontrolled grazing and deforestation are also common causes of degradation.

The western highlands of Cameroon are characterized by steep isolated slopes and hills which suffer very much from excessive runoff causing soil and water conservation problems. The degradation of the soils and watersheds in Ako has depleted soil and water resources over the years, which have intensified water scarcity and soil problems. Studies by Amawa (1999) revealed that water channels have narrowed and some stream sources have disappeared. This is caused mostly by the removal of the natural forest, tree cover, loss of vegetation and the transformation of the natural forests to farmland, which leads to removal of the topsoil, therefore, reducing the capacity of natural resources to contribute to food security and other benefits such as fodder and fuelwood (Tesfa and Sangharsh, 2016).

Ngala and Amawa (2014) observed that, changes in soil quality varied across sites, soil types, and production systems. Furthermore, soil quality is only one of the many variables influencing agricultural yields, which is, in turn, only one of many factors influencing food consumption, food availability, and farm income. However, studies have revealed that agroforestry which is the integration of a tree component within the farming system, either on bounds or on boundaries (sequentially with crops) or intercropped in an agroforestry configuration type, can lead to increased land productivity, soil conservation and watershed protection, while diversifying the farming enterprise (Pardon et al., 2017; Atta-Krah et al., 2004). Agroforestry is considered a sustainable agricultural practice that combines primary production with other ecosystem services (ES) (Torralba et al., 2016) such as carbon sequestration, protection of (ground) water quality through reduction of nitrogen leaching, biodiversity conservation and mitigation of soil erosion (Cardinael et al., 2015a).

The agroforestry systems found in the study site were: Coffee agroforestry systems, cocoa agroforestry systems, trees on croplands and palm agroforestry systems. The potentials of these agroforestry systems have not yet been estimated. This study seeks to answer the following questions: (1) What are the farmer's perceptions on the activities degrading the watersheds and soil in Ako sub division? (2) How is the soil

characteristics under agroforestry systems?

METHODOLOGY

Location of study area

The research was carried out in Ako Sub Division, a fragile agro ecological component of the Western Highlands of Cameroon situated between latitudes 6°45' and 7°0' to the North of the equator, and between longitudes 10°38' and 10°52' to the East of the Greenwich Meridian (Figure 1).

The typical primitive society here is the Mbembe tribe commonly called "Njaris". It has an estimated population of 8434 inhabitants. Their main occupation is farming, business and livestock rearing.

The area of Ako has an equatorial climate, which is hot and humid with two distinct seasons; dry (December to March) and rainy seasons (April to November). The average precipitation is between 2500 and 3000 mm and the mean annual temperature is between 28 and 30°C.

This region has a series of seasonal streams and a few streams which run throughout all the seasons and rivers that meander through the area and empty into river Donga, which is located to the north, separating Cameroon from Nigeria.

The relief of Ako can be described as undulating from Nkambe at an altitude of ~1250 m above sea level (asl), where there is a steep descent through the hills to Berabe at about 800 m asl. The area to the north towards Abuenshie is fairly flat (259 m), with the centre Buku and Buku-up having an altitude of about ± 350 m.

Data collection

Farmers' perceptions of the activities degrading the soil and watershed

In order to capture the farmers' perceptions on the activities degrading the soil and the watershed, household interviews were conducted using semi-structured questionnaires. Interviews were followed by a visit with the respondents to validate responses. To increase validity and reliability of data, multiple methods including focus groups (composed of elders, male and female farmers and community leaders) were carried out. The theme covered here was the activities which degrade the soil and the watershed. The questionnaires were composed of open and closed-ended questions including:

1. Issues concerning households and farm characteristics.
2. Perceptions of the activities degrading the soil and the watershed such as poor farming methods, deforestation, fuel wood and timber extraction, livestock rearing and bee farming.

Soil samples under different agroforestry systems

In order to determine soil properties in the existing agroforestry systems, nine representative soil samples were collected from sample farms at the depth of 0 to 15 cm along a transect in a 'Z' manner. Nine (9) soil samples were taken from four different agroforestry systems with 2 samples each for cocoa, coffee, palm tree and trees on cropland based agroforestry system and one

*Corresponding author. E-mail: njini.loveline@yahoo.com.

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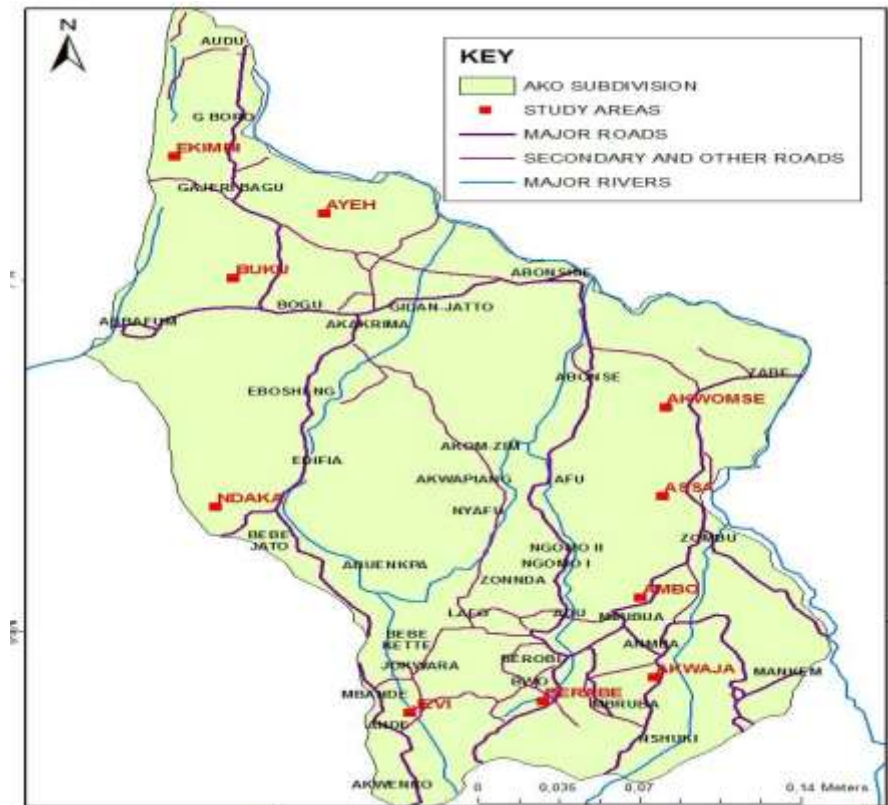


Figure 1. Map of Ako sub division and villages where samples were taken in the Western Highlands of Cameroon.

sample from a mono-cropping system. The soil samples were taken from localities with environments having similar features. Six different samples were collected from each geomorphic surface (at a depth of 0 to 15 cm) using a cutlass and thoroughly mixed and one representative composite sample of 2 kg each was taken and air - dried for 3 days and taken to the laboratory of the Department of Soil Science at the University of Dschang for analysis.

Laboratory analysis

Air dried samples were crushed to pass through a 2 mm sieve; coarse fragments larger than 2 mm were removed by dry sieving. Each soil sample was analyzed to determine the level of nutrients; total nitrogen, available phosphorus, cation exchange capacity (CEC), exchangeable bases, pH, texture, and soil organic matter contents using standard methods (Pauwels et al., 1992). Soil organic carbon was estimated by wet oxidation with potassium dichromate and titration with ferrous sulfate (Walkey and black, 1934). Soil pH was measured in a 1: 2.5 soil solution ratio in 1 N KCl (pH kcl) and distilled water (pH H₂O). Exchangeable cations were determined by the complexometric method. The concentrations of exchangeable (Na⁺) and potassium (K⁺) in the extract were obtained by flame photometry, and for calcium (Ca²⁺) and magnesium (Mg²⁺) by complexometry using a 0.002 M Na₂-EDTA solution. Total nitrogen was determined by the kjeldahl method wet digestion. Available Phosphorus was determined by Bray II method (Bray and Kurtz, 1945). Cation exchange capacity (CEC) was determined by percolating 2.5 g of soil with 100 mL of 1 N ammonium acetate buffered at pH 7, removing the excess with

ethanol and displacing the absorb NH₄⁺ ions with 1 N KCl, determining the collected NH₄⁺ ions by distillation and titration with 0.01 N sulfuric acid.

Data analysis

To get the percentages of the activities degrading the soil and watershed, Microsoft excel 2007 was used. The main activities were group and presented in the form of histograms based on their level of degradation. The critical soil values by Beernaert and Bitondo (1992) were used as basis to compare the soil samples analyzed from each agroforestry system. The soil nutrients were said to be high or low if it fell within the range of the values for low or high as shown on the Table 1.

RESULTS AND DISCUSSION

Farmers' perceptions of the activities degrading the soil in Ako

The results indicate that according to farmer's perception based on the degradation gradient, poor farming practices (33.10%); bush fires (23.39%) and overgrazing (26.34%) caused the highest damage to the soil (Figure 2). This is in line with the findings of Muia and Ndunda (2013) which indicated that the reduction of forest and

Table 1. Critical values of nutrients and soil properties.

Property	Critical value				
	Very low	Low	Medium	High	Very high
OM (%)	<1	1-2	2-4.2	4.2-6	>6
Total N (%)	< 0.5	0.5-1.25	1.25-2.25	2.25-3.0	>3.0
Ca (cmol(+)/kg)	<2	2-5	5-10	10-20	>20
Mg (cmol(+)/kg)	<0.5	0.5-1.5	1.5-3	3-8	>8
K (cmol(+)/kg)	<0.1	0.1-0.3	0.3-0.6	0.6-1.2	>1.2
Na (cmol(+)/kg)	<0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2
Bray 2 – P (mg/kg)	<7	< 7-16	16-46	>46	
CEC (cmol(+)/kg)	0-20	21-40	41-60	61-80	81-100
C/N	<10 = good, 10-14 = medium and >14 = poor				
pH	<4 Acidic 5.3 - 6.0 moderately acid, 6.0-7.0 = slightly acid, 7.0-8.5 = moderately alkaline				

Adapted from Beernaert and Bitondo (1992).

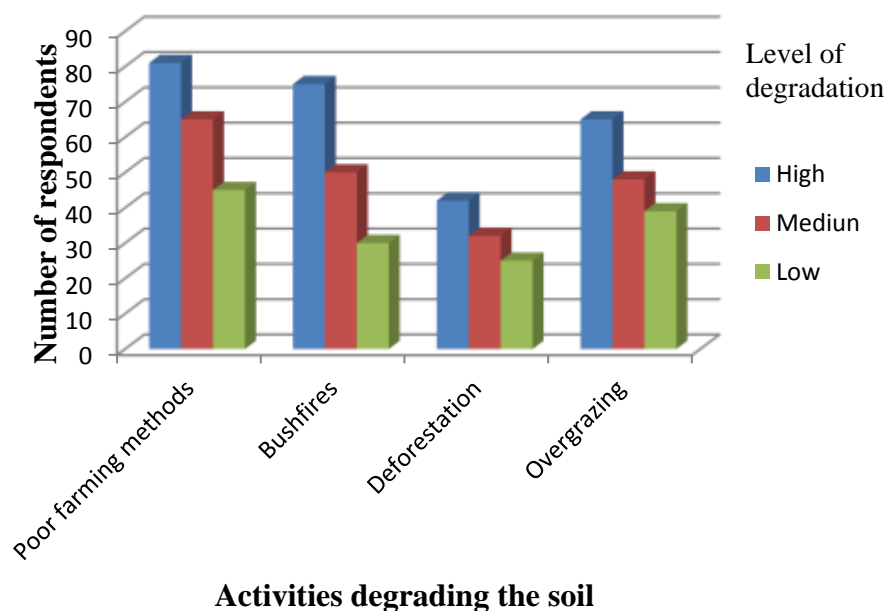


Figure 2. Farmers' perception of the activities degrading the soil - according to the site degradation gradient in Ako sub division, North West region Cameroon.

vegetation cover due to inappropriate farming methods and overgrazing leading to an increase in soil erosion and the reduction of soil fertility. Deforestation exposes the soil to water erosion (Muia and Ndunda, 2013) leading to a decline in soil fertility and loss of arable land. According to Wollega (2017), farmers perceived expansion of grazing land (7.4%) and lack of vegetation cover (22.2%) as the causes of soil erosion. Based on the findings by Tesfa and Sangharsh (2016) farmers reported improper soil and conservation practices (64.1%), traditional farming practices (68.5%), free grazing (69.6%), over cultivation (82.6%), deforestation (82.6%) as serious causes of soil and land degradation.

Farmers' perceptions of the activities degrading the watershed

The results showed that deforestation (29.58%), bush fires (15.77%), and poor farming practices (16.70%), were considered by farmers as the main activities which degrade the watershed respective of the degradation gradients (Figure 3). This is in line with reports by Hayal *et al.* (2017) in Lake Ziway which indicated that deforestation in the watershed (57%) caused soil erosion and siltation of the lake. According to Muriuki *et al.* (2005), farmers perceived the reduction in forests and vegetation cover due to poor farming methods as a factor

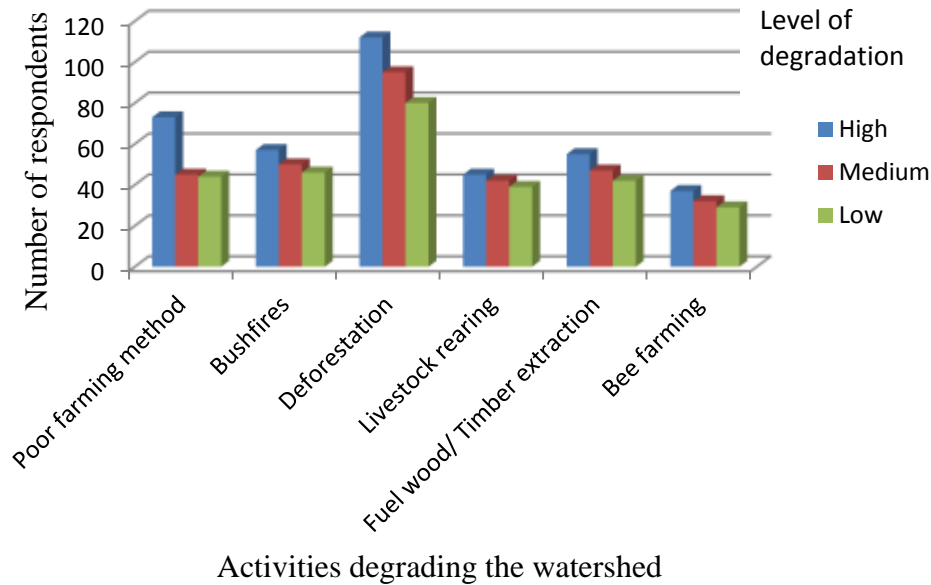


Figure 3. Farmers' perception of the activities degrading the watershed- according to the site degradation gradient in Ako sub division, North West region Cameroon.

degrading the watershed. These reports indicated that, livestock rearing (10.36%) and honeybee harvesting (9.14%) were less damageable to the watershed.

Farmers' perceptions of soil fertility status in Ako

Farmers who thought the fertility of their farms was high constituted 40%. Twenty six percent of the farmers said their farms were moderately fertile, while 33.1% of them said their farms were low in nutrients. Only one farmer was of the opinion that the soil is deficient in nitrogen and crops perform poorly on such soils. Because farmers had the belief that their soils were fertile, they did not require additional nutrients to increase yields. Studies by Kabwe (2010) in Zambia showed that only 25% of farmers perceived their soils as good. This indicates that Ako farmers had a positive perception regarding the soils on which they cultivate.

This positive perception concerning soil fertility potentials was recorded across all age groups and communities. This observation is supported by previous studies of Lemenih et al. (2005) who estimated that, following the clearance of forest, the soil releases large quantities of nitrogen due to rapid mineralization of organic matter but that the soil organic matter reached a steady state after approximately 25 years and there after ceased to be a nitrogen source for agriculture. Karlton et al. (2011) observed that, decline in crop productivity is as a result of inadequate compensation of plants nutrients particularly nitrogen.

Forty percent of the farmers affirmed their soils were fertile because there was no significant drop in yields,

while some (35%) of them thought their soils were less productive. Reports by Karlton et al. (2011), indicated that 92% of farmers in Beseku believed that the fertility of their soils was declining over time due to over cropping, and these farmers employ different methods to sustain soil fertility such as crop rotation and the used of compost (Figure 4). The latter group attributed this to phosphorus deficiency (darker green leaf, and purplish or red pigment). The deficiency of this element impairs most of the chemical processes that takes place in plants and thus results in poor crop yields.

Soil nutrients status under agroforestry systems in Ako

The results of the physical and chemical properties of the soils in Ako (Table 2) indicate that most of the samples are characterized as sandy, and the highest amounts of sand is observed in the trees on cropland and cocoa AFS. Sandy soils generally have good drainage and are easy to cultivate, but water and nutrient losses can be difficult to control. Mengel and Kirkby (1987) observed that, sites with high percentage of clay and silt are good for agriculture, as they provide good aeration and water and nutrient retention. These soils are low in the later parameters indicating low agronomic potentials.

The soils in all the agroforestry systems were moderately acidic. Average soil pH (H₂O) was 5.44 and 4.83 for pH (KCl) (Table 2). Generally, pH (KCl) ranged from 4.4 to 5.6 and was slightly lower than that of pH water that ranged from 5.2 to 5.9. The variation of ΔpH (pH (KCl) - pH (H₂O)) was negative throughout. This

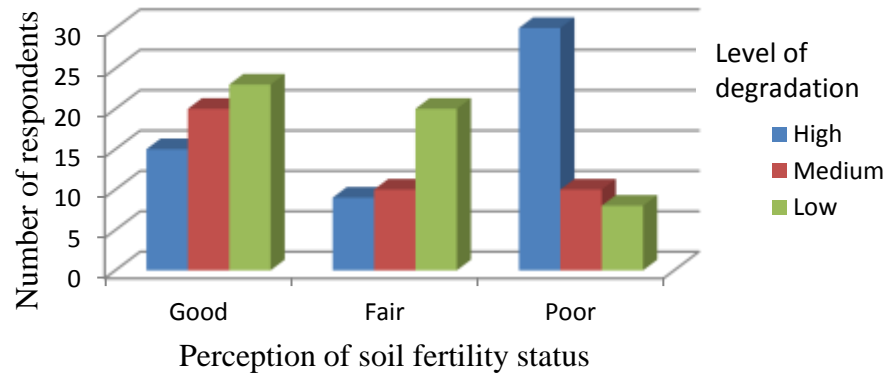


Figure 4. Farmers perception of soil fertility status.

indicates that the net charge on the exchange complex is negative, and thus exhibits cation exchange capacity properties. However, according to Yerima and Van Ranst (2005a), some tropical soils due to intensive rainfall and weathering are dominated by positive charges with anion exchange capacity predominant.

Percent of organic matter ranged from 2.99% in tree associations on cropland to 7.44% in coffee AFS with an average value of 2.4% in the entire area. The organic matter critical values varied from medium to high (Beernaert and Bitondo, 1992) (Table 2). In the tropics, soil organic matter is central to sustaining soil fertility on smallholder farms (Swift and Woomeer, 1993; Woomeer et al., 1994). Studies by Pardon et al. (2017) showed that the potential influence of trees on soil organic carbon was confirmed on the boundary planted fields with significantly higher soil organic carbon found near the middle-aged to mature tree rows.

In addition, soil organic carbon increases soil flora and fauna (associated with soil aggregation, improved infiltration of water and reduced soil erosion), complexes toxic Al and manganese (Mn) ions (leading to better rooting), increases the buffering capacity on low-activity clay soils, and increases water-holding capacity (Woomeer et al., 1994). Continuous cropping, with its associated tillage practices, provokes an initial rapid decline in soil organic matter, which then stabilizes at a low level (Woomeer et al., 1994). The highest percentages of organic matter were found in Coffee agroforestry systems and low organic matter contents were observed in monocropped systems where sand was in high concentration. This is associated with high mineralization of organic matter in sandy soils and higher organic matter in clay soils due to organic matter - clay complexes (Yerima and Van Ranst, 2005b). The low organic matter contents observed in monocropped system is due to continuous tillage which increases the mineralization of organic matter. Limited tillage reduces organic matter mineralization as was observed in coffee and cocoa agroforestry systems with values of organic matter ranging from high to very high (4.64 to 7.44).

Total nitrogen ranged from 0.1 in palm agroforestry systems to 0.22% in cocoa agroforestry systems (Table 2). From the critical values by Beernaert and Bitondo (1992) (Table 2), total nitrogen is very low (< 5). Nitrogen is highly mobile and easily lost. This necessitates that trees which contain nitrogen should be incorporated in farms to maintain the production of crops in the areas that are already vulnerable given that they are dominated by the sandy fraction. The percentage of total nitrogen ranges from 0.14 in palm to 0.17% in coffee agroforestry systems; this implies a long-term nitrogen deficiency which is manifested by low yields and less productive soils. In addition, the deficiency of nutrients like phosphorus could alter the recycling and the availability of nitrogen to farmlands

The C/N ratio varies from 10.02 in monocropped systems to 25.86 in cocoa agroforestry systems. This indicates that the soils range from good, to medium and poor in the agroforestry systems. Despite the fact that the soil are rich in organic matter, the very high C/N ratio witnessed in some areas indicate difficulties in mineralization.

Available phosphorus is associated with organic matter. It ranged from a lowest value of 0.18 in coffee agroforestry systems to low in trees on cropland to 0.56 mg/kg in cocoa agroforestry systems. Available phosphorus concentrations lower than 16 mg/kg in soils are considered low to ensure adequate phosphorus supply to most plants (Landon, 1991). The availability of phosphorus might also be limited due to the nature of the parent material that is generally granitic (Kometa, 2013), and high phosphorus sorption (Yerima and Van Ranst, 2005a). Available phosphorus is low indicating that the amount of phosphorus in farms in Ako is very low. Soils from palms agroforestry system, trees on cropland, palms agroforestry system and cocoa agroforestry systems have pH_{water} values less than 5.5. Below this pH, Al-solubility increases and phosphorus is fixed by iron and aluminium. Also at pH_{water} values less than 5.3, solubility of Mn increases and can lead to toxicity in plants (palms agroforestry system and monocropping). Therefore,

Table 2. Physico - chemical analysis of soil samples taken across different agroforestry systems in Ako.

AFS	Coffee AFS		Palm AFS		Trees on cropland		Monocropped	Cocoa AFS	
Sand (%)	58	52	49	39	49	73	59	41	68
Silt (%)	12	28	22	30	24	8	18	39	18
Clay (%)	29	19	27	30	25	17	23	19	13
pH _{water}	5.6	5.6	5.3	5.2	5.3	5.2	5.2	5.6	5.9
pH _{KCl}	4.9	5.0	4.6	4.6	4.6	4.6	4.6	5.1	5.6
Organic matter (%)	3.24	7.44	3.37	6.17	2.99	2.99	2.86	4.64	3.62
Nitrogen (%)	0.13	0.22	0.16	0.14	0.17	0.16	0.17	0.16	0.17
C/N ratio	14.92	19.56	12.19	25.87	10.10	10.90	10.02	16.36	12.51
Ca ⁺⁺ cmol(+)/kg	0.88	0.60	0.36	0.20	0.76	1.28	0.20	0.56	1.28
Mg ⁺⁺ cmol(+)/kg	1.92	3.00	2.52	0.20	1.88	3.20	1.00	3.12	5.92
K ⁺ cmol(+)/kg	0.20	0.30	0.10	0.10	0.30	0.11	0.13	0.02	0.21
Na ⁺ cmol(+)/kg	0.01	0.01	0.02	0.02	0.02	0.04	0.05	0.03	0.01
CEC cmol(+)/kg	19.20	25.04	20	22.4	18.16	17.60	16.56	21.20	20.88
Base saturation					16.78				
Bray II Phosphorus (mg/kg)	0.18	0.34	0.22	0.20	0.18	0.20	0.14	0.36	0.56

AFS = Agroforestry system.

phosphorus deficiency is a limitation to crop production in Ako. Phosphorus deficiency affects the growth of crops by interrupting with the internal transfer of energy needed to maintain plants metabolic activities (Krupnik and Jenkins, 2006).

Calcium and magnesium dominate the exchange complex but their concentrations were low ranging from 0.20 cmol (+)/kg in the palm AFS to 0.88 cmol (+)/kg in coffee agroforestry systems, for calcium (with a variance of 0.169) and 0.20 cmol (+)/kg in palm agroforestry system to 1.28 cmol (+)/kg in cocoa agroforestry systems. According to Landon (1991), deficiencies of calcium are normal in soils with pH ≤ 5.5, which have been obtained in most sites of this study. Continuous cultivation without returning residues to soil depletes this nutrient. Major sources of magnesium in soils include amphiboles, olivine, pyroxene, dolomites and phyllosilicate clay minerals (Todd, 1980). The low values of magnesium in the soils of the study area indicate that the aforementioned minerals are not present in substantial amounts.

The cation exchange capacity (CEC) of the soil according to the critical values of soil nutrients varied from very low-to-medium, ranging from 18.16 cmol (+)/kg in cocoa to 25.04 cmol (+)/kg in coffee agroforestry systems with a standard deviation of 2.62. A high CEC in these highly weathered soils indicates high levels of organic matter in these soils and these systems should be maintained.

Conclusion

Various activities such as deforestation (29.58%), poor

farming methods (16.70%), bushfires (15.77%), and fuel wood/timber extraction (14.84%) were reported by the respondents as the activities degrading the watersheds; while deforestation was highly perceived as the main activity. The surface soils were slightly acidic in all the agroforestry systems with an average pH (H₂O) of 5.4 and 4.8 for pH (KCl). The organic matter contents varied from moderate to very high ranging from 2.99 in trees on cropland to 7.44% in coffee agroforestry systems. All the soils were highly deficient in phosphorus with values ranging from poor in coffee agroforestry system to very poor in cocoa agroforestry systems. The nutrient balance is extremely low most probably attributed to farming practices carried out in this area. Based on the level of organic matter, soils from coffee agroforestry system and cocoa agroforestry system with limited tillage had high CEC values associated with high organic matter contents and these agroforestry systems should thus be maintained.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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