Journal of Agricultural Science and Technology A 5 (2015) 723-731
doi: 10.17265/2161-6256/2015.09.003

Farmers' Perceptions of Soil Fertility Status in the Savannah Zone of Centre Cameroon

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Abstract: In Cameroon, most farmers rely on their perceptions for fertility evaluation and choice of agricultural land units. However, because of environmental change, this knowledge is mostly disregarded. The use of farmers' knowledge is important for the identification of relevant information for the choice of agricultural land units. The objective of this study was to compare farmers' perceptions of soil fertility with a conventional scientific approach in two locations of the forest margin zone of Center Cameroon. Through interviews and soil analysis, this study spelled and weighed the relationships between farmers' perceptions and soil fertility status. One hundred and twenty households' heads were interviewed and 30 soil samples collected. Farmers' perceptions were used to assess the topsoil fertility status across the studied areas, while a conventional scientific approach was used to quantify soil fertility status by the means of a soil fertility index (SFI). Results showed that farmers, for soil differentiation, used color, texture, depth, drainage and vegetation. Soil' names delivered key messages for their location. Although the low overall SFI approximated by the conventional approach, farmers' perceptions could differentiate fertility levels between soils. This knowledge is relevant for the design of technical innovations in perceived fertility niches.

Key words: Cameroon, fertility, perception, savanna, soils, smallholder farmers.

1. Introduction

Slash and burn agriculture as practiced by smallholder farmers is generally considered as the major cause of land degradation and soil fertility depletion in the tropics [1]. In the savanna margin zone of Center Cameroon (SFZC), over 70% of smallholders rely on traditional methods for identifying productive agricultural land units [2]. The causes and effects relations of such knowledge with soil fertility, however, are not yet codified [3]. The fertility is a convention allowing to evaluating and classifying environment according to the general condition (constraints, potentialities) which they offer in the medium term for a given farming system. Certain indicators, visual, indices or bio-physico-chemical analytical parameters are usable for this evaluation under precise conditions. Chemical tests still constitute an important scientific tool for fertility diagnosis because of its use in relation to crop production. However, for situation where speed and efficiency are necessary, detailed knowledge of soil quality related to farmer perceptions is of utmost importance. Thus, there is an urgent need to decipher the determinants and the consistency of farmer approach, because they may be useful when searching for technologies to overcome soil constrains [4].

To date, farmers' knowledge on soil fertility status of SFZC remains limited, but are recognized elsewhere [2, 3, 5-7]. Soil color can be used for rough assessment of soil fertility [8, 9], while its particle size composition is of paramount importance in determining soil properties. Taulya [10] showed the topsoil depth influence on soil productivity. In Southern Cameroon, farmers preferred soils with high moisture retention [11], and water table management is currently used as an agricultural tool [12], while Brabant and Gavaud [13] showed that the presence of a hardpan at shallow depth could reduce both the

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infiltration rate of water and biological activity, and thus soil fertility. In the North Cameroon, M'biandoun et al. [14] noticed the existence of relationships between plants and soil fertility. Strong correlations between agricultural lands quality and exchangeable cations were found by Shah [15]. Moukam and Ngakanou [16] found that organic carbon content may be taken as a crude measure of soil fertility. While Bekunda et al. [17] showed that the fertility concept remains poorly defined. However, the relevance of traditional systems of evaluation [18, 19] and the complexity of interactions between soil properties [20] raised the need to develop fertility indicators accessible to all [21]. In the SFZC, it is important to know if traditional knowledge differs from that suggested by scientific data. It is possible to postulate the existence of common soils to all stakeholders, but perceived differently. This study sought to establish, through surveys and soil analysis, the relationship between farmers' perceptions of soil and their fertility status in two locations of the SFZC.

2. Materials and Methods

2.1 Survey Sites

Two locations—Tobagne (TOB) and Kédia (KED) located between 04°29′38″-04°30′04″ N and 11°02′52″-11°02′52″ E of the district of Bokito (1,600 km^2), representative of SFZC, were chosen for this study. Population density ranged from 19.2 habitants/km^2 in TOB to 119.2 habitants /km^2 in KED. Lemande and Yambassa are the main local languages used. The target population for this study consisted of 120 household heads (30 in TOB and 90 in KED). The climate is humid sub-equatorial transition, with 1,300 mm annual rainfall distributed in 122 d and with 21-25 °C average temperature. The vegetation is mainly herbaceous and shrub savannas dominated by *Imperata cylindryca* with remnant forests galleries. Landforms in these areas derived from gneiss in KED and amphibolites in TOB. A total of 30 composite soil samples representing a range of 10 soil types from the study zone were collected, and 10 mini-pits were dug in two transect of about 1,000 m length each.

2.2 Methods

2.2.1 Survey Approach

The questionnaire administered to farmers was about local name, localization, main characteristics of known soil types and order of importance according to assumed fertility status. Transect walks and informal interviews were then conducted with selected farmers to help identify vegetation and indices that farmers used for the identification of fertility potential.

2.2.2 Soil Sampling and Characterization

The key question was whether local soil fertility indices could be given a scientific meaning. To answer this, the top 20 cm of identified soils located by GPS were sampled. At least 16 auger samples were collected from each site, bulked and thoroughly mixed to give one composite sample that was sub-sampled for laboratory analysis. Mini-pits descriptions and physicochemical analysis based on relevant properties helped for soil differentiation and classification. Color was evaluated by the "Munsell" color chart. Texture was evaluated by Robinson pipette method and drainage was evaluated by the depth of apparition of mottles or moisture regime. Soil depth was evaluated by the combining the thickness of A and E horizon. Soil pH was determined in a water suspension of 1:2.5. Exchangeable bases were determined by atomic absorption. Nitrogen and carbon were determined by the Kjeldahl and Walkley-Black method. To evaluate the fertility status of these soils, a soil fertility index (SFI) was used to compare the fertility of these soils, as Eq. (1):

$$\mathrm{SFI} = (S^2/A + LF) \quad (1)$$

where, S^2 is the square of the sum of exchangeable bases, A is the percentage of clay and LF is the percentage of silts.

Levels of chemical characteristics were compared with values established for soil analysis interpretation for fertility test [16]. This generated data allowed to comparison of farmers' perceptions and soil analysis.

3. Results

3.1 Soil Perception

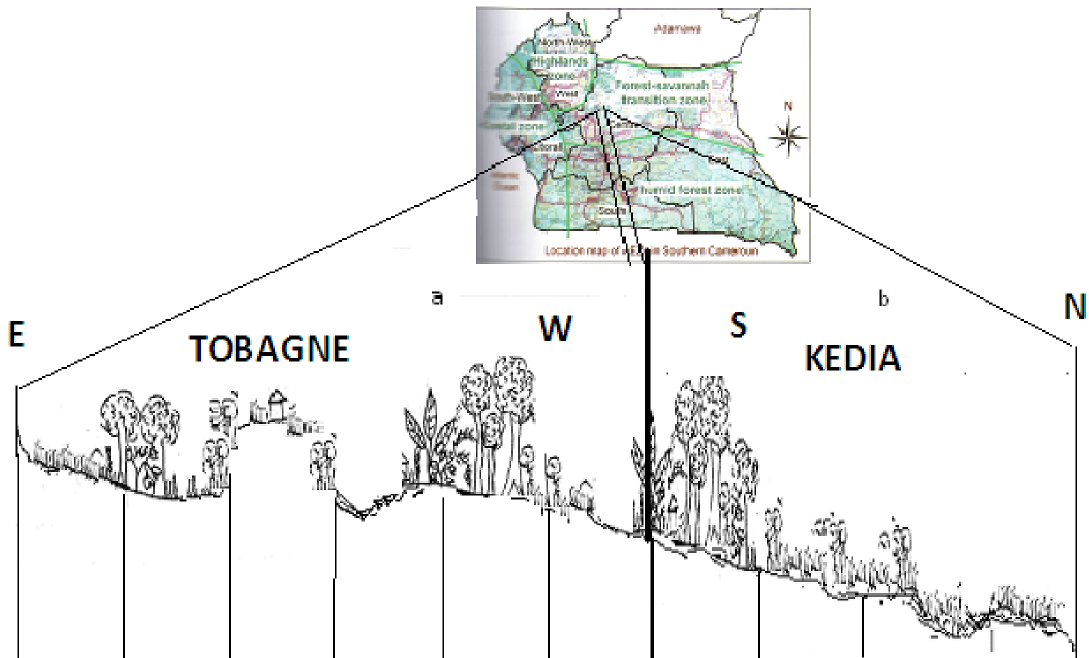
Ten soil types, six at TOB and four at KED, was compiled across the two villages during the transect walk (Fig. 1). Color, texture, depth, water regime and vegetation were advanced by 94% of respondents as main differentiating criteria between soil types. Despite variations in language, farmers in both villages acknowledged that, Apomben and Omboum soils of TOB corresponded to Kipoumboua soils in KED, Emess mess soils in TOB corresponded to Atsakaye soils in KED, Ombolote soils in TOB corresponded to Ndala soils in KED. KED farmers mentioned no equivalence of Elouk louk soils of TOB.

3.2 Color Perception

Color was evaluated visually by the farmers, and at both locations, two colors were commonly used to group soils. In TOB four out of six cases against two out of four cases at KED were perceived as black soils. In two out of six cases at TOB and two out of four cases at KED, soils were perceived as red. Soils were perceived as blacker in TOB than in KED (Fig. 2a).

3.3 Depth Perception

The perception of soil depth was based on the existence of a free physical barrier opposing the penetration of the hoe. Soils were perceived as more deep in TOB than in KED (Fig. 2b).



Local name	C	A	F	B	D	E	G	H	I	J
Location	N4°32'27'' E11°03'95''	N4°31'98'' E11°03'35''	N4°31'53'' E11°33'13''	N4°31'61'' E11°02'93''	N4°31'33'' E11°03'54''	N4°31'38'' E11°02'57''	N4°29'58'' E11°05'10''	N4°34'24'' E11°06'54''	N4°34'09'' E11°09'56''	N4°30'04'' E11°05'49''
Vegetation	Galery forest	Savannah shrub	Savannah	Savannah shrub	savannah	savannah	Savannah shrub	savannah	Savannah	Savannah
Color	Black	Red	Black	Red	Black	Black	Red	Red	Black	Black
Texture	Loamy	Sandy clay	Sandy	Sandy	Loamy	Loamy	Sandy clay	Sandy	Sandy	Loamy
Depth	Deep	Shallow	Deep	Shallow	Deep	Deep	Shallow	Shallow	Deep	Deep
Drainage	Good	Good	Bad	Good	Bad	Bad	Good	Bad	Bad	Bad
Fertility ranking	1	6	5	4	3	2	4	3	2	1

A)Ombolote, B) Emess mess, C)Elouk louk, D) Omboum, E) Apomben, F) Eleugn, G) Ndala H)Atsakaye, I) Kipoumboua, J) Kyoye

Fig. 1 Localization of the study area and transects in studied villages TOB (a) and KED (b).

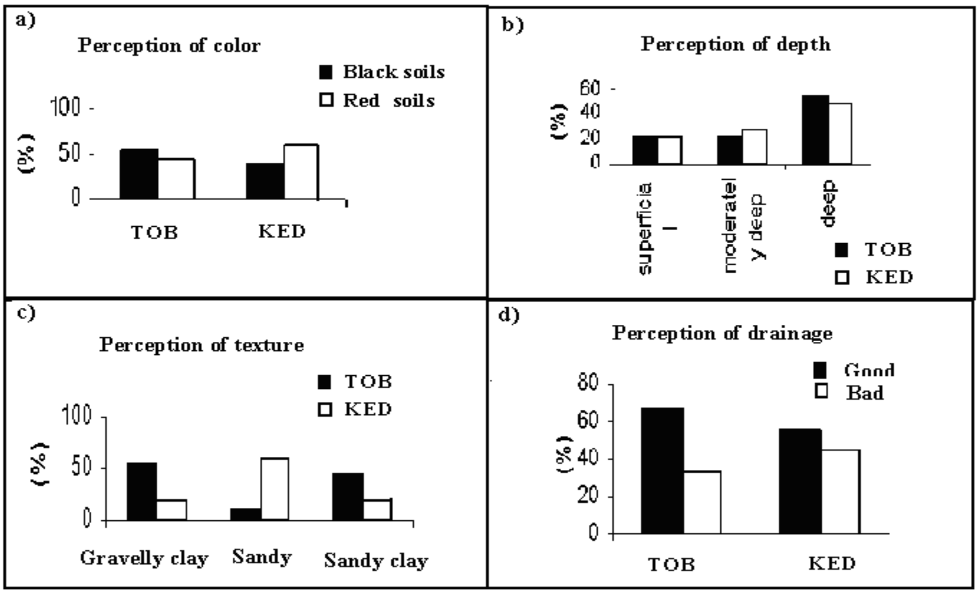


Fig. 2 Farmer perception on color (a), depth (b), texture (c) and drainage (d).

3.4 Texture Perception

At both locations, texture was evaluated manually by fingers. Three texture classes were perceived. For the majority of respondents, it appeared that soils were more gravelly to sandy clay in TOB and sandier at KED. Soils were perceived as more clayey in TOB than in KED (Fig. 2c).

3.5 Drainage Perception

In both locations, drainage was perceived based on soil flooding. Hydronymy provided essential elements to differentiate moisture regimes in areas permanently flooded (Eleugn, Kyoye), temporarily flooded (Apomben, Omboum, Kipoumboua) or better drained (Ombolote, Emess mess, Ndala, Atsakaye), and each name used described an observable fact. Soils were perceived as more drained in TOB than in KED (Fig. 2d).

3.6 Vegetation Perception

In both locations, plants species (herbaceous and woody) were perceived as soil indicators. In TOB, 86% of the respondents identified plant species as soil indicators, while only 66% in KED could do the same exercise.

3.7 Fertility Perception

The respondents of both locations ranked soils according to perceived fertility status (Figs. 1a and 1b), which was perceived through color, texture, depth, water regime and productivity. In TOB, Elouk louk, Apomben and Omboum soils were classified as the more fertile, while Emess mess, Eleugn soils were intermediate and Ombolote was the poorer. In KED, Kipoumboua and Kyoye soils were the best soils, with Atsakaye soils as intermediate and Ndala soils as the worst.

According to 80% of respondents in TOB, 90% in KED, fertile soils were darker, stuck to crops, easy to work, deep and well drained, while unlike soils were considered as poor. Eighty percent of respondents said that soils were more fertile in TOB, because they were more productive because of higher crop performances.

In another hand, the observation of a large number of cockroaches, snakes and spiders in a field were seen as a sign of good fertility status. The infliction of peanut vines on roads at planting time rendered soils more fertile. Soils unsuitable for crops were tagged by the fact that malicious traditional ceremonies or tragic events took place there.

3.8 Transect Studies and Soil Analysis

The transect studies provided information about soils and their distribution pattern across the two locations (Figs. 1a and 1b). Toposequence slopes were more accentuated in TOB than in KED. These studies highlighted in particular the role of colour, texture, drainage and depth as differentiating factors playing a role in soil distribution pattern. The results of soil descriptions (Table 1) and measurements of some properties (Table 2) that depict soil conditions allowed a tentative classification in three major groups of the American classification (entisols, inceptisols and ultisols). Of all these types, ultisols were the most common.

The colour of the rich fields in TOB ranged from 10YR5/3 to 7.5YR6/0, while those of the poor field ranged 10YR5/3 to 7.5YR6/2. In two out of six cases,

Table 1 Summary description of studied soils in the two villages.

Village	Depth (cm)	Colour (Munsell)	Mottle	Texture	Structure	Limit	Remarque
Tobagne (TOB)	Ombolote **(**ultisol**)**						
	0-11	10YR5/3		SA	Fine granular	Net	Well drained angular quartz
	11-23	10YR5/6		AS	Moderately subangular blocky	Net	
	23-90	5YR3/4	5YR4/6	ASg	Subangular blocky	Grad	
	90-120	10YR5/6		ASg	Subangular blocky	Grad	
	Emess mess (ultisol)						
	0-8	10YR5/3		SL	Fine granular	Net	Ferruginous gravel
	8-20	7.5YR4/6		SA	Moderately subangular blocky	Net	
	Omboum (inceptisol)						
	0-10	10YR5/3		SL	Moderately fine granular	Diffuse	Moderately well drained
	10-18	10YR4/2		SL	Weak to moderately firm	Diffuse	
	18-30	10YR5/4		S	Subangular blocky	Diffuse	
	Elouk louk (entisoll)						
	0-10	10YR5/3		LS	Moderately fine granular	Diffuse	Moderately well drained
	10-23	10YR5/3		SA	Weak to moderately fine	Diffuse	
	23-50	10YR4/4		SA	Subangular blocky	Diffuse	
	50-120	10YR4/4		SA	Subangular blocky	Diffuse	
	Apomben (inceptisol)						
	0-20	7.5YR6/0	10YR7/8/	LS	Moderately fine granular	Net	Fine mica flakes
	20-80	7.5YR7/2	5YR5/6	LA	Moderately fine granular	Net	
	80-120	7.5YR7/2	5YR6/6	LA	Moderately fine granular	Net	
	Eleugn (inceptisol)						
	0-20	10YR6/2	10YR7/8/	LS	Weak fine granular	Diffuse	Poorly drained
Kédia (KED)	Ndala (ultisol)						
	0-10	10YR3/2		SL	Granular	Net	Well drained
	10-20	10YR4/2		SA	Moderately subangular blocky		
	Atsakaye (ultisol)						
	0-7	10YR4/2		SL	Fine granular	Net	Ferruginous gravel
	10-20	10YR4/2		SA	Moderately subangular blocky	Net	
	20-40	10YR5/4		A	Moderately subangular blocky	Net	
	Kipoumboua (inceptisol)						
	0-20	7.5YR6/0		LS	Moderately fine granular	Net	Fine mica flakes
	20-80	7.5YR7/2	10YR7/8/	LA	Moderately fine granular	Net	
	Kyoye (inceptisol)						
	0-10	10YR6/2	10YR7/8/	LS	Moderately fine granular	Diffuse	Water table

soil colour was darker in rich than poor soils. Soil colour of the rich fields in KED ranged from 10YR6/2 to 7.5YR6/0, while those of the poor fields ranged from 10YR3/2 to 10YR4/2. In two out of four cases, soil colour was darker in rich than poor fields. Comparisons showed that while rich soils of TOB were darker than those of KED, poor soils of KED were darker than those of TOB. However, differences were not significant. Moreover, aaccording to the Munsell code, black soils have hues of 5YR, 2.5YR and 10YR, and chroma of zero or one. Red soils have hues of 2.5YR or 10R and chroma of six or more.

Textural analysis (Table 2) showed that overall soils were sandy clay (70%), sandy clay loam (20%) and sandy loam (10%). Although TOB soils were more clayey than those of KED, they were about 6.7% poorer in fine particles (silts and clays) in three out of four cases.

All soils were shallow (depth usually less than 40 cm). However, for the same soil type, the A1 horizon was in 80% of cases thicker in TOB. The depth differences, however, were not significant.

The differences of observed drainage restriction due to mottle apparition in soil profiles were not significant. The closeness of differences might be due to the similarities in ecosystems.

In both locations, there was no plant specific to a soil type. Plants occurred similarly in poor or in rich soils. Higher crop performances were registered for all rich soils (three out of six in TOB and two out of four cases in KED), and poor crop performances were for poor soils (two out of six in TOB and two out of four cases in KED).

In general, a narrow range of mean values of soil organic matter content was observed between soils. Soil organic carbon varied from 1.2% to 2.8%, and nitrogen varied from 0.05% to 0.10% with higher organic values in TOB (Table 2). Soil organic carbon of the rich soils in TOB ranged from 1.9% to 2.8%, while those of the poor soils ranged from 1.3% to 1.4%. In four out of six cases, organic carbon was higher in the rich than the poor soils. Soil organic carbon of the rich soils in KED ranged from 1.6% to 2%, while those of the poor soils ranged around 1.2%. In two out of four cases, organic carbon was higher in the rich than the poor soils. Nitrogen values were low throughout and exchangeable cations showed low to medium levels.

In both locations, the SFI values ranged from 0.2 to 1.5. In TOB, SFI values of the rich fields ranged from 0.5 to 0.9, while those of the poor fields ranged from

Table 2 Selected analytical characteristics of studied soils*.

Soil	TOB						KED			
	A	B	C	D	E	F	G	H	I	J
pH	5.9	6.5	7.2	5.5	6.3	6.8	5.6	5.9	6.1	6.0
Clay (%)	29.3	22.7	14.3	14.4	8.0	4.2	18.3	13.3	16.7	7.3
Silts (%)	18.9	13.0	13.5	19.1	18.1	17.2	16.9	28.1	21.3	22.2
Sands (%)	57.1	60.4	72.2	65.4	73.4	80.1	64.6	57.7	61.6	70.2
C (%)	1.4	1.9	2.8	2.2	1.9	1.3	1.2	1.6	2.0	1.2
N (%)	0.06	0.08	0.10	0.09	0.09	0.06	0.05	0.08	0.09	0.05
Ca (cmol/kg)	1.8	0.9	1.8	1.6	2.6	3.0	1.6	1.2	2.3	2.6
Mg (cmol/kg)	0.9	1	2.3	1.6	1.3	1.4	0.9	1.2	2.2	1.2
K (cmol/kg)	0.4	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.4
Na (cmol/kg)	0.06	0.08	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10
SBE (cmol/kg)	3.1	2.2	4.7	3.6	4.3	4.9	2.9	2.7	4.9	4.3
SFI	0.2	0.2	0.9	0.5	0.9	1.5	0.3	0.3	1.0	1.3

A: Ombolote, B: Emess mess, C: Elouk louk, D: Omboum, E: Apomben, F: Eleugn, G: Ndala, H: Atsakaye, I: Kipoumboua, J: Kyoye. SBE: sum of exchangeable bases. SFI: soil fertility index.

* Mean of three replications.

0.2 to 1.5. In three out of six cases, SFI values were consistently higher in the rich than the poor fields. In KED, SFI values of the rich fields ranged from 1 to 1.3, while that of the poor fields was 0.3. In all cases, SFI values were consistently higher in the rich than the poor fields. Apart one case, SFI values were higher in all soils in KED than their counterparts in TOB. This means greater chemical fertility in KED.

4. Discussion

The current study was designed to verify the relevance of data generated by farmers' perceptions in order to improve their interpretation. Out of 10 soil types, it emerged that farmers of the two locations acknowledged three soil groups of the American classification system. The same criteria were used for soil recognition. Differences in soil distribution pattern across the two locations were indicative of dissimilar environments. In both villages, although comparables, soils types differed in physical and chemical characteristics.

While color perception did not always match those of the Munsell color chart, differences in colour perception between rich and poor soils in the two locations were small. This may reflect the narrow range of organic matter of the soils and suggested an awareness of a relationship connecting soil color and fertility. This conclusion was joined in those of Defoer et al. [8], Koné et al. [9] and Shah [15]. Although TOB had the highest clay content, whilst KED had the highest clay and silt content, farmer's perceptions of soil texture in both locations were in opposition with soil analysis. They failed to differentiate between closely adjacent but discreet particles size class. Their perception was composite, but consistent with the particle size class named. This could be explained by the fact that soils were classified together with their known behaviour and highlighted farmers' knowledge of areas, where crop development was favored, difficult or impossible.

Soil depth as criterion for differentiation of fertility status corroborated the findings of Taulya [10] and Brabant and Gavaud [13] about the influence of topsoil depth on soil fertility. In fact, in cropped fields, soil surface exposure to heavy rains brings about erosion, which leads to a rapid diminution of topsoil thickness.

Drainage as criterion of soil fertility was in line with the findings of Kanmegne et al. [11] in South Cameroon. The use of water table management to minimize soil nutrient efficiency is a popular agricultural tool [12].

Plants seen as fertility indicators were in opposition with the works of M'biandoun et al. [14], and could be explained by the environmental degradation currently occurring in the SFZC.

Comparisons of SFI to farmers' rankings revealed farmers' contradictions. Higher fertility levels at KED compared to TOB, contrary to expectations, could be explained by the fact that they were dissimilar soils, but perceived in the same way, or because of a lack of focus in evaluating efficient soil type's attributes.

However, the diversity of soil fertility status suggested that there was a scope for harnessing indigenous knowledge of perceived differences. Because of the lack of soil analysis, validation of farmer's knowledge is interesting, because the diagnosis is simple, synthetic and readily available, which is in line with Gruver and Weil [21]. Soils' names deliver key messages needed for their location and fertility levels [18, 19]. This approach is similar to those used in the Cameroon forest zone [3]. In the study area, farmer's perceptions had a particular focus on relationships developed with peasant beliefs. However, many beliefs may be false or even dangerous. The application of this evaluation method to the increasing land use changes occurring in SFZC has still a critical need for detailed understanding of it functioning.

5. Conclusions

The purpose of this study was to evaluate the relevance of data generated by farmers' perceptions of soil fertility status. In the SFZC, farmers need practical and low costs techniques for the choice of agricultural land units. The failure to accurately diagnose soil fertility status may have dramatic socioeconomic and ecological consequences. These results confirm that several measured soils characteristics showed good relationships with farmer's perceptions. Some relationships as vegetation assessment and farmer's perceptions did not have significant relationships, suggesting their inappropriateness or new methods needed to be developed. However, the results of this study suggested an awareness of relationships connecting soil quality and fertility.

Acknowledgments

The authors thank Strengthening Partnership in Research Activities in Cameroon (REPARAC), whose funding has enabled this study. They are also grateful to Alfred Bekwake and all farmers in the two villages who shared their wealth of knowledge.

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