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Farmers' perceptions, indicators and soil fertility management strategies in the sudano-guinea savannahs of Adamawa, Cameroon

Adamou Ibrahima [1*], Paul Souhore [2], Boukar Hassana [3], Hamadou Babba [1]

[1] *Faculty of Science, University of Ngaoundere, P O Box 454 Ngaoundere, Cameroon*
[2] *Regional School of Agriculture of Maroua, P. O. Box 237 Maroua, Cameroon*
[3] *Department of chemical engineering, University Institute of Technology (UIT), University of Ngaoundere, P.O. Box 455 Ngaoundere, Cameroon*

Abstract

A survey was carried out in the sudano-guinea savannahs of Cameroon to assess farmers' indigenous knowledge of soil fertility concept, their indicators and management strategies of soil fertility. A sample of 569 households was chosen at random in the five divisions of the Adamawa region, namely Djerem, Faro-et-Deo, Mayo-Banyo, Mbere and Vina. Findings showed that farmers refer to bio-physical indicators before assessing the fertility of farmland. The fertility indicators of plant species are essentially *Terminalia macroptera* (11.16%) and *Andropogon* gayanus (10.67%), those indicating poorness soil included *Imperata cylindrica* (11.38%) and *Hymenocardia acida* (11.08%). The mostly faunal indicative of soil fertility are earthworms (43.00%) and termites (10.91%). Black soil (49.02%) and the presence of earthworm casts (35.31%) indicated soil fertility while red soils (61.52%) indicated soil poorness. The farmers improved the soil fertility by supplying agricultural inputs, using household waste and animal manure as well as practicing various crop rotations, and bush fallows. However, these indicators and management types vary according to divisions of Adamawa region and explained by climate and space availability. Now some management strategies are needed to be modified and adapted before they become effective. This should be based on a thorough knowledge of farmers and scientific technics.

Keywords: Soil Fertility; Farmer Indicators; Management Strategies; Adamawa Savannahs; Cameroon

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[*] Corresponding author. *E-mail address:* aibrahima@hotmail.com

1. Introduction

In Cameroon, although agricultural activities are important, food insecurity stands with acuity, especially in the northern part of country, despite the fact that the majority of the population is made of agriculturalists and animal rearers (Mapongmetsem, 2005; Mapongmetsem et al., 2011). It is therefore important to think fundamentally about agricultural production in general and in particular on soil fertility depletion of this region of Cameroun, in order to try out with trial solutions. In the face of inadequate proposed and imposed solutions to farmers, researchers are known increasingly unanimous that farmer's knowledge must be taken into account in the management of soil fertility (Soumana, 2000; Ndaka Bonguen et al., 2015).

Moreover, Groote et al. (1998) believe that the integration of this farmer's knowledge on soil fertility by inputs, in particular organic fertilizers and by the presence of plants species improving soil fertility would be one of the increasing conditions of production potentialities (Rahman, 2003; Bezabih et al., 2016). Promising results have been obtained in some parts of Africa, particularly in West Africa (Enyong et al., 1999; Soumana, 2000; Dawoe et al., 2012; Fofana et al., 2012; Diagne et al., 2013), East Africa (Mairura et al., 2007; Maro et al., 2013; Swai et al., 2015; Berazneva et al., 2016) or Horn of Africa (Abera and Belachew, 2011; Yeshaneh, 2015; Bezabih et al., 2016). However, in Cameroon and in particular in the Northern part of the country, very little information is available on the farmer's knowledge on soil fertility. Indeed, M'Biandoun et al. (2003), in their study in Kaele and Maroua in the Far north, and Garoua in the North Cameroon region, evaluated guide vegetation species and those indicative of soil fertility in these areas according to farmers perception. Similarly, Ibrahima et al. (2007) highlighted the evidence of farmer perception, indicators and strategies of soil fertility management in Mbe area of Vina Division in the Adamawa region of Cameroon. The main objective of this study is the evaluation of the perception of farmers' indicators of soil fertility in the Mbe Division of Adamawa region. The propose of the surveys is to identify physical and biological indicators of soil fertility and soil de gradation according farmer perception on the one hand, and to study farmer strategies of soil fertility management on the other hand, in the sudano-guinea savannahs of the five divisions of the Adamawa region.

2. Materials and methods

2.1. Study sites

The study was conducted in the agricultural buffer zones of the sudano-guinea savannahs of Adamawa Cameroon, situated between the 6th and 8th degree of latitude North and between the 11th and 15th degree of longitude East. The climate is humid sudano-guinea type (Suchel, 1971), with a unimodal rainfall distribution. Mean annual rainfall is about 1500 mm. The rainy season extends from July to September and dry season stretches from November to March. Mean annual temperature is 23°C and mean relative annual humidity is 65% (Carrière, 1989). While Ferralitic soils are the dominant types (Boutrais, 1974), with rich clay (40 à 60%), low organic matter (less than 3%), low soil exchange capacity from 15 to 20 meq/100g and the pH 4.7

to 5.6 (Brabant and Humbel, 1974). Vegetation of Adamawa is a humid savannah type, consisting of shruby and woody savannahs. These savannahs originally populated with *Daniellia oliveri* and *Lophira lanceolata* (Letouzey, 1968). There were also hydromorphic prairies that were sometimes inundated and contained *Hypparhenia rufa*, forest galleries with *Syzygium guineense* var. *guineense* and *Berlinia grandifolia*, degraded fallow lands and savannahs, occasionally used as grazing land which were composed of *Acacia hockii*, *Afzelia africana* (Letouzey, 1968). Now, this vegetation is much reduced under the influence of zoo-anthropic factors such as wild fires and rearing (Yonkeu, 1993; Mapongmetsem et al., 2011).

The population of Adamawa region is about 1 015 622 with 15.9 inhabitants per km^2. This population is cosmopolitan and composed of various tribes that are natives (Boum, Gbaya, Dii, ..) or allogeneic (Fulani, Haoussa,..) (Anonymous, 1994). Fulani are agropastoralists whereas hunting is very important with the Gbaya. The Mboum, Dii and other ethnic groups of the region are mainly agriculturalists while the Mbororo are nomadic. Agriculture is still traditional. Exploited area are small (as 0.5 to 1 ha). Livestock remains the main economic activity practiced by the more than 20% of the rural population. Other activities like hunting, fishing and crafts are practiced at artisan scale in the region. The most relevant problems in the region include the permanent decline soil fertility, damages by Striga on cereals, partridge and ruminants on seedlings and termites on crops as expressed through yellowing and fall of yam leaves.

2.2. Methodology

Surveys were carried out in the five divisions of Adamawa region, namely, Djerem, Faro-et-Deo, Mayo-Banyo, Mbere and Vina, from December 2005 to February 2006 and December 2006 to February 2007, in the four (4) first listed divisions. In the case of Vina Division, data in use were obtained from a previous survey from May to October 2002 on farmer's perception on soil degradation. In each division, three agricultural villages were sampled with the help of Divisional delegates and chief of villages. In each division, a sample of hundred (100) households was constituted, except the Vina Division whose sample is composed of 174 households. In fact, in the Vina Division, villages border the regional Capital are more populated and situated along the main road linking two regional capitals Ngaoundere and Garoua, while the villages of other Division are far from the regional Capital, less populated and their access is difficult. The sample was made up of persons of both sexes and of different ages (Table 1), distributed over the entire population (particularly the indigenous): the full-time farmers (more than 50 %) and part-time farmers, that is, those who associate agriculture to other activities like animal rearing, trade, fishing and teaching. Strangers who had not made up to 10 years in the region were excluded from the sample, because we assumed that they know little or do not know enough about the local cultural systems. The sample unit was the farm household with the heads of the households as the respondent.

For the survey itself, farmers were interviewed either in their farmers or in their homes, individually or in groups through a questionnaire with closed questions where they had to answer by yes or no and open questions where they needed some comments. The main focus was the farmer's concept of soil fertility and soil fertility management strategies in the Adamawa Savannahs. Questions were asked on the farmer's

concept of fertility, what they consider to be biophysics' indicators of soil fertility and how they manage soil fertility.

Table 1. Characteristics of household survey in the 5 divisions of Adamawa region (% of responses)

	Adamawa Divisions						Mean
Parameters	**Djerem**	**Faro-et-Deo**	**Mayo-Banyo**	**Mbere**	**Vina**	**Total**	
Sample size	**97**	**101**	**97**	**100**	**174**	**569**	**38.62**
Sex							
Men	**82.47**	**83.17**	**90.72**	**87.00**	**71.84**		**83.04**
Women	**17.53**	**14.85**	**9.28**	**13.00**	**28.16**		**16.56**
Age (year)							
]15-40]	**32.99**	44.55	37.11	33.00	47.13		38.96
]40-60]	46.39	41.58	43.30	54.00	**37.36**		44.53
> 60	14.43	13.86	19.59	13.00	**15.52**		15.28
Religion							
Muslim	15.46	34.65	76.29	24.00	-		37.60
Christian	58.76	26.73	20.62	57.00	-		40.78
Atheist	17.53	0.00	0.00	0.00	-		4.38
Marital status							
Single	1.03	20.79	4.12	16.00	-		10.49
Maried	71.13	79.21	95.88	81.00	-		81.80
Number of person per household							
]0-2]	2.06	18.80	4.12	4.00	-		7.25
]2-4]	3.09	16.83	8.25	11.00	-		9.79
]4-8]	27.84	422.57	29.90	30.00	-		32.58
> 8	50.52	20.79	56.70	50.00	-		44.50
Mean activities							
Famers	74.02	66.94	79.31	81.82	**83.23**		77.45
Breeding	11.02	12.40	5.17	14.05	**4.19**		9.05
Trade	10.24	8.26	10.34	0.83	**5.39**		6.90
Official	-	5.79	0.86	-	**0.60**		1.38
Masonry	-	-	1.72	1.65	-		0.61
Pastor	-	-	-	0.83	**1.80**		0.61
Technician	0.79	-	-	-	**1.80**		0.61
Black-smith	-	-	-	-	**1.80**		0.46
Fishing	1.57	-	-	-	-		0.31
Tree felling	-	-	-	0.83	-		0.15
Bakery	-	-	-	-	**0.60**		0.15
Year of experience							
]5-10]	11.34	17.82	24.74	18.00	-		17.97
]10-20]	7.22	36.63	34.02	26.00	-		26.08
]20-30]	32.99	19.80	19.59	16.00	-		22.03
> 30	32.99	22.77	21.65	40.00	-		29.37
Number of fields per household							
1	27.84	52.48	-	32.00	-		28.35
2	41.24	4.95	-	25.00	-		17.72
3	21.65	1.98	-	32.00	-		13.92
4	4.12	-	-	8.00	-		3.04
> 4	4.12	2.97	-	3.00	-		2.53
Field area (ha)							
]0-0.5]	68.04	6.93	37.11	54.00	-		41.27
]0.5-1]	25.77	14.85	35.05	17.00	-		23.04
]1-3]	6.19	15.84	21.65	29.00	-		18.23
]3-5]	-	3.96	2.06	-	-		1.52
> 5	-	0.99	4.12	-	-		1.27

3. Results

3.1. Farmer's concept of soil fertility

Tribes from Adamawa region use some expressions to define the concept of soil fertility (Table 2). For many of these tribes, just one expression is used for this, namely *Kassan da kew* for Haussa, *Taa bay* for Toupouri and *Damé* for Moundang, which means good soil, black soil or clay soil respectively. In the contrary, some others used many expressions, from 2 for the Mbere and Voute tribes to 5 for the Gbaya tribe. For the latter tribe, the expression most commonly use among the 5 is *Non ode* (32.03% of response), which in English means good soil.

It is worthy to note rapprochements in the significance of those expressions in the tribes from the same region or from different regions (Table 2). For the Mbere, Mboum and Dii, tribes of Adamawa region, the concept of fertility is linked to a soil containing oil. Similarly for the Mboum and Dii, tribes from Adamawa and the Toupouri, a tribe from the Far North region, the soil fertility is linked to the black color of the soil with the following expressions as the *Tecceri pirri*, *Hack-dii* and *Taa bay* respectively.

In the entire region of Adamawa, the expression mostly used to define the concept of soil fertility is good soil (62.87%), followed by soil rich with fertilizers (12.74%), black soil (6.45%) and soil having oil (4.29%) (Table 2). In the contrary, according to divisions, expressions in use vary therefore, if in the Djerem (87.50%), Faro-et-Deo (57.69%), Mbere (71.76%) and Vina (54.00%), it is the term good soil which was used to define soil fertility, in the Mayo-Banyo, instead, it is the term soil rich with fertilizers (47.42% of responses). Some other expression may subsequently be used (Table 2). In the Djerem and Vina, Divisions, in addition to the term good soil, black soil was also used.

Table 2. Expressions used by farmers to indicate soil fertility in the Adamawa region and their translation (% of responses*)

Expressions	Tribes	Divisions of Adamawa region					Mean
		Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	
Non ode	Gbaya	32.03	-	-	23.53	-	11.12
De onou	Gbaya	30.47	-	-	3.53	-	6.80
Bog non	Gbaya	20.31	-	-	-	-	4.06
No ndo ngue maje	Laka	-	-	-	12.94	-	3.24
Do nan madji	Laka	1.56	-	-	-	-	0.31
Kassan da keew	Haoussa	-	-	6.19	-	-	1.24
Lesdi boodi	Peulh	-	8.65	1.03	-	-	1.94
Tecciri bella	Mboum	3.13	-	-	31.76	4.00	7.78
Hack-ké	Dii (Duru)	-	-	-	-	50.00	10.00
Ndja'a bu'ubong	Yamba	-	-	20.62	-	-	4.12
San à fin	Nyem nyem	-	13.46	-	-	-	3.37
Boug ego	Péré	-	35.58	-	-	-	8.89
Good soil		**87.50**	**57.69**	**27.84**	**71.76**	**54.00**	**62.86**
Tou non		0.78	-	-	-	-	0.16
Tecciri pirri	Mboum	1.56	-	-	-	-	0.31
Hack-dii	Dii (Duru)	-	-	-	-	28.74	5.75
Taa bay	Toupouri	-	-	-	-	1.15	0.23
Black soil		**2.34**	**-**	**-**	**-**	**29.89**	**6.45**
Lesdi mardi konal	Peulh	0.78	9.62	47.42	5.88	-	**12.74**

Soil having fertilizers							
Lougguéré	Peulh	-	15.38	-	-	-	3.08
Techiri hii pay	Kari	-	-	-	1.18	-	0.24
De fera	Gbaya	-	-	-	1.18	-	0.24
Place or land of cultures		**-**	**15.38**	**-**	**2.35**	**-**	**3.55**
Lesdi mardi sembé	Peulh	0.00	0.96	-	2.35	-	**0.66**
Soil having power							
Decay soil	Mbéré	-	-	-	2.35	-	**0.47**
Noun ndjal	Mbéré	-	-	-	4.71	-	0.94
Tecciri ye ka mara	Mboum	-	-	-	3.53	-	0.71
Hack-koun	Dii (Duru)	-	-	-	-	13.22	2.64
Soil having oil		**-**	**-**	**-**	**8.24**	**13.22**	**4.29**
Tecciri panake	Mboum	-	-	-	1.18	-	**0.24**
Soft soil							
Mbe non	Gbaya	7.81	-	-	-	-	**1.56**
New soil							
Damé	Moundang	-	0.96	-	-	-	**0.19**
Clay soil							
Kanii	Vouté	-	-	6.19	-	-	**1.24**
Nda'a man ndjadi	Konja	-	-	3.09	-	-	**0.77**
Nda'a le allam	Vouté	-	-	5.15	-	-	**1.03**
Daidi nday	Wawa gawla	-	-	5.15	-	-	**1.29**
Tombo iya gari	Mambila	-	-	3.09	-	-	**0.77**
A'bong	Ngoung	-	-	2.06	-	-	**0.52**
San a wouam	Nyasao	-	0.96	-	-	-	**0.24**
Koui rewoi	Guiziga	-	0.96	-	-	-	**0.24**

** Sums below 100% are due to no reply*

3.2. Farmers' indicators of fertile and poor soil

To determine the fertile soil, the famers of Adamawa region use indicators that we grouped under two main types: the biological and physical indicators (Figure 1). The biological indicators made up of flora and fauna, while the physical ones included physical characteristics of the soils, earthworm casts and the presence of termite hills. Biological indicators (56.89%) are a little bit more than the physicals (43.11%). These indicators may be ante cultural or post cultural. Among the biological indicators, plant indicators of fertile soil were much numerous (32.75%) and varied than the animal ones (24.14%).

The vegetation indicating fertile soil possesses some characteristics that famers recognize because of their long experience. For the farmer of the Adamawa region, a fertile soil could be characteristic of vigorous and high vegetation (37.17%) or dense (32.53%), with big trees and tall herbs (23.92%) (Table 3). In addition to this vigorous vegetable, farmers add green pigmentation (17.10%) and black (13.24%) of the vegetation. The sampled plant species fell within thirteen (13) families (Table 4) of which the wide known and most commonly used were the poaceae (26.39% of responses), the Caesalpiniaceae (12.12%), Combretaceae (11.54%) and the mimosaceae (11.26%). The other families were scarcely mentioned (<8%) as indicators of fertile soil. According to division, the importance of families is variable (Table 4). Farmers of Vina Division prefer the use of Poaceae (63.22%), those of Djerem Division, the Combretaceae (29.29%) and Poaceae (27.78%), those of Faro-et-Deo Division, the Mimosaceae (30.62%) and the Moraceae (17.71%) and those of

Mbéré Division, the Cesalpiniaceae (37.34%). It should be noted that in Mayo-Banyo, the populations concerned did not answer this question.

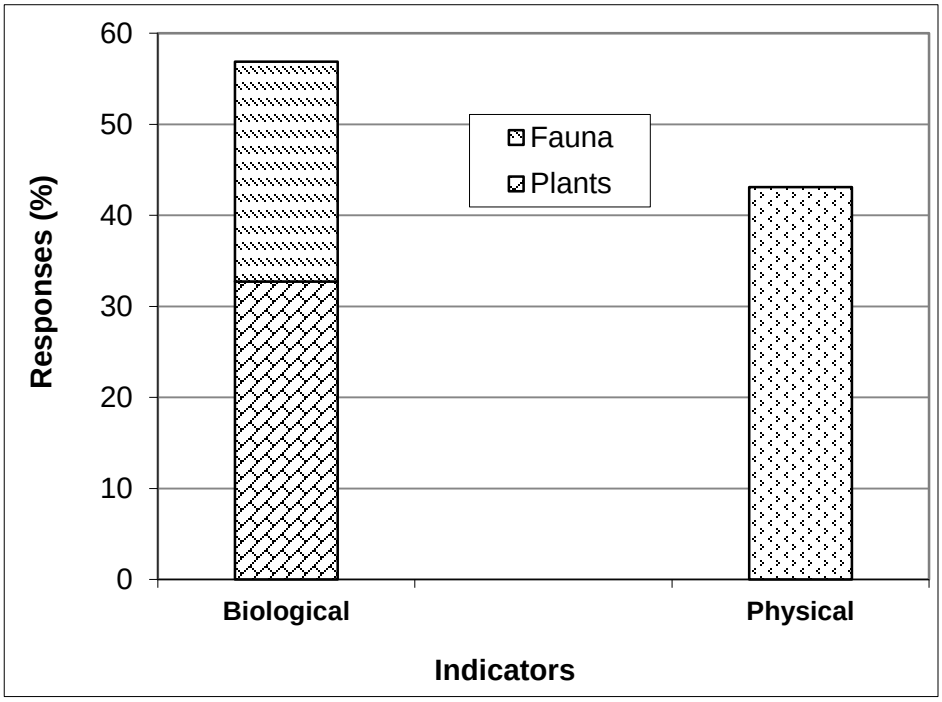

Figure 1. Mains Farmers' indicators of soil fertility in the humid savannahs of Adamawa region

Plant species did not all have the same importance as indicators of fertile soil (Table 5). In the entire region, many plant species were used as indicators of fertile soil but two plant species, *Terminalia macroptera* (11.16%) and *Andropogon gayanus* (10.67%), constituted a common index for fertile soil. The importance of species also varies according to Divisions (Table 5). Two species are mostly appreciated in the Djerem Division, *Terminalia macroptera* (29.29%) and *Andropogon gayanus* (22.73%). In Faro-et-Déo and Mbere Divisions, only one species was cited, *Leucana leucocephala* (20.57%) and *Daniellia oliveri* (23.42%) respectively, while in the Vina Division, four (4) plant species, *T. macroptera* (11.39%), *A. gayanus* (11.08%), *P. purpureum* (11.29%) et *R. cochinchinensis* (11.19%) were widly emphasized by farmers. Farmers of Mayo-Banyo did not answer this question.

Like flora, fauna was also used by the farmers of the Adamawa region as indicators of fertile soil (Table 5). Among the animals species that contribute directly to fertile soil, the earthworms (43.00%), and termites (10.91%) were the most commonly known and valued by the farmers. Big fauna include cattle (8.99%), elephants (8.99%) and rabbis (8.73%) also used by the farmers as guides to estimate whether a soil is fertile or not. A part from Mayo-Banyo Division where 44.93% of farmers cited cattle as indicators of fertile soil, in

other Divisions, particularly in the Faro-et-Deo Division (100% of responses), the majority of farmers interviewed claimed the abundance of earthworms in an arable land was an index of soil vitality.

Table 3. State of vegetation indicator of fertile soil in the 5 divisions of Adamawa region (responses en %)

State of vegetation	Divisions of Adamawa					Mean
	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	
Bushy vegetation	32.10	1.98	-	42.57	53.45	32.53
High vegetation	12.69	-	94.85	3.96		37.17
Green vegetation	12.69	-	-	-	21.51	17.10
Black vegetation	8.21	-	-	11.88	19.63	13.24
Bushy and high vegetation	6.72	-	-	7.92	-	7.32
Bushy and black vegetation	1.49	-	-	-	-	1.49
Presence of large trees and tall grasses	14.18	-	-	33.66	-	23.92

- indicates that there is no response

Table 4. Plant family indicators of fertile soil in the 5 divisions of Adamawa regions (% responses)

Families	Divisions of Adamawa region					Mean
	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	
Poaceae	27.78	-	-	14.56	63.22	26.39
Caesalpiniaceae	0.51	0.48	-	37.34	10.16	12.12
Combretaceae	29.29	1.44	-	2.53	12.89	11.54
Mimosaceae	-	30.62	-	5.06	9.36	11.26
Asteraceae	7.07	6.70	-	14.56	3.50	7.96
Moraceae	9.6	17.71	-	-	-	6.82
Anacardiaceae	7.58	-	-	10.76	0.61	4.74
Euphorbiaceae	0.51	11.48	-	0.63	-	3.16
Verbenaceae	-	11.96	-	-	-	2.99
Sapotaceae	-	8.61	-	-	-	2.15
Fabaceae	-	-	-	6.33	-	1.58
Annonaceae	4.55	-	-	-	-	1.14
Ochnaceae	1.01	-	-	0.63	-	0.41

- indicates that there is no response

In the entire Adamawa region, like in each Division, among the physical indicators cited, the black soil and abundance of earthworm casts were considered as the most important by the farmers (Table 5). Termite hills and red soil were considered the less important by farmers, except those from Vina Division where 15.48% of them estimated that termite hills in farm land were signs of soil fertility.

Table 5. Farmers' indicators of fertile soil in the traditional land uses in the 5 divisions of Adamawa region of Cameroon. (% of responses)

Species	Families	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	Mean
Vegetation Indicators							
Andropogon gayanus	Poaceae	22.73	-	-	8.86	11.08	10.67
Imperata cylindrica	Poaceae	5.05	-	-	5.70	10.47	5.30
Laudetia flavida	Poaceae	-	-	-	-	9.13	2.28
Pennisetum purpureum	Poaceae	-	-	-	-	11.29	2.82
Pennisetum polystachion	Poaceae	-	-	-	-	10.06	2.52
Rottbollina cochinchinensis	Poaceae	-	-	-	-	11.19	2.80
Daniellia oliveri	Caesalpiniaceae	0.51	-	-	23.42	-	5.98
Isoberlinia doka	Caesalpiniaceae	-	-	-	-	10.16	2.54
Piliostigma thonningii	Caesalpiniaceae	-	0.48	-	13.92	-	3.60
Acacia polyacantha	Mimosaceae	-	-	-	-	8.54	2.14
Leucaena leucocephala	Mimosaceae	-	20.57	-	-	-	5.14
Parkia biglobosa	Mimosaceae	-	9.09	-	-	-	2.27
Entada africana	Mimosaceae	-	0.96	-	5.06	0.82	1.71
Aframamum Latifolium	Anacardiaceae	3.03	-	-	10.76	-	3.45
Haematostaphis barteri	Anacardiaceae	4.55	-	-	-	-	1.14
Lannea schimperi	Anacardiaceae	-	-	--	-	0.61	0.15
Anogeissus leiocarpus	Combretaceae	-	-	-	-	1.50	0.38
Terminalia macroptera	Combretaceae	29.29	1.44	--	2.53	11.39	11.16
Ficus gnaphalocarpus	Moraceae	9.60	7.18	-	-	-	4.19
Ficus ingens	Moraceae	-	10.53	-	-	-	2.63
Annona senegalensis	Annonaceae	4.55	-	-	-	-	1.14
Chromolaena odorata	Asteraceae	7.07	6.70	-	14.56	3.50	7.96
Uapaca togoensis	Euphorbiaceae	0.51	11.48	-	0.63	-	3.16
Senna javanica	Fabaceae	-	-	-	6.33	-	1.58
Lophira lanceolata	Ochnacea	1.01	-	-	0.63	-	0.41
Vitellaria paradoxa	Sapotaceae	-	8.61	-	-	-	2.15
Vitex doniana	Verbenaceae	-	11.96	-	-	-	2.99
Animal indicators							
Earthworms		34.25	100.00	0.97	45.00	34.78	43.00
Termites		2.74	-	-	20.00	31.81	10.91
Beefs		0.00	-	44.93	-	-	8.99
Elephants		24.66	-	-	10.00	10.29	8.99
Rabbits		13.70	-	-	25.00	4.94	8.73
Goats		-	-	29.47	-	-	5.89
Sheep		-	-	24.15	-	-	4.83
Does		12.33	-	-	-	2.97	3.06
Buffalos		12.33	-	-	-	-	2.47
Hedgehogs		-	-	-	-	6.17	1.23
Squirrels		-	-	-	-	4.34	0.87
Partridges		-	-	-	-	3.97	0.79
Antelopes		-	-	-	-	0.68	0.14
Hens		-	-	0.48	-	-	0.10
Physical indicators							
Black soil		53.49	38.56	66.39	55.69	30.96	49.02
Earthworm casts		44.77	36.86	22.13	42.51	30.25	35.31
Soil texture		-	14.83	1.64	-	11.93	5.68
Soil compactness		1.16	4.66	9.84	-	11.38	5.41
Termite hill		-	-	-	-	15.48	3.10
Red soil		0.58	5.08	-	1.80	-	1.49

- indicates no reply

Unlike a fertile soil, criteria indicating soil poorness or infertile is very few, particularly the fauna (Table 6). Abundance of termites is an indication of soil infertile according to 28.57% of the farmers of Djerem Division and 100% of those of Mbere Division. Those of other Divisions did not answer this question.

The most important plant species indicators of infertile soil in the entire Adamawa region are *Birkissi* (13.05% of responses), *Imperata cylindrica* (11.38%) and *Hymenocardia acida* (11.08%). However, at the level of Divisions, the importance of these indicators varied (Table 6). In fact, more than 60% of the farmers in the Djerem Division think *Birkissi* appears in soil poorness, while 40.90% of those of the Vina Division claimed that soil poorness was showed through the presence of *Striga hermontica*. For the farmers of Faro-et-Deo Division, three plant species namely, *Hymenocardia acida* (39.58% of responses), *Saglabo* (37.50%) and *Terminalia sp.* (22.92%) constituted the major indicators of a soil infertile. As to the farmers of Mayo-Banyo Division, they most refer to *Imperata cylindrica* (49.25% of responses) and *Acacia nilotica* (40.30%), and at last those of Mbere Division used *Melinus repens* (38.85% of responses) and *Pennisetum purpureum* (23.74% of responses) as major indicators of soil infertile.

Physical indicators of infertile soils that farmers in the Adamawa region used are mainly the color and texture of soils (Table 6). Both at the Regional level and the Divisions of Djerem, of Mayo-Banyo and of Mbere, more than 61% of farmers interviewed think a red soil is an indicator of soil poorness or infertile soil. In the contrary, the majority of the farmers in the Vina Division think silting (49.05%) indicated mainly an infertile soil.

3.3. Famer's soil classification

Four criteria are used by the farmers of the Adamawa region to classify soils (Table 7). Among those, production yields (65.20% of responses) are the major criteria used in the farmers of Adamawa region. The second regional criterium is the soil work (26.89%). Other criteria such humidity (7.39% of responses) and soil color (0.52%) are also took into consideration by farmers to distinguish the soil type, but these are less important criteria. Since production yield is the major criterion in the region for classification of soil in all the Divisions in the Adamawa region (Table 7), and the soil work comes in the second position, except in the Faro-et-Deo Division where the latter criterion comes in the third position (20.37%) after soil humidity (35.65%).

Farmers of Adamawa region distinguished eight (8) types of soil, ranged from clayey soil (1.38%) to black soil (39.78% of responses). According to Divisions, number of soils and their importance varied (Table 7). Farmers from Djerem, Mayo-Banyo and Mbere Divisions distinguished five to six soil types whose black and red color are important. Those of Faro-et-Deo Division distinguished also five types of soils where soil red (30.26%), black (26.67%) and sandy of soil (24.62%) are the most dominant. Lastly, in the Vina Division, only two types of soils were distinguished among the four mentioned by farmers: black soil (51.40% of responses) and sandy-clayey soil (39.09%).

Table 6. Farmers' indicators of poor soils in the traditional land uses of Adamawa region (% of responses)

Species	Families	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	Mean
Vegetation indicators							
Birkissi		60.91	-	-	4.32	-	13.05
Hymenocardia acida	Hymenocardiaceae	-	39.58	-	15.83	-	11.08
Imperata cylindrica	Poaceae	5.46	-	49.25	2.16	-	11.38
Acacia nilotica	Mimosaceae	-	-	40.30	-	5.12	9.08
Striga hermontica	Scrofulariaceae	-	-	-	-	40.90	8.18
Melinus repens	Poaceae	-	-	-	38.85	-	7.77
Saglabo		-	37.50	-	-	-	7.50
Pennisetum purpureum	Poaceae	2,73	-	10.45	23.74	-	7.38
Tridax procumbens	Asteraceae	-	-	-	-	25.60	5.12
Opus sp.	Poaceae	-	-	-	-	25.36	5.07
Terminalia sp.	Combretaceae	0.91	22.92	-	-	-	4.77
Kpegne		15.45	-	-	0.72	-	3.23
Hoofi		14.55	-	-	-	-	2.91
Boussou		-	-	-	14.39	-	2.88
Acacia seyal	Mimosaceae	-	-	-	-	3.02	0.60
Animals indicators							
Termites		28.57	-	-	100.00	-	25.71
Caterpillars		71.43	-	-	-	-	14.29
Physical indicators							
Red soil		82.24	34.66	90.70	100.00	-	61.52
Silting		-	0.00	0.00	-	49.05	9.81
Soil texture		-	39.20	5.81	-	-	9.00
Soil compactness		6.54	25.57	2.33	-	-	6.89
White soil		2.80	0.00	1.16	-	24.8	5.75
Light-colored soil		0.00	0.57	-	-	26.15	5.34
Stony soil		3.74	-	-	-	0	0.75
Hard soil		3.74	-	-	-	0	0.75
Black soil		0.93	-	-	-	0	0.19

Soil texture means finger adhesion and smooth. – indicates no reply

Table 7. Farmers' classification of soil types in the 5 divisions of Adamawa region

	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	Mean
Farmers' criteria for soil classification						
Production yields	61.65	43.98	98.90	67.18	54.31	65.20
Soil work	36.84	20.37	-	32.82	44.41	26.89
Soil humidity	-	35.65	-	-	1.28	7.39
Soil color	1.50	-	1.10	-	-	0.52
Soil types						
Black soil	36.29	26.67	44.08	40.49	51.40	39.78
Red soil	35.52	30.26	45.02	40.49	-	30.26
Sandy clayey soil	14.67	-	-	9.71	39.09	12.70
Sandy soil	4.25	24.62	7.11	5.26	-	8.25
Lateritic soil	-	16.92	0.47	-	-	3.48
Stony soil	9.27	1.54	-	-	0.47	2.25
Limonous soil	-	-	0.47	-	9.04	1.90
Clayey soil	-	-	2.84	4.05	-	1.38

- indicates that there is no response

3.4. Indicators of soil tiredness and death

Farners from the Adamawa region use many indicators for the evaluation of soil tiredness (Table 8). More than half of farmers clamed production yield (51.66%) is the best indicators of soil tiredness. However, other indicators such as the soil work (17.01% of responses), its color (10.08%) and silting soil (8.93%) and abundance of *striga hermontica* (8.30%) are equally used by farmers to estimate the soil tiredness. The number and importance of indicators varied according to Divisions, except production yield that is commonly used in the five Division of Adamawa region, with farmers' answers from 31.00% to 96.94% in Vina and Mayo-Banyo Divisions respectively (Table 8). The farmers of Mayo-Banyo Division used only production yield while those of Mbere Division refer to two main indicators, production yield (51.72%) and soil work (39.66%). For those of Djerem Division, three indicators were used that are production yield (47.06%), soil work (24.06%) and soil color (18.72%). In Faro-et-Deo and Vina Divisions, farmers refer to four main indicators, production yield (31.56 and 31.00%), selting soil (20.63 and 24.00%) and abundance of *Striga hermontuca* (15.63 and 25.86%).

Not only that farmers possess indicators of soil tiredness, but they equally use empirical knowledge to estimate duration of cultivations from where the soil is tired or dead. (Table 8). In the entire Adamawa region, 47.95% of farmers think soil tiredness occurs after 3 and 6 years of continuous cultivation and 26.38% think the soil death starts as from 10 years. Like in the Adamawa region, more than 43% of farmers of the five divisions think soil tiredness is between 3 and 6 years after continuous cultivation, except farmers from Djerem and Mayo-Banyo divisions, who think the tiredness takes place from 0 to 3 years. Similary, the soil death is between 6 and 10 years continuous cultivation according to 39.60% of farmers opinion of Faro-et-Deo Division, and from 10 for those of Mayo-Banyo Division (89.690%). Farmers from other Division did not give their opinions on this point of view.

Table 8. Cultivation time (in years) fore tiredness and death of soil

Parameters	Divisions of Adamawa region					Mean
	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	
Indicators of soil tiredness						
Yield	47.06	31.56	96.94	51.72	31.00	51.66
Soil work	24.06	2.19	-	39.66	19.14	17.01
Soil color	18.72	27.81	1.02	2.87	-	10.08
Sandy	-	20.63	-	-	24.00	8.93
Abondance of *Striga hermontica*	-	15.63	-	-	25.86	8.30
All	5.88	2.19	-	-	-	1.61
Time of cultivation before soil tiredness						
] 0-3]	51.55	21.78	57.73	12.00	-	28.61
] 3-6]	45.36	43.56	27.84	66.00	57.00	**47.95**
] 6-10]	-	17.82	1.03	14.00	22.00	10.97
> 10	-	2.97	8.25	-	21.00	6.44
Time of cultivation before soil death						
] 0-3]	-	7.92	-	-	-	1.98
] 3-6]	-	22.77	5.15	-	-	6.98
] 6-10]	-	39.60	-	-	-	9.90
> 10	-	15.84	89.69	-	-	**26.38**

3.5. Agricultural practices and soil fertility restoration.

Farmers of the Adamawa region used different types of laborer for farming (Table 9). This laborer is first from the family (55.76%), but farmers sometime got laborers from the villages (29.69%). However, a small number of farmers used foreigners (14.20% of responses), or national (2.37%) and international (11.83%). These laborers varied according to Divisions (Table 9). In fact, farmers from Djerem division only used laborers from among villagers (100%), while these laborers are essentially from nationals in the Mbere (100%) and Vina (100%) Divisions. Origin of laborers from Faro-et-Deo Division are diversified. They use mainly their family members (50.29%), but also others villagers (29.14%), nationals (8.57%) and foreigners (10.29%). For the farmers from Mayo-Banyo, half of the laborers come from the family members (51.11%) and the rest are foreigners (48.89%).

So several techniques are used to clear or work land in the Adamawa region. Farm labor is through traditional methods such manual labor (38.62%) and wildfires (32.94%) (Table 9). Tools in use are hoe, cutlass, axe, and shovel. There are also plough (11.44%), tractors (7.77%), and low herbicides (2.11%). In the five Divisions of this region, manual labor and wildfires are by far the mostly used means of clearing farm lands, except in the Mbere and Vina Divisions where a plough (31.89%) and herbicides (20.74%) took the second position after manual labor (Table 9). The use tractors in the Djerem Division (22.55%) and Faro-et-Deo (8.55%) Divisions should be underline. There is an intensive use of herbicides in the Vina Division (20.74%).

Table 9. Mean used for field work or traditional technics

	Djerem	Faro-et-Deo	Mayo-Banyo	Mbere	Vina	Mean
Manpower						
Family labor	57.49	50.29	51.11	54.40	65.53	55.76
Village labor	42.51	29.14	-	44.51	32.27	29.69
Nationale labor	-	8.57	-	1.10	2.18	2.37
Foreign labor	-	10.29	48.89	-	-	11.83
Farmers' cultivation techniques						
Manual labour	35.64	41.88	38.37	38.58	45.71	38.62
Bush fires	29.09	37.61	36.73	28.35	16.09	32.94
Plough	10.91	2.56	0.41	31.89	8.04	11.44
Tractors	22.55	8.55	-	-	9.42	7.77
Herbicides	-	7.26	-	1.18	20.74	2.11

To alleviate low fertility which is generally perceive through gradual decrease in production, farmers in the Adamawa region adopted several strategies such as the use of agricultural fertilizers, fallow practice and crop rotations (Table 10). The strategy mostly used by farmers is fertilizers (51.61%) followed by fallows (43.89%). However their importance varied according to Divisions. Farmers from Mayo-Banyo Division declared at 86% prefer to use of fertilizers, followed by thoses of Faro-et-Deo Division (67.19%). Farmers who used less fertilizer (19.17%) and practiced more fallows (80.83%) are farmers from the Djerem Division. Among those fertilizers, chemical fertilizers are the mostly used (42.22%) in the Adamawa region, followed by animal dungs (37.86%), with quantities ranging from 1 to 4 bags of 50 kgs (Table 10). The majority of

farmers use only one bag (36.99%). Cattle dung is largely used in the entire five Divisions of Adamawa region. The only Division where chemical fertilizers are used by more than 80% of farmers is the Vina Division (88.00%) and the Djerem seen the Division where animal dung is mostly in use (73.91%). Other Divisions combine two or three types of fertilizers. In fact, farmers from Mayo-Banyo used chemical fertilizers (60.32%) and animal dung (30.16%), those from Mbere, animal dungs (47.30%) and vegetation manure (37.84%) and those from Faro-et-Deo, chemical fertilizers (25.88%), animal dung (32.94%) and vegetal wast (28.24%). Cattle dung considered the best by farmers from Adamawa region (49.90%). Whereas only farmers from Faro-et-Deo Division say earthworm casts are very good for cultures (18.63%).

Farmers of Adamawa region used both chemical fertilizers and practiced fallows (43.89%) to restore or improve the soil fertility (Table 10). The duration of fallow varied between 1 and 6 years, with the majority of farmers estimating it to be between 2 and 4 years (56.70%). In the Djerem Division, this practice is dominant and tends to be exclusive, with 80.83% of farmers who affirmed practicing it. At last, the third strategy in use by farmers in Adamawa region to improve the soil fertility is crop rotation (Table 10). Only more than 20% of farmers from Mbe Division have confirmed this practice (22.50%) in their Division.

Table 10. Farmers' strategies of management and different types of fertilizers (% of responses)

	Djerem	Faro –et-Deo	Mayo Banyo	Mbere	Vina	Mean
Soil management						
Use all type of fertilizer	19.17	67.19	86.90	44.31	40.50	51.61
Fallow practices	80.83	32.81	13.10	55.69	37.00	43.89
Crop rotations	-	-	-	-	22.50	4.50
Fertilizer types						
Chemical fertilizers	26.09	25.88	60.32	10.81	88.00	42.22
Animal manure (cow, bats..)	73.91	32.94	30.16	47.30	5.00	37.86
Vegetation manure	-	28.24	7.14	37.84	1.00	14.84
Household waste	-	12.94	2.38	4.05	3.00	4.48
Quantity of fertilizers (bacs)						
] 0–1]	33.33	25.80	26.32	62.50	-	36.99
] 1–2]	16.67	13.64	19.74	37.50	-	21.89
] 2–4]	-	25.00	32.89	-	-	19.30
> 4	-	18.18	15.79	-	-	11.32
Fallow duration (years)						
] 0–2]	30.93	-	-	-	-	30.93
] 2–4]	56.70	-	-	-	-	56.70
] 4-6]	10.31	-	-	10.75	-	10.53
More efficient animal manure						
Beefs	21.90	44.12	79.80	53.77	-	49.90
Sheep	-	1.96	5.05	5.66	-	4.22
Goats	4.76	7.84	1.01	-	-	4.54
Hens	-	3.92	1.01	-	-	2.47
Horses	-	-	2.02	-	-	2.02
Earthworms	-	18.63	-	-	-	18.63
Bats	2.86	-	-	-	-	2.86

4. Discussion

4.1. Concept of soil fertility

Farmers from sudano-guinea Savannahs of Adamawa Cameroon are conscious of the notion of soil fertility. However, the term fertility in the literal sense of word does not exist in the languages of the tribes involved in the study. They use local expressions such as *hack-dii* and *Hack-koun* for the Dii tribe, *teciri bella*, *teciri pirri*, *teciri ye ka mara* and *teciri ye panake* for the Mboum, *lesdi boodi* and *lesdi mardi konal* for the Fulani, *taa bay* for the Toupouri tribe and *Dame* for the Moundang tribe, to express soil fertility. These expressions meaning "good soil" (*hack-ke*, *teciri bella* and *lesdi boodi*), "black soil" (*tecciri pirri*, *hack-dii* and *taa bay*) "soil having oil" (*tecciri ye ka mara* and *hack-koun*) suggested that the concept of soil fertility for the farmers of Adamawa Cameroon refer more to the physical structure, the presence of vegetation or animals in the farm lands and soil production since a soil (good soil) is the one that crop yields more. This confirmed the literature results (Okoba, 2005; Abera and Belachew, 2011; Ndaka Bonguen et al., 2015; Swai et al., 2015; Bezabih et al., 2016). Somé et al. (1998) showed that, for the farmers of sudanian zone, soil fertility is not a vague concept, but a physical reality expressed by the presence of plant species, soil aspect, or agricultural productivity. The perception of soil fertility by the African farmers in the south of Sahara is perceived through their relationships with land that they consider as a feeding mother and a gift from heaven (Rjtz, 1991). In level of farmer values, soil fertility is not appears as a significant value. This shows how difficult it is to give a literal translation to the word fertility in most of African languages (Somé et al., 1998). Farmer knowledge on soil qualities is through notions such good or bad soil, or a soil having decay (Somé et al., 1998; Mairura et al., 2007) or oil. A black soil and decay soil are those that are rich in organic matter, derived from litter decomposition to give humus, a dark-brown organic component of soil that captures and fix minerals and plays an important role in plant nutrition. Serpantié and Ouattara (2001) confirmed the assertion that humus is a good indicator of components of soil fertility. Moreover, by linking the soil fertility to oil, a farmer probably thinks that the soil possesses a precious substance that transfers to a plant for its development.

4.2. Farmers' indicators of soil fertility and infertility

When the farmers of the Adamawa savannahs of Cameroon have to do with hitherto unexploited or secondary vegetation covered farmland, they use a series of bio-physical indicators of soil fertility, composed of plants, animals and soil physical quality to decide on the outcome of their agricultural undertaking. According to the logic of farmers, a vigorous, thick and rich vegetation covered farmland, composed of tall trees and high herbs, associated with an abundant animal life to which farmers add the soil color and texture, abundance of earthworms and their casts, but also the presence of termites gives sign to a vitality and fertility of soil. Similarly, poor soils are characterized by a biological complex that is also poor. Scattered herbaceous plants dominate the vegetation of these soils whose colors are light and very rich in gavel. Such soil does not inspire farmers in Adamawa region for agricultural purposes. These various biological (flora and fauna) and physical indicators used by farmers in the Adamawa savannahs to differentiate between empirically fertile and infertile soils have been mentioned in the works of Donfack (1998) at Maroua, Pabame

(2002) at Ngong and M'Biandoun *et al.* (2003) at Kaele, Maroua, and Garoua. All these previous works were carried out in the dry (or Sudanian) savannahs of the North and Far-North regions of Cameroon. These various indicators have also been reported in the Kanmegne (2004) and Ndaka Bonguen et al (2015) works that carried out in the tropical humid forest of Southern Cameroon, and those of Quansah et al. (2001), Fofana et al. (2012), and Dawoe et al. (2012) in the Sudanian savannahs of West Africa, and Odendo et al. (2010) in Southern Africa. Pali (2003), in his study conducted in Eastern Uganda, showed that high yield, soil moisture conservation and darkening of the soil color were the farmers' key indicators of soil fertility improvement. In the same way, Omiti et al. (1999), Onduru et al. (2002), Okoba (2005), and Mairura et al. (2007) showed that farmers in eastern and central highlands of Kenya used low yield, stunted crop growth, soil color and certain weed infestation as key indicators of soil fertility decline.

Meanwhile, the quality of taxa, their diversity and indicator importance vary according to the regions and agro-ecological zones (M'Biandoun et al., 2003). With respect to the plant families used as indicators of soil fertility, our findings reveal, overall Adamawa savannahs of Cameroon, that the Poaceae took the first place, followed by the Caesalpiniaceae, Combretaceae and Mimosaceae. Whereas in the Djerem Division, the Combretaceae occupied the first place, followed by the Poaceae, in the Faro-et-Deo Division, the Mimosaceae, followed by the Moraceae, which are the most frequently cited as indicators of soil fertility, and finally in the Mbere Division, the Caesalpiniaceae are the most frequently cited, as are the Poaceae and the Asteraceae. Likewise, this variation in indicator importance with regards to ecological zones is also noticeable with plant species. For instance, *Terminalia macroptera*, *Andropogon gayanus*, *Chromolaena odorata*, *Daniellia oliveri*, *Imperata cylindrica* and *Leucaena leucocephala* were the most commonly used as soil fertility indicator by the farmers of overall sudano-guinea savannahs of Adamawa Cameroon. On the other hand, in the Sudan savannahs of Northern Cameroon, it is mostly *Acacia albida*, *Vitellaria paradoxa*, *Rottboellia cochinchinensis*, *Adropogon tectorum*, *Adropogon gayanus*, that are mostly cited as fertile soil indicators (Pabame, 2002; M'Biandoun et al., 2003). Blanchard (2010) showed, in her study in Dentiola village of Mali, that *Vitellaria paradoxa*, *Parkia biglobosa, Acacia albida*, *Adansonia digitata*, *tamarindus indica* are cited as indicators of soil fertility. Similarly, a single species may indicate soil fertility or infertility depending on the ecological zone. In fact, *Imperata cylindrica* is an indicator plant species of a fertile soil in the Vina Division, which is located in the Sudan part of the Adamawa savannah, drier, less dense in vegetation and inhabitants (21.2 inhabitants.km^{-2}). While this same species indicated the infertile soil in the Mayo-Banyo Division which is located in the guinea part of the Adamawa savannahs, which is more humid and denser in vegetation and inhabitants (25.2 inhabitants.km^{-2}). These results can be explained by the different climatic conditions and the availability of cultivated land, as reported by M'Biandoun et al. (2003) in their study on indicators of soil fertility in northern Cameroon. In fact, *Commelina bengalensis* is considered by the farmers of the Mafa Kilda zone as a fertile soil indicator, whereas the same species is considered by the farmers of the Fignole zone as an indicator of degraded soil. In Fignole, the climate is rainier than Mafa kilda. Biodiversity is more important, soils are still very rich and especially croplands are available, which allows long fallow and a very demanding choice of better plots of cultivation. On the other hand, in Mafa kilda, space is saturated and farmers can no longer be as demanding in the choice of lands of cultivation. So a soil that is considered fertile to Mafa kilda would be put in lying fallows in Fignole because it is already relatively poorness, and the farmers prefer to

start a new clearing, since space is available. Our findings showed that biological indicator constitutes more the farmers' indicators than soil quality (58.00% versus 42.00%) as shown by Quansah et al. (2001) in the Ghanian savannahs. According to their findings, the vegetation constitutes more the farmers' indicators than soil quality (64.00% versus 24.00% of responses), while in the humid forest zone, it is instead the soil quality that is currently used as soil fertility indicator (91.00 versus 1.00%). The bio-geographical context and density of the vegetation cover explained this difference (Quansah et al., 2001; M'Biandoun et al., 2003).

In short, the abundance and diversity of the indicators cited illustrate the fact that farmers in the Sudano-guinea savannahs of Adamawa Cameroon, as other parts of Africa (Swai et al., 2015; Bazebih et al., 2016; Berazneva et al., 2016), because of their long experience in agricultural systems, have indicators that they use to assess their immediate environment. They have an established perception and empirical knowledge of soil fertility indicators. Moreover, it is because of their mastery of these indicators that these farmers saw with great anxiety the deterioration of their lands and their landscape. It is also for this same reason that Soumana (2000) thinks that the farmer should be recognized as a meticulous observer of his environment. His holistic vision of soil fertility and soil itself has given rise to a system of perception of farmers with its plant, animal and physical components, all intimately intertwined. The use of these indicators is crucial in particular for these farmers deprived of any other means. By determining the interrelationships between the phyto-faunal complex and their influence on soil fertility, the farmer of Adamawa shows evidence that he can establish a close link between soil, plants and animals. From these indicators, he can also empirically determine the type of crop to be grown. For example, a soil richly covered with *Isoberlinia doka*, associated with the presence of earthworms, is for the farmer, a soil that favors the cultivation of millet and other cereals. Virtually all the farmers interviewed agreed that soil covered by *Terminalia macroptera* is convenient for yam cultivation. The roots of this plant species, according to some farmers, seem to have a positive effect on soil fertility. For cassava, a slightly dark and gravelly soil would be more indicated and in particular to the late or traditional variety called gatarane in Dii language. Maize and groundnut in general can fit in a vegetal cover of diee.

4.3. Soil tiredness, death and fertility management

With the exception of the two Divisions, Faro-et-Deo and Mayo-Banyo, in the savannahs of Adamawa Cameroon, farmers did not mention the death of farmland, unlike those in Mali and Ghana, is the major complaint of the farmers (Soumana, 2000, Quansah et al., 2001). Rather, most farmers in the Adamawa savannahs of Cameroon report soil tiredness, which is characterized by a steady decline in yields, a lack of abundant vegetation cover, and the appearance of particular types of weeds such as *Striga hermontica*, a change in the soil color, an increase in work effort and silting. The plant species indicating the soil tiredness replaced the plants indicating the fertile soil. These findings did not seem to differ from those found in the literature. The notion of soil tiredness is not limited to the African farmer (Soumana, 2000), and even more so to those of the savannah of Adamawa Cameroon. The expression appeared in France in the 1980s, in speaks of farmers who spoke about heterogeneous phenomena that are certainly different from those that affect the soil in Adamawa savannahs of Cameroon. However, soil tiredness reflects only the different degrees of land use. The decline in soil fertility is perceived by most farmers in the Adamawa savannahs as a

major constraint on agricultural production. There are various ways in which soil fertility is maintained or improved. The main ones include first the input of agricultural inputs, then the practice of fallow, and finally the crop rotations in the entire savannahs of Adamawa Cameroon. However, the trend is not the same in the entire Divisions of Adamawa region. For example, more than half of the farmers in the Djerem and Mbere Divisions practiced fallow land as a major means for soil fertility management, compared with 19.17% and 44.31% of farmers using agricultural inputs respectively for the same Divisions. For these Divisions, the majority of the populations surveyed are the Gbaya. As in other parts of Africa, fallow is the most common traditional agricultural practice in Cameroon (Anonymous, 1994, 1999; Kanmegne, 2004). At present, with population growth, the fallow period is limited to between 2 and 4 years, as found in the Donfack (1998) and Pabame (2002) studies in the northern Cameroon. Since the practice of short fallow periods can no longer lead to the reconstitution of soil fertility, improved fallow trials are under consideration, with the introduction of trees (Hermand, 1997) or leguminous plants such as *Sesbania sesban* (Mapongmetsem and Ibrahima, 1999) in the fields. Planted fallows have the role of accumulating high biomass and regenerating soil properties in a shorter time than natural fallows. These systems are not yet widespread in the savannahs of Adamawa Cameroon. Some farmers after clearing leave some plant species like *Terminalia macroptera* grow in the fields.

Although they are well aware of the potential of natural fertilizers in the restoration of soil fertility, farmers in the Adamawa savannahs gave several reasons to justify the low use of this type of fertilizer. The use of animal manure is the likely cause of the growth of many herbs in the fields. As for their use, insufficiency (or low availability) and difficulty of collection is a probable cause of low interest shown by some farmers in the Adamawa savannahs of Cameroon. These findings have also been reported by Quansah et al. (2001) and Dawoe et al. (2012) for Ghanaian farmers and Boutrais (1998) for the Dourou farmers of Adamawa region of Cameroon. According to these authors, the number of cattle was small enough to supply enough manure for large fields. Passarges (1984) justified this small number of cattle (traditional breeding) among the Dourou of Adamawa region by the presence of the tsetse fly. Livestock is limited to poultry. A study in the Niamey region revealed that farmers attach more importance to small ruminant droppings than to cattle. This is because the nitrogen and phosphorus content is higher in the latter (Williams et al., 1995). These high rates are probably the cause of the plant burns (dieback) caused by this type of manure, mentioned by the farmers of Adamawa region of Cameroon.

Household waste and sewage are generally used in home gardens (small farms) because they are not available in large quantities and their spread is more difficult. Animal manure would be very useful, because according to Boutrais (1998), if properly used, it can handle two contradictory phenomena: maintaining soil fertility and reducing weeds that stifle crops. According to Landais et al. (1991), animal husbandry is a good alternative to the restoration of soil fertility through long fallow periods in large systems, as animals can reclaim crop residues *in situ* after harvest by allowing the rapid transformation of the latter into fertilizing elements.

More than half (56.61%) of the farmers in Adamawa region of Cameroon or 86.90% of those in the Mayo-Banyo Division, used chemical fertilizers in their fields for some crops such as maize. The high percentage of this fertilization in the region is justified by its immediate availability, particularly since the cotton company

(Sodecoton), which supplies farmers with chemical inputs in the form of credit to pay back after the harvest. These inputs are provided for the sole purpose of treating the cotton plant and fertilizing the cotton fields. Unfortunately, farmers use them abnormally on other crops. This would lead to environmental degradation by soil pollution and decline in soil organisms. Fortunately, the drastic decline in the purchasing power of farmers caused by the failure of modern farming systems, the use of chemical fertilizers has declined significantly over the past decade. In addition, the traditional cropping system is enhanced by the presence of local driving forces such as PADI, Mutual-help-groups, cotton-producing groups and the Women for Christ group which helps farmers to abandon the use of chemical fertilizers by collecting and distributing animal manure and household waste.

Traditional knowledge of farmers for the composting of household waste and various residues, for the decomposition of crop residues or for the collection of waste is very low. But in densely populated areas and intensive agriculture, composting and recycling of household waste is beginning to be developed (Ceccolini, 2002).

5. Conclusions

Farmers have a fairly good knowledge of the concept of soil fertility according to their own indigenous system, depending on the experience and transmission of knowledge from generations to generations. They used biological and physical indicators that are empirical and allow them to assess soil fertility. Similarly, they also used various strategies to maintain or improve the soil fertility of their farmlands in order to increase agricultural production. Many of these are well integrated into local conditions and can lead to the conservation and regeneration of natural resources of soil. However, all these empirical indicators and strategies are not effective. Therefore, modifications, adaptations or introduction of new technics are needed (Altieri, 2002). Such changes should take into account the rationality and knowledge of farmers.

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