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Perceptions and Characterization of Local Knowledge on Soil Fertility Management by Maize Farmers in Central Benin

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Abstract

The problem of soil fertility leads farmers, according to their perception, to practice local and or introduced methods to manage the productivity of their farm. This study aimed to document local knowledge on soil fertility management by maize farmers in central Benin. A semi-structured survey was used to collect information from 1248 maize farmers in six communes in central Benin. The data were analyzed using descriptive statistics and multivariate analysis. Results showed that farmers consider declining soil fertility as one of the major constraints to maize production. About 45% of the farmers surveyed linked declining soil fertility to unsuitable fertilization practices. Maize farmers' soil fertility management methods are mainly based on synthetic chemical fertilizers such as urea (46%), NPK (15-15-15), NPKSB (14-23-14-5-1) and NPKSBZn (13-17-17-0.5-2.5) and Triple Superphosphate (45% P_2O_5). The application rates differed according to the type of fertilizer. Socio-demographic characteristics such as area planted, age, experience in maize production, membership in a farmer's organization, level of education, gender and income level of the farmer significantly determine the type of soil fertility management method practiced. These factors should be taken into account by extension programs.

Keywords: Fertilizer, maize farming, agroecology, soil fertility

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1- Introduction

Food and nutrition security is a major concern in Africa and a fundamental challenge to human well-being and economic growth (Bationo et al., 2007). Low agricultural production results in low incomes, poor nutrition, vulnerability to risks and lack of self-reliance. This is the result of a combination of factors including declining soil fertility due to poor agricultural practices and climate change (Houndété *et al.*, 2020). Indeed, strategic crops for food security such as maize are the most impacted (Akplo, 2020).

In Benin, the strong anthropization of natural environments, overexploitation of land and unsustainable agricultural practices have contributed to profound changes in agricultural production. These changes have led to accentuated soil degradation (Azontondé *et al*., 2016). The level of degradation varies across agro-ecological zones but is more pronounced in the South and North where agro-demographic pressure on land is high to meet the needs of growing populations. Farming systems in Benin are based on family farms (Houinsou, 2013) and are characterized by a reduction in the length of fallow periods without other measures to restore nutrients used by previous crops (Saïdou *et al*., 2018). The soil is exploited without any input of organic and or mineral fertilizers (Houinsou, 2013). Saïdou *et al*. (2003) revealed negative balances of 28 and 11 $kg.ha^{-1}$ for nitrogen and potassium, respectively, on the plateaus of southern Benin.

Farmers' understanding of these constraints varies from one individual to another, but also from one environment to another (Doumde *et al*., 2003). The study conducted by Gnangle *et al.* (2011) on climate change indicates a variation in local perceptions depending on the socio-cultural categories of the farmers. However, farmers are putting in place different coping systems to deal with these problems (Vodounou and Doubogan, 2016). These include, for example, the agroforestry system, minimum tillage, crop association, the practice of mulching, the use of plants that improve soil fertility, and the use of organic matter such as compost, manure, and crop residues (Igué *et al*., 2013). The study conducted by Agossou *et al.* (2012) revealed that the measures adopted by producers in southern and central Benin in the face of constraints are the change of the cropping calendar and technical itineraries, a modification of associations/rotations, the introduction of new crops and varieties, the intensification of the use of mineral fertilizers, etc. These practices developed by the latter are the result of their experiences and realities.

Endogenous knowledge is not abstract like scientific knowledge, it is concrete, strongly linked to intuition, historical experiences and directly perceivable and evident (Farrington and Martin, 1987). The perception of maize farmers with respect to declining soil fertility and the capitalization of

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farmer' practices in the face of these constraints become necessary. This study focused on maize farmers' perception of declining soil fertility and on capitalizing on farmers' knowledge of soil fertility management practices used in central Benin.

2- Methodology

2- 1- Survey methodology

To better appreciate the perception of maize farmers on the decline in soil fertility, an exploratory survey was conducted to determine the sample size. This exploratory survey was conducted in the Collines and Zou departments (Figure 1). The choice of these departments is justified by the fact that the level of land degradation in these areas is around 60 to 70% (Azontondé *et al*., 2016). In the Collines department, the survey was conducted in the Communes of Savalou, Glazoué, Bantè, and Ouessè, while in Zou, this exploratory survey was conducted in the Communes of Djidja and Zogbodomey.

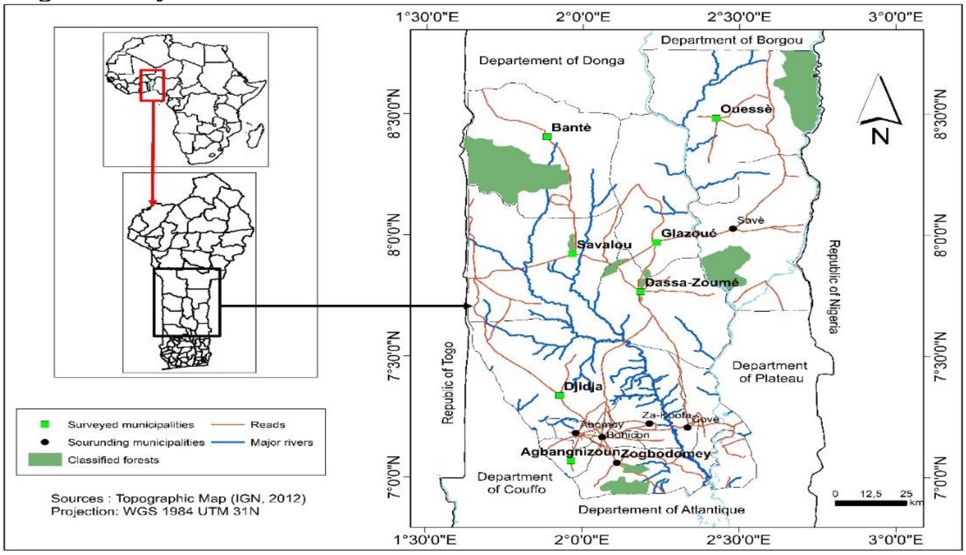

Figure 1. Location of surveyed communes in the different Agroecological Zones (AEZ)

In each commune, 40 maize farmers were interviewed using a semi-structured questionnaire. The number of farmers surveyed was determined by the formula of Dagnelie (1998):

$$\boldsymbol{n} = \frac{U_{1-\alpha/2}^{2} \times P(1-P)}{d^{2}}$$

Where n is the size of the sample considered, P is the proportion of people who mentioned the decline in soil fertility as a constraint to maize

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production (P= 0.94), U1-α/2 is the 95% confidence level (typical value of 1.96); d is the 5% margin of error (typical value of 0.05)

At the end of the exploratory survey, the determination of the sample size made it possible to survey a total of 1248 farmers, i.e., 127, 236, 193, 218, 231 and 243 farmers in the Communes of Bantè, Djidja, Glazoué, Ouessè, Savalou and Zogbodomey, respectively. These farmers were selected randomly throughout each of the Communes.

Based on the questionnaire and focus group, data were collected from a representative sample of farmers and resource people (extension agents and NGOs). In addition to socioeconomic characteristics, the questionnaire collected data on maize production constraints in the study area and soil fertility management methods used by maize farmers.

2-2- Data analysis

In order to assess the relationship between farmers' perceptions of the causes of soil fertility decline and their socioeconomic characteristics, the collected data were subjected to a Chi-square test of dependence. The relationship between the socioeconomic characteristics of the respondents and the different soil fertility management methods was analyzed through a Factorial Component Analysis (FCA). The FCA was performed with the FactoMineR package of R software version 4.2.1.

3- Results

3-1- Characteristics of the respondents

Descriptive statistics on the socio-economic characteristics of the selected farmers are presented in Table 1. It was found that the sample is predominantly male (89.8%) and married (99.41%). The most represented age group is the adult class (30-60 years). The majority of respondents were selected from the Collines department. The number of years of experience of respondents in maize cultivation varied from 1 to 30 years, and those who were very experienced (> 10 years of experience) were the most represented. Only 6% of respondents do not belong to any farmer organization. In terms of educational level, a large proportion of farmers do not have access to formal schooling. Most of the farmers surveyed have a low level of income.

Table 1. Characteristics of respondents

Characteristics	Modalities	N	Frequency (%)
Sex	Male	1696	89.80
	Female	193	10.20
Matrimonial status	Single	11	1,00
	Maried	1880	99,00
Age	Young (<30 years)	151	8.00
	Adult (30-60 years)	1648	87.20

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	Old (> 60 years)	90	4.80
Departments	COLLINES	1164	61.60
	ZOU	725	38.40
Experience in maize cultivation	Very experienced (> 10 years)	1303	69.00
	Experienced (5-10 years)	372	19.70
	Little experienced (2-5 years)	190	10.10
	Very inexperienced (1-2 years)	24	1.30
Membership in OP	Yes	1776	94.00
	No	113	6.00
Level of education	Uninstructed	1588	84.10
	Primary	165	8.70
	Secondary	60	3.20
	University	76	4.00
Income level	High	130	7
	Medium	525	28
	Low	1234	65

3-2- Constraints in maize production

Maize producers face several problems during production. The decline in soil fertility remains one of the major problems recorded in all the Communes surveyed (Figure 2). More than 96% of producers mentioned this constraint in all the Communes surveyed.

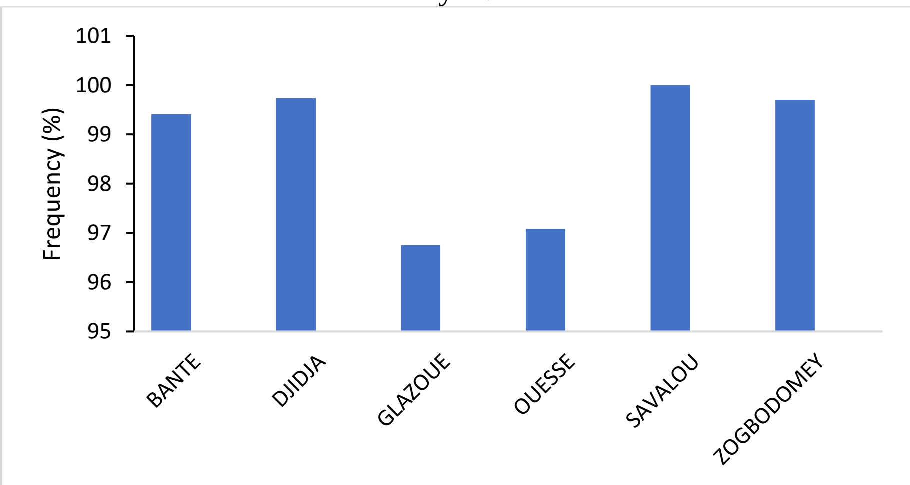

Figure 2. Producers facing declining soil fertility by Commune surveyed

Soil fertility management methods

3-3- Farmers' perception of the causes of the decline in soil fertility.

The causes of the decline in soil fertility are assessed in different ways by the farmers (Figure 3). In fact, 45% of respondents linked the decline in soil fertility to poor fertilization practices. Monoculture, export of residues, or

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burning of residues in agricultural plots had citation frequencies above 10%. Causes such as poor tillage practices and water erosion were cited less frequently than others.

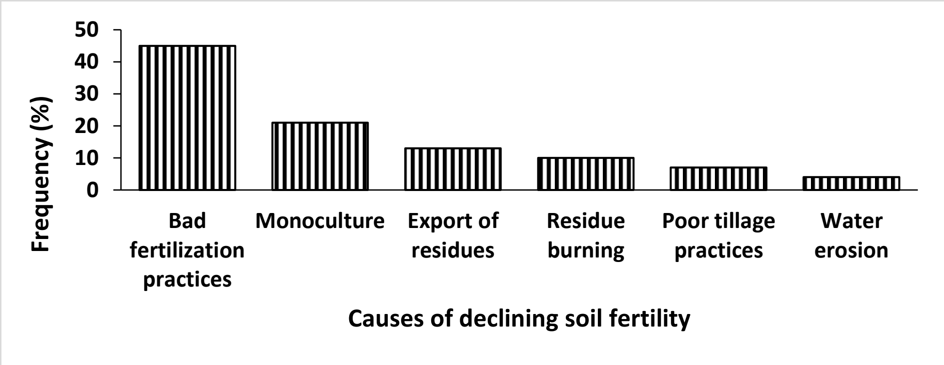

Figure 3. Cultivation practices causing the decline in soil fertility

Farmers' perceptions of the causes of declining soil fertility vary significantly according to the socio-demographic characteristics of the respondents (Table 2). Age, experience in maize production, membership in a farmer organization and level of education significantly determine farmers' perceptions.

Table 2. Determinants of maize farmers' perceptions of declining soil fertility

Determinants	Chi-square	Probability (α=0.05)
Gender of respondents	3,543	0,234ns
Marital status	2,345	0,453ns
Age of respondents	8,546	0,0064*
Experience in maize cultivation	18,545	<0,0001***
Membership in a farmer organization	42,456	<0,0001***
Level of education	22,456	<0,0001***
Income level	2,236	0,345ns

*ns: no significant; *: Significant at 5% level (α = 5%); ***: Significant at 0.1% level (α = 0.1%)*

3-4- Practices used for soil fertility management by maize farmers

A total of ten (10) soil fertility management practices were cited by the maize producers surveyed (Figure 4). The use of simple or complete chemical fertilizers was the most cited practice and was adopted by almost all the respondents. Crop rotation or association with leguminous seeds such as cowpea (*Vigna unguiculata*), soybean (*Glycine max*) or groundnut (*Arachis hypogea*) are used quite a bit for soil fertility management in maize production in the study area. The use of organic fertilizers (biochar, compost and manure), the practice of fallowing, rotation with leguminous cover crops (Mucuna, Aschynomene), the burial of crop residues and the use of biofertilizers are uncommon practices in maize production in the study area.

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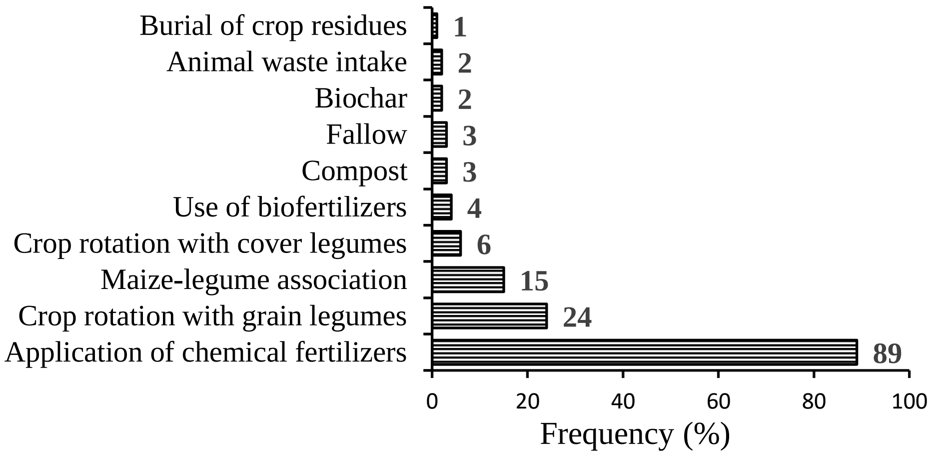

Figure 4. Soil fertility management practices used by maize farmers

The fertilizers used by maize farmers are summarized in Table 3. The fertilizers used can be grouped into two categories: synthetic chemical fertilizers and biofertilizers. Chemical fertilizers are represented by urea (46% N), Triple Superphosphate (45% P_2O_5), Katrium chloride (60% K_2O), and NPK complete fertilizers. Synthetic chemical fertilizers, particularly urea, are used by almost all respondents. The doses, timing and method of application differ from one fertilizer to another. Application rates vary from 50 to 100 kg/ha for urea and Katrium chloride, and from 100 to 200 kg/ha for NPK (15-15-15), NPKSB (14-23-14-5-1) and NPKSBZn (13-17-17-0.5-2.5). The reported application rates for Triple Superphosphate (45% P2O5) range from 50 to 200 kg/ha. With the exception of urea, which is applied in split doses (15th and 45th day after sowing), the other synthetic chemical fertilizers are applied in single doses between 15 and 30 days after sowing in closed stacks. The biofertilizer is represented by the liquid fertilizer "Super Gro" which is applied by foliar application at the dose of 10 l/ha (half at 15 days after sowing and the second half at 45 days after sowing).

Table 3. Types, doses, periods and modes of application of fertilizers for maize production in the study area

Fertilizers	**Frequency (%)**	**Application rates (kg.ha^{-1})**	**Application periods (DAS*)**	**Application methods**
Urea (46%N)	95	50 à 100	15 & 45	Closed poquet
Superphosphate Triple (45% P_2O_5)	70	50 à 200	15-30	Closed poquet
NPK (15-15-15)	60	100 à 200	15-30	Closed poquet
Katrium chloride (60% K_2O)	40	50 à 100	15-30	Closed poquet

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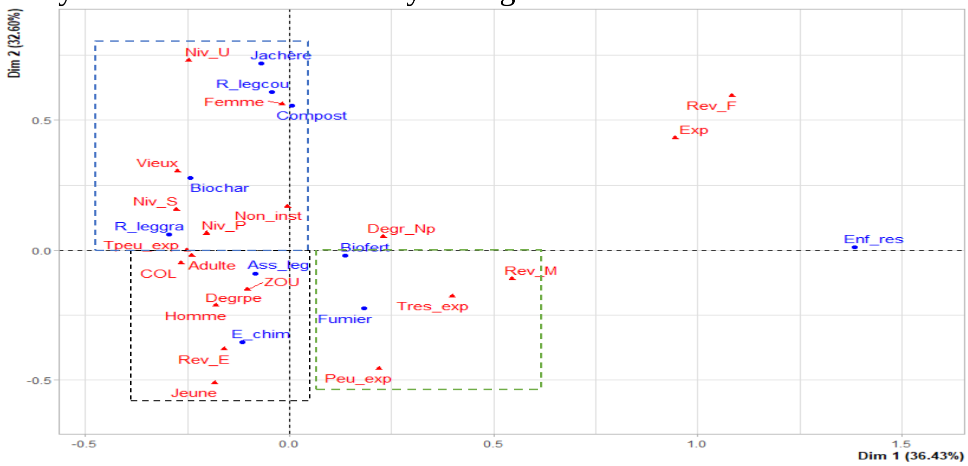
NPKSB (14-23-14-5-1)	32	100 à 200	15-30	Closed poquet
NPKSBZn (13-17-17-0,5-2,5)	20	100 à 200	15-30	Closed poquet
Super Gro (liquid biofertilizer)	12	10 l/ha	15 & 45	Foliar application

**DAS : Days After Sowing*

Figure 5 illustrates the component factor analysis performed to understand the relationship between the characteristics of the farmers surveyed and soil fertility management practices. The first two axes capture 69.03% of the information in the original matrix. Older farmers; farmers with secondary, primary or no education and farmers with very little experience in maize production preferentially use biochar and maize rotation with seed legumes. Farmers with a university education and women preferentially adopt compost, fallow, and rotation with cover legumes. Adults and youth, men, farmers with high income levels, and those who already perceive declining soil fertility use the combination of maize with seed legumes and synthetic chemical fertilizers. Farmers with a medium income level, those with little experience, and those with a lot of experience prefer to use biofertilizers and farmyard manure for soil fertility management.



Non_inst : not educated Niv_P : primary level ; Niv_Sec : secondary level Niv_U : university level ; Niv_S : higher level R_legcou : rotation with cover legumes ; R_leggra : rotation with seed legumes ; Ass_leg : association with legumes ; E_chim : chemical fertilizers ; Biofert : biofertilizers; Enf_res: residue burial; Rev_E: high income; Rev_M: medium income; Rev_F: low income; Tpeu_exp: very little experienced; Tres_exp: very experienced; Peu_exp: little experienced; Exp experienced; Degrpe: perceived soil degradation; Zou: Department of Zou COL: Department of the Hills. Biochar: by-product of biomass pyrolysis

Figure 5. Projection of soil fertility management practices and socio-demographic characteristics on the factorial components

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4- Discussion

The results showed that maize farmers consider declining soil fertility as one of the major constraints to maize production and use a variety of soil fertility management approaches. These include the use of synthetic chemical fertilizers, the use of biofertilizers, maize-cover legume or seed legume rotation, maize-cover legume or seed legume combination. Although some of these practices are environmentally friendly, the majority of farmers surveyed use chemical fertilizers. These results confirm those of Kouelo (2016) who observed that farmers rely heavily on chemical fertilizers such as NPK and urea to control declining soil fertility in southern Benin. This abandonment of sustainable soil fertility maintenance practices is certainly due to increasing food demand (Mukendi *et al*., 2017). Traditional crop rotation systems have evolved into a monoculture system where maize is grown all year or several years on the same plots. According to Abebe (1998) cited by Bahilu *et al*., (2016), other challenges of soil fertility decline in Ethiopia are related to cultural cropping practices such as traditional cultivation, removal of vegetative cover (such as straw or stubble), burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands. This change in production system is certainly one of the main causes of the advanced state of land degradation in Sub-Saharan Africa (Bationo *et al*., 2006) and in Benin (Azontondé *et al*., 2016).

The results of the present study showed that some socio-economic characteristics such as the area planted, age, experience in maize production, membership in a farmer organization, level of education and income level of the farmer significantly influence the type of soil fertility management method. Significant relationships which existed between some selected socio-economic characteristics and farmers' perception point to the fact that, the main solution to the problem of soil fertility decline lies in the behaviour of the farmer who is subject to economic and social pressures of immediate environment (Adeola, 2010). The positive influence of age was demonstrated by Mango *et al*. (2017) and Fikru (2009). However, Ngondjeb *et al*. (2011) found that household age is negatively correlated with the adoption of new technologies in agriculture. Our results demonstrate that literacy and education are key pillars that increase farmers' predisposition to accept and adopt agricultural technologies such as soil fertility management methods. Such conclusions were made by Brett (2004). Furthermore, the preferential adoption of soil regeneration by the literate and those with advanced education is indicative of the fact that these practices require an appreciation of the technology that access to education has enabled them to have. We found a significant positive correlation between membership in a farmer organization and adoption of at least one soil fertility management method. This observation justifies the fact that within farmers' organizations, farmers

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exchange their own experiences with each other and are well informed about different technological innovations (Nyangena & Juma, 2014). Membership of social organization had positive relationship with farmers' perception suggesting that membership of such groups could enable members to be exposed to information on soil management practices. Similar findings have been reported. Kouelo *et al*., 2015 reported that membership of a farmer organization is a significant determining factor of the causes of soil fertility in the southern villages of Benin. Access to extension contact which had positive relationship with farmers' perception, also indicate the importance of extension to rural farmers (Mwakubo *et al*., 2006 cited by Adeola, 2012).

Conclusion

The objective of this study was to inventory local knowledge on soil fertility management by maize farmers in central Benin. The results showed that maize farmers consider the decline in soil fertility as one of the major constraints to maize production. They mostly use synthetic chemical fertilizers to manage their soil fertility to the detriment of organic or biological methods that are sustainable. Also, it was found that socio-economic characteristics can influence the choice of a soil fertility management method. Therefore, the results of this research suggest that: (a) extension of agricultural technologies including fertility management methods should take these factors into account and (b) policy makers should encourage technical supervision, literacy and training of farmers.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All of the data are included in the content of the paper.

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