Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities

Edited by

Andre Bationo
Tropical Soil Biology and Fertility (TSBF) Institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Nairobi, Kenya

Boaz Waswa
Tropical Soil Biology and Fertility (TSBF) Institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Nairobi, Kenya

Job Kihara
Tropical Soil Biology and Fertility (TSBF) Institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Nairobi, Kenya

Joseph Kimetu
Tropical Soil Biology and Fertility (TSBF) Institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Nairobi, Kenya

Springer

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN-13 978-1-4020-5759-5 (HB)
ISBN-13 978-1-4020-5760-1 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.
www.springer.com

Printed on acid-free paper

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Modeling farmers' decisions on integrated soil nutrient management in sub-Saharan Africa: A multinomial Logit analysis in Cameroon

Guy Blaise Nkamleu
International Institute of Tropical Agriculture, B.P. 2008, Messa-Yaoundé, Cameroon; Fax: (237) 2 237437, E-mail: g.b.nkamleu@cgiar.org

Abstract

Much of the technical work on integrated soil nutrient management in sub-Saharan Africa has not considered the determinants of farmers' adoption decisions. It is important that technical research on these integrated soil nutrient management options be guided by consideration of the factors that determine farmers' decisions to combine organic and inorganic nutrients. Economists investigating consumer demand have accumulated considerable evidence showing that the observed decision choice on an agricultural technology is the end result of a complex set of inter-technology preference comparisons made by farmers.

This study analyzes the factors that affect farmers' decisions to adopt different soil nutrient management practices in Cameroon. The technologies evaluated are inorganic fertilizers, organic fertilizers, and combine use of organic and inorganic fertilizers. A Multinomial Logit model was used to capture choice probabilities across these soil nutrient management categories. Data from a random survey of 217 peri-urban farmers are used in the investigation. The results show that the factors affecting farmers' choices across the soil nutrient management categories are different and should be taken into consideration in efforts to promote integrated soil nutrient management practices within agroecosystems in rural areas of Cameroon. The study ends by raising a number of implications for strategies to promote integrated soil nutrient management among peri-urban gardening and fruit tree farmers in Cameroon

Key words: Cameroon; inorganic fertilizers; Multinomial Logit; nutrient management; organic fertilizers; Soil fertility

Introduction

The major challenge facing agriculture in many parts of sub-Saharan Africa is how to increase farm production to meet changing food needs without degrading the natural resource base. A factor that limits sustainable productivity increases is the inherent low fertility of the soils. The fertility status of the soils in the region is manifested by high soil acidity, aluminum toxicity, low nutrient reserves, nutrient imbalances and multiple nutrient deficiencies of low activity classes such as *Ultisols* and *Oxisols* (Nair 1993; SMSS 1986), and high levels of susceptibility to erosion, crusting and acidification of the *Alfisols* (Sanchez 1976). Rapidly shortening fallow -a result of high demographic pressure- threatens the ecological sustainability of slash-and-burn agricultural systems (Kleinman et al. 1995; Smaling et al. 1993).

Although the use of chemical fertilizers can help improve the fertility of these soils, the amounts used by farmers are extremely low, averaging less than 10 kg of fertilizer nutrients per hectare in sub-Saharan Africa (Pretty 1995). Even with the supplementary use of chemical fertilizers, crop yields have been found to decline under continuous cultivation due to declining of organic matter levels under continuous cultivation (Kang et al. 1995; FAO 1985; Moormann and Greenland 1980). In several parts of sub-Saharan

A. Bationo (eds.), Advances in Integrated Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities, 887–899.

Africa, the food production strategy preferred by governments has been the widespread promotion of inorganic fertilizers. Coupled with the use of high levels of fertilizer subsidies and subsidized interest rates on smallholder agricultural credit, several countries experienced positive growth rates in food production in the 1980's. In some countries like Malawi and Zimbabwe, the use of hybrid maize and fertilizers became widespread. But with the implementation of structural adjustment programs, currencies were devalued and markets for inputs were liberalized, increasing the prices of chemical inputs substantially, often rising to several times the grain prices. The rising fertilizer-grain price ratio led to a substantial decline in the use of inorganic fertilizers, and the collapse of the so called "green revolution" in Malawi (Carr 1997) and in other parts of sub-Saharan Africa. It is now widely recognized that for sustainable food production, efforts must now be directed towards other sources of soil nutrients. Given the potential adverse effects of chemical fertilizer on the environment, strategies for soil nutrient management on tropical soils have increasingly focussed on integrated soil nutrient management technologies (FAO 1991, cited in Conway 1997). This involves the combined use of both organic and inorganic soil nutrient sources, including biological nitrogen fixation, crop rotations, cereal legume intercrops, improved fallows, composting, green manuring, animal manure, and chemical fertilizers (Waddington et al. 1998; Conway 1997; ICRAF 1996; Nair 1993). Such strategies rely on the use of nutrients that are both external and internal to the farm agroecosystems, with particular emphasis on better nutrient cycling and lowering the costs of soil nutrient management.

Farmers already use animal manure, green manure, composts and chemical fertilizers, often in an integrated manner, for the maintenance of soil fertility. But socio-economic ex-post adoption studies of integrated soil fertility practices of farmers in West and Central Africa are few (Matlon 1994; Kabore 1988; Prudencio 1983). A larger number of studies have examined the use of chemical fertilizers with the objective of better targeting chemical fertilizer-based interventions in farming systems (Adesina 1996; Posner and Crawford 1992; Hailu 1990; Daramola 1989; Kelly 1988; Falusi 1975). Although more limited, studies of farmers' use of organic nutrient sources, especially animal manure, have also been conducted in areas where there exist important crop livestock interactions (Coulibaly 1995; Siridie and Giraudy 1994; Matlon 1994; Williams et al. 1993; Adesina 1992; Prudencio 1983). Many authors have argued that there is need to consider complementary use of organic and inorganic nutrients in strategies for soil fertility improvement (Conway 1997; Matlon and Adesina 1997; Sanders et al. 1996; Matlon 1994; Adesina 1992; Bationo and Mokwunye 1991).

Current efforts to promote the use of integrated soil nutrient management among farmers in East and Southern Africa have shown that there are some scope for reducing the use of inorganic fertilizers by optimal combination of organic and inorganic inputs (Waddington et al. 1998). However, much of the technical work on integrated soil nutrient management in sub-Saharan Africa has not considered the determinants of farmers' adoption decisions. It is important that technical research on these integrated soil nutrient management options be guided by consideration of the factors that determine farmers' decisions to combine organic and inorganic nutrients. This paper seeks to help fill this gap.

Several studies that examined the determinants of farmers' decisions to adopt soil fertility management technologies have focussed on one technology (Adesina 1996; Daramola 1989; Falusi 1975). In studies where more than one technology was considered (Matlon 1994; Hailu 1990; Kabore 1988; Prudencio 1983), the analytical methods used did not permit the integrated analysis of decision probabilities across different soil nutrient management categories. Because farmers' decisions on organic and inorganic soil nutrient management strategies may be interdependent – as they both require the use of cash and/or labor, both of which are limiting, smallholder farm models used to examine farmers' adoption decisions should consider adoption decisions across input categories in an integrated manner. It has been maintained out that to achieve sustainable production increases without depleting soil nutrient resources, it will be increasingly important to consider integration of these nutrients, with particular attention to the agronomic, ecological and socio-economic factors in decision making (Conway 1997).

The objective of the paper is to assess the factors that affect farmers' choices between organic, inorganic sources of nutrients, and integrated soil nutrient management in Cameroon. A multinomial Logit model (Cramer1991; Maddala 1983) is used to capture decision choices across these alternative strategies. The paper is divided into five sections. Section two discusses the survey methods and analytical model. Section three presents the empirical model specification, while section four discusses the results. The paper ends in section five with conclusions and recommendations for improving farmers' use of integrated soil nutrient management within their agroecosystems.

Materials and methods

Survey

To examine farmers' use of different soil nutrient management strategies, a survey was conducted in two peri-urban areas of Cameroon from August to December of 1995. The survey covered a total of 217 farmers randomly selected in the zones of Yaounde (82 farmers) and Bafoussam (135 farmers). The two zones are different in terms of agroecological factors, farming systems, degree of urbanization and population density. Yaounde is situated at 730 m altitude, in the forest margin. Rainfall is high and varies between 1,500 mm to 2,000 mm per year. The major crops consist of industrial cash crops (primarily cocoa), and food crops like cassava, maize, cocoyams and groundnuts. Fruit trees are important in the home gardens (Tchatat 1996), while the development of horticultural crops is intensive in peri-urban areas. The group of farms surveyed here is representative of home gardens and peri-urban horticulture farms. Bafoussam is located in the western highlands, with an altitude of 1,500 m. Soils are ferralitic, and cropping systems are highly diverse, with the major crops being maize, beans, and cassava. Farmers also cultivate coffee in plantations. Livestock, mainly small ruminants (pigs, goats and sheep), are important in this zone.

Although reliable national statistics are unavailable, the use of composts by farmers is believed to be increasing in these peri-urban areas in Cameroon. Commercialized composts are made from recycled urban wastes and sold to farmers in peri-urban areas in small packages, as well as in 25 kg and 50 kg bags. In addition, farmers use decomposed plant material, kitchen refuse, and household wastes. These are often left in heaps around the household and left to decompose. The decomposed material is then applied to fields differentially, depending on the type of field (home garden or food crop field), cropping history and distance of the fields to the homestead. Farmers also burn vegetation and apply ash. They also perform direct application of animal refuse, crop residues and household waste. Almost all farmers make direct applications of refuse and residues. In this study, the analysis excludes those cases and organic fertilizer is referred here to composts (bought or self manufactured).

A first rapid Rural Appraisal (RRA) was used to assess the utilization patterns of the lands in the two above-mentioned peri-urban zones. This was followed by a detailed household survey to identify relevant agroecological factors (cropping systems, land, water and soil fertility management strategies etc.), and socioeconomic characteristics of farmers.

A list of farmers established from the RRA allowed the opportunity of selecting households randomly, with known probability of selection.

Analytical model

Few studies have been made of how farmers make soil fertility decisions in SSA. Orasanu and Connolly (1993) claim that most research on decision-making has focused on the decision event, not the process. According to Ohlmer et al. (1998), current knowledge of the decision making process can be described as a set of eight functions or elements: values and goals, problem detection, problem definition, observation, analysis, development of intention, implementation, and responsibility bearing.

More recently, using psychological concepts, Nuthall (2001) argued that understanding decision capability requires more than a study of the decision processes used (e.g. as reported by Ohlmer et al. (1998). The study of learning and thinking processes (cognitive psychology) is relevant and related to managerial ability. That is, it must be clear how humans observe information, how information is stored and retrieved, how it is processed and so on. These processes are assumed to be inherent/implicit in the decisions made by farmers in modeling decision making.

Economists investigating consumer demand have accumulated considerable evidence showing that the observed decision choice on an agricultural technology is the end result of a complex set of inter-technology preference comparisons made by farmers (Ohlmer et al. 1998). Despite all the development in decision theories by anthropologists, sociologists, philosopher, farmers still largely rely on perception and intuition to make a decision (Nuthall 2001; Ohlmer et al. 1998).

Variables which affect farmers' access to information, and hence their perception (e.g. extension, education, media exposure, individual characteristics, etc.), are typically used in economic models of the determinants of adoptions (Polson and Spencer 1991; Kebede et al. 1990). Several empirical studies have tried to capture the influence of socioeconomic variables on farmers' adoption decisions. In most cases, the use of Probit or Logit model is applied (Nkamleu 1999; Adesina 1996; Hailu 1990; Kebede et al. 1990; Rahm and Huffman 1984). In these models, farmers are assumed to make adoption decisions based upon an objective of utility maximization.

A multinomial Logit model (Nkamleu andCoulibaly 2000; Cramer 1991; Madalla 1983) is applied in this analysis. The advantage of multinomial Logit is that it permits the analysis of the adoption decisions across the various soil fertility management alternatives – allowing the determination of choice probabilities for different categories of soil nutrient management practices. This approach is more appropriate than Probit or Logit models which have been conventionally used in studies of farmer's adoption of soil fertility management practices (Hailu 1990; Daramola 1989), when there exist multiple soil nutrient management strategies. No study in West and Central Africa has applied the multinomial logit to analysis of farmers' soil nutrient management decisions.

Instead of having two dichotomous (0, 1) alternatives as in the multi variate Logit or Probit models, the Multinomial Logit has S possible states or categories that is s = 1, 2, 3 . . . , S., – which are disjunct and exhaustive (Cramer 1990).

In the analysis of the adoption of soil nutrient management systems in this study we consider four categories, namely, 1) farmer uses no organic or inorganic fertilizers, 2) farmer uses only chemical fertilizers, 3) farmer uses only organic fertilizers (defined as composted material made from decomposed plant material, kitchen refuse, and household waste), and, 4) farmer uses both organic and inorganic fertilizers (referred to henceforth in the paper as "integrated soil nutrient management").

Because the multinomial Logit model does not treat these nutrient management categories in any continuous order, it is different from ordered Logit or Probit models (Ameniya 1981).

Let there be a random sample of farmers, I = 1, 2, 3 . . . , N. Given four alternatives soil fertility management strategies, s = 1, 2, 3, 4, the multinomial logit model of soil nutrient management assigns probabilities P_{is} to events characterized as " i^{th} farmer in s^{th} category" . Let the vector of characteristics of the farmers be denoted by x_i. Following Cramer (1991), define Y^i as a vector of S categories in which there is a single nonzero element, and another vector I_s having zeros everywhere but 1 at the s^{th} location. The event that the I^{th} farmer is found in the s^{th} nutrient management category or state can then be given as $Y_i = I_s$, with the probability $P_{is} = P_r\ (Y_i = I_s)$, for s = 1, 2, 3, 4. The multinomial probability model of soil nutrient management is then represented as $P_{is} = P_s\ (x_i, \Theta)$, where Θ are unknown parameters to be estimated. To estimate this model there is need to normalize on one soil nutrient category, which is then referred to as the soil nutrient "reference state". In this analysis we take the first category, i.e., farmers that do not use any fertilizers whether organic or inorganic as the "reference state". The multinomial probability model for soil nutrient management decisions across *S* states (s =1, 2, 3, 4) can then be specified as:

$$P_s = (X_i, \Theta) = \exp(X_i^T \beta_s)/(1 + \Sigma_t \exp(x_i^T \beta_t)) \quad \text{(1a)}$$
$$\text{for s not equal to 1}$$

$$P_1 = (X_i, \Theta) = 1/(1 + \Sigma_t \exp(x_i^T \beta_t) \quad \text{(1b)}$$

Models (1a) and (1b) are used for the estimation of the multinomial soil nutrient management model. The Multinomial Logit model of investment in soil nutrient management technologies was estimated using LIMDEP© (Green 1992).

Empirical model

An empirical specification is employed to investigate the relationship between socio-economic characteristics and the use of inorganic and organic fertilizers. Descriptions of variables included in the empirical model are given in Table 1. The discussion and justification for the independent variables included in the model are provided below.

EXP measures the number of years of farming experience of the farmer. With experience it is expected that farmers will be able to better assess the differential benefits of organic and inorganic inputs, and to apply optimal (financially) levels of inputs across their fields. It is hypothesized that EXP is positively related to the utilization of organic and inorganic fertilizers, and the use of both in a combined fashion.

GROUP measures whether or not the farmer belongs to a farmer's cooperatives. Since farmers in local organizations are more likely to be in contact with research, development and extension agencies, they are more likely to adopt innovations. Studies in Cameroon have shown that farmers belonging to farmers' organizations had significantly higher likelihood of adopting alley farming (Adesina et al. 2000). It is hypothesized that GROUP is positively related to adoption of inorganic, organic, and integrated soil nutrient management.

AREA measures the cultivated area by the farmer in square meter. The effects of farm size on the use of new innovations is generally related to economies of scale effects or lower acquisition costs by large farmers due to preferential access to inputs and credit (Polson and Spencer 1990; Norris and Batie 1987). However, for organic and inorganic fertilizers, economies of scale effects are not likely to occur. Due to high costs of chemical fertilizers following the devaluation of the currency and the removal of input subsidies, acquisition costs have risen substantially. Besides, farmers with large farms may also have sufficient land to put some under fallow as a method of soil fertility maintenance. It is hypothesized that AREA is negatively related to the use of organic and inorganic fertilizers, and integrated soil nutrient management.

EXT measures the frequency of contacts by the farmer with extension agents. Contact with extension improves farmers' technology understanding, perception of profit potential (Nkamleu 1999). Because the application of organic inputs, and especially integrated nutrient management is more knowledge based, than the use of inorganic fertilizers, farmers in contact with extension agents may be better able to manufacture and apply appropriate quantities of composts, and organic and inorganic fertilizers. It is hypothesized that EXT is positively related to the adoption of inorganic, organic fertilizers, and integrated soil nutrient management.

EDUC measures the level of education of the farmer. The effect of education on farm productivity and efficiency has been intensely debated (Shultz 1975). Studies in developed agriculture have shown that education improves allocative efficiency of farmers and farm productivity. Huffman (1974) found that educated farmers were better able to adjust to disequilibria created by the introduction of nitrogen fertilizers for hybrid corn in Iowa, by adjusting nitrogen application levels to shifts in relative factor prices. Studies in developing countries with smallholder agriculture have found that farmer education significantly affects productive efficiency among smallholder farmers (Rahm and Singh 1988). Given that integrated soil nutrient management technologies are knowledge-based, it is expected that education will enhance the probability of adoption of such technologies. A recent study by Nkamleu and Adesina (2000) showed that the level of education positively affects the acceptance of chemical fertilizer in peri-urban lowland systems of Cameroon. It is hypothesized that EDUC is positively related to the adoption of inorganic, organic fertilizers, and integrated soil nutrient management relative to the reference state.

LVSTOCK indicates if the farmer keeps livestock. Farmers with livestock may be better able to take advantage of animal manure for soil fertility management on their fields (William et al.1993). Because farmers using livestock manure are less likely to buy chemical fertilizers, a negative relationship is hypothesized with the adoption of inorganic fertilizers. Farmers with access to livestock manure are also less likely to buy composts since both inputs are substitutes.

FMSIZE measures households' family size. Family labor is the most important source of labor supply for farm households. While labor is hired for activities such as field clearing, application of organic and inorganic inputs rely exclusively on family labor inputs. Due to the high labor demands for applying organic and inorganic fertilizers, the larger the family size the higher the labor available for application of these inputs. It is hypothesized that FMSIZE is positively related to the adoption of organic and inorganic fertilizers, and of integrated soil nutrient management practices .

SEX indexes the gender of the farmer (0 = female, 1 = male). In an analysis of the adoption of chemical fertilizers by rice farmers in Cote d'Ivoire, Adesina (1996) found that women's rice fields were less likely to receive chemical fertilizers than men's fields – reflecting the effects of capital constraints faced by women. In Burkina Faso, Matlon (1994) found that men generally had greater likelihood of adopting animal manure and inorganic fertilizers on their fields than women. However, in Cameroon, the majority of the food crop fields are managed by women. Also, because women are in charge of the collection of household refuse for use as composts, it is expected that the probability of their use of organic composts will be higher than those of men. It is therefore hypothesized that SEX is positively related to decision choices for organic fertilizers, but negatively related to decisions for inorganic fertilizers.

ASSET is the capitalized value of agricultural mechanic equipments and is an index of capital assets available to the farmer. Given that there is a positive correlation between capital assets and wealth, farmers with higher asset values are more likely to have financial resources for investments in soil fertility management technologies. It is hypothesized that ASSET is positively related to the adoption of

Table 1. Descriptive Statistics for Variables in Empirical model

Variable	Description	Mean	Standard deviation
EXPE	Years of farming experience.	13.544	11.47
GROUP	Whether or not the farmer belongs to a farmers' cooperative. 0 = No 1 = Yes.	0.54839	0.4988
AREA	Farm size (square meter).	16371	1.18E+05
EXT	Frequency of contacts with extension. 0 = have no contact, 1 = not frequent contacts, 2 = frequent contacts.	0.75115	0.7346
EDUC	Farmers' level of education proxy 0 = no formal education. 1 = primary school, 2 = secondary school, 3 = post secondary.	1.1889	0.79131
LVSTOCK	Indexes if the farmer keeps livestock: 0 = No 1 = Yes.	0.51152	0.50102
FMSIZE	Family size.	9.9032	9.9212
SEX	Gender of the farmer 0 = female, 1 = male.	0.76037	0.42785
ASSET	value of agricultural equipments (FCFA)	30344	67354
DIST	distance of field from the homestead (m)	6834.6	54661
CASHCRP	Cultivation of cash crops 0 = No 1 = Yes	0.5023	0.50115
REGION	Dummy variable for area. 0 = Yaoundé area, 1 = Bafoussam area.	0.62212	0.48598

organic and inorganic fertilizers, and integrated soil nutrient management.

DIST is the sum distance of the farmers' fields from the homestead. Due to the highly bulky nature of composts, transportation costs for use on distant fields will be very high. Farmers are thus more likely to apply them on fields closer to the homestead. Also, distant fields may lie longer in fallow and consequently have a better soil fertility index. It is hypothesized that DIST is negatively related to choice decisions on organic and inorganic fertilizers. Since farmers may not have sufficient amounts of either inorganic or organic nutrients for exclusive use on distant fields, it is more likely that farmers will pursue a strategy of mixing these inputs for distant fields. Thus, it is hypothesized that DIST is positively related to use of integrated soil nutrient management.

CASHCRP is a dummy variable, which indexes if the farmer cultivates a cash crop. Given higher returns to cash crop cultivation, farmers are likely to invest in soil nutrient management technologies for these crops. It is hypothesized that CASHCRP is positively related to farmers' choice of the three soil nutrient management technologies relative to the reference state.

REGION is a dummy variable which takes the value of 1 for farmers in Bafoussam area and 0, for Yaounde area. Very high population pressure and evident problems of soil nutrient depletion in Bafoussam have increased the sensitivity of farmers to investment in soil nutrient management. Commercialized composts made from urban wastes are extensively used by farmers in the region. The Yaounde zone is in a forest zone, where relatively low population density does not yet pose major problems for soil fertility. It is hypothesized that the probability of adoption of organic and inorganic fertilizers, and integrated soil fertility management practices will be higher in the Bafoussam area than in Yaounde. A positive sign is hypothesized for REGION.

The descriptive statistics on the variables included in the empirical models are given in Table 1.

Results and discussion

Table 2 shows the distribution of farmers by their methods of soil nutrient management. Four categories were identified. First, 30% of the farmers did not use either organic or inorganic fertilizers. Second, 30% of the sample farmers used only inorganic fertilizers. Third, 26% relied on the use of organic soil nutrients alone. Fourth, 14% relied on integrated use of both organic and inorganic nutrients. The extent of use of soil nutrient management practices is higher in Bafoussam than Yaounde. This may be due to the very high population pressure in Bafoussam and rapid shortening of fallows

Table 2. Soil Fertility Management Categories for Sample Farmers by Region, Cameroon

	Bafoussam	Yaoundé	Total
Farmer uses neither inorganic or organic fertilizers	18 (13.3%)	47 (57.3%)	65 (30%)
Farmer uses only inorganic fertilizers.	53 (39.3%)	12 (14.6%)	65 (30%)
Farmer uses only organic fertilizers	36 (26.7%)	20 (24.4%)	56 (25.8%)
Farmer integrates the use of organic and inorganic fertilizers	28 (20.7%)	3 (3.7%)	31 (14.3%)
Total	82 (100%)	135 (100%)	217 (100%)

which have increased incentives for farmers' investment in better soil fertility management practices. In Yaounde, the existence of forest cover and sufficient amount of land for fallowing may explain the lower use of soil nutrient management technologies.

The model results are presented in Table 3. Percentages of correct prediction for each fertility management categories are gave in Table 4. As a whole, ten of the twelve variables included in the model had significant effects in explaining farmers' choices on the three soil nutrient management technologies relative to the reference state. GROUP has a positive effect on the adoption of the technologies, and was significant at 1% in influencing choice decisions on organic fertilizers. Grassroots farmers' organizations are making many efforts to convince farmers to experiment in alternatives to chemical inputs. AREA was significant and negatively related to adoption of inorganic fertilizers, organic fertilizers and integrated use of organic and inorganic fertilizers, at 1%, 1%, and 10%, respectively. For inorganic fertilizers it is likely that the relatively high costs of input use given the high quantities needed to fertilize large fields lowers the likelihood of use as farm size increases. The results suggest that smaller sized farms are more likely to adopt all soil fertility improvement strategies.

Contact with extension (EXT) is positively and significantly related to farmers' adoption of organic fertilizers, at 1% level, and integrated soil nutrient management, at 5% level. No significant effect was found for decision choice on inorganic fertilizers alone. The lack of significant effect on inorganic fertilizer use suggests that inorganic fertilizers are probably no longer viewed as "new" soil fertility management technologies by farmers. However, use of organic fertilizers (manufactured composts), and integrated soil nutrient management are relatively new to many farmers.

Farmer education (EDUC) had a positive effect on the adoption of organic fertilizers and integrated soil nutrient management, at 5% and 10%, respectively. Integrated soil nutrient management requires greater management skills than those required for the application of inorganic fertilizers alone or organic fertilizers alone, since it require combination of two inputs in correct proportions. These results suggest that increased farmer education improves likelihood of use of integrated soil nutrient management practices. The positive effect on the adoption of organic fertilizers suggest that educated farmers are better able to comprehend the benefits of biodegradable organic sources of nutrient management on their farms. EDUC has no significant effect on the adoption of inorganic fertilizers alone. These results suggest that farmer training could have a positive impact on adoption of organic fertilizers.

The possession of livestock (LVSTOCK) has a negative effect, significant at 1%, on the utilization of organic inputs for soil fertility management. Purchased composts made from urban wastes and internally manufactured composts from household wastes (includes animal refuse) are substitutes for animal manure. Farmers using animal manure are less likely to adopt composts. It seems that farmers preferred to use manure directly than making compost with.

Family size (FMSIZE) has a positive and significant effect on the adoption of all three types of soil nutrient management practices. This result strongly suggests that the higher the availability of labor for application of these soil nutrient management practices, the greater the likelihood of adoption.

Sex (SEX) has a positive but non-significant effect on adoption of inorganic fertilizers and integrated soil nutrient management. However, SEX has a significant and negative effect on the use of organic

Table 3. Multinomial Logit Model of Investment in Soil Nutrient Management Practices, Cameroon

Variables	Coefficient		
	Inorganic fertilizers	Organic fertilizers	Integrated Soil Nutrient Management
Constant	−1.7969	−.8558	−8.1109
	(−1.944)**	(−1.914)**	−4.993)***
EXPE	2.94E-02	−6.25E-03	1.67E-02
	(0.93)	(−0.166)	(0.467)
GROUP	0.66088	1.6031	0.732
	(1.22)	(2.57)***	(1.098)
AREA	−5.09E-05	−1.86E-04	−2.90E-05
	(−2.637)***	(−3.188)***	(−1.663)*
EXT	0.31292	1.3923	0.98962
	(0.76)	(3.137)***	(2.186)**
EDUC	−0.28422	0.99565	0.80214
	(−0.662)	(2.045)**	(1.624)*
LVSTOCK	−0.51411	−2.4671	−0.87241
	(−0.818)	(−3.286)***	(−1.16)
FMSIZE	0.12185	0.11112	0.1057
	(1.953)**	(1.64)*	(1.644)*
SEX	0.31702	−1.5015	1.4414
	(0.424)	(−2.114)**	(0.992)
ASSET	1.19E-05	1.70E-05	1.38E-05
	(1.783)*	(2.329)***	(1.875)*
DIST	−5.05E-05	−1.77E-04	6.82E-05
	(−1.17)	(−1.781)*	(1.817)*
CASHCRP	0.81218	4.12E-02	0.95916
	(1.362)	(0.061)	(1.384)
REGION	0.45664	1.9449	3.9432
	(0.562)	(2.367)***	(3.326)***

$X^2(54) = 212.107$ ***.
Percentage of correct predictions of farmers by soil nutrient management categories = 65%
Sample = 217.
Values in parentheses are corresponding t-values. *** =Significant at 0.01; **= significant at 0.05; * = significant at 0.10.

Table 4. Percentages of prediction for each fertility management categories

Actual	Predicted				
	None	Organic Fertilizer	Inorganic Fertilizer	Integrated	Total
None	72.3%	10.8%	12.3%	4.6%	65
Organic Fertilizer	12.3%	70.8%	12.3%	4.6%	65
Inorganic Fertilizer	14.3%	5.4%	71.4%	8.9%	56
Integrated	9.7%	48.4%	12.9%	29%	31
Total	66	71	60	20	217

Percentages are given by the ratio of number predicted over actual number. For the option None for example, % of correct prediction is 72.3% (47/65). The row total should be equal to 1.

nutrients alone, suggesting that the probability of using organic nutrients alone is higher for women than men. This result contrasts with those obtained in Burkina Faso by Matlon (1994) for animal manure use between men and women, as well as Adesina (1996) finding in Cote d'Ivoire for inorganic fertilizer use by farmers. In these studies the authors found that women had lower likelihood of use of these inputs than men. In many parts of Sahelian West Africa, men have control over the use of animal manure on their fields since animal traction equipments belong to men. Compost is made mainly from household waste, the management of which is controlled by women. This explains the higher likelihood of use of composts by women.

Farm assets (ASSET) positively and significantly influence the adoption of all of the three soil nutrient management practices. Thus, the higher the capital availability within farm households the greater is the likelihood of farmers using all the three soil nutrient management practices.

Field distance (DIST) is negatively related to the use of inorganic fertilizers and organic fertilizers, but positively related to the use of integrated soil nutrient management practice. The coefficients are significant at 10% for organic nutrients and integrated soil nutrient management. This result corroborates the findings of Adesina (1996) on inorganic fertilizer use in Cote d'Ivoire, and Prudencio (1983) on animal manure use in Burkina Faso. The distant fields are less intensively cultivated and may thus have natural fertility. Moreover, such fields are also generally larger, the possibility of using only inorganic or organic manure alone is likely to be lower, since farmers may not have sufficient amounts of either inorganic or organic nutrients for exclusive use on those fields. Farmers are more likely to pursue an integrated soil nutrient management practice on such fields, combining organic and inorganic nutrients. This particular finding will need further investigation to better understand farmers' behavior on distant fields.

Cultivation of cash crops (CASHCRP) positively affects farmers' choice of the three soil nutrient management technologies, but the effect is not significant. Region (REGION) is positively related to adoption of all three soil nutrient management practices, and is significant at 1% level, respectively, for use of organic nutrients and integrated soil nutrient management. These results indicate the probability of farmers' adoption of soil nutrient management practices are higher in the more densely populated areas than in areas with low population densities. Globally, the econometric model estimated has a good predictive power as shown in Table 4.

The estimated coefficients in the multinomial logit model were used to calculate the predicted probabilities of farmers' adoption across the three soil nutrient management technologies. In the first scenario, three factors were considered: gender, level of education, and intensity of contact with extension agents. Results (Table 5) show that the probability of adoption of organic fertilizers were higher for women than men, regardless of the level of education and contacts with extension. However, the probability of adoption of integrated soil nutrient management is higher for men than women, and increased with the level of education and contacts with extension. In the second scenario, predictions of decision probabilities across the three soil nutrient management categories were developed using three factors: zone, distance of the fields to the village or homestead, and cultivated area. Results (Table 6) show that while the probability of use of inorganic fertilizers declines with increasing distance of the fields from the homestead, the probability of use of integrated soil nutrient management increased with distance from the homestead. Second, the probability of use of the three soil nutrient management technologies declined with increasing farm size. Third, estimated probabilities of use of inorganic fertilizer is higher in Yaounde than in Bafoussam, but the probabilities of use of organic nutrients and integrated soil nutrient management technologies are higher in Bafoussam.

Conclusions

This paper determined, using a multinomial Logit model, factors that affect farmers' decision choices across different categories of soil nutrient management technologies in Cameroon. The results showed that factors affecting farmers' adoption of inorganic fertilizers, organic fertilizers and integrated soil nutrient management are not necessarily the same, and generalizations should be avoided. The results have a number of implications for strategies to promote integrated soil nutrient management among farmers in Cameroon.

First, soil fertility management technologies, especially integrated soil nutrient management systems, should be targeted more to the higher density areas. The

Table 5. Multinominal Logit Model's predicted probabilities of farmers' soil fertility management choices by gender, level of education and intensity of contact with extension

	No contact with extension						
	Women				**Men**		
	Inorganic fertilizer	organic fertilizer	Integrated soil nutrient management		Inorganic fertilizer	organic fertilizer	integrated soil nutrient management
Education				**Education**			
0	0,430	0,013	0,016	0	0,490	0,002	0,055
1	0,350	0,037	0,037	1	0,390	0,007	0,130
2	0,260	0,100	0.081	2	0,270	0,017	0,270
3	0,160	0,220	0,150	3	0,160	0,036	0,460
	Not Frequent Contact						
	Women				**Men**		
	Inorganic fertilizer	organic fertilizer	Integrated soil nutrient management		Inorganic fertilizer	organic fertilizer	integrated soil nutrient management
Education				**Education**			
0	0,480	0,042	0,034	0	0,530	0,007	0,120
1	0,370	0,120	0,077	1	0,390	0,020	0,250
2	0,230	0,260	0,140	2	0,230	0,043	0,450
3	0,110	0,450	0,200	3	0,110	0,074	0,640
	Frequent Contact						
	Women				**Men**		
	Inorganic fertilizer	organic fertilizer	Integrated soil nutrient management		Inorganic fertilizer	organic fertilizer	integrated soil nutrient management
Education				**Education**			
0	0,480	0,130	0,068	0	0,510	0,021	0,220
1	0,310	0,290	0,128	1	0,330	0,049	0,420
2	0,150	0,500	0,180	2	0,160	0,088	0,610
3	0,055	0,660	0,200	3	0,065	0,130	0,730

rising population pressure on arable land creates incentives for farmers' adoption of soil nutrient management technologies.

Second, integrated soil nutrient management should be targeted to smallholder farms. The very high quantities of compost that would be needed for effective use on large farms may be non-economical; labor costs for transport and application over large fields may also be very high. Small farms can also better manufacture and use composts from household wastes in order to enhance nutrient cycling in their agroecosystems.

Third, results showed that the likelihood of use of organic nutrients and inorganic nutrients is lower for fields far from the homestead. This implies that the use of such techniques is likely be preferred by farmers on their home gardens, or fields close by the house. High levels of soil nutrient cycling have been reported in the home gardens in Cameroon (Tchatat 1996). Such fields are generally small enough for effective use of these inputs. Also, the proximity of these fields to the homesteads lowers farmers' transport costs for collecting and applying home-produced composts from household refuse or kitchen wastes. Distant fields are generally larger, the possibility of using only inorganic or organic manure alone is likely to be lower, efforts are needed to help farmers in integrated soil nutrient management for these fields. These could

Table 6. Multinominal Logit Model's predicted probabilities of decision choices among soil nutrient management practices in Cameroon by region, distance of the fields and cultivated area

			YAOUNDE REGION			
			AREA *(ha)*			
		0.5 hectare			**2 hectare**	
Distance of field (km)	Inorganic fertilizer	organic fertilizer	integrated soil nutrient management	Inorganic fertilizer	Organic fertilizer	integrated soil nutrient management
0	0.519	0.175	0.011	0.436	0.019	0.012
10	0.474	0.045	0.032	0.319	0.004	0.029
25	0.290	0.004	0.115	0.169	0.2E-03	0.093
50	0.063	3.8E-05	0.486	0.037	2.9E-06	0.396
			AREA *(ha)*			
		5 hectare			**10 hectare**	
Distance of field (km)	Inorganic fertilizer	organic fertilizer	integrated soil nutrient management	Inorganic fertilizer	Organic fertilizer	integrated soil nutrient management
0	0.149	0.1E-03	0.008	0.014	1.2E-08	0.002
10	0.095	2.8E-05	0.017	0.008	2.1E-09	0.004
25	0.045	1.5E-06	0.048	0.004	1.5E-10	0.012
50	0.011	1.5E-08	0.220	0.001	1.7E-12	0.064
			BAFOUSSAM REGION			
			AREA *(ha)*			
		0.5 hectare			**2 hectare**	
Distance of field (km)	Inorganic fertilizer	organic fertilizer	integrated soil nutrient management	Inorganic fertilizer	Organic fertilizer	integrated soil nutrient management
0	0.284	0.424	0.189	0.345	0.068	0.318
10	0.238	0.101	0.519	0.186	0.010	0.563
25	0.065	0.004	0.847	0.046	0.001	0.827
50	0.004	1.05E-05	0.979	0.003	9.9E-07	0.970
			AREA *(ha)*			
		5 hectare			**10 hectare**	
Distance of field (km)	Inorganic fertilizer	organic fertilizer	integrated soil nutrient management	Inorganic fertilizer	Organic fertilizer	integrated soil nutrient management
0	0.158	0.001	0.279	0.019	7.8E-08	0.102
10	0.079	7.6E-05	0.457	0.011	1.2E-08	0.185
25	0.021	3.02E-06	0.717	0.004	6.4E-10	0.389
50	0.001	8.6E-09	0.936	0.4E-03	2.8E-12	0.779

include integrated use of organic and inorganic nutrients, improved planted fallows or other agroforestry technologies.

Fourth, farmer education was found to have significant positive effect on the probability of use of organic nutrients and integrated soil nutrient management. The farming population in Cameroon is becoming increasingly dominated by younger farmers due largely to reverse migration from urban to rural areas arising from recent economic crisis (Pokam 1997). The majority of the migrants are young educated workers that were retrenched from public sectors as a result of public sector adjustment programs. These growing populations of educated farmers will be better able to use integrated soil nutrient management techniques. However, there is need to also continue to target these technologies to non-educated farmers. One approach is to rely on farmer- participatory learning approaches, and researchers in Cameroon can learn from experiences elsewhere. Conway (1997) cites the case of the

Manor House Agricultural Centre in Western Kenya where farmers are being trained in the use of sustainable agricultural practices. Farmers' use of composting in the area is increasing rapidly due to this approach. Extension agents can play an important role in this: results from this paper show that farmer contacts with extension agents have strong positive effects on farmers' use of organic nutrients and integrated soil nutrient management.

Finally, efforts to promote integrated soil nutrient management should consider the important role that farmers' organizations can play. Farmers' organizations are effective in creating change within local communities. Results from this paper show that farmers in farmers' organizations have a higher likelihood of using organic fertilizers NGOs' activities on promoting organic farming in Cameroon are largely directed to farmer groups and for good reason: they create economies of scale in the diffusion of information to farmers on the benefits of nutrient cycling in rural communities.

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