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ANALYSIS

Soil fertility management and socio-economic factors in crop-livestock systems in Burkina Faso: a case study of composting technology

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Abstract

The relation between technology adoption and farmers' socio-economic characteristics has increasingly been given attention in developing countries. However, most of the studies conducted by economists dealt with the adoption of external technologies. Here, we test the determinants of compost adoption, an alternative indigenous technology for soil fertility management. The results of analysis of data from Burkina Faso, using Logit model, strongly support the hypothesis that farmers' socio-economic characteristics and their agro-ecological location significantly affect their adoption decisions. There are two main conclusions of this study: first, the agro-ecological location of farmers influence their decision to widely adopt compost technology. Second, among farmers' characteristics affecting compost adoption, three groups can be distinguished. The most important socio-economic characteristics are farmers' age, their comparative perception on the yield effect of compost with regards to other fertilizers and their annual agricultural income. A second group of characteristics include the institutional factors, which are represented by the farmers' participation in extension workshops. A third group of factors comprises the farmer's labor force participating rate, the number of ruminants owned and farmers gender.

Keywords: Compost technology; Adoption model; Farmers' characteristics; Burkina Faso

1. Introduction

Soil degradation is common in developing countries, particularly in the sub-Saharan zone of West Africa (Oucho, 1998). This is mainly due to soil fragility associated with high population pressure and limited arable land for subsistence requirements. In general, these result in rapid

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environmental deterioration and subsequently unsustainable development. The debate on the population-land relationship has been going on for several decades (Allan, 1965). It has focused on African traditional practices in both crop and animal husbandry. These practices are characterized as extensive systems, a low level of external inputs and poor resource base leading to reduction in soil productivity. This progressive decline affects the flow of renewable resources from the soils through the reduction of soil fertility (Pierce, 1990).

In response to this, research centers have developed technology packages to overcome the decline in soil fertility. These technologies have focused on the use of imported inorganic fertilizers to maintain and/or increase crop productivity. Their effects on crop yield have been argued to be profitable (Nagy et al., 1987). In order to promote the adoption of these technologies, governments or rural development projects with the assistance from international donors often subsidize costs (Hilhorst et al., 2000). However, despite these efforts, the adoption levels of soil fertility management technologies are still poor in these ecological and socio-economic settings.

Explanations given for failure of technology transfer include the high cost of chemical fertilizers, ignorance of application techniques and the conservative attitude of farmers (Chambers, 1991). Also implicated in the failure is the top-down approach to technology transfer from scientists through extension agents to farmers. The approach is faulted in its perception of farmers as passive recipients of technologies (Whyte, 1981). Recently, new concepts of research and development have changed this perception. Farmers are now seen as partners in research activities and extension services. Many studies have focused on the necessity for farmers' involvement in technology development and transfer.

Based on this approach, several studies were carried out throughout Africa, including Burkina Faso. In the participatory surveys, socio-economic factors affecting farmers' decisions to adopt soil fertility technologies were evaluated. Chuma et al. (2000) and Campbell et al. (1997) reported that land availability and farmers' wealth were determinants of the choice between different soil fertility management practices in Zimbabwe. In a participatory appraisal carried out in Burkina Faso, Lompo et al. (2000) reported that farmers' resources endowment affects the adoption of composting. Other studies have also linked socio-economic factors with technology adoption (Dufumier, 1994; Baidu-Forson et al., 1997; Norman et al., 1981; Pingali et al., 1987).

Despite the potential importance of socio-economic factors on adoption of soil fertilization technologies, there have been few empirical studies of it in Burkina Faso. An exception is the literature on the link between soil fertility management and food crop production (Prudencio, 1983), but that study did not determine how soil fertility management could be influenced by farmers' socio-economic characteristics. As the fallow period becomes shorter, the land for cultivation is scarce and government's subsidies for chemical fertilizers are no longer possible, the issue of decreasing soil fertility can no longer be solved without considering to farmers' characteristics.

This study addresses the gap in the empirical literature on the adoption of soil fertility technology by testing hypothesized relations using an analysis of technology adoption.

2. Conceptual framework and modeling the adoption of compost technology

The conceptual framework of this study is based on a new approach to consumer theory developed by Lancaster (1966). It is assumed that adoption is an activity in which technologies, singly or in combination, are inputs and in which the output is a collection of characteristics. The neoclassical economic theory assumes that each decision-maker is able to compare two alternatives a and b in the choice set using a preference-indifference operator $\geq$. If $a \geq b$, the decision-maker either prefers a to b, or is indifferent. Utility rankings are therefore assumed to rank collections of technology indirectly through the characteristics that they possess. A given agricultural technology embodies a number of important characteristics that may influence adoption decisions. In addition, given characteristics of technology, other socio-economic and demographic characteristics of the farm household may influence technology adoption. Then the observed adoption choice for an agricultural technology (e.g., compost as fertilizer) is likely to be the result of a complex set of interactions between comparable technologies and farmers' socio-economic and demographic characteristics.

A Logit model was used to model the compost adoption process. Let the perceived benefits derived from using compost and other fertilizer be represented by $b(co)$ and $b(o)$, respectively. Assume that B_i is the discounted benefit from production with and without composting, and I_i is the 'utility index' of adopting compost for individual ith. The index I_i is a function of the socio-economic characteristics of the farmer and the perception that he has on the compost compared with other soil fertility technologies. The farmer's behavior towards compost is described by Eqs. (1)–(3).

$$I_i = X'_i\beta \quad (1)$$

$$B_i \leq 0 \quad \text{if} \quad I_i \in [0, -\infty[\quad (2)$$

$$B_i \succ 0 \quad \text{if} \quad I_i \in]0, +\infty[\quad (3)$$

where X_i is the vector of socio-economic and demographic characteristics of the farmer and his perceptions of compost compared to other fertilizer; β is a vector of parameters to be estimated.

As the value of the explanatory variables X_i change, the value of the index I_i varies over a real number line. The larger the value of I_i, the greater the utility individual i receives from choosing to apply compost, and thus the greater will be P_i, the probability that the individual i adopt the compost as an option for soil fertility management. That is the discounted benefit from production with compost will be greater than zero (Eq. (3)). The observed outcome is that farmer is applying compost. On the other hand, if the utility index which measures the individual's 'propensity' to apply compost lies between zero and minus infinity (Eq. (2)), the discounted benefit from production with compost will be negative or equal to zero, and no compost application will be observed.

The logical function used to model the dependent variable is defined as follows:

$$P_i = F(I_i) = F(X'_i\beta) = \frac{1}{1 + \exp(-X'_i\beta)} \quad (4)$$

The parameters are estimated by maximizing the value of log-likelihood stated as follows:

$$L(\beta) = \sum_{i=1}^{N} \langle I_i \ln[F(X'_i\beta)] + (1 - I_i) \ln[1 - F(X'_i\beta)] \rangle \quad (5)$$

where $F(.)$ represents the cumulative normal density function.

3. Empirical modeling and hypothesis considerations

The estimation of the empirical models is discussed below. All the models are based on Eq. (1) from which the subsequent derivations are made using SHAZAM software (White, 1993). The dependant variable (Y_i) was chosen as binary variable with a value 1 for those farmers who apply compost and 0 otherwise.

Explanatory variables for the village's models are respectively, farmers' subjective assessments of: yield performance (YEFPER) of using compost instead of other fertilizers (1 if positive assessment, 0 otherwise). This variable is the result of large array of the compost's properties, including the impact on soil fertility conservation and water retention among others. In addition to this subjective assessment of the effect of using compost, the following socio-economic and demographic variables were included as explanatory variables in the village's models: the age of the farmer (AGE), the rate of labor force participation in farming (LFPR), the gender (GDR) of the farmer (1 for a man, 0 for a woman), the farmer's participation (PWKSHP) in the extension workshops (1 if yes, 0 otherwise), owning draft animal (OWDRAN) (1 if farmer owns draft animal, 0 otherwise), the number of ruminant livestock (NURUM) owned by the farmer, and the estimated annual agricultural income (AGRINC) that farmer derived from selling crops.

The rate of labor force participation in farming was estimated using the following formula:

$$LFPR_i = \frac{LAF_i}{PFC_i} \times 100;$$

where LAF_i and PFC_i are the numbers of the active labor force working with the farmer i, and the total number of persons that farmer is taking care of, respectively.

For the overall model, a variable reflecting the cropping potential of the agro-ecological zones (CPAEZ) in which the villages are located has been included. Farmers located the Namaguema village were assigned with the value 1 indicating that this area is more favorable to crop production regardless of the agro-climatic conditions. Farmers in Lelly (Sahelian zone) were given the value 0.

We hypothesized that AGE has a negative influence on the decision to adopt compost technology, as older decision-makers are less likely to accept innovation. On the other hand, a larger labor force participation rate (LFPR) is associated with compost adoption, as compost is labor-intensive technology (Pingali et al., 1987). Since male farmers are likely to be more aware of the depletion of soil fertility, the GDR variable is hypothesized to positively influence the decision to adopt compost. Farmers attending extension workshops are expected to upgrade their knowledge on crop and livestock production technology. Hence, PWKSHP is hypothesized to positively influence compost adoption. Farmers with a positive subjective assessment of the impact of compost on crop yield (YEFPER) are likely to adopt compost.

Draft animals and herd livestock are also important inputs for producing compost. Owning draft animals helps to reduce manpower needs to fill and empty the compost pit, while herd animals contribute to improve the production of the compost. Thus, farmers who own draft animals (OWDRAN) and large ruminant herds (NURUM) are able to apply compost on a larger area.

The utilization of compost as fertilizer aims at sustainability increasing crop production and at generating surplus for market. When the production surplus increases, agricultural revenue will also increase, which in turn provides an incentive for farmers to adopt compost use. We therefore hence expected AGRINC to positively influence the decision to adopt compost.

The inter-zonal variable, CPAEZ is expected to increase the probability of adopting compost. Indeed, where the agro-climatic conditions allow efficient use of compost, farmers will be more likely to invest in soil fertility management.

4. Data and study area

The data used to estimate the models were obtained from a survey conducted in Burkina Faso in 2000. The survey covered socio-economic and demographic characteristics of farm households, land and livestock resources, farm income, fertilizer availability and utilization, farmers' perception on the status of their land fertility and on the effect of compost with comparison to other fertilizers, in two villages for 116 households. Based on the previous study conducted by the Departement Productions Animales (DPA, 1997), two samples of farmers were randomly selected in proportion to the number of farmers in each village.

These villages are representatives of two agro-climatic zones and two farming systems. One village (Lelly) is located in the Sahelian zone, with low agro-climatic potentials (Pigeonnière and Jomni, 1998). In that zone, most cropping consists of millet and sorghum (subsistence food grains). The number of observations for this zone is 47 farm households. The other village (Namaneguema) belongs to the Soudanian zone, which, compared to the Sahelian zone, has a much higher agroclimatic potentials. In the latter zone, more crops are grown including millet, sorghum, maize, and groundnut. The number of observations for this zone is 69 farms households. Table 1 shows the characteristics' profile of enumerated farmers.

Table 1
Average farms households' characteristics

Variables	Lelly	Namaneguema	Overall
Compost application (yes = 1)	27	42	69
Women (% of observed adopters)	25.92	7.14	14.49
Farmer's age (years)	46	48	47
	[25–85]	[21–99]	[21–99]
Labor force participating ration (% of active members)	51.43	49.23	50.12
	[25–73.91]	[20–77.78]	[20–77.78]
Number of ruminants (heads)	23	20	21
	[0–100]	[0–79]	[0–100]
Annual agricultural income (× 1000 CFA)	89.888	28.420	53.325
	[0–385]	[0–208]	[0–385]
Gender composition (% of women)	18.84	25.53	21.55
Participating in extension workshop (% of participants)	59.57	46.38	51.72
Owning draft animals (% of owners)	17.02	46.38	34.48
Sample size	47	69	116

5. Results of the Logit model estimation

The results for the compost model in Lelly are given in Table 2. The analyses show that farmers' age (AGE) and gender (GDR) were negatively related to the probability of adoption of compost, at 1 and 5% levels, respectively. On the other hand, three farmers' productive resources were positively significant in explaining adoption decisions: the labor force participating ratio (LFPR), the number of ruminants owned by farmers (NURUM) and the annual agricultural income (AGRINC). The coefficient of the yield effect perception (YEFPER) was also positively related (at 5% level) to the probability of compost adoption. The results indicate that farmers' participation in extension workshops (PWKSHP) was positively significant (at 5% level) in explaining compost adoption decisions. Owning draft animals (OWDRAN), though positively related to adoption decisions, was not significant.

Results for Namaneguema model (Table 3) show that three socio-economic characteristics of farmers were significant in the decision making to adopt compost technology. Farmers' age (AGE) was negatively related to the probability of adop-

Table 2
Estimated Logit model for factors affecting compost adoption in Lelly, Burkina Faso

Variables	Estimated coefficient	S.E.	T-ratio
Intercept	1.0131	2.8294	0.3581
Farmer's age (AGE)	−0.3225	0.1248	−2.5835***
Labor force participating ration (LFPR)	0.1465	0.7029×10^{-1}	2.0841**
Gender (GDR)	−14.544	6.3811	−2.2793**
Workshop participation (PWKSHP)	11.450	5.5308	2.0702**
Own draft animals (OWDRAN)	−0.5806	3.1035	−0.1871
Number of ruminants (NURUM)	0.1607	0.8557×10^{-1}	1.8773*
Comparative yield effect of compost with regards to other fertilizer (YEFPER)	4.7010	2.1368	2.2000**
Annual agricultural income (AGRINC)	0.6158×10^{-1}	0.3046×10^{-1}	2.0219**

*** Significance at 1%.
** Significance at 5%.
* Significance at 10% two-tailed level.
Log-likelihood function, −8.1386; likelihood ration test, 47.8322 with 8 D.F.; Maddala R^2, 0.6386; percentage of right predictions, 0.9362.

Table 3
Estimated Logit model for factors affecting compost adoption in Namaneguema, Burkina Faso

Variables	Estimated coefficients	S.E.	T-ratio
Intercept	−0.9537	2.0329	−0.4691
Farmer's age (AGE)	-0.8202×10^{-1}	0.3053×10^{-1}	−2.6867***
Labor force participating ration (LFPR)	0.1507×10^{-1}	0.3017×10^{-1}	0.4994
Gender (GDR)	3.9901	1.3403	2.9770***
Workshop participation (PWKSHP)	1.1318	0.7352	1.5394
Own draft animals (OWDRAN)	0.7278	1.1219	0.6487
Number of ruminants (NURUM)	-0.4277×10^{-1}	0.3201×10^{-1}	−1.3363
Comparative yield effect of compost with regards to other fertilizer (YEFPER)	1.9818	0.8249	2.4026**
Annual agricultural income (AGRINC)	0.1934×10^{-1}	0.1598×10^{-1}	1.2103

*** Significance at 1%.
** Significance at 5%.
Log-likelihood function, −26.210; likelihood ration test, 39.9468 with 8 D.F.; Maddala R^2, 0.4395; percentage of right predictions, 0.8116.

tion. On the other hand, farmers' gender (GDR) and the yield effect perception (YEFPER) were positively significant at 1 and 5% level, respectively. The labor force participating ratio (LFPR), the farmers' participation in extension workshop (PWKSHP), owing draft animals (OWDRAN), the number of ruminants owned by the farmer (NURUM) and the annual agricultural income (AGRINC), expected to be positively related to adoption decisions, were not significant.

The results of the overall model, taking the agro-ecological location of farmers into account, are summarized in Table 4. The statistical analysis of the parameters estimates shows that three farmers' characteristics have significant effects on the probability of compost adoption. The age of the farmer (AGE) has a negative impact on adoption, with this effect being significant at 1% level. Farmers' participation in an extension workshop (PWKSHP) and the annual agricultural income (AGRINC) were positively related to adoption at 1% and 5% level, respectively. In other respects, farmers' perceptions of yield effect (YEFPER) had a significant positive impact on

Table 4
Estimated Logit model for factors affecting compost adoption in Burkina

Variables	Estimated coefficients	S.E.	T-ratio
Intercept	−0.6496	1.3872	−0.4683
Farmer's age (AGE)	-0.5392×10^{-1}	0.1890×10^{-1}	−2.8529***
Labor force participating ration (LFPR)	0.4070×10^{-1}	0.2010×10^{-1}	0.2025×10^{-1}
Gender (GDR)	0.5038	0.6822	0.7384
Workshop participation (PWKSHP)	1.5836	0.5168	3.0641***
Own draft animals (OWDRAN)	0.5512	0.6608	0.8342
Number of ruminants (NURUM)	-0.8577×10^{-3}	0.1901×10^{-1}	-0.4512×10^{-1}
Comparative yield effect of compost with regards to other fertilizer (YEFPER)	1.2479	0.5804	2.1501**
Annual agricultural income (AGRINC)	0.1709×10^{-1}	0.8347×10^{-2}	2.0470**
Comparative potential between agro-ecological zones (CPAEZ)	1.2864	0.5699	2.2571**

*** Significance at 1%;
** Significance at 5%.
Log-likelihood function, −53.135; likelihood ration test, 50.3416 with 9 D.F.; Maddala R^2, 0.3521. Percentage of right predictions, 0.7845.

adoption. The agro-ecological location of farmer was also significant (at the 5% level).

6. Discussion

The results of this study show some important patterns in the role of farmers' characteristics, the perception they have on the yield effects of compost and the institutional factors affecting adoption behavior. Empirically, the significance and the direction of the effect of these factors on agricultural technologies are not yet well established.

In this study, the age of the farmer (AGE) had a negative impact on adoption, with a significant effect in the three models. Older farmers are less likely than younger ones to adopt compost. The latter are likely to be more knowledgeable about new practices and may be more willing to bear risks due to their longer planning horizons. Nagassa et al. (1997) reported similar findings on fertilizer adoption in Ethiopia, but the impact was not significant. Our results also lend support to the earlier finding of Savadogo et al. (1998) on the adoption of improved land use technologies in Burkina Faso.

Farmers' perceptions of yield effect (YEFPER) and their annual agricultural income (AGRINC) have a strong significant impact on adoption in the three models. The significant impact of the latter emphasize the importance of developing agricultural technologies that can contribute to generating income by increasing crop yield. The yield effect must be clearly perceived by farmers. Hence, yield performance of agricultural technologies needs to be evaluated by farmers under their own soil conditions (Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995).

As compost technology is labor intensive, the size of the household, measured in term of labor force participating ratio (LFPR), should have a positive impact on its adoption. These effects are significant in Lelly, but not in Namaguema and the overall models. The results of Lelly are consistent with those of Savadogo et al. (1998). Kebede et al. (1990) and Nagassa et al. (1997) reported positive but non-significant effects of labor availability on fertilizer adoption in Ethiopia, which are similar to our results for Namaneguema and the overall model. These findings suggest that even if labor is available, the difficulty in committing a household's active member to a particular technology could be an important issue at farm level.

The impact of an institutional factor such as extension on the adoption of compost showed ambiguous results. The effect of participating in extension workshop (PWKSHP) was positive and significant in Lelly and for the overall model, but not significant in Namaneguema. The results of Lelly and the overall model support the findings of Nagassa et al. (1997), while those in Namaguema are consistent findings of Adesina and Baidu-Forson (1995). These results raise the problem of how relevant extension workshops attended by farmers are, with regard to compost technology. In general, agricultural extension workshops in Burkina Faso, deal with packages of agricultural technologies.

The results also suggest that particular attention be given to gender issues in agricultural technology adoption studies. In fact, gender (GDR) has a positive and significant impact on adoption in Namaneguema, and a negative effect in Lelly, but is not significant in the overall model. Only the results of Namaneguema are consistent with the hypothesis regarding the impact of gender on the adoption of composting. In the location, men are likely to be more willing to adopt compost than women. The former are landowners in Burkina Faso rural and can allocate land to whomever and whenever they want. They can also get the land back at any time. Since compost technology has a medium to long-term effect, women might be reluctant to invest in such a technology, if they are not sure of profiting from it.

However, results of Lelly call for caution about the gender effect on the adoption of such technology as compost the application of which relies on several aspects of the production systems, including custom rules of access to land and the available of other income-generating activities for women. When women have 'little' access to land and the usage rights are not very constraining, as it is in Lelly compared to Nameneguema, they would likely be less reluctant to adopt medium to long-term technology, such as composting. In addition, labor allocation in Lelly and Namaneguema is slightly different. In the latter, women are required to contribute intensively to the household farm works before their own, while this is not the case in Lelly. Although the available data do not allow testing the effect of labor allocation on the adoption, this issue seems determinant and requires further investigations.

Lastly, the number of ruminants owned by farmers (NURUM) is an important determinant of compost quantity and quality by incorporating manure into compost. This factor is positively related to the probability of compost adoption in Lelly. This effect occurs as the indirect effect of participating in extension workshops where importance is given to how to optimize livestock and crop by-products utilization. Livestock owners don't entrust their animals to external herders in this region, as do farmers with big herd size in Namaneguema. This type of livestock rearing allows them to collect manure and improve the quality as well as the quantity of the compost.

7. Conclusion

The analyses in this paper showed that farmers' characteristics and agro-ecological conditions are very important determinants of compost adoption behavior. Four sets of points are of note regarding the links between a labor demanding technology such as composting and the probability that farmers adopt it.

First, the negative impact of the farmer's age raises the problem of which category of farmers should be involved in the development of such a technology. To date, resource persons for agricultural technology development are heads of household, who are mostly over 50 years old. The results suggest that younger farmers should be included in the process of compost technology transfer, as they are likely to be prone to innovation. Younger farmers also have to eventually take over the responsibility from their father. Therefore, they would have longer term planning than elders. The opposite effects of the gender in the three models suggest that this variable needs specific attention with regard to the local socio-cultural conditions of land use, the existence of other income alternative sources for women, and labor allocation for crop production. This latter appears to be most important in Namaneguema where women usually contribute a lot to set the household's farm before they are allowed to work on their own. In this case, less time is left with them to prepare the compost and apply it in their farm plot. The effect of the intra-household labor allocation will need to be investigated.

Second, the greater agricultural income of farmers, more likely is the probability of them to adopt compost technology. The increasing effect of compost on crop yield allows farmers to generate crop production surpluses for selling, which in turn increases the agricultural income. Having assessed this impact, farmers are able to evaluate the trade-off between composting and other soil fertility technology. This is the basis of their comparative perception of the effect of compost with regards to other fertilizes.

Third, the ambiguous impact of extension workshop participation adds a crucial empirical dimension to the debate: the literature has traditionally focused on (1) whether farmers are participating or not in extension workshops, and (2) the number of times farmers were visited by the extension service. Further investigation on the impact of extension on technology adoption should consider the content of extension workshops, as this may not be related to the technology being evaluated.

Fourth, irrespective of the farmers' socio-economic characteristics, their agro-ecological location was of great importance in decision-making with respect to adopting of compost. In the less-favorable Sahelian zone, composting is less rewarding than other fertilizers, because of water constraint.

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