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Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger

J. Baidu-Forson*

Senior Research Fellow, United Nations University, Institute for Natural Resources in Africa, Private Mail Bag, Kotoka International Airport, Accra, Ghana

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Abstract

Technical change, through the introduction of land-enhancing conservation technologies, is essential to economic growth in the Sahel. Tobit analysis was used to identify factors that motivate level and intensity of adoption of specific soil and water management technologies. The results show that higher percentage of degraded farmland, extension education, lower risk aversion, and the availability of short-term profits are important for increasing the adoption and intensity of use of improved 'tassa' and half-crescent shaped earthen mounds. Age and attitudes to differential gains between farm and non-farm income showed no influence on adoption. Three main policy implications emerge from these findings. First, technologies should be targeted to locations that have large percentages of degraded farmlands. The probability of adoption and intensity of use are likely to be high at such locations. Second, there is the need to provide extension education that demonstrates risk reduction capacities of conservation techniques. This will make available information capable of stimulating adoption of land-enhancing technologies. Finally, policy-makers should not seek to target innovations to younger farmers because age has no relationship to adoption of the improved 'tassa' and half-crescent shaped earthen mounds. Lessons from the case study have broad relevance to cropped areas in the Sahel.

Keywords: Tobit analysis; Soil and water conservation; Sahel

1. Introduction

In Africa, food output growth per capita has been declining and ca. 500 million hectares of the land resource is experiencing various stages of degradation Sanders et al., 1995, citing Oldeman et al., 1991). Specifically, in the crop farming zones of the Sahel soil degradation maps show that ca. 2.07 million square kilometers are classified as having high degradation of at least 25% (UNEP, 1993). Yet, economic growth and development in the Sahel region of West Africa, extending from Chad to Senegal, is primarily dependent on the growth of agricultural sector which accounts for over 75% of gross domestic product. Increasingly, many crop farmers in the Sahel are incapable of producing enough food to satisfy household consumption. The direct consequences are the occurrence of famines and reduced productivity of labor. Technological transformation of traditional farming practices is urgently needed to cope with increasing food and fiber demands of the population

*Tel.: +233-21-500-396; fax: +233-21-500-792; e-mail: unra@ghana.com

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which is growing at ca. 3% per annum and the increasing degradation of land resources as fallow periods are shortened. This requires the introduction of farming techniques that address short-term food availability concerns of Sahelian crop farmers without compromising the sustainability of crop production. The adoption of land-enhancing technologies is seen as critical to the future development of the Sahelian region (Ramaswamy and Sanders, 1992; Sanders et al., 1995). Much of the technological change is particularly expected in rainfed agriculture (Day et al., 1992) because of limitations to achieving large output gains from irrigation (Biwas, 1986). Also, the potential area where irrigation can be economic and sustainable is limited in the Sahel. However, the application of water–harvesting techniques is capable of providing improvements in crop yields in the Sahel, although they are less widespread (Tabor, 1995).

The specific objective of this paper is to identify socioeconomic, institutional factors, and attitudinal profiles of Sahelian farmers, which influence adoption of land-enhancing techniques needed to achieve technical change in the Sahel. The specific techniques investigated in this paper are improved 'tassa' and half-crescent shaped earthen mounds, which are enriched with nutrient concentrations at planting holes. 'Tassa' refers to a traditional cropping technique of digging of small planting holes to hold pockets of rainwater that can eventually moisten the soil horizon. The next section reviews theoretical models and specifies the theoretical framework used to investigate adoption of the specific land-enhancing technologies studied. Section 3 discusses the empirical model and includes the specific motivation of the paper, a definition of the variables and hypotheses to be tested based on previous studies and theory. Information on the study area and survey methods is presented in Section 4. Results are discussed in Section 5 while Section 6 contains the concluding remarks on lessons learnt and the implications for strategies to promote technical change in the Sahel.

2. Theoretical model

Analytical models widely used to assess adoption of conservation technologies include probit or logit models (e.g. Jamison and Moock, 1984; Rahm and Huffman, 1984). However, Lynne et al. (1988) point out possible loss of information if a binary variable is used as the dependent variable. Instead of specifying adoption as a single dichotomous choice, Lynne et al. (1988) proposed the use of an extension of Tobit estimation method (TPLS III). This accounts for a dependent variable that has zero limit and measurement error peculiarly associated with the choice of a number of practices as a proxy for conservation efforts in the absence of data on expenditures. Feather and Amacher (1994) also employed a two-stage process to allow varying intensity levels of use once the initial decision to adopt this procedure has been made.

Farm households in the Illela region differ in the proportion of cultivated land on which an improved soil and water management technology 't' is adopted. As noted earlier on, non-adoption occurs, even in areas of diffusion of improved technologies. Therefore, there is a cluster of households with zero adoption of the improved technology at the limit. The application of Tobit analysis is preferred in such cases because it uses both, data at the limit as well as those above the limit to estimate regressions (McDonald and Moffit, 1980). The dependent variable specified in this paper (PIMTECH) was derived from field measurements. Therefore, a direct application of Tobit estimation sufficiently provides the needed information on adoption probability and intensity of use of technologies.

Let $U(t)$ represent the perceived utility from adoption of improved technology t while utility from existing traditional farming practice is $U(0)$. Also, let X_i represent the set of socioeconomic, institutional factors and beliefs which influence adoption decisions of the ith farmer. Thus, $U(X_{it})$ and $U(X_{io})$ designate utilities from improved and traditional practices. Following the exposition of McDonald and Moffit (1980), the stochastic model which underlies Tobit is specified as: $t_i = X_i\beta + u_i$, if $X_i + u_i > 0$, positive unobserved latent variable, where $U(X_{it}) > U(X_{iO})$ and adoption of improved soil and water management technology t occurs; $t_i = 0$, if $X_i + u_i \leq 0$, in cases of non-adoption of t, where $U(X_{iO}) > U(X_{it})$;

Here, $i = 1,2,\ldots,N$ denotes the sample size surveyed, t_i the dependent variable, and X_i represents a vector of independent socioeconomic, institutional and attitudinal variables, β a vector of unknown coefficients or parameters to be estimated, and u_i

the independent normally distributed error term assumed to be normal with zero mean and constant variance σ.The relationship between the expected value of all observations, $\boldsymbol{E}_t$ and the expected conditional value above the limit $\boldsymbol{E}_t^*$ is given by:

$$\boldsymbol{E}_t = \boldsymbol{F}(z)\boldsymbol{E}_t^*$$

where $\mathbf{F}(z)$ is the cumulative density normal distribution function and $z = X\beta/\sigma$. Consideration of the effect of the kth variable of X on t led to decomposition as follows:

$$\delta \boldsymbol{E}_t/\delta X_k = \boldsymbol{F}(z)(\delta \boldsymbol{E}_t^*/\delta X_k) + \boldsymbol{E}_t^*(\delta \boldsymbol{F}(z)/\delta X_k).$$

This equation suggests that the total change in elasticity of t can be disaggregated into: (1) a change in probability of the expected level of use of t for farmers who already are adopters; and (2) change in the elasticity of the probability of being an adopter. Since the sample of 114 farmers constitutes a sufficiently large sample, Tobin (1958) and Amemiya (1973) show that consistent estimates of β and σ are obtained by using maximum likelihood techniques, where plim $(b) = \beta$ and plim $(s) = \sigma$. The Tobit model in this paper is estimated using Shazam 7.0.

3. Previous studies, hypotheses and variables studied

Although the economic theory provides limited guidance on variables that can explain resource conservation actions of farmers (Norris and Batie, 1987), it is known that population growth stimulates adoption of intensification technologies (Boserup, 1965; Ruthenberg, 1983). Therefore, as population density increases in the semi-arid zones of West Africa, farmers are expected to intensify crop production (McIntire et al., 1992). The growing literature on resource conservation and adoption behavior provides insights into institutional, socioeconomic and attitudinal variables which can explain adoption and intensity of use of specific technologies by farmers in the Sahel. Attitudes to risk, institutional contacts and farm size have been identified as having significant bearing on conservation decisions of farmers (Nowak and Korsching, 1983). Farmers exhibit reluctance to adopt technologies that expose the farm enterprise to greater risks and must also be convinced that technical change will indeed bring about greater rewards than existing practices (Napier et al., 1991). Several studies have shown the significant effect of extension education on adoption of land-improving technologies (Jamison and Lau, 1982; Feder and Slade, 1984; Jamison and Moock, 1984; Rahm and Huffman, 1984). Attitudes and context factors such as income and the nature of farm terrain were found to affect conservation behavior (Lynne et al., 1988). Although the literature reviewed contains important findings, the paucity of empirical findings on household-level factors likely to influence adoption of land conservation in sub-Saharan Africa, particularly in the Sahel, is evident. The investigation reported in this paper is motivated by the urgent need for empirical studies which identify factors which can contribute to the development of strategies to promote adoption of land improvement and conservation technologies critical to the achievement of technical change.

Findings of the past studies suggest a number of variables (Table 1) that could be investigated to ascertain their importance in promoting the adoption of improved 'tassa' and half-crescent shaped earthen mounds in the Sahel. They include attitude toward investment risk (RISK), extension education (EXTN) and percentage of cultivated land classified locally as degraded (PCAD). It is hypothesized that adoption of these specific technologies will be enhanced by lower risk aversion, dissemination of knowledge and demonstration of the level of gains from the technologies and the potential risk reduction characteristics, and a larger percentage of degraded land. An important characteristic of rainfed farming in the Sahel is the high dependence on household labor to accomplish farm operations. In addition to land, they are the main resources used in crop production. Based on the hypothesis of population-density-driven intensification (Boserup, 1965; Ruthenberg, 1983; McIntire et al., 1992), a variable on land-to-household labor ratio (LLRATIO) is investigated to ascertain the likelihood of such evidence at the household level in the Sahelian environment.

It is generally very difficult to obtain reasonably reliable estimates of income from farm households in the Sahel, due principally to unwillingness of sedentary farmers to divulge all sources and levels of income. Therefore, no informative variable that embodies income effect could be investigated.

Table 1
Description of variables specified

Variable acronym	Variable meaning. Question asked or how obtained?	Type of measure	Type(s) of response (s)
AGE	Age of respondent: Asked for age of farm owner/operator	years	Number of years in age
EXTN	Extension: Ascertained presence or absence of extension services of promoting soil and water conservation techniques under Niger/IFAD project	dummy	1 if project present; 0 if project absent
FWLB	Willingness to quit farming: Would you quit farming for non-farm employment providing same level of income? If no, would you do so at specified levels of excess gains from non-farm employment?	rankings	1, not quit under any circumstance; 2, quit if farm and non-farm income (NFI) are same; 3, quit if NFI is 10% more; 4, quit if NFI is 20%–50% more; 5, quit if 50 < NFI < 100% more; 6, quit if NFI ≥ 100%
MAXP	Maximize profit now: Primary goal is to maximize profits immediately even at the expense of future profits	rankings	1, strong disapproval; 2, disapproval; 3, uncertain; 4, approval; 5, strong approval
RISK	Investment risk: Assessed on basis of choice between alternative chances of recovery of FCFA 100 000 (CR) associated with percentage net profit (PNP)	rankings	1, CR = 33% PNP = 50%; 2, CR = 50% PNP = 33%; 3, CR = 75% PNP = 25%, 4, CR = 95% PNP = 10% (1 denotes least risk aversion)
PIMTEC	Percentage of cultivated land having improved soil and water conservation technology: Conducted field measurements	percent	hectares of: total cultivated area; and area having improved technology
PCAD	Percentage of cultivated land classified locally as degraded: Conducted field measurements	percent	hectares of degraded land cultivated and total land cultivated
LLRATIO	Land-to-labor ratio: Obtained from a ratio of measured cropped area and size of farm household	—	hectares of total land cultivated and adult equivalent (AE) household composition: adult male = 1 AE; adult female = 1 AE.

Based on findings that farmer attitude influences the 'amount of effort' in conservation (Lynne et al., 1988) and justification of the use of beliefs to infer attitudes (Fishbein and Ajzen, 1975), the beliefs of farmers were solicited. In view of erratic rainfall amounts and distribution in the Sahel, uncertainty and risks to monetary investment characterize crop farming. Yet, yield gains from adoption of improved 'tassa' and half-crescent shaped earthen mounds are most high if the technologies benefit from investment in inorganic fertilizer and manure. Since this requires cash outlays, a variable to ascertain the risk attitudes of farmers (RISK) was specified. In risky environment, it is expected that farmers would have a preference for short-time returns. This partly explains the mining of soil resources to unsustainable levels prior to abandonment. A variable (MAXP) was specified to investigate belief/attitude to securing short-term maximization of profits. It is hypothesized that adoption of improved 'tassa' and half-crescent shaped earthen mounds will be higher for farmers whose attitude indicates a preference for short-time returns. This is because the technologies are capable of producing immediate significant increments in crop yields. Migration out of farming (FWLB) to seek non-farm labor wages is an important viable option for the population of dry and degraded zones of the semi-arid tropics. However, on the strength of the attachment of the population to farming, the variable on migration out of farming (FLWB) should not significantly influence adoption of improved 'tassa' and half-crescent shaped earthen mounds as conservation techniques. Table 1 provides detailed descriptions of variables and statements used to solicit beliefs relative to maximization of profit now at the expense of future profits (MAXP), attitude to investment risk (RISK), and willingness to quit farming (FWLB).

Age (AGE) is the only respondent characteristic investigated to ascertain its influence on adoption of soil and water conservation improvements in the Sahel. There is inconsistent evidence on the relationship between age and innovativeness because of the several studies reviewed: half show no relationship, while 19% and 33% support the hypothesis of younger and older people, respectively, favoring adoption of innovations (Rodgers, 1983). Based on this evidence, it is hypothesized that age will have no relationship to adoption of innovations in the Sahel. Other personal factors such as years of experience in farming, size of farm labor, dependence ratio and farm size are typically closely correlated with the age of the farm operator in the Sahel. Therefore, these factors were not used alongside the variable for age. However, the inclusion of land-to-labor ratio variable, LLRATIO, in a sense captures information on some of the personal factors. All the sample farmers claimed ownership of cultivated areas. Therefore, land tenure which exhibits mixed influences on adoption of conservation technology (Lynne et al., 1988) was not a variable of interest. Similarly, since most farmers are illiterate, an informative variable on literacy or schooling effect could not be specified.

A dependent variable, PIMTEC, was specified to denote the percentage of cultivated area on which improved 'tassa' and half-crescent shaped earthen mounds have been adopted.

4. Study area, sample and survey methods

Field research was conducted from January to December of 1996 in the Illela region of Niger. Annual rainfall in the region ranged from 202 mm (recorded in 1973) to 621 mm (recorded in 1974). The average rainfall amount over the 1970–1994 period was 405.7 mm. In addition to the erratic distribution of the meager rain that falls, much of the rainwater is lost to runoff. Soil ceiling or crusting constitutes important constraint to retaining enough water in the soil profile for use by the pearl millet, *Pennisetum glaucum* L. Br, crop. Unavailability of adequate cultivable farmlands for an increased population is manifested in accelerated movement onto marginal lands and degradation of cultivated land as fallow periods are shortened or even eliminated. The severe biophysical and socio-economic conditions prevailing in the Illela region, as in much of the cropped zone of the Sahel, contribute to frequent food deficits in farm households and recourse to periodic seasonal migration to coastal countries to escape famine.

Improvement of water harvesting provides farmers with a capability to sow early. This led to the evolution of the traditional 'tassa' technique. The effectiveness of this traditional water-harvesting practice was enhanced through provision of information and practical demonstrations on the concentration of scarce organic matter in the small planting holes instead of the traditional hand-spreading method. The extension of information on land-enhancing and conserving improvements to farmers was provided by the Niger/International Fund for Agricultural Development (IFAD) project which started in 1989 in the Illela region of Niger. Educational trips were also arranged for farmer representatives from the region to visit similar agro-ecological zone in Burkina Faso, where a technique called 'zai' has been extended by non-governmental agencies in the Yatenga region (Critchley et al., 1992). The abundance and proximity of stones to farms in the Illela region facilitated the use of stone 'bunds' if needed to complement the water and nutrient concentration techniques. Coupled with the later introduction of crescent-shaped earth mounds and the recycling of crop residues these techniques constitute important elements of improved soil and water management technology capable of promoting technical change in cereal production in the Sahel.

The survey covered 114 farmers randomly selected from 16 villages stratified to include representative samples of areas with (9 villages) and without (7 villages) Niger/IFAD extension intervention. Although most of the adopters are located in villages benefiting from extension support of the project, there are adopters in villages outside the project areas (Table 2). On the other hand, there are non-adopters even within villages in which the project operated. Also, the adoption of improved water, nutrient and water management technologies occurred on both, non-degraded and degraded lands (Table 2). Low

Table 2
Adopters and non-adopters of improved 'tassa' and half-crescent shaped earthen mounds in Illela region of Niger

	Adopters	Non-adopters
Project intervention areas	48	30
Non-project areas	14	22
Cultivated non-degraded areas	38	52
Cultivated degraded areas	24	0

Note: Project intervention areas denote where government of Niger/IFAD Project introduced improved 'tassa' and half-crescent shaped earthen mounds and provided direct extension education and support to farmers. Non-project areas denote where there is no direct extension education and support to farmers.

productivity, the appearance of particular plants and poor capacity for natural re-vegetation are indices used in classifying lands as degraded in local communities across the Sahel.

The field research involved measurement of cultivated areas and the administration of structured questionnaires to assess socioeconomic and attitudinal characteristics of respondents.

5. Discussion of results

The signs on correlation between variables were as expected. In several cases, the correlation coefficient is <0.2 (Table 3). Those >0.2 occur between the dependent variable, PIMTEC, and PCAD and EXTN variables. Notwithstanding correlation with other independent variables, PCAD and EXTN are likely to provide a significantly high explanation of variation in the dependent variable. The negative sign of the correlation between adoption of improved 'tassa' and half-crescent shaped earthen mounds (PIMTEC) and the land-to-labor ratio lends support to the hypothesis of adoption of intensification as population grows relative to land resources (Boserup, 1965; Ruthenberg, 1983; McIntire et al., 1992). Contrary to the expected characteristic of most small farmers, the relative frequencies of choice of an alternative chance of recovery of investment and associated net gain suggest the exhibition of low risk aversion (Table 3). It is likely that farmers are attuned to the risk of crop production in the Sahelian environment and, therefore, exhibit a strong desire for larger returns to investment. However, the large majority of the farmers do not admit to aiming at short-term profits at the expense of future profits (MAXP). As the frequencies of rankings for FWLB suggest, most of the farmers would not want to quit farming under any circumstance.

5.1. Estimated tobit models

The high squared correlation of 0.478 between observed and expected values indicate the existence of useful information in the estimated Tobit model (Table 4). All the variables, except LLRATIO, had the expected signs. However, variation in the proportion

Table 3
Correlation between variables and frequency of degree of approval of statements associated with attitudinal variables

Variable	AGE [a]	EXTN [b]	FWLB	MAXP	RISK	PIMTEC [d]	PCAD	LLRATIO [e]	1	2	3	4	5
AGE [a]	1.0000										N/A [f]		
EXTN [b]	0.1609	1.0000									N/A [f]		
FWLB [c]	−0.0838	−0.2120	1.0000						72	13	6	2	9
MAXP	0.0644	0.0925	0.0939	1.000					95	13	0	1	5
RISK	−0.0845	0.0022	0.2095	0.0735	1.0000				71	24	11	8	N/A [f]
PIMTEC [d]	−0.1709	0.2444	−0.1294	0.1016	−0.1942	1.0000					N/A [f]		
PCAD	−0.0851	0.1529	−0.2280	−0.0293	−0.1919	0.6292	1.0000				N/A [f]		
LLRATIO [e]	0.1057	−0.1202	0.0894	0.0715	−0.1222	−0.1078	−0.1606	1.0000			N/A [f]		

[a] Mean = 42.7; minimum = 18; maximum = 79.
[b] 0, 1 dummy.
[c] Rankings: 1 = strong disapproval; 2 = disapproval; 3 = uncertainty; 4 = approval; 5 = strong approval. Twelve respondents gave a ranking of 6 (see Table 1 for definition of rank level 6 for FWLB).
[d] Mean = 0.14; minimum = 0.00; maximum = 1.00.
[e] Mean = 2.0; minimum = 0.1; maximum = 12.1.
[f] See Table 1 for statements used in soliciting degree of approval of respondents. N/A = Not applicable.

Table 4
Estimated Tobit model for factors influencing adoption of improved soil and water management technology in Illela region of Niger

Variable	Normalized coefficient	Standard error	*T*-ratio	Elasticity of	
				adoption index	expected level of use intensity
Constant	−0.321	0.527	−0.609		
Age (AGE)	−0.007	0.009	−0.750	−0.603	−0.362
Extension (EXT)	0.706	0.260	2.718[b]	1.009	0.606
Quit farming (FWLB)	0.043	0.067	0.649	0.191	0.114
Risk attitude (RISK)	−0.376	0.142	−2.645 [b]	−1.268	−0.762
Max profit now (MAXP)	0.211	0.115	1.835 [c]	0.579	0.348
Degraded land (%) (PCAD)	2.151	0.338	6.361 [a]	0.714	0.429
Land/labor ratio (LLRATIO)	0.009	0.059	0.155	0.039	0.023

Note: Dependent: Percentage cultivated area having improved 'tassa' and half-crescent shaped earthen mounds (PIMTEC). Log-livelihood function = −37.462; Mean square error = 0.412E-01, mean error = 0.199E-01. Squared correlation between observed and expected values = 0.478. Predicted probability of Y >limit given average X(I) = 0.498. Observed frequency of Y >limit=0.544 at mean values of all $X(I)$, $E(Y) = 0.116$.

[a] Parameters were evaluated using one-tailed *t*-test for 1% significance levels.
[b] Parameters were evaluated using one-tailed *t*-test for 5% significance levels.
[c] Parameters were evaluated using one-tailed *t*-test for 10% significance levels.

of farmlands cultivated to the improved technologies (PIMTEC) is strongly explained by the following: the proportion of cultivated land recovered from degradation and on which improved 'tassa' and half-crescent shaped earthen mounds were adopted (PCAD); investment risk attitude (RISK); and individual contact with extension (EXTN). Attitude towards short-term profits at the expense of future profits (MAXP) only weakly explains the variation in PIMTEC. On the other hand, age (AGE) and quitting farming (FWLB) have no significance in explaining variations in PIMTEC.

The significance of risk attitudes (RISK) on the adoption of land-enhancing technology in the Illela region is similar to earlier findings of Nowak and Korsching (1983) for Iowa farmers. The higher the level of risk aversion the lower the level of adoption of land-enhancing technology. Therefore, a farmer whose beliefs and attitudes show a higher level of aversion toward risk exhibits a lower potential for adoption of improved soil and water management technology. However, the elasticity from the Tobit results suggests that if technologies have demonstrated risk reduction characteristics it should be possible to motivate adoption or increase in the level of use intensity of land-enhancing technologies. 'Tassa' and half-crescent shaped earthen mounds enriched with nutrient and organic matter concentration should reduce risks of food deficits by improving on yields from traditional cropping practices. However, because of the risk to funds invested in the purchase of inorganic fertilizer, it is necessary for extension efforts to educate farmers and demonstrate risk reduction capabilities of improved 'tassa' and 'half-crescent' technologies to stimulate adoption.

As expected, extension (EXTN) positively influenced level of adoption of 'tassa' and half-crescent-shaped earthen mounds enriched with concentration of nutrients and organic matter in planting holes (Table 4). This is similar to the finding that the availability of extension has positive significant effect on probability of adoption of chemical inputs (Jamison and Lau, 1982; Jamison and Moock, 1984). Farmers as individuals are known to gain from access to improved information provided through extension (Birkhaeuser et al., 1991). The estimated elasticities from Tobit show that extension education makes a substantial contribution to motivating adoption or intensity of use of land-enhancing technologies. Evidence of rapid adoption of land rehabilitation techniques in parts of Niger and Burkina Faso is credited to effective farmer to farmer extension education, although this factor is often underrated (Critchley et al., 1992). This provides support for institutional mechanisms designed to provide support for the diffusion of knowledge among farmers and demonstration of gains from new technologies.

The estimated parameter for PCAD suggests that the larger the proportion of cultivated land recovered from degradation, the greater the tendency to invest in land-enhancing technology (Table 4). If increasing population density induces the recovery of degraded lands (Critchley et al., 1992), then intensification can be expected. As land degrades, the gains and attractiveness of adoption of land-improving technology should increase sharply over traditional practices.

The estimated Tobit model shows that the attitudinal variable for immediate maximization of profits (MAXP) barely has significance in explaining variation in PIMTEC. Therefore, in future studies it would be worthwhile to replace this attitudinal variable on profits with a variable that embodies perceived relative gains from the improved and the traditional technologies. The implication of the positive sign is that the availability of land-enhancing technologies that provide short-term profit would lead to a greater probability of the level of adoption and intensity of use. This confirms observation that farmers of the Sudano-Sahelian zone exhibit preference for short-term returns to their investments (Baidu-Forson, 1994). The attitudinal variable on the income differential that would encourage the abandonment of farming in favor of income from non-farm sources does not significantly influence variation in PIMTEC. This may be due to a realization of existing severe limitations on options for households to earn non-farm income within the region and much of the Sahel.

In sum, from the findings in this paper, it can be deduced that strategies to enhance adoption of improved soil and water management include the demonstration of short-term profits and risk reduction characteristics of technology, and support for dissemination of knowledge on gains from adoption. Follow-up studies should investigate the replacement of variables denoting attitudes to risk and short-term profits with specific variables that more directly measure farmer's relative perceptions of improved and traditional technologies. It is also evident that land-enhancing technologies would be more readily adopted if targeted to areas experiencing degradation in large portions of cultivable lands.

The results of this study show that age (AGE) has no significant effect on the adoption of 'tassa' and earthen mounds shaped in the form of half crescent which have been improved with the concentration of biological and chemical inputs. This result is contrary to the observed negative influence of age on adoption of biological and chemical inputs because of the conservative outlook of older farmers (Cotlear, 1986). However, this contrary observation confirms the inconsistency of evidence about the relationship between age and innovativeness (Rodgers, 1983).

6. Concluding remarks

Donors, national policy-makers and extension personnel are concerned about frequent food deficits and accelerating degradation of land resources in the Sahel. Increasingly, attention is focused on achieving both technical change in agricultural production practices and improved natural resource management. This is evident from the direct and indirect (through non-governmental agencies) investments in diffusing improved soil and water conservation technologies to farmers. Identification of factors that influence farmer adoption and intensity of use of improved soil and water conservation practices in the Sahel would contribute to the elaboration of strategies to achieve technical change in crop production in the Sahel.

Several lessons useful to the development of strategies to motivate technical change in the Sahel emerge from the case study presented in this paper. First, investment in land-enhancing and conserving technologies becomes more attractive as an increasing percentage of available cultivated land is degraded. This suggests a strategy of targeting diffusion of land-enhancing technologies particularly to areas with greater percentage of arable land degraded. Another broad implication of the finding of this study is the need to provide extension support to promote adoption of improved soil and water conservation technologies through the provision of knowledge and demonstration of gains from technologies. Third, research on improved soil and water conservation techniques should pay attention to the provision of tangible short-term benefits and risk reduction to enhance probability of adoption and intensity of use. Finally, development agencies and policy-makers should not target land-enhancing technologies on the basis of age. This is because there is inconsistency in the evidence on the effect of age on adoption of innovations.

In this study, the range of personal variables investigated was limited because of the similarities among respondents as well as the non-availability of data that are not highly inter-correlated. Future research may still want to investigate and include, where possible, other personal variables, which are empirically or theoretically known to influence adoption of innovations.

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