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ADOPTION OF WATER AND SOIL CONSERVATION TECHNOLOGIES: DETERMINANT FACTORS IN THE CENTRAL PLATEAU OF BURKINA FASO

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ABSTRACT

In Burkina Faso, agricultural production lags behind the population growth rate because of unfavourable climatic conditions coupled with continuous soil degradation. To improve populations' livelihoods in the rural areas, a range of water and soil conservation techniques (WSCT) has been proposed. But the implementation of these techniques is not widespread as it should in view of their capital importance. This study tried to identify the reasons behind the poor adoption of WSCT. To that end, a survey was carried out in five villages of the central plateau region of Burkina Faso; and the data were used to determine a logit multinomial model that was used to assess the probability of adopting one or different combinations of WSCT. Results show that the cost of the WSCT is the main factor that prevents their adoption. However, populations are well aware of the importance of these techniques in slowing down the pace of land degradation since they are willing to adopt a combination of several WSCT when there is a possibility of assistance to reduce the implementation cost and also when the efficiency of the combination is proven. Therefore, for the purposes of food security, it is imperative to identify the most efficient and cheapest combination of WSCT and then assist smallholder farmers in their implementation in each agro-ecological zone of the Sahel. In other words, government of the Sahel region must include assistance in adopting WSCT in their short and long term political agenda to improve life standards in rural areas.

Keywords: Burkina faso, Water and soil conservation, Technologies, Multinomial logit model.

1. INTRODUCTION

In Burkina Faso, the primary, secondary and tertiary economical sector respectively provide 40, 43 and 17% of the GDP. The primary sector encompasses agriculture (25% of the GDP), livestock (12% of the GDP), forestry and fishing (3% of the GDP). Among the three economical

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sectors, the primary sector is the key one, because it represents the livelihoods for about 86% of the country population. Therefore, the country is largely dependent on the primary sector that itself largely depends on climate conditions, because the lack of means prevents farmers from adopting technologies such as irrigation and sedentary animal rearing that reduce the climate impact.

From the end of the 1960s, the Sahel has experienced a protracted dry period that profoundly affected the ecosystems productivity [1]. Rainfall reduction coupled with the anthropogenic activities over the dry period contributed to interrupt the fragile balance between soils and vegetation in this region. The rupture of this balance made soils more sensitive to erosion that is triggered by runoff and winds. Erosion is one of the most important causes of land degradation in the Sahel region. On the ground, land degradation is translated into decrease in land productivity, shrinking of grazing areas and loss or rarefaction of grazed species. Consequently, Sahel is now facing food insecurity as a major problem when the population growth rate remains one of the most important in the world.

To cope with land degradation and to improve and stabilize land productivity, waters and soils conservation techniques (WSCT) have been proposed by researchers. The efficiency of these techniques has been proven throughout the Sahel [2]. But on the ground, the adoption of these techniques is not widespread as it should be with regards to their importance. For instance, in the central plateau of Burkina where land degradation is very important, only 300,000 ha of land are under these techniques [3]. Therefore, the reasons behind populations' reluctance to adopt these vital technologies need to be more understood for the purposes of food security and environmental protection.

This paper aims to better understand the reasons underlying the adoption of the WSCT in the central plateau of Burkina Faso. This study aims to analyze the factors that determine the adoption of WSCT techniques in Central Plateau region of Burkina Faso. To that end, a survey has been carried out and the identified variables were used to estimate a logit multinomial model that served to assess the adoption probability of adopting a WSCT or a combination of WSCT. Results show that the cost of the WSCT or combinations of WSCT is the first impediment to their widespread adoption.

2. THEORETICAL FRAME

The innovation theory proposed by Rogers [4] explains the way that a technological innovation follows from its invention up to its use at large scale. Its release is a process through which it is communicated anytime to the members of a social system through certain channels.

Innovation is an idea, a practice or an object seen as new by an individual or group of individuals. The release pattern of an innovation stipulates that a technology moves from its source up to final users through one or numerous agents. Moreover, an innovation release by potential users is a function of the majority of the end users' personal attributes. Thus Rogers [5] considers that its adoption should not be seen as a simple choice, rather as a set of events leading to its perpetual use. Therefore, the author identifies five elements that could determine the adoption or the release of a new technology: the relative advantage, the compatibility, the complexity, the testability and the observability.

Relative advantage refers to the degree with which the innovation is seen as better than the already existent ones. Thus, it is not necessary that the innovation has more advantages than the previous ones, but the important aspect is that it must be seen as advantageous.

Compatibility is the measure of the degree with which an innovation is seen as consistent with the existent values, the past experiences, the social practices and the users' standards. Therefore, an idea that is incompatible with the current values and standards should take more time to be adopted than a compatible innovation.

Testability refers to the possibility of testing an innovation and modifying it before its use. Indeed, opportunity to test an innovation allows eventual users to have more trust in the product, because they already get used to it when it is released.

Observability measures the clarity of the results and benefits of an innovation. Thus the more the adoption results of the innovation are clear, the more the innovation will be readily adopted.

However, each of the innovation characteristics, considered separately, is not sufficient to predict its adoption. The combination of the five characteristics should increase the adoption chances of the innovation [6, 7].

In 1986, Davis in an acceptance model of technology finds two psychological factors that determine the adoption of a technology. These factors are the perception of the utility and the perception of the use facility of the technology. Thus, in front of two technologies with the same functionalities, the user will choose the one that seems easier to be used [8]. Among the two variables, the utility perception and the use facility perception of the technology, that influence the user's general behavior, the use facility influence is more significant.

3. METHODOLOGY

3.1. Study Area and Data Collection

The central plateau is a land located in the central part of Burkina Faso and it spreads over 70,668 km^2 representing 25% of the total surface of the country. The soils in this area are generally shallow, poor in main nutrient elements and with a poor water holding capacity. However, it is the most populated area in the country with a population that increased from 4,878,967 in 1996 to 6,0514,434 inhabitants in 2006, i.e. an annual increase rate of 2.2%.

According to the land resource availability, the maximal population density can go up to 40 inhabitants / km^2 [9], but the current population density in this area is more than 50 inhabitants / km^2. Thus the agro-demographic threshold of land use in this part of the country is passed, and that results in advanced degradation of the natural resources. The combined effects of rainfall reduction and the use of inadequate agricultural techniques resulted in food insecurity in this area. Therefore to improve their livelihoods, the populations of the central plateau have to choose and implement a range of simple techniques aiming to improve and stabilize agricultural productions.

In this study we worked in five (5) villages chosen in two provinces in agreement with the development strutures and the NGOs on the ground. These villages are: Bourou and Boursouma in the Yatenga province; Baniou, dana and Gomponsom in the Passoré province (figure 1). Indeed, the villages were retained because they have benefited from the assistance of NGOs and development projects, and they are experiencing a dynamic agrarian policy.

In each of the considered villages, an exhaustive list of the households was constituted and a sample of 150 households, i.e. 30 households per village, were randomly drawn for a survey.

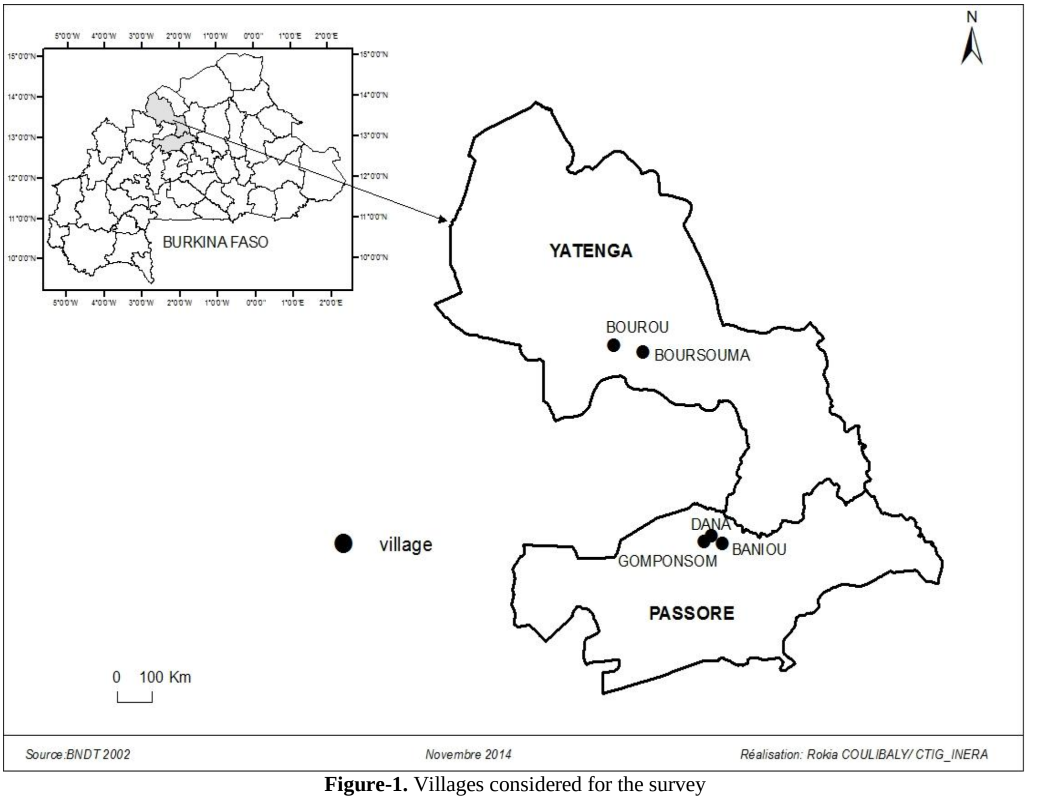

Figure-1. Villages considered for the survey

3.2. Choice of the Multinomial Logit Model

The theoretical basis of a model lies on its mathematical translation of the exact or approximate relationship existing between two or many variables [10]. This translation requires knowledge of the process or system that is intended to be represented or analyzed. Benoît-Cattin [11] in Kébé [12] argues that a construction of a model requires a good perception of the reality, major phenomena, interactions at stake, relative importance and extension domain. In other terms, the modeling process (i.e. the technique that is used to construct a model) should explain the characteristics of the system including its evolution and transformation in view of certain objectives [13]. Thus, the construction of a model, beforehand, supposes quantitative and mainly qualitative knowledge of the object or system that is intended to be modeled.

In adaptation studies, modeling was oftentimes used as analysis tools. These models are ranged from the linear programming to models with limited qualitative or discrete variables. Many authors [3, 14, 15] used the linear programming model to measure the impact of the adoption of new technologies on producers' profit. With this type of model, decision regarding the adoption of a technology can be made by taking into account its economical profitability. However, this model is limited since it doesn't include certain types of factors, such as the psychological factors, that influence the adoption of technologies.

Clay, et al. [16] used both the Logit model and the linear model to analyze the determinant factors of farmers' investment in soil conservation in Rwanda. These models include economic, social, agronomic, psychological and environmental factors. In particular, the Logit model that includes discrete variables gives a good estimation of the adoption probability of technologies. Zoungrana [17] analyzed the adoption of soil conservation technologies with the Probit model. This model is similar to the Logit model since it allows the use of both quantitative and qualitative variables.

The two (Logit and probit) models are able to estimate the adoption probability of technologies. However, they are limited since they solely use dichotomy variables without multinomial dependent variables. Therefore, they cannot allow choice among many alternatives, and they cannot also estimate the probability associated to each alternative. On the contrary, the Logit multinomial model is able to take into account polytomic variables. It can measure the adoption probability of one or a combination of technologies. Moreover, this model is based on the random utility model that is a theoretical model of behavior measuring the utility or the attractiveness of each option of adoption. Because of these characteristics, the multinomial Logit model is well appropriated for the present analyses.

In this work, the modeling is focused on unranked choices since it is difficult to rank a priori the different technologies or combinations of technologies. It is based on the maximization of a random utility function. The dependent variable is thus a multinomial variable with unranked modalities.

3.3. Model Specification

Let's consider "i" like the households number in the sample, thus i = 1…..n

The households are distributed in "J" groups; and each household "I" belongs only to one group of technology or to a combination of technologies.

Let's consider "j" like the possible choices of WSCT; thus j = 0, 1, 2, …J.

It is assumed that the adherence of the household "i" to the group "j" depends on a set "K" of explicative variables x_{ik}.

We consider "k" like the explicative variables of the adoption of WSCT; k = 1, 2…K

For each choice "j", the utility reached by the household "i" is written:

$U_{ij} = \beta_j' x_{ij} + \varepsilon_{ij}$ (1)

Where $\beta_j' x_{ij}$ is the determinist part of the utility function; ε_{ij} the random part or the error therm.

$\beta_j' x_{ij}$ represents the parameter associated with the explicative variable x_i with regard to the option "j". The explicative variable is a determinant factor of the adoption of WSCT.

The household is supposed to choose the technology that provides it with the highest level of utility.

Let's consider "y_{ij}" like a variable that is worth 1 if the household "i" made a choice of WSCT and 0 in the reverse case. Then the probability that the choice j is made by the household i is written:

$P(y_{ij} = 1) = P(U_{ij} \geq U_{il})$ for all $l \neq j$; (2)

$P(\beta_j' x_{ij} + \varepsilon_{ij} \geq \beta_j' x_{il} + \varepsilon_{il}) = P(\varepsilon_{il} - \varepsilon_{ij} \leq \beta_j' x_{ij} - \beta_l' x_{il})$. (3)

Assuming that the error terms ε follows the Gumbel distribution, we can then write:

$f(\varepsilon) = \exp(e^{-\varepsilon})$. (4)

The probability that the household "i" chooses the modality "j" $(\forall j = 0,\dots,J)$ is written:

$$\Pr ob(y_i = j) = \frac{\exp(\beta'_j x_{ij})}{\sum_{j=0}^{J} \exp(\beta'_j x_{ij})} = \frac{\exp(\beta'_j x_{ij})}{1 + \sum_{j=1}^{J} \exp(\beta'_j x_{ij})} \quad (5)$$

Where the vector β_o is normalized at 0: $\beta_o = 0$

Under the normalization hypothesis of $\beta_o = 0$, the probability associated with the modality of reference 0 (absence of adoption) is defined as:

$$\Pr ob(y_i = 0) = \frac{1}{\sum_{j=0}^{J} \exp(\beta'_j x_{ij})} = \frac{1}{1 + \sum_{j=1}^{J} \exp(\beta'_j x_{ij})} \quad (6)$$

Where the parameters of the vectors (β_j) can be different according to the modalities j.

Thus the parameters of the model are interpreted as deviations from the reference (absence of adoption or modality 0).

The model is based on the hypothesis of the independency on impertinent alternatives. The arbitrage between two types of choices is supposed not to be influenced by the other available choices. According to equation (5), the ratio of the probability P(j) to the probability P(k) depends only on the explicative variables associated to the two choices. It is not influenced by the presence or the characteristics of other choices.

3.4. Specification of the Parameters

The estimation method used herein is the maximum likelihood method. Its estimator is endowed with proprieties of efficiency and with asymptomatic normality that make the statistical inference particularly interesting.

The likelilihood ratio associated with the independent multinomial Logit with m+1 modalities is written taking into account m vectors of parameters β_j (j=1,…, m), because of the normalization β_o = 0. Thus, the estimation of the parameters of the Logit multinomial model is carried out through the maximization of the log-likelihood in linkage with the vectors of the parameters ($\beta_1, \beta_2, ...\beta_m)$:

$$\log L(y, \beta_1, \beta_2, ...\beta_m) = \sum_{i=0}^{N} \sum_{j=0}^{m} y_{ij} \log[\Pr ob(y_i = j)] \qquad (7)$$

With Y_{ij} =1 if $Y_i = j$ and 0 otherwise.

The dependent and explicative variables are in table 1.

In the following, "j" varies from 0 to 5 and concerns a group of technologies or a combination of WSCT.

The choice of the explicative variables to be included in the model was guided by socio-economic literature in the domain of the adoption of technologies. Indeed, numerous studies show that many factors determine the adoption of these technologies. Among these factors are:

- Household size that is often mentioned as an essential variable in the option of new technologies [18, 19](It represents a source of manpower. The variable "household size" is positively linked to the adoption of new technologies;

Table-1. statistical summary of the dependent variables

variables	Average or %
Dependents variables	
Technologies/combination of technologies	Adoption rate
Group 0 : none technology	4,48
Group 1 : one technology (dike stone , compost or manure, zaï)	8,96
Group 2 : two technologies (stone cord +compost ; zaï + compost ; stone cord + zaï ; half-moon + compost)	40,14
Group 3 : three technologies (dike stone +compost+zaï ; dike stone + half-moon + compost ; zaï + half-moon + compost ; dike stone + zaï + RNA)	44,94
Group 4 : four technologies (compost + zaï+ dike stone +mulching ; dike stone + compost + hal-moon + zaï);	0,75
Group 5 : five technologies (dike stone + zaï + mulching + half-moon + compost ; dike stone + zaï+half-moon + compost + living fences	0,75
Explicative variables	
Cost of the technology (X0F)	48000
Expected yield (Kg)	1255,36
Household size (number)	12,57
Farm size (ha)	4,32
Risk (%) weak middle high	25,18 10,83 6,4
Perception of the facility (%) not easy quite easy easy	 62,04 28,63 9,33
Perception of the utility (%) Very useful quite useful useful	 63,96 26,26 9,78

Source: Field Survey

- Farm size (i.e. the cultivated surface) that have been shown to be positively correlated to the adoption of WSCT [20]. However, studies did not show any significant relationship [21, 22], while others found negative correlation [23] between these two types of variables. Consequently, the global influence of the farm size on the adoption of WSCT is less conclusive;
- Expected yield that is seen as the first motivation of the adoption of the WSCT. By easing water infiltration, improving soil structure and better protecting soils against runoff, the WSCT allow an increase in yields [24]. The expected yield positively influences the adoption of WSCT;
- Cost of technology that is required for the application of certain techniques. Generally, farmers are without these required means, because they have to face food shortage at the same moment [25-28]. The cost of the technologies is expected to be negatively correlated to the number of WSCT adopted;
- Use facility of the technology that is an important adoption factor of certain technologies. The more difficult is a technology implementation, the lesser it will be adopted. The complexity of the innovation disfavors its adoption;
- Perception of the utility of the technology that depends on the expected profits, but also on the renaissance of the social success as an innovator farmer. It is positively related to the adoption of technologies;
- The risk associated with the adoption of technologies [16,25,29-31]; that is supposed to be positively related to the number of the adopted technologies.

3.5. Interpretation of the Coefficients of the Model

In the specification of the Logit multinomial model, the coefficient associated with the modality 0 is normalized at 0 ($\beta_o = 0$). Therefore, the writing of the probability in the above-mentioned format means normalization of the parameters of the model that are the differences between the original parameters β and the vector of the parameters of the reference modality, i.e. β_o. Thus, the parameters of the Logit multinomial are interpreted as deviations from the referential (situation of none adoption) i.e. from the parameter of the modality 0. The marginal effect of a variable is obtained through the derivation of the probability associated with each choice in linkage with that variable. As in the case of models with binary dependent variable, the interpretation of the coefficients is not direct, because the marginal effects that take into account these coefficients and the probabilities associated with each choice have to be calculated. In the multinomial logit case, the marginal effects are obtained by multiplying the coefficients with a certain combination of probabilities.

4. ESTIMATION RESULTS OF THE MODEL

Estimations results of the multinomial logit model in the version 8 of the Stata software are indicated in table 2.

Table-2. Estimation results of the multinomial Logit model

Technology	Coefficients	Standard. Deviation	Z	P>Z	Marginal effect	Z	P>Z
Probability of adopting one technology							
Cost	-6.311008***	1.146958	-5.50	0.000	-0.0345488	-1.21	0.227
Facility	0.1244665*	0.2675408	0.47	0.642	0.0028201	0.63	0.529
Utility	-0.1963432	0.3173703	-0.62	0.536	-0.0088051	-1.11	0.266
Farm size	0.5927408	0.384076	1.54	0.123	-0.0004451	-0.08	0.934
Household size	-0.1903279	0.1127115	-1.69	0.091	-0.0026911	-1.00	0.315
Expected yield	-0.4874255	0.9535067	-0.51	0.609	0.0046512	0.29	0.770
Risk	-0.7076787	0.6751335	-1.05	0.295	-0.0112062	-0.93	0.351
Cons	92.83205	17.28966	5.37	0.000	-	-	-
Probability of adopting two technologies							
Cost	-5.084995***	1.052767	-4.83	0.000	-0.3640332	-3.52	0.000
Facility	0.0057664	0.1857118	0.03	0.975	0.0172843	0.48	0.633
Utility	0.2291505	0.1758194	1.30	0.192	-0.017326	-0.38	0.704
Farm size	0.7373844***	0.2795553	2.64	0.008	0.0813171	1.80	0.072
Household size	-0.0709134	0.0618854	-1.15	0.252	-0.0123922	-0.95	0.340
Expected yield	-1.1359**	0.4612785	-2.46	0.014	-0.2736788	-2.42	0.016
Risk	-0.1386203	0.4685017	-0.30	0.767	-0.0036721	-0.04	0.967
Cons	77.5068	15.44663	5.02	0.000	-	-	-
Probability of adopting three technologies							
Cost	6.311007***	1.146958	5.50	0.000	0.1466089	1.55	0.122
Facility	-0.1244665	0.2675408	0.47	0.642	0.00065	0.13	0.899
Utility	0.1963432	0.3173702	0.62	0.536	-0.0082387	-1.00	0.316
Farm size	-0.5927408	0.384076	-1.54	0.123	-0.0198798	-1.49	0.135
Household size	0.1903279*	0.1127115	1.69	0.091	0.0016906	0.86	0.392
Expected yield	0.4874255	0.9535067	0.51	0.609	0.0234432	1.04	0.299
Risk	0.7076787	0.6751335	1.05	0.295	0.0042991	0.32	0.749
Cons	-92.83205	17.28966	-5.37	0.000	-	-	-
Probability of adopting four technologies							
Cost	-3.64195***	0.9988913	-3.65	0.000	0.2519731	2.69	0.007
Facility	-0.0940674	0.1803052	-0.52	0.602	-0.0207544	-0.59	0.557
Utility	0.3775534*	0.2277186	1.66	0.097	0.0343698	0.75	0.451
Surface	0.3982703	0.2571337	1.55	0.121	-0.0609923	-1.39	0.165
Household size	-0.0046353	0.0534778	-0.09	0.931	0.0133927	1.08	0.279
Expected yield	0.1490242	0.5230435	0.28	0.776	0.2455845	2.17	0.030
Risk	-0.0954299	0.4104068	-0.23	0.816	0.0105791	0.13	0.900
Cons	47.5002	14.65516	3.24	0.001	-	-	-
Probability of adopting five technologies							
Cost	-4.045883***	1.374478	-2.94	0.003	4.38e-10	0.00	1.000
Facility	0.1033059	0.5123983	0.20	0.840	1.09e-10	-	-
Utility	5.540855	1469.605	0.00	0.997	4.69e-09	0.00	0.999
Surface	0.7181979	0.6465843	1.11	0.267	9.10e-11	-	-
Household size	-0.4074238	0.3237387	-1.26	0.208	-3.15e-10	-0.05	0.958
Expected yield	0.6032348	1.35169	0.45	0.655	1.18e-09	0.00	0.999
Risk	16.50057	4408.814	0.00	0.997	1.48e-08	0.00	0.999
Cons	-46.24354	-	-	-	-	-	-
Mac Fadden	**R^2 = 0,5448**						

Cost = cost of the adoption of the technology; Facility = facility of the adoption of the technology; Surface = farm size; Utility = perception of the utility of the technology by the farmer; risk = rainfall risk.

4.1. Economic Validity of the Coefficients

4.1.1. Adequacy of the Model

In the case of the models with discrete or limited dependent variables, the adequacy of the model is indicated by the index of the likelihood ratio, also called the Mac Fadden's R^2.

This index gives the percentage of the variation of the dependent variable due to the presence of the explicative variables. In table 2, R^2 = 0.5448 means that 54.48% of the variations of the probability of adopting a WSCT or a combination of WSCT are explained by the set of the explicative variables included in the multinomial logit model. Therefore, the specified model is generally adequate.

The likelihood ratio test of the model is used to measure its overall fit. Herein, the calculated value is 217.3507, while the theoretical value is 20.01 on the table of the χ^2 distribution with 8 degrees of liberty at the level of 1%. Because the calculated value is superior to the theoretical value at this level, the difference nullity hypothesis is then rejected.

4.1.2. Statistical Significance of the Coefficients of the Model

The significance of the coefficients from the model was determined at the threshold of 1%, 5% and 10%, respectively meaning highly significant, fairly significant and significant. The results of this test are reported in table 2 under the column "P>Z".

In the case of adoption of one WSCT, the coefficients of the variables cost and household size are significant at 1% and 10% levels, respectively. The coefficients are not significant for the other variables.

Regarding the adoption of two WSCT, the coefficients of the variables cost and farm size are significant at 1%, while the coefficient of the expected yield is significant at 5%.

For three WSCT, the coefficients of the variables cost and household size are significant at 1% and 10%, respectively.

The coefficients of the variables cost and utility are respectively significant at 1% and 10% for the adoption of four WSCT.

Only the coefficient of the variable cost is significant at 1% for the adoption of five WSCT.

5. DISCUSSION

In table 2, the Mac Fadden's R^2 indicates that 54.48% of the variations of the probability of adopting a WSCT or a combination of WSCT are explained by the set of the explicative variables included in the multinomial logit model. Moreover, the χ^2 test is highly significant (1% level) and that means that the coefficients of the multinomial logit model are different to 0. Therefore, the derived multinomial logit model is globaly adequate. In other words, the explicative variables in the derived logit multinomial model significantly influence the choice of a WSCT or a combination of WSCT in the study area.

The negative sign of the coefficients of both "household "size" and its marginal effect implies that the household size has an individual negative effect on the probability of adopting one technique. In other terms, the bigger the household size is, the smaller the adoption probability of one WSCT is. That is because an increment of the household size, increases the global consummation level of the households, and then prevents them from getting the necessary means to implement a WSCT. Another reason of that is because of the availability of more manpower, large-size households prefer to focus on increasing the farm size or the number of farms than applying costly and time-consuming WSCT. On the contrary, small-size household that cannot exploit larger surfaces are oblige to improve their land productivity through the application of WSCT. But the negative coefficients of the marginal effect of variable "cost" underlines that the principal reason behind the non-adoption of a WSCT is the lack of financial means. Indeed, these negative coefficients indicate that the higher the cost of a WSCT is, the lesser it is adopted. The implementation of the efficient WSCT is costly according to CES/AGF [32]. that estimated the cost of the implementation of the zaï technique at around 45,000 XOF/ha.

Results in table 2 also show that the cost of the WSCT is one of the impediments that prevent the adoption of a combination of two WSCT. Moreover, it also appears that the higher the expected yield is, the lesser a combination of two WSCT is adopted. That is because when none or one WSCT is expected to lead to good yield, households are then reluctant to adopt a combination of two WSCT that is costlier and more time consuming. Contrarily, an increase in farm size increases the probability of adopting a combination of two WSCT. The reason behind that can be the shortage of arable lands in the central plateau of Burkina Faso that is the highest populated part of the country. Indeed, the difficulty of acquiring new arable lands in this area prompts farmers to adopt a combination of two WSCT to significantly slow down the degradation process and then take advantage of these lands over a long period.

Regarding the adoption of a combination of three WSCT, results seems to be controversial since they are the opposite of what we have been seeing so far. Indeed, it appears that households are more willing to adopt a combination of three WSCT when the cost of its implementation is higher or when the household size is bigger. However these results can be well understood after the relaxation of one of the fundamental hypotheses of the model according to whichthe adoption of WSCT happened at individual household level. That means that two or more households cannot work together to implement a WSCT. But this hypothesis does not reflect the reality on the ground since during the fieldwork we have noticed that smallholder farmers are organized in groups with a system of mutual assistance to carry out difficult farm works such as stone breaking of the implementation of WSCT. Furthermore, it exist rural development projects such as the sustainable rural development program that provides farmers' groups with technical and material assistance in stone breaking and transportation for the implementation of WSCT. This type of assistances reduces the real costs of WSCT adoption and then eases the adoption of a combination of three WSCT that might be more efficient than one WSCT or a combination of two WSCT. Likewise, under the hypothesis of assistance in the implementing of WSCT, large-size households will be more willing to implement three combined WSCT to enhance their land productivity for the purposes of food security. That is in concordance with the positive coefficients of the marginal effect of "cost" in the case of adoption of four or five combined WSCT indicating that the costlier these combinations of WSCT are, the more they are adopted. Also, the positive coefficient of the marginal effect of the variable "perception utility" in the adoption of a combination of four WSCT clearly highlights the fact that households are ready to adopt a combination of several WSCT if its efficiency in improving crop production is proven. That is in concordance with Davis [33] according to who smallholder farmers adopt combinations of WSCT when these ones are really able to substantially increases their land productivity.

During the field work, it was also noticed that only a small part of the sample membership (1.5%) has implemented a combination of more than three WSCT on their farmlands. The poor rate of adoption of a combination of more than three WSCT may be linked to the lack of means since the above-mentioned results clearly point out the cost of implementation of a WSCT or a combination of WSCT as the first factor preventing its adoption in case of absence of any assistance. But another reason that can be behind the poor adoption of combinations of more than three WSCT is the perception of their utility. Indeed if they are seen to have the same or less efficiency comparatively with combinations of two or three WSCT, they will be poorly adopted. More investigation will be useful to better understand the real reasons behind the poor adoption of combinations of WSCT in the study area in particular and in the all Sahel region in general.

6. CONCLUSION

The results of the estimations of the multinomial logit model allow a better explanation of the choices that are operated by the farmers in terms of adoption of the conservation technologies of soils and waters. Indeed, for the adoption of the WSCT, the households proceed to maximization under constraint. Base on the information on the characteristics, the expected profitability of the technologies and the available resources, farmers proceed to interactions to reach their objective of maximizing the production. The choice is firstly oriented on the technologies and the resources that they have. They proceed to interactions to reach their objective of maximization. Taking into account the remaining resources, they will adjoin other technologies, certainly less efficient, but susceptible to contribute to this objective.

In this study, the estimation results of the model show that the set of the retained explicative variables adequately explains the probabilities of adoption of different combinations of WSCT. These variables are the adoption cost of the WSCT, the household size, the farm size, the expected yields, the perception of the utility of the WSCT, the perception of the facility of and the use of the technologies and. The interesting element is that the adoption cost of the WSCT is a factor that determines the adoption probability of WSCT. In other terms, the implementation cost of these techniques influence the households' behavior. For a popularization of WSCT, this variable must be taken into account as an instrument of political policy.

The variable "households' size" also plays an important role, because if it increases, the adoption probability of a WSCT decreases. In the same time, a household will be ready to adopt more WSCT when their total induced utility increases. In other words, the population increase has a stimulatory effect on the technological innovation, because households want to use more productive techniques to meet the additional need brought by the demographical impulsion. This result is in concordance with the Boserup [34] theory of creative pressure of the population. Population pressure is a very important development factor of the WSCT.

The variable “farm size” intervenes as determinant factor of the adoption of the WSCT. That indicates the importance of the land availability for the implementation of WSCT. Indeed, if land access is reduced for a household, it will not be able to use more than two WSCT if the perceive the benefit effects.

The variable “perception of the utility” of the WSCT has an individual effect on the adoption of a combination of four techniques. Nevertheless, the psychological factor influences the adoption of other techniques, despite the non significant effect of this effect.

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