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Adoption potential for fire-free agricultural practices by smallholders in the Eastern Amazon of Brazil

Arisbe Mendoza-Escalante[a], Jan Börner[a] and Bettina Hedden-Dunkhorst[a]

a Center for Development Research (ZEF), University of Bonn, Walter Flex Str. 3, 53113 Bonn, Germany. E-mail: arisbe.mendoza@uni-bonn.de

Abstract
In the Eastern Amazon Region of Brazil the shortening of natural fallow periods constitutes major challenge in preserving secondary forests, which are considered an important resource for human livelihoods. In response to this challenge, fire-free agricultural practices (the combination of mulch technologies and fallow improvement techniques) have been developed as promising agricultural production technologies that may contribute to the conservation of soil quality and secondary vegetation. Awareness of the adoption potential of such technologies would help to design appropriate extension approaches and policy interventions to support smallholders. In this paper, a case study of 270 farmers in the Bragantina Region was carried out to investigate, which factors affect the willingness of smallholders to adopt mulch technologies. The analysis confirmed that income, farm size, knowledge of fire-free agricultural practices, soil quality, and fertilizer use are factors associated with the potential acceptance of the technologies.

1 Introduction

The problem of soil degradation due to the shortening of natural fallow periods in the Eastern Amazon Region of Brazil and elsewhere in the world is multi-dimensional and inherently dynamic. There is an on-going decision-making process on the part of the farmer whether to adopt and implement mulch technologies (*Mt* henceforth). However, the decision to adopt those practices is heavily influenced by the complex interplay of physical, biological, demographic, institutional, and socioeconomic factors, which may uniquely affect a given farm enterprise. Variations in the impacts of these factors on the decision of the farmers, i.e., whether or not to include *Mt* in their land management strategies, accounts for the difficulty in targeting technology packages that would be socially acceptable and, at the same time, economically viable from the point of view of the farmers.

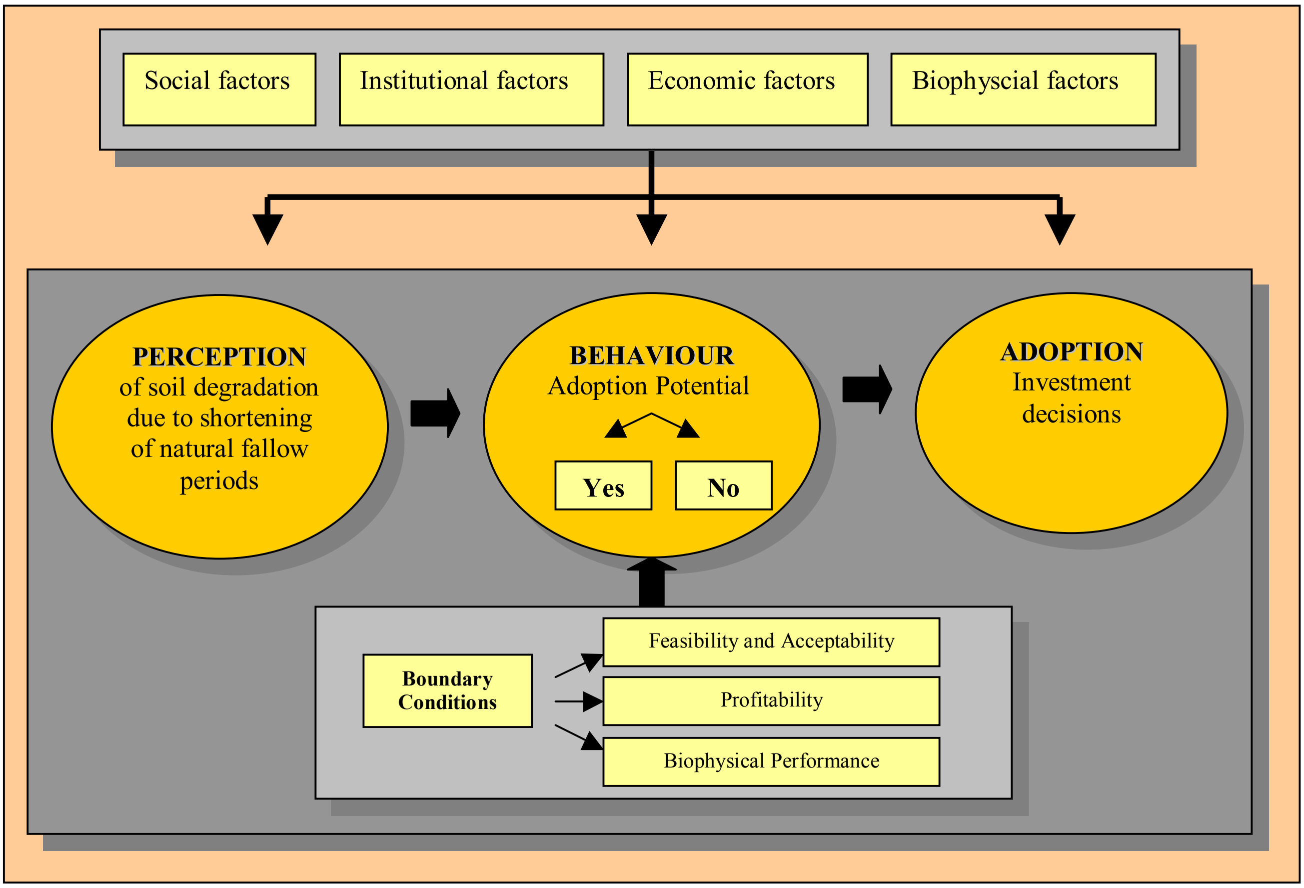
This study aimed to identify the factors that are likely plausible to affect farmers' willingness to adopt *Mt* at the first stages of the decision process. Understanding the decision-making process of the farmers is an essential take-off point in the development of policy instruments that will achieve soil and secondary vegetation conservation objectives. Identification of factors that eventually lead to conservation investments might help policymakers and extension agents to define incentives, institutional mechanisms and policies that could be implemented to facilitate *Mt* adoption and that can be useful in designing appropriate policy instruments and measures for effective soil and secondary vegetation conservation. The reminder of this paper is organized as follows: In Section 2 we set up the conceptual framework of our study. Section 3 presents the theoretical framework utilized. In Section 4 we provide details of the methodology used, explain the sampling procedure, survey design, and econometric analysis. Results from the econometric analysis are presented in Section 5 while Section 6 concludes.

2 Conceptual Framework

There is a host of interdependent factors that influence a farmer to allocate resources for soil and secondary vegetation conservation, i.e. to invest in a soil conservation technology (BARBIER, 1990; BURT, 1981; FEATHERSTONE AND GOODWIN; NAPIER ET AL. 1994; SEITZ AND SWANSON, 1980). Thus, the decision to adopt *Mt* should consider the interactive play of social, institutional, economic and biophysical factors in the adoption process. This decision process can be understood as a system with different parts that are interlinked.

Based on the modified framework used by FRANZEL (2002) and GARCIA (2001), the adoption potential of *Mt* can be assessed by looking at the boundary conditions, namely: 1) profitability; 2) feasibility; and, 3) biophysical performance. Those aspects are simultaneously influenced by social, institutional, biophysical, and economic factors. Our analysis focused on the stage of potential adoption behaviour, more specifically we discussed the assessment of boundary conditions defined by identifying the variables that are most important in determining who potentially will and will not use *Mt* (Figure 1).

Figure 1: Conceptual framework for the adoption potential of mulch technologies



This framework suggests that the farmer must first recognise the existence of soil degradation due to shortening of natural fallow periods as a problem. The farmer's awareness is a result of his/her own personal experiences regarding the relationship between crop productivity and soil quality affected by the fallow periods. Once the problem is perceived, the farmer then decides whether to adopt *Mt*. The decision to adopt the technology or not will depend on the profitability, feasibility and acceptability, boundary conditions and biophysical performance of *Mt*. That in turn is also seen to depend on the four factor categories identified in the upper part of the figure, which interact and shape the farmer's choice. That decision will then lead to the determination of the amount of resources that farmers are willing to allocate to *Mt* in the adoption stage. Economic variables used for assessing boundary conditions in our case study included agricultural revenue, off-farm income, and fertilizer use (as a proxy for input costs). Household size was included as a social variable[1]. Critical institutional factors analysed were tenure status and knowledge of fire-free technologies[2]. Finally, biomass[3]and farm size were incorporated as biophysical variables.

3 Theoretical Framework

The boundary conditions for adoption potential of *Mt* were identified using a random utility model (COPPER, 1997). A double bounded dichotomous choice (DBDC) contingent valuation approach was used to determine the willingness to pay (WTP)[4] of potential adopters. This approach has shown to provide respondents with a more market-like structure than a simple open-ended question directly eliciting WTP. DBCD extends the referendum format one step further to increase it's statistical efficiency and information intensity and lessen its sensitivity to poor initial bid settings or anchoring biases (HANEMANN, 1985). Under the DBCD contingent valuation approach the respondent is prompted to provide a yes or no response to a money bid amount contained in the valuation question, where the bid amount is varied across the respondents. If the respondent says 'yes' to the starting bid value, a higher bid is offered to him/her and if the respondent says 'no', a lower bid is offered.

It is assumed that farmers will be willing to pay a certain amount per hectare and adopt *Mt* on a given hectare if utility with the new income minus the cost of *Mt* is at least as high as utility without *Mt*. *Mt* will be evaluated against the individual farmer's previous choice, which should represent his/her optimal technology choice. Following HUBELL ET AL. (2000) and QAIM ET AL. (2003), formally, it will be assumed that a farmer adopts *Mt* only if the utility (benefit) the farmer receives is greater with adoption:

$$U(1, y_1 - P; x) \geq U(0, y_o; x) \tag{1}$$

Where 1 indicates *Mt* and 0 indicates the current agricultural practices, y_0 and y_1 are net income (profits) without and with *Mt*, respectively, and x is a vector of farm and farmer attributes that may affect the farmer's perceptions of *Mt* and WTP. Utility is only partially observable, implying that $U = V(i, y_i; x) + \varepsilon$, where $V(i, y_i; x)$ is the observable portion of the utility function associated with technology i and ε is a random variable with mean zero. The farmer's willingness to adopt at price P can then be expressed as:

$$V(1, y_1 - P; x) + \varepsilon_1 \geq V(0, y_0; x) + \varepsilon_0 \tag{2}$$

Where ε is assumed independent and identically distributed with $E(\varepsilon) = 0$. This is based on the assumption that the farmer compares his/her utility from the proposed *Mt* with the current agricultural practices and decides whether to accept or reject the offered price levels. It implies that the probability that farmer i will be willing to adopt *Mt* can be expressed as the difference of his/her utility functions with and without *Mt*. This means that:

$$\begin{aligned} \Pr ob(WTA = 1) &= \Pr ob\,[\, \varepsilon_1 \geq u_0 = v(0, y; x) + \varepsilon_0 \,] \\ &\equiv \phi_\varepsilon [\Delta v(.)] \\ &= 1 - \psi(.) \end{aligned} \tag{3}$$

[1] Additional factors such as education and age of the household head were initially included in the analysis but due to unsatisfactory results excluded later.
[2] Proxy for information access.
[3] Proxy for soil quality.
[4] We used the WTP approach as a proxy of adoption potential.

where ϕ_ε is the cumulative distribution function of ε, $\varepsilon = \varepsilon_0 - \varepsilon_1$, $\Delta v = v(1, y - P; x) - v(0, y; x)$ and $\psi(.)$ is the cumulative distributive function of the WTP.

The probability of the outcomes can be expressed using the bivariate probit model[5] as follows:

$$P_{yy}\left(Yes_1 \middle| bid_1,\ Yes_2 \middle| bid_2\right) = \phi_2\ \ (wtp_1 > bid_1, wtp_2 > bid_2, \rho)$$
$$P_{yn}\left(Yes_1 \middle| bid_1,\ No_2 \middle| bid_2\right) = \phi_2\ \ (wtp_1 > bid_1, wtp_2 < bid_2, \rho)$$
$$P_{ny}\left(No_1 \middle| bid_1,\ Yes_2 \middle| bid_2\right) = \phi_2\ \ (wtp_1 < bid_1, wtp_2 > bid_2, \rho)$$
$$P_{nn}\left(No_1 \middle| bid_1,\ No_2 \middle| bid_2\right) = \phi_2\ \ (wtp_1 < bid_1, wtp_2 < bid_2, \rho)$$

where ϕ_2 is the joint bivariate normal cumulative distribution function.

The farmer evaluates *Mt* as one of four possible dichotomous outcomes $\{(yes_1, yes_2)(no_1, yes_2)(yes_1, no_2)(no_1, no_2)\}$. In the double bounded dichotomous choice the likelihood of the sample is estimated using the following;

(4) $$LL = \sum_{i=1}^{n} n_{yy} Log(\Pr_{yy}) + n_{yn} Log(\Pr_{yn}) + n_{ny} Log(\Pr_{ny}) + n_{nn} Log(\Pr_{nn})$$

where $n_{yy}, n_{yn}, n_{ny}, n_{nn}$ are the number of farmers in the sample who answer with the four alternatives to the first and the second bid offers.

4 Methods

4.1 Description of the study area: The Bragantina Region

The Bragantina Region is located in the north east of the state of Pará (Brazil) to the east of the state capital Belém. Compared to other parts of the Brazilian Amazon the region is special due to its location and history. For the analysis presented here, three aspects of this distinctiveness deserve our attention: First, the proximity to the state capital presents an exclusive position in terms of access to regional and some national and international markets. Moreover, the districts are comparatively well connected through a system of mainly paved roads and population density is higher and more stable than at the agricultural frontiers of the Amazon. Second, most of the areas suitable for agriculture have been cultivated at differing levels of intensity for more than 40, sometimes 100 and more years (PENTEADO, 1967). Consequently, the dominant small-scale or so-called family farming systems[6] are fallow-based and/or rely heavily on external nutrient sources. The humid tropical climate is influenced by the Atlantic Ocean and soils are considered rather homogeneous, while quality differs according to land use history and, at the micro level, the dominant oxi- and ultisols are occasionally associated with sandy soils (FALESI, 1967; DA SILVA AND CARVALHO, 1986). Lastly, although commercial farms and cattle holdings expand, the region can still be called culturally homogeneous. In the past decade and besides the continuous popularity of slash and burn agriculture[7], farmers opted for essentially two strategies of capital demanding intensification, either through the cultivation of permanent and semi-permanent crops,

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[5] The discussion for the selection of bivariate probit model is under section 4.3.
[6] We broadly define family farms as operational holdings up to 100ha. In our study region almost 70% of the farms fall into this category.
[7] Here defined as fallow based farming system on a continuous piece of land, on which the fallow vegetation is regularly cut down and burned for a 1 to 2 year period of production.

such as black pepper or passion fruit, or in to a lesser extent through the use of mechanization in the cultivation of annual crops, e.g. beans, cassava and corn. Both strategies require external inputs like fertilizers and/or pesticides, because the traditional fallow is practically abolished as a natural nutrient source. Meanwhile, many poor farmers intensify the traditional system by shortening fallow periods, which, in the absence of external nutrient supply, results in decreasing agricultural yields.

4.2 Data Set and Survey Implementation

The analysis presented in this paper is based on primary data, which were collected from 270 farmers. The survey was carried out from October 2002 to December 2002, covering the 2001/2002 cropping season. The sampling was done in two stages including stratification in the first and random selection in the second stage. Three districts were selected that captured regional differences in distance to the capital, degree of intensification, institutional environment and intensity of the dry season. Households were selected randomly from randomly selected communities in each district.

To implement the DBDC approach, a pre-tested survey questionnaire was conducted. Our questionnaire included questions regarding farming systems and farm-household characteristics among other questions. Turning to the dichotomous choice contingent valuation question, the farmers were asked if they already heard about fire-free agricultural practices, then we asked their opinion about those technologies and we turned to the explanation of *Mt,* which included a set of advantages and disadvantages.

We explained that *Mt* would be implemented with a tractor driven bush-chopper and that it implies the use of fertilizer during the first year. Once the technology was explained we asked if he/she will be willing to experiment *Mt* at *x* price (initial bid)[8] per tarefa[9] and we included a follow up question: if a farmer had accepted the initial bid amount, he/she was asked to pay Reais (R$) 10 more than the first bid; if not, the follow-up bid was R$10 less than the initial bid.

4.3 Econometric Analysis

As mentioned above, we opted for the DBDC approach. Under such elicitation procedure, we have two discrete responses from every farmer i.e., responses to the first and second bids. This means that neither a continuous nor a simple dichotomous model can be used to analyse the response of the farmers. Also, since the second response is not unrelated to the information provided in the first response, estimating the two responses independently or pooling them together to estimate a single equation may lead to invalid results (ABAY, 2003). Therefore we used the bivariate probit model, which is one of the most appropriate methods to deal with two dichotomous and related responses (CAMERON AND QUIGGIN, 1994; AN AND AYALA, 1996; GREENE, 1997). We used a log-linear model because this fitted the data better than the linear model. Therefore, the variables to measure the potential adoption are tested by estimating the following equations:

(5)

$$Y_1 = \beta_0 + \beta_1 * \log(bid) + \beta_2 * income + \beta_3 * householdsize + \beta_4 * tenurestatus + \beta_5 * fertilizeruse + \beta_6 * knowledgefirefree + \beta_7 * farmsize + \beta_8 + soilquality + \varepsilon_1$$

[8] The bid values varied across farmers (ranged from R$60 - R$150) and were randomly assigned.

[9] 1 Tarefa = 0.33 Hectare

$$Y_2 = \alpha_0 + \alpha_1 * \log(bid) + \alpha_2 * income + \alpha_3 * householdsize + \alpha_4 * tenurestatus + \alpha_5 * fertilizeruse + \alpha_6 * knowledgefirefree + \alpha_7 * farmsize + \alpha_8 * soilquality + \varepsilon_2$$

The description of the variables included in the analysis is presented in Table 1. It follows a discussion of the hypothesized relationships of the explanatory variables to the potential adoption of *Mt*.

Table 1: Description of variables and hypothesized effect on the potential adoption of *Mt*.

Variable	Description	Expected sign
Social factors		
Household size	Family size of the farm household	+/-
Institutional factors		
Tenure status	Dummy variable for tenure status of the farmer =1 if the operated farm is owned =0 otherwise	+
Knowledge fire-free practices	Dummy variable for knowledge of fire-free practices =1 if the farmer has any knowledge of fire-free practices =0 otherwise	+
Economic factors		
Predetermined bid (R$)	Randomly varied across respondents in the interval {60 to 150 R$} with bid sets of 60, 70, 80, ….150.	-
Income	Household income (includes revenue of crop production and cattle production + off-farm income)	+
Fertilizer use	Dummy variable for fertilizer use =1 if the farmer reported any use of fertilizer =0 otherwise	+
Biophysical factors		
Farm size	Total operated farm area (ha)	+
Soil quality	Dry weight (biomass) from rice obtained from a biological test for soil fertility (grams)	+/-

Expected sign: (-) an increase in the explanatory variable is hypothesized to decrease the dependent variable; (+) an increase in the explanatory variable is hypothesized to increase the dependent variable; (+/-) hypothesized effect could take either sign.

Social factors: Household size could be seen in two ways. It could have either a positive or negative impact on the *Mt* potential adoption. On the one hand, the larger the family size, the higher the probability that future generations will farm the land and reap the long-term benefits of *Mt*. On the other hand, it could reflect the need for supplemental income for family living expenses and since the *Mt* is a capital-intensive and labor saving technology, one can expect a decrease in the probability that a farmer will adopt *Mt*.

Institutional factors: The tenure status of the farmer normally plays a significant role in the potential adoption of *Mt* and was expected to be positively related. If the farmer has no secure tenure status it is less likely he/she that will make conservation investments, than in the case of ownership. Therefore, farmers with insecure tenure may not be willing to adopt *Mt* due to uncertainty about capturing the long-term benefits. Knowledge of fire-free agricultural practices was seen as a factor that positively affects potential adoption. If a farmer is not familiar with fire-free practices it is less likely that he/she will potentially adopt *Mt*.

Economic factors: Among the economic factors, the predetermined bid value was expected to have a negative effect on potential adoption of *Mt*, the higher the bid values the lower the probability of farmers to pay the offered bids. Income was expected to be positively related to potential adoption, i.e. higher income would give the farmer opportunities to invest in *Mt*. The use of fertilizer was also expected to be positively related to potential adoption. *Mt* as a technology package implies the use of fertilizer during the first year, therefore farmers already using fertilizer are more likely to adopt *Mt*. Besides, the size of the farm can influence the decision of farmers to invest in *Mt*. Studies from developed countries show that larger farms are more likely to use conservation technologies than smaller farms (e.g. ERVIN AND ERVIN 1982).

Biophysical factors: The role of soil quality was thought to be ambiguous. It could indicate that a farmer under favorable soil conditions is more likely to adopt *Mt* due to high yield expectations or it could reflect the need of alternative agricultural practices due to the trend of agricultural intensification by shortening fallow periods, which, in the absence of external nutrient supply, results in decreasing agricultural yields. In this case, a farmer with poor soil quality will potentially adopt *Mt* in order to increase agricultural yield.

5 Results of the Econometric Analysis

We were interested in the factors that affect the decision of farmers to experiment *Mt* (to pay the first bid, the second bid, or both). Therefore, an attempt was made to determine the impact of various variables on the willingness of farmers to adopt *Mt* (measured by the WTP). First a descriptive analysis was used to investigate if there are any statistically significant relations between the social, institutional, economic and biophysical characteristics of the farmers and their responses to both the first and second bids. Next, a regression analysis was done to net out the impact of each variable on the WTP decision of farmers. Table 2 presents summary statistics of the variables included in our analysis. The results for the descriptive analysis are shown in Table 3.

Table 2: Summary Statistics

Variables	Mean	Standard Deviation
Social factors		
Household size	6.177	2.783
Institutional factors		
Tenure status (dummy)	0.649	0.478
Knowledge fire-free practices (dummy)	0.877	0.328
Economic factors		
Income (R$)	9390.915	11743.817
Fertilizer use (dummy)	0.741	0.438
Biophysical factors		
Farm size	21.174	28.284
Soil quality indicator	2.293	0.688

Table 3: Cross tabulation of WTP decisions and various socio-economic factors

Variables		WTP the 1st bid		WTP the 2nd bid	
	Mean[10]	%	ANOVA[11] F-values	%	ANOVA[8] F-values
First bid (initial bid)	104.944 (28.737)				
Lower bid (offered to those not WTP the first bid)	94.944 (28.737)				
Higher bid (offered to those willing to pay the first bid)	114.944 (28.737)				
Second bid (the lower of higher bid)	108.450 (30.218)				
WTP the first bid	0.675				
WTP the second bid	0.671				
WTP the first and the second bid	0.571				
WTP the first but not the second bid	0.103				
Not WTP the first but WTP the second bid	0.096				
Not WTP the first and the second bid	0.225				
Income quintile					
1st quintile (lowest)		58.18		47.27	
2nd quintile	9390.915	55.56	4.545	66.67	5.079
3rd quintile	(11743.817)	64.81	(0.001)*	72.22	(0.001)*
4th quintile		70.37		66.67	
5th quintile (highest)		88.89		83.33	
Tenure status			0.097		0.738
Owner status	0.649	68.181	(0.755)	65.340	(0.391)
Not owner status	(0.478)	66.315		70.526	
Fertilizer use			7.706		15.245
Use any fertilizer	0.741	72.139	(0.006)*	73.134	(0.000)*
Not use of fertilizer	(0.438)	54.285		50.000	
Knowledge of fire-free practices	0.877		11.038		4.842
Have any knowledge	(0.328)	70.886	(0.001)*	69.620	(0.029)**
Does not have knowledge		42.424		48.484	

Note: The figures are for 2002. The exchange rate was 1 U$=3.843 Reals
* significant at 1%; ** significant at 5%

Out of the total respondents who are willing to experiment *Mt*, 67.5 percent are willing to pay the first bid and 67.1 percent the second bid. 57 percent are willing to pay the first and the second bid, 10.3 percent would accept only the first bid and 9 percent only the second bid. That means that approximately 77 percent of the farmers are willing to pay either the first or the second bid and the remaining 23 percent are not willing to pay both the first and the second bids.

We did not find any statistical difference between farmers having secure tenure status and farmers that do not have tenure status in accepting the first (ANOVA=0.755) and the second (ANOVA=0.391) bids. Fertilizer use has a statistically significant positive impact on the willingness to adopt *Mt* at both the first and the second bids. Out of all farmers surveyed, around 70 percent who have knowledge of fire-free practices are WTP the first and second bid and, as can be seen from Table 3, we found a statistically significant difference between farmers with certain knowledge of fire-free practices and those who did not report any knowledge in accepting both bids.

[10] Standard deviation in parentheses
[11] Numbers in parentheses are significance levels of the F-test.

Income is one of the most important variables that affect the decision of farmers to answer affirmatively to the first and the second bids. For instance, nearly 58.18 percent of farmers in the highest quintile are willing to pay the first bid compared to 88.89 percent in the lowest quintile. The difference is slightly higher in the case of WTP of farmers to pay for the second bid.

The descriptive analysis, however, does not give a clear picture of the influence of each variable since it is difficult to control the impact of the other variables. Therefore, equation (5) is maximized to determine the estimates of the bivariate probit model and the results are presented in Table 4. The first and second columns show the impact of each variable on the decision of farmers to pay the first bid and (given the response to the first bid) the second bid, respectively. The last column displays the combined marginal effects (i.e. marginal effect on WTP the first bid and marginal effect on WTP the second bid) of each variable.

Table 4: Estimates of bivariate probit model[12]

Variables	Effect on WTP the 1st bid	Effect on WTP the 2nd bid	Combined marginal effects[13]
Constant	-4.744	-1.006	
	(1.740)*	(1.600)	
Household size	0.066	-0.023	
	(0.033)**	(0.031)	
Tenure status	-0.217	-0.508	-0.131
	(0.194)	(0.196)*	(0.061)**
Knowledge fire-free practices	0.800	0.441	0.261
	(0.267)*	(0.255)	(0.093)*
Log income	0.349	0.323	0.128
	(0.000)*	(0.100)*	(0.033)*
Fertilizer use	0.448	0.501	0.187
	(0.208)**	(0.202)**	(0.072)*
Farm size	0.003	0.011	0.002
	(0.004)	(0.005)**	(0.001)**
Soil quality	0.441	0.067	0.098
	(0.145)*	(0.134)	(0.046)**
Log bid	-0.013	-0.452	
	(0.308)	(0.300)	
ρ (1,2)	0.808		
	(0.063)*		
Log lik. Function	-235.800		

* significant at 1%; ** significant at 5%

All estimated coefficients had signs consistent with expectations excluding the tenure status variable that has taken an unexpected negative sign; and, with the exception of the coefficients of the bid value and household size variables all other coefficients were statistically significant at the 5 % level or better. Thus, increases in household income, farm size and soil quality were more likely to increase the probability that a farmer would be willing to pay the offered bids. In the same line, fertilizer use and knowledge of fire-free practices augmented the probability as well.

To get a better perspective on the response of WTP to changes in the explanatory variables, marginal effects evaluated at the means of explanatory variables are given. Thus, keeping all other factors constant, tenure status has taken an unexpected sign but it is significant only in the case of the second bid, meaning that being landowner decreases the probability of adopt *Mt*. This

[12] Standard errors in parentheses

[13] The marginal effects are shown only for significant variables. They are computed at the means of explanatory variables. For dummy variables, the change in probability is calculated due to the change in the value of independent variable from 0 to 1.

result can be due two reasons. First, consistent with the findings of the descriptive analysis, there is no statistically significant difference between farmers with and without secure tenure status in accepting to pay the offered bids. This indicates that the tenure status variable is not necessarily best interpreted as signifying that insecurity leads to non-adoption of *Mt*, in this case tenure status matters little in a farmer's decision to invest in *Mt*. Second, non-landowners may consider *Mt* as one way to increase agricultural production and investments in soil quality might be a way to secure access to land as well. We hope to get further insight to that issue by disaggregating the land tenure variable into different types of tenure right, but in general the tenure status is not such a big issue in the Bragantina Region than elsewhere.

Knowledge of fire-free agricultural practices has some effect on the WTP decision, especially on the first bid. Farmers with certain knowledge of fire-free practices are more willing to pay the first bid than the farmers who do not have any knowledge. This could be explained by the fact that the majority of farmers reporting knowledge of fire-free practices stated also the use of tractors for land preparation. Therefore, one can assume that farmers familiar with the use of tractors are more likely to adopt *Mt* since the technology is based on the use of a tractor-driven bush chopper.

Ceteris paribus, fertilizer use has a strong impact on both decisions (to accept the first and second bid). This means that farmers using fertilizer have a higher probability to answer positively to the WTP questions. It is important to remark that use of fertilizer is one of the premises of the *Mt* and as expected, farmers using fertilizer are more likely to adopt *Mt* than farmers who do not use any fertilizer. Everything else constant, a unit increase [14] in the soil quality of farmers is likely to increase the probability of accepting the first bid and (given the first response) the second bid by 9.8 percent. This can be explained by higher expected yields due to favourable soil conditions. This result has a strong impact suggesting that farmers in our study area are aware of the problem of decreasing agricultural productivity and they are likely to adopt *Mt* given the current soil quality conditions they have.

Keeping other factors constant, a unit increase in farm size increases the probability of farmers willing to pay for the second bid by 0.2 percent. This implies that farmers with larger holdings are more likely to adopt *Mt*. This can be attributed to the labor saving nature of *Mt*. A farmer with more land availability would be more willing to use *Mt* since the time for land preparation is reduced. Like in many contingent valuation studies, income has a positive, consistent, and statistically significant impact on the willingness of farmers to pay the first and the second bids. A one percent increase in income, ceteris paribus, increases the probability of farmers' willing to pay for the first bid and (based on the response to the first bid) the second bid by 12.8 percent.

Albeit not statistically significant, the bid values have a negative effect in line with the theory of demand, suggesting that the probability to accept both the first and the second bid decreases in 0.2 percent as the price increases in one percent. However, since the bid values were not statistically significant in explaining the WTP decisions, we can imply that the farmers in our survey were not sensitive to the price of *Mt* in comparison to other variables such as income, farm size, fertilizer use, soil quality and knowledge of fire-free practices. This result indicates that the prices offered to the farmers were low in relation to the prices they might be able to pay.

[14] A unit increase in biomass that ranged from 0 - 4.639 grams of dry weight.

The value of ρ[15] is very high and highly significant in our specification. This indicates that the second decision is endogenous in the system and if individual probit models are estimated, the results will be inefficient (GREENE, 1997).

6 Discussion and Conclusions

This paper reported the results of a contingent valuation survey that estimated the determinants of willingness to adopt *Mt* in the Eastern Amazon Region of Brazil. Farmers were surveyed using the double bounded dichotomous contingent valuation approach.

We analysed the second stage of the farmer's decision-making process (namely, adoption potential) and identified the variables determining the adoption potential of *Mt*. The assessment of the boundary conditions was simplified to the identification of those variables we hypothesized as being important triggers of the WTP decision. The model showed that institutional factors (i.e. knowledge of fire-free practices); economic factors (i.e. income and fertilizer use) and, biophysical factors (i.e. farm size and soil quality) were important variables in explaining the decision to potentially adopt or not *Mt* either explaining the positive answer to the first, to the second or to both bids. Land tenure security was found not to be major constraint on *Mt* adoption potential.

The empirical findings in the model representing the stage of potential adoption can be useful in developing and targeting policy strategies for the promotion and diffusion of *Mt*. Some of the possible policy approaches to promote soil and secondary vegetation conservation through *Mt* might include the voluntary compliance through education/extension services. For example, since knowledge of fire-free practices is an important factor determining the willingness to adopt, information campaigns through cooperatives, trade unions, radio, exposure through demonstration etc. might encourage farmers to adopt *Mt*. Land tenure security was found not to be a major constraint on *Mt* adoption potential, hence e.g. credit programmes that would support technology adoption should not be implemented on the basis of title deeds.

Further analysis is needed to identify which factors determine each stage of the farmer's decision-making process, as indicated in the conceptual framework since the potential adoption process and the adoption itself are dynamic and the importance of specific factors varies as farmer move from one stage to another.

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[15] The rho (ρ) statistic is the correlation between error terms in both equations.

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