THE DETERMINANTS OF ADOPTION OF SUSTAINABLE AGRICULTURE TECHNOLOGIES: EVIDENCE FROM THE HILLSIDES OF HONDURAS

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ABSTRACT

Recent years have seen a growth of interest in the adoption and diffusion of low-input sustainable agricultural technologies among smallholder agriculturalists in developing countries. This paper examines the adoption of one such technology, *labranza mínima,* a form of minimum tillage, among resource-poor agricultural households in villages in central Honduras. Logistic regression is used to analyze the determinants of adoption of minimum tillage among a sample of 250 agricultural households. The results show that plots with irrigation, plots farmed by their owners and plots with steeper slopes were more likely candidates for minimum tillage adoption. Farmer household characteristics are not generally found to represent significant influences on adoption. Importantly, household income does not appear to be a determinant of adoption, suggesting that minimum tillage is an appropriate low-input technology for resource-poor households. The results also indicate that previous use of leguminous cover crops, soil amendments (including chemical fertilizers), and commercial vegetable production are all associated with minimum tillage adoption. Results from studies like this are useful in targeting low-input technologies and programs promoting them among the farm household population.

Keywords: technology adoption, sustainable agriculture, minimum tillage

Sustainable agricultural systems have been characterized as those that can "indefinitely meet demands for food and fiber at socially acceptable economic and environmental costs" (Crosson, 1992). Producers, researchers and non-governmental organizations (NGOs) have increasingly sought to identify, validate and implement practical farming technologies and methods which meet "sustainability" criteria, although the challenges of doing so have been great. This has been especially true in developing countries where chronic rural poverty is often closely linked to a rapidly degrading resource base.

In Honduras, a small, mountainous country in Central America which is ranked among the Western Hemisphere's poorest, hillside farmers face many of the same problems found elsewhere in the developing world. Degraded soils and increasing land scarcity have make the traditional slash-and-burn farming system increasingly inefficient. Production increases of the two main staple foods, maize and beans, have historically been below that of population growth (CIMMYT, 1992), threatening household food security. Modern technologies such as improved varieties and chemical inputs have helped spur yields among some farmers, but these do not prevent erosion nor do many farmers possess the financial resources to use them. With increasing population and decreasing availability of new land to exploit, maintaining adequate fallows has become increasingly difficult and continuous cropping has become commonplace. This has resulted in a "vicious cycle" of soil degradation, crop yield declines, further pressure on available lands to generate required food supplies, and often, migration out of agriculture.

To address the many constraints faced by resource-poor hillside farmers, development NGOs and other organizations have increasingly promoted limited external input or "sustainable" agriculture technologies such as conservation tillage and the use of leguminous cover crops. It is widely believed that these low-cost innovations, not requiring large capital investments and relatively easy to implement, can help poor farm households become more productive by improving fallow management and increasing yields.

While the interest in these low-cost innovations among local NGOs and development organizations has been intense, relatively little work has been done to formally examine the socio-economic factors that may influence the adoption and diffusion of these technologies. This is the focus of this study – the assessment of the determinants of adoption of "sustainable agriculture" practices among a sample of Honduran hillside farm households. In addition to providing insights regarding agricultural sustainability on Central American hillsides, the results have implications for more effectively evaluating, targeting and disseminating these technologies in the future.

ADOPTION OF SUSTAINABLE AGRICULTURE TECHNOLOGIES

Economists have devoted great attention traditionally to the technology adoption process at both individual farmer and aggregate levels (Feder, Just and Zilberman, 1982, etc.). At the individual farmer level, considerable work has focused on identifying biophysical, human capital and economic determinants of adoption of modern agricultural innovations such as high-yielding "Green Revolution" varieties and complementary inputs such as irrigation, fertilizers and pesticides. However, while the adoption of low external input technologies has received considerable attention in developed countries (see, for example: Rahm and Huffman, 1984; Smit and Smithers, 1992; and Weersink, et al, 1992), in the developing world, research has been significantly less, especially compared to the importance of these systems among farmers globally.

There are exceptions to this dearth of analysis. Anderson and Thampapillai (1990) found that a wide variety of factors including land tenure arrangements, access to credit and farmers' risk attitudes influence soil erosion and the rationality of adopting soil conservation practices among farmers. Hwang, et al. (1994) also suggested that poor access to credit and lack of secure tenure, as well as low output prices, were limiting the adoption of soil conservation practices among farmers in the Dominican Republic. In the case of the Philippines, farmers recognized the soil-regenerating and erosion-limiting properties of cover crops or "green manures," but declined to plant them because of additional labor expense (Fujisaka, 1993). Other studies have, for farmers in various locations, onfirmed the influences on technology adoption of factors related to underlying farm characteristics (Polson and Spencer, 1991; Nkonya, et al., 1997; Clay, et al, 1998), economic and labor market factors (Feder, et al., 1992; Fujisaka, 1993; Neill and Lee, 2001), demographic and human capital variables (Sureshwaran, et al., 1996; Shively, 1997), and social and institutional variables.

In the hillside agriculture systems of Central America, the focus of this study, recent research has partially addressed these and similar issues. One particular system -- the maize-*mucuna* (velvetbean) system of the North Coast region of Honduras -- has received the attention of several researchers including Ruben (1997), Buckles, Triomphe and Sain (1998), and Neill and Lee (2001). However, the conditions influencing this "success story" among sustainable agriculture systems are fairly unique and it is difficult to generalize this well-known example to elsewhere in the region.

MODELING SUSTAINABLE AGRICULTURE ADOPTION IN THE HONDURAN HILLSIDES

In the research reported here, 256 farm households (both adopters and non-adopters) farming 388 plots distributed over 16 communities in Central Honduras were interviewed with the goal of identifying the key factors influencing their adoption of several sustainable agriculture practices. These farmers are almost universally smallholders, poor, and have been the target of extension and development efforts by various NGOs in recent years. Table 1, drawn from the survey, summarizes the various "sustainable" practices which were identified as practiced by substantial numbers of farmers. These range from the practice of simply avoiding burning their fields (95%) to the construction of stone conservation barriers (10%). Of particular interest here is *labranza mínima* or minimum tillage, which in this region includes a set of practices including contour planting, incorporation in the soil of manure and other organic matter, and greater density of maize seed planting. Nearly 30% of the sample households engaged in this set of practices, which has been widely promoted by NGOs. Another practice of particular interest to this research is the planting of leguminous cover crops or "green manures" to improve fallow management, soil qualilty and crop yields.

Table 1. Adoption of Sustainable Technologies and Practices in Central Honduras[1]

Technology or Practice	% of Sample Plots Where Practice Was Adopted (n=388)
No longer burning	95
Labranza mínima	29
Applying animal manure to maize plots	10
Planting green manure in maize plot	11
Live soil conservation barriers	17
Stone soil conservation barriers	10
Drainage ditches for soil conservation	17

[1] Table does not reflect adoption rates of all farmers in the Cantarranas area since *labranza mínima* adopters were selected using a choice-based sampling strategy.

Table 2. Yields for Cantarranas Maize (Quintales/Hectare)*

Plot Type	Mean	Std. Dev.	Median
All	16.61	13.40	14.29
Conventional	14.84	11.79	12.87
Labranza mínima	20.85	15.90	17.14
Green Manure	22.80	13.78	22.86

*One quintal = 100 lbs.

Table 2 shows the variation in maize yields from the sample survey. While yields are quite low overall, the use of *labranza mínima* practices resulted in a roughly 40% increase in yields above those obtained from conventional tillage practices. The use of green manures and cover crops, although confined to a smaller set of adopters, resulted in even higher yields compared to conventional practices. In trying to understand the factors at work in influencing these differential outcomes, Table 3 shows a comparison of key summary statistics from *plots* (not households) using traditional maize and bean cultivation and those employing *labranza mínima* practices. It is clear that the latter were generally smaller in size, more commonly irrigated, more likely to be owned, and more typically characterized by medium or steep slopes. Of the 256 households in the survey, 105 practiced *labranza mínima* on some or all of their plots, while 151 households did not. Heads of households which employed *labranza mínima* technologies were more likely to be literate (77% vs. 68%), had received more schooling (2.8 vs. 2.1 years), were less likely to have recently migrated to the area (11% vs. 20%), and these households were far more likely to have been visited by an extensionist in the year prior to the survey (72% vs. 22%). Further survey details are provided elsewhere (Authors, 2001).

Table 3. Plot Characteristics.

Variable	Conventional Plots (n = 275)	*Labranza mínima* Plots (n = 113)
Size[c]	.79 Ha.	.42 Ha.
Irrigated (Yes = 1)[b]	12%	35%
Tenure Status:		
Owned (Yes = 1)[b]	65%	89%
Rented (Yes = 1)[b]	27%	11%
Borrowed (Yes = 1)[b]	8%	0%
Land Quality:		
Good (Yes = 1)	39%	32%
Fair (Yes = 1)	55%	61%
Poor (Yes = 1)	6%	6%
Slope:		
Flat (>10% slope, Yes = 1)[b]	34%	20%
Medium Sloped (10-40%, Yes = 1)[a]	52%	63%
Steeply Sloped (>40%, Yes = 1)[b]	13%	17%

[a] Difference significant for z-test of binomial proportions at ∀ = .05

[b] Difference significant for z-test of binomial proportions at ∀ = .01

[c] Difference significant for two-sample t-test at ∀ = .01

The determinants of adoption of (1) *labranza minima* practices and (2) the use of cover crop/green manures were analyzed econometrically using the cumulative logistic probability function or "logit" approach. This approach assumes that the dichotomous choice of whether or not to adopt the technology on each plot (yes = 1; no = 0) can be represented by a logistic regression model which explains the probability of adoption (Greene, 1996) as:

$$\textbf{Probability of adoption} = \mathbf{P(y = \mathit{1})} = \frac{\mathbf{e}\beta_0 + \beta_1 x_i}{\mathbf{1} + \mathbf{e}\beta_0 + \beta_1 x_i}$$

The "logit" transformation of the probability of adoption, P(y = 1) can be represented as

$$\mathbf{log\ [P(y = 1)\ /\ (1 - P(y = \mathit{1}))]} = \beta_0 + \beta_1 x_i$$

which gives the logarithm of the "odds" of technology adoption conditional on the various explanatory variables influencing adoption. The variables which were here hypothesized to influence adoption are summarized in Table 4, as are the expected signs in the adoption equations. Most of the expected signs follow from the previous literature and the authors' familiarity with hillside agriculture in Central Honduras; space constraints do not permit elaboration here (for further details, see Authors, 2001).

Table 4. Definition of Variables for Adoption Study.

Variable	Description	Expected Sign
Dependent variable:	Sustainable agriculture technology adopted on plot: 1 = yes; 0 = no	N/A
Farmer Characteristics		
AGE	Age of farm household head (years)	-
EXPER	Farming experience (years)	+
EDUC	Formal education (years)	+
TOTALINC	Annual household income (Lempiras, 1992 base)	?
Plot Characteristics		
Y1PRED	Probability of adopting *labranza mínima* (0 # Y1PRED # 1)	+
IRRIGATE	Plot has irrigation: 1 = yes; 0 = no	+
OWN	Producer owns plot land: 1 = yes; 0 = no	+
MEDSLOPE	Plot slope 10 – 40%: 1 = yes; 0 = no	+
MUYSLOPE	Plot slope > 40%: 1 = yes; 0 = no	+
QUALITY	Farmer considers land "fair" or "poor" for crops: 1 = yes; 0 = no	+

One distinctive aspect of this analysis is that in order to estimate the conditional probability of adopting a subsequent technology, an estimate of the probability of adopting *labranza mínima* (variable Y1PRED) was used as a regressor in the equation for cover crop adoption. Because decisions to adopt several innovations may be simultaneous, using actual observations of adoption or non-adoption of *labranza mínima* may lead to correlation with the error term in subsequently estimated models. To avoid this problem and the inefficient coefficient estimates which result, an instrumental variable approach was followed, where the predicted value from the *labranza mínima* adoption was included as a regressor in the subsequent adoption equation for cover crops/green manures.

The underlying hypothesis (confirmed by field observations and discussions with NGO representatives) is that farmers view *labranza mínima* as a "first step" to the adoption of a wider set of sustainable agriculture practices, and they may be more amenable to recognizing the benefits of and then adopting other technologies.

EMPIRICAL RESULTS AND CONCLUSIONS

Table 5 shows maximum likelihood estimates of the logistic regression models, estimated odds ratios, measures of goodness-of-fit and changes in probabilities associated with each coefficient. All of the nine estimated coefficients in the *labranza mínima* adoption model exhibit the expected signs and six are significant at the 10% level or better. The coefficient of age of head of household (variable AGE) is negatively associated with adoption, indicating some lack of receptivity of older farmers toward newly introduced technologies. The coefficient measuring the availability of irrigation (IRRIGATE) is positively signed and significant, with adoption (as measured by the odds ratio) more than four times as likely with irrigation available than without. (In fact, lack of water and irrigation potential is widely considered as the key constraint to sustainable agriculture adoption in hillside agriculture in Honduras). Plots which are owned (variable OWN) are also more than four times as likely to employ *labranza mínima* techniques, most likely because the security of land access is necessary to induce farmers to make the necessary investments in their land. Increased adoption is also estimated to be positively associated with plot steepness (variables MEDSLOPE and MUYSLOPE) and negatively with land quality (QUALITY), indicating that this technology is indeed "appropriate" for hillside farmers, as promoted by NGOs and other development organizations. Farmers are able to reduce risk exposure by trying new techniques on their more marginal lands, typically sloped, relatively less productive parcels (at least initially) adjacent to their residences. Farm household income is not a significant determinant of adoption, contrary to the results of most studies of "Green Revolution" and related technologies. This appears to confirm that *labranza mínima* techniques are indeed accessible to resource-poor farmers regardless of differences in income levels.

The estimation equation for the cover crops adoption equation shows, as expected, that the coefficient of the instrumental variable representing *labranza mínima* adoption is positive and significant; the presence of *labranza minima* increases the odds of adopting green manures over six times. In fact, both are promoted by NGOs to hillside farmers as low-cost technologies providing multiple benefits. Plot ownership yields a positive and significant coefficient, consistent with the fact that farmers typically view green manuring as a long-term investment in soil improvement, the benefits of which are more likely to be realized with land ownership. Neither farmers' age, experience or income levels are estimated to have a uniquely distinguishable effect on green manure adoption (as distinct from their effects already incorporated in the instrumental variable). Again, in the case of the income variable, this seems to confirm the underlying "appropriateness" of the technology among a wide variation of resource-poor farmers.

Table 5. Maximum Likelihood Estimates and Goodness-of Fit Measures for the *Labranza Mínima* Model.

Variable	Coefficient	Odds Ratio	t-Ratio	Change in probability
Constant[a]	-2.7980		-3.993	
AGE[c]	-0.0329	0.72	-1.677	-0.0154
EXPER	0.0277	1.32	1.455	0.0170
EDUC	0.0786	1.08	1.204	0.0004
IRRIGATE[a]	1.5416	4.67	4.944	0.1642
OWN[a]	1.4916	4.44	4.148	0.1557
MEDSLOPE[b]	0.7567	2.13	2.489	0.0575
MUYSLOPE[a]	1.1316	3.10	2.691	0.1015
QUALITY[c]	0.4771	1.61	1.732	0.0320
TOTALINC	0.1404(x10^{-4})	1.01	0.510	0.0007

Hosmer-Lemeshow Test: 3.19 (p = .922)[*]
Likelihood Ratio Test: 66.19[a]
(%) Correct Predictions: 283 (75%)
Note: Explanation of signficance levels (a)-(c) follows at end of Table 6.

Table 6. Maximum Likelihood Estimates and Goodness-of Fit Measures for Cover Crop/Green Manure Adoption.

Variable	Coefficient	Odds Ratio	t-Ratio	Change in probability
Constant[a]	-3.9949		-3.851	
Y1PRED[c]	1.8603	6.43	1.797	0.0877
AGE	-0.0240	0.98	-0.764	-0.0004
EXPER	0.0178	1.02	0.604	0.0003
OWN[c]	1.2954	3.65	1.872	0.0450
QUALITY[b]	1.0735	2.93	2.381	0.0330
TOTALINC	0.7236 (10^{-5})	1.00	0.233	0.0000
Hosmer-Lemeshow Test: 0.24 (p = .889)				
Likelihood Ratio Test: 28.07 [a]				
# (%) Correct Predictions: 335 (89%)				

[a] Indicates significance at ∀ = 0.1
[b] Indicates significance at ∀ = 0.5
[c] Indicates significance at ∀ = .10

The results of this analysis show that adoption of conservation tillage and cover crops practices are influenced primarily by maize plot characteristics, including irrigation, plot ownership, plot slope and perceptions of soil quality. Assured land access in the form of plot ownership, as in prior studies, is confirmed as highly important in influencing adoption. Unlike many studies of adoption of Green Revolution technologies, however, human capital variables and farm household incomes appear to play a reduced role in influencing adoption. In part this is likely due to the simple to understand, low-cost nature of these technologies. Also, their aggressive promotion by local NGOs and development organizations, and the innovative farmer-led extension methods which have been widely employed by these organizations.

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