Soil Conservation Decisions and Upland Corn Productivity: A Philippine Case Study

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ABSTRACT

This paper empirically investigates whether farmers who adopt soil conservation measures derive productivity gains. A twelve-year (1994-2006) panel data in Bukidnon, Philippines was used to quantify the indirect relationship between soil conservation technology adoption and upland corn productivity. A two-stage econometric analysis was done. First, the probability of adoption was estimated. The associated inverse Mill's ratio obtained from the first stage was used to correct the second stage endogenous switching stochastic frontier model estimation of the determinants of corn yield.

Results showed that in normal times, upland corn productivity is positively affected by abatement of soil erosion. Results further suggest that farmers adopting soil conservation technologies become less flexible in their land use decisions during periods of drought, thereby experiencing lower yields than the non-adopters.

INTRODUCTION

As agriculture intensifies due to increased demand and open trade, degradation of the natural resource base that supports it is commonly observed. This is especially true for upland agriculture in the Philippines which has been identified as one of the causes of environmental degradation. Associated with degradation are externalities that affect downstream agricultural systems. Although part of these externalities are internalized by upland farmers in terms of productivity losses, efforts to quantify these losses are scanty. While agricultural research investments address these externalities, their corresponding impact in mitigating such losses are unknown most of the time. Additionally, what has not been studied so far, at least in the Philippines, is the impact of adoption of soil conservation on crop yields in times of climate change.

Focus and Scope of the Study

Upstream analysis is confined to upland corn production, the dominant crop cultivated in the upland farms in the Philippines. Corn production, given adoption of inappropriate techniques, leads to environmental problems partly internalized by farmers as it affects their production. Among these are water sedimentation, accumulation of inorganic substances in the ground water, and increased resistance of pests and diseases. Among these most prominent environmental externalities associated with upland corn production is soil erosion. Thus, the issue of corn and soil erosion is prioritized and is the focus of the study.

The focus and scope of the study is the role of upland corn production in the future of agricultural production. As population increases and lowland farm lands are converted to alternative uses, the uplands will have an increasing role in food security and will be, eventually, the bread basket of the country. Furthermore, some research and development (R and D) investments were devoted to technologies aimed to mitigate soil erosion. An impact evaluation of these spent resources is warranted if new directions and spending prudence will be forthcoming.

The remainder of this paper is organized as follows: Part II is a review of existing evidence on environmental degradation and upland agriculture, with emphasis on upland corn production and soil erosion. Part III is an empirical case study of a panel data of upland corn farmers in Lantapan, Bukidnon, Philippines, the analysis of which provides evidence on the in-situ impact of soil erosion and upland farm productivity, and yield effects of the weather conditions. Part IV contains the summary and policy implications.

EFFECTS OF SOIL EROSION ON AGRICULTURAL PRODUCTIVITY: CASE OF UPLAND CORN PRODUCTION

Next to rice, corn is considered a major cereal crop in Asia. Aside from being a staple food, it is also a significant component of the animal feeds industry. Despite research advancement in the past decade, and the introduction of major factors in food production such as irrigation, hybrid technology, and fertilizers (Concepcion undated), maize production in Asia exhibited a modest growth of only 6 percent from 1995-2005 (FAOSTAT). Since 1995, the Philippines has posted the lowest maize yield vis-a-vis the rest of its Southeast Asian counterparts. This is despite a three-fold increase in fertilizer application from two to four bags in the 1970s to 6-10 bags in the 1990s. This growth is also considered very low relative to the potential yield of corn in comparison with high-yielding varieties (HYVs), and utilizing the best possible agronomic management (Concepcion undated).

There is also an observed yield difference across agroecozones in the country (Table 1). Hybrids commonly produce 1.6 to 6.0 t/ha, and those planted at the rainfed lowland of Mindoro Occidental can yield as high as 5.5 to 9.0 t/ha. Traditional varieties, on the other hand, only yield minimally at 0.1 to 2.5 t/ha in the rolling-to-hilly areas, and 1.0 to 2.0 t/ha in the upland plains (Gerpacio et al. 2004).

Farmers attribute yield gap to erratic and unpredictable weather conditions, storms, use of sub-optimal fertilizer input[1], capital constraints, pests, lack of information, poor

Table 1. Maize yield by type of material and maize agro-ecozone, 24 surveyed villages, the Philippines

Type of Maize Material	Range of maize yield by agro-ecozone (t/ha)		
	Rainfed lowlands	Upland plains	Rolling-to-hilly
Local/traditional			
Most common	-	1.0 – 2.0	0.1 – 2.5
Minimum attained	-	0.5 – 1.5	0.1 – 3.0
Maximum attained	-	1.0 – 2.0	0.2 – 3.8
Improved OPVs			
Most common	-	2.0 – 4.0	0.9 – 2.4
Minimum attained	-	1.0 – 3.5	1.0 – 2.1
Maximum attained	-	2.0 – 4.5	2.0 – 4.5
Hybrids			
Most common	4.6– 6.0	3.0 – 5.7	1.6 – 5.0
Minimum attained	3.0– 5.0	1.5 – 5.0	2.0 – 4.3
Maximum attained	5.5– 9.0	4.0 – 7.0	4.0 – 7.0

Source: IFAD-CIMMYT-Philippines RRA/PRA Survey 2001 (from Gerpacio et al. 2004)

crop management practices, soil acidity, and declining soil fertility. The latter is exhibited by continued loss of fertile topsoil due to soil erosion (Gerpacio et al. 2004). The long-term adverse effect of erosion on agricultural productivity is becoming evident (Mendoza 1986). It does not only cause farmlands to go out of production but also demands increasing inputs and investments to maintain high productivity levels.

Upland Soil Erosion and Corn Production

Shively and Coxhead (2004) identified hillside soil erosion and downstream sedimentation as important agricultural externalities being faced by developing countries. The 1993 figures from the Philippines' Bureau of Soils and Water Management (BSWM) show that 45 percent of the Philippine land area was moderately to severely eroded, with a third (38%) of Mindanao's agricultural lands falling under the same category (Pulhin 2001). Acceptable soil loss limit for tropical countries, is at 10-12 metric tons per hectare per year. Shively et al. (2004), however, reported that soil loss for Philippines is between 74 and 81 million tons annually, which affects between 63 percent and 77 percent of the country's total land area.

Of the estimated 4 million hectares of cultivated areas in the country, 2.3 million hectares, with slopes of more than 30 percent, are planted with grain crops, particularly corn (Maglinao et al. 1996; Paningbatan et al. 1992). In fact, all top four maize-producing provinces in the Philippines from 1996-2000, namely: Bukidnon, Isabela, South Cotabato and Cotabato, are categorized as upland plains maize agroecozones. In aggregate, these areas comprise 41 percent of the total national maize production. As Gerpacio et al. (2004) noted, soil

[1] Yield gaps can be circumvented if crop and nutrient management are fine-tuned to site-specific conditions. These entail adjustment by farmers to both timing and amount of fertilizer N, P, and K, as well as the use of split applications to better match crop demand for nutrients (Witt 2006).

erosion is a common problem in these upland areas planted with corn due to its naturally hilly topography.

Several researchers assert that soil erosion constrains the sustainability of crop production (Shively 2003; Presbitero et al. 1995; Midmore and Poudel 1996). Its severity is established to be negatively correlated with crop yield and positively correlated with slope steepness (Jankauskas et al. 2007). A classic example is the study by Poudel et al. (1999) which he found differences in soil quality and productivity between the upper and lower slopes of the Manupali watershed in Northern Bukidnon due to soil erosion. They found out that crop yields for tomato, corn, and cabbage on lower slopes were higher by 40, 36, and 78 percent, respectively, than similar crops planted on the upper slopes.

Technology Adoption and Soil Loss

Literature provides numerous accounts on how farming systems affect the severity of soil erosion in the uplands. For instance, findings show that rate of soil erosion using traditional tillage is more than 10 times[2] the acceptable rate of soil erosion (Tacio 1993). Technologies to minimize these losses are available such as, conservation tillage which has been known to effectively reduce soil erosion. For moderate slopes, soil erosion is reduced by approximately 50 percent under uphill and downhill planting while for steep slopes, the hazard of rill erosion is increased (Al Kaisi 2000).

No till technology adopted in developed economies for corn and soybean led to improved biodiversity and reduced on-farm soil erosion (Dick et al. 1991). Further evidence from the Philippines revealed that corn yield variations were mainly due to tillage practices (Labios et al. 2004). Grass strips plus ridge tillage (GRT) management system could potentially sustain crop productivity on highly eroded steepland soils in the humid tropics (Thapa et al. 2000). Alley cropping is an effective means of reducing soil erosion (Comia et al. 1994).

There were also economic gains in the use of soil conservation measures. Using data from a sample of upland corn farms in the country, Shively (1997) demonstrated that in the long run, hedgerows tend to increase corn yields. This leads to a long-term higher economic returns vis-a-vis traditional corn farming (Nelson et al. 1996). However, in the short run, it tends to reduce the area available for other crops, supporting similar findings of Mendoza (1986), and was also seen to reduce the performance of corn in the remaining alleys. The study shows that it takes approximately eight years for hedgerows to compensate for the area they occupy. The Sloping Land and Agricultural Technology (SALT), considered an eco-friendly farming technique, provides farmers with an annual income nearly seven times more profitable than traditional corn cultivation (Watson 1995).

Despite these claims, why are soil conservation strategies not widely adopted by farmers?

Coxhead (2002) asserts that the failure to adopt soil conservation measures is related to tenure insecurity, economic and institutional factors. Gerpacio et al. (2004) noted that hedgerow technology was not sustained due to its intensive labor requirement and the farmers' perception that shading affects their corn crop. High establishment costs are also a major disincentive in adopting this technology (Nelson et al. 1996).

Based on his study, Mendoza (1986) ruled out lack of awareness as one major factor explaining farmer behavior. Results show that farmers knew what constitute an unsound

[2] 1,163.4 metric tons per hectare per year over a period of six years

agricultural practice for both lowland and upland environments. They are also aware of the measures needed to solve the ecologically unsound practices. Yet, the authors argued that the production environment has become increasingly difficult in the past years due to erratic rainfall, heavier rain downpour, drought, and strong typhoons. Increasingly, climatic risks will affect the farmers' decisions on soil conservation. The next section investigates adoption gains and losses using the Philippine case study.

EMPIRICAL ASSESSMENT OF THE EFFECTS OF SOIL LOSS ON UPLAND AGRICULTURAL PRODUCTIVITY

This paper posits that soil loss and decline in productivity of upland agriculture can be partly explained by the adoption of cultivation techniques. Earlier, evidence showed that cultivation techniques (such as tillage practices) affect the rate of soil erosion. Soil erosion, in turn, affects the productivity of upland farms. In the absence of perfect measures of soil erosion, the study focused on the indirect relationship between technology adoption and upland farm productivity.

The relationship can be expressed following yield determination function[3] for corn for household i at time t:

$$y_{it} = f(\Omega_{it}, \theta_{it}, S_{it}, d_{it}) \quad (1)$$

where:

- y_{it} is the level of corn yield
- Ω_{it} is a vector of household/plot characteristics
- θ_{it} is a vector of economic variables
- S_{it} measures the level of soil quality (i.e., the resource base is a direct input to production)
- d_{it} is the current level of soil conservation

The yield is also affected by inefficiencies in input allocation. Thus, often the potential yield given adoption of a particular technology is not achieved. Empirically, the yield determination function can be rewritten to accommodate both random errors (ε_{it}) and systemic errors (μ_{it}) representing technical inefficiencies. In sum, a stochastic frontier specification is adopted for the yield determination function as represented by the following equation:

$$y_{it} = f(\Omega_{it}, \theta_{it}, S_{it}, d_{it}) + \varepsilon_{it} + \mu_{it} \quad (2)$$

where:

- ε_{it} is the random error term
- μ_{it} is the truncated error term that represents technical inefficiency

Taking a first order Taylor expansion of the right hand side of the yield determination function results into the following:

$$y_{it} = \alpha + \frac{\partial f}{\partial \Omega}\Omega_{it} + \frac{\partial f}{\partial \theta}\theta_{it} + \frac{\partial f}{\partial S}S_{it} + \frac{\partial f}{\partial d}d_{it} + \epsilon_{it} + \mu_{it} \quad (3)$$

Here, we have collected other terms and lumped them into the constant α. We can rewrite this by treating the partial derivatives of the production determination functions as coefficients. We can obtain the following empirical specification for the yield determination function as:

$$y_{it} = \alpha + \beta_{\Omega}\Omega_{it} + \beta_{\theta}\theta_{it} + \beta_{S}S_{it} + \beta_{d}d_{it} + \varepsilon_{it} + \mu_{it} \quad (4)$$

Production, as shown in scientific literature, affects the amount and quality of soil. The common way of representing the soil quality dynamics in continuous time is:

$$\dot{S} = -\gamma(y_{it}) + \psi d_{it} \quad (5)$$

[3] Note that this is different from a production function that essentially has only product and factor prices for its arguments.

S_{it} is the level of soil quality at time t. Using the equation for the deterministic part of the yield determination function, we have:

$$
\begin{aligned}
S_{it+1} - S_{it} &= -\gamma(y_{it}) + \psi d_{it} \\
&= -\gamma(\alpha + \beta_{\Omega}\Omega_{it} + \beta_{\theta}\theta_{it} \\
&\quad + \beta_s S_{it} + \beta_d d_{it}) + \psi d_{it} \\
S_{it+1} - S_{it} &= \eta S_{it+1} - \gamma(\alpha + \beta_{\Omega}\Omega_{it+1} \\
&\quad + \beta_{\theta}\theta_{it+1} + \beta_s S_{it+1}) + \psi d_{it+1}
\end{aligned} \tag{6}
$$

Here, d_{it} is adoption of soil conservation, Ψ measures the effect of adoption on the evolution of soil quality in a plot. γ and η, on the other hand, measure the natural rate of soil renewal and the effects of production on soil quality, respectively. Expanding the equation (6) implies:

$$S_t = g(y_{t-1}, S_0, d_{it}, d_{it-1} \ldots\ldots d_{i0}, \Omega_{it}, \theta_{it})$$

where:

$$
\begin{aligned}
S_{it+1} = &-(\alpha' + \beta'_{\Omega}\Omega_{it} + \beta'_{\theta}\theta_{it} + \beta'_S S_{it}) \\
&+ \psi' d_{it}
\end{aligned} \tag{7}
$$

where:

$$
\begin{aligned}
\alpha' = \alpha\gamma; \beta'_{\Omega} = \beta_{\Omega}\gamma; \beta'_{\theta} = \beta_{\theta}\gamma; \beta'_S \\
= -1 + \beta_S\gamma; \psi' = -\gamma\beta_d + \psi
\end{aligned}
$$

Substituting the soil dynamics equation (7) into equation (4), the empirical specification for the yield determination function is:

$$
\begin{aligned}
y_{it} &= \alpha^{*} + \lambda_{\Omega}\Omega_{it} + \lambda_{\Omega}^{**}\Omega_{it-1} + \lambda_{\theta}\theta_{it} \\
&\quad + \lambda_{\theta}^{**}\theta_{it-1} + \lambda_d d_{it} + \lambda_d^{**} d_{it-1} \\
&\quad + \vartheta^{*} S_{it-2} + \varepsilon_{it} + \mu_{it} \\
y_{it} &= \alpha^{*} + \beta_{\Omega}\Omega_{it} + \beta_{\theta}\theta_{it} + \beta_d d_{it} \\
&\quad + \beta_{\Omega}^{*}\Omega_{it-1} + \beta_{\theta}^{*}\theta_{it-1} + \psi^{*} d_{it-1} \\
&\quad + \varepsilon_{it} + \mu_{it}
\end{aligned} \tag{8}
$$

An econometric issue is evident from the specification. Adoption or non-adoption of a soil conservation measure is often endogenous and is a function of a set of variables, say z_{it}. In particular, conditioned on a matrix of determinants z_{it}, the farmer would adopt if:

$$\text{Prob}(d_{it} = 1) = \text{Prob}(y_{adopt} > y_{\text{no adoption}}) \tag{9}$$

Because of this, upland farmers are modeled as self-selecting between regimes of adoption and non-adoption. An endogenous switching model is used, coupled with the estimation of the stochastic frontier. This means a two-staged estimation procedure is followed.

In the first stage, the probability of adoption is estimated through a panel probit. The associated inverse Mill's ratio obtained from the first stage is used to correct the second-stage stochastic frontier estimation for self-selection and measurement errors. In particular, the following adjusted/corrected stochastic frontier equations will be estimated for adopters (a) and non-adopters (na) (Equations 10, and 11) of the production frontier for non-adopters and multiplying these with the corresponding variable values for adopters.

$$
\begin{aligned}
y_{it}^{a} = \alpha^{a*} + \beta_{\Omega}^{a}\Omega_{it}^{a} + \beta_{\theta}^{a}\theta_{it}^{a} + \beta_{d}^{a} d_{it}^{a} \\
+ \beta_{\theta}^{a*}\theta_{it-1}^{a} + \varepsilon_{it}^{a*} + \mu_{it}^{a} - \sigma_{\mu*\varepsilon*}^{a}\frac{\varphi(\eta z)}{\Phi(\eta z)}
\end{aligned} \tag{10}
$$

$$
\begin{aligned}
y_{it}^{na} = \alpha^{na*} + \beta_{\Omega}^{na}\Omega_{it}^{na} + \beta_{\theta}^{na}\theta_{it}^{na} \\
+ \beta_{\Omega}^{na*}\Omega_{it-1}^{na} + \beta_{\theta}^{na*}\theta_{it-1}^{na} \\
+ \psi^{na*} d_{it-1}^{na} + \varepsilon_{it}^{na*} + \mu_{it}^{na} \\
+ \sigma_{\mu*\varepsilon*}^{na}\frac{\varphi(\eta z)}{1 - \Phi(\eta z)}
\end{aligned} \tag{11}
$$

The two-stage estimation is a modification of the instrumental variables estimation which relies on the identification of instruments that can act as over identifying restrictions. Good instruments are variables that are highly correlated with the unmeasured variable (in the case, soil erosion) but does not affect the yield determination function or does not affect the random error term ε^{*k}_{it}, k=a, na.

The instrumental variables interpretation of the model highlights an important outcome of the empirical analysis. Aside from explaining the effect of soil erosion in yield and farmers' behavior with respect to soil conservation adoption, the study also simplifies the search for indicators that represent soil erosion and upland farm productivity relationship into a search for good instrumental variables.

Computing the Productivity Gains from Adoption

To compute for productivity gains from adopting soil conserving technologies, we need to compute for the counterfactual, also called the Average Treatment Effect on the Treated (ATT). The ATT is the production level of adopters if they did not adopt these technologies, all things constant. Similarly, we can calculate the counterfactual production for the non-adopters or the Average Treatment Effect on the Untreated (ATU). In equation form, these two concepts would be:

$$ATT = E[y_1 - y_0 \mid d = 1]$$
$$ATU = E[y_0 - y_1 \mid d = 0]$$

ATT calculation uses the coefficients of the production frontier for non-adopters and multiplies these with the corresponding variables for adopters. Conversely, ATU calculation entails using the coefficients of the production frontier for adopters and multiplies these with the appropriate variable values for non-adopters. What we derive from these are the analyses of production gains and losses of adopters and non-adopters, before and after the climate shock in 1998.

The Data Set

The data set for this study came from the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP). Since 1994, the project intensively collected data on upland household and farming practices in the municipality of Lantapan, Bukidnon[4]. Data collection was for various purposes. The baseline survey in 1994 was intended to understand factors affecting farmers' land- and labor-use decisions. The survey in 2006 focused on land- and labor-use decisions and the corresponding income effects of farm households in the context of the climate phenomenon, La Niña, that affected the country during the last quarter of 2005 until the first quarter of 2006. Annual surveys were conducted from 1994 to 2002. This period brackets one of the worst climate shocks, an El Niño in 1998, in the study community.

For this empirical study, a six-year panel data, encompassing a total of twelve years was constructed. This includes survey years for 1994, 1996, 1998, 1999, 2002 and 2006. One hundred ninety (190) households were originally interviewed for the baseline data (1994 survey). Succeeding surveys, however, had significant attrition, hence, the final survey round contained only 50 percent of the original interviewed households. In terms of plot level information, there was even larger attrition at 57 percent. There were originally 224 plots in the baseline survey but only 97 plots were included during the last survey round in 2006. Reasons for the decline in the number of plots and respondents include plots given back to the owners, farmers stopped farming as plots were rented out, or some respondents migrated.

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[4] The municipality of Lantapan is contained wholly within the Upper Manupali River watershed, which runs west from a point about 15 km south of Malaybalay City along the southern boundary of the Mount Kitanglad Range Nature Park. Description of the study site and characteristics of households are extensively described in Coxhead and Buenavista (2001), and Coxhead and Shively (2005).

Household and Farm Characteristics

The results of the comparative analysis of mean characteristics between adopters and non-adopters are in Table 2. Tenure of plots was more secure among adopters than the non-adopters. Adopters also possessed plots that have steeper slopes. There was no significant difference between age of household head, education and ethnicity between adopters and non-adopters. Location in the watershed was also found not significantly different between the two groups.

In terms of mean input use, and using the panel data as observation points, adopters and non-adopters have quite distinct characteristics (Table 3). Non-adopters used higher seed rates than adopters and this was statistically significant. Both used manure, but adopters used higher rates, though not significantly from the non-adopters' rate. Nitrogen (N), potassium (K) and phosphorous (P) use were significantly lower among adopters. Family labor was significantly higher among adopters while hired labor use was not significantly different in the two treatments.

The data for plots planted with corn were analyzed. There were 152 corn plots in 1994 which declined to 44 plots planted in 2006. There were episodes of corn farm expansion

Table 2. Farm and household characteristics of adopters and non-adopters of soil conservation technologies, Lantapan, Bukidnon, 1994-2006

	Non-adopters	Adopters
Age of HH head	45.06	46.33
Tenure (% secured)	65.88	82.32*
Slope (% steep)	53.50	83.54*
Education[a] of Household Head	2.28	2.11
Watershed (% in upper watershed)	59.20	61.34
Ethnicity (% migrant)	40.73	39.59

*significantly different at 5 percent level
[a] 1-incomplete elementary; 2-complete elementary; 3-incomplete high school; 4-complete high school; 5-incomplete college; 6-complete college

Table 3. Mean input use of adopters and non-adopters of soil conservation technologies, Lantapan, Bukidnon, 1994-2006

	Non-adopters	Adopters
Seeds (kg/ha)	23.41	18.98*
Manure (kg/ha)	53.04	73.42
N (kg/ha)	46.69	24.20*
P (kg/ha)	32.73	11.46**
K (kg/ha)	11.62	8.98**
Family Labor (man-days/ha)	25.32	32.61*
Hired Labor (man-days/ha)	26.01	19.73

*significantly different at 5 percent level; **significantly different at 10 percent level during 1999 and 2000 but these were small compared to the large number of plot attritions. Corn plot attrition is around 80 percent, which is larger compared to the attrition rate for the whole sample.

At first glance, there has been a steady decline in the number of plots with soil conservation technology, which can be attributed to the effect of attrition. Considering that most of the soil conservation technologies that have been adopted are permanent structures, looking at the absolute numbers can be misleading. The proportion (or percentage) of plots with conservation technology, however, reveals that on average 63 percent of corn plots have soil conservation technology (Table 4).

In terms of yield effect of adopting soil conservation technology, Figure 1 shows the yearly trend in the productivity of farms that integrated soil conservation technology and those that did not. These trends were obtained after removing outlier farms or those that had unusually high output-per-hectare. Clearly, the trends for adopters are increasing compared to non-adopters. This can be treated as a causal evidence of the positive inter-temporal effects of soil conservation.

Empirical Results

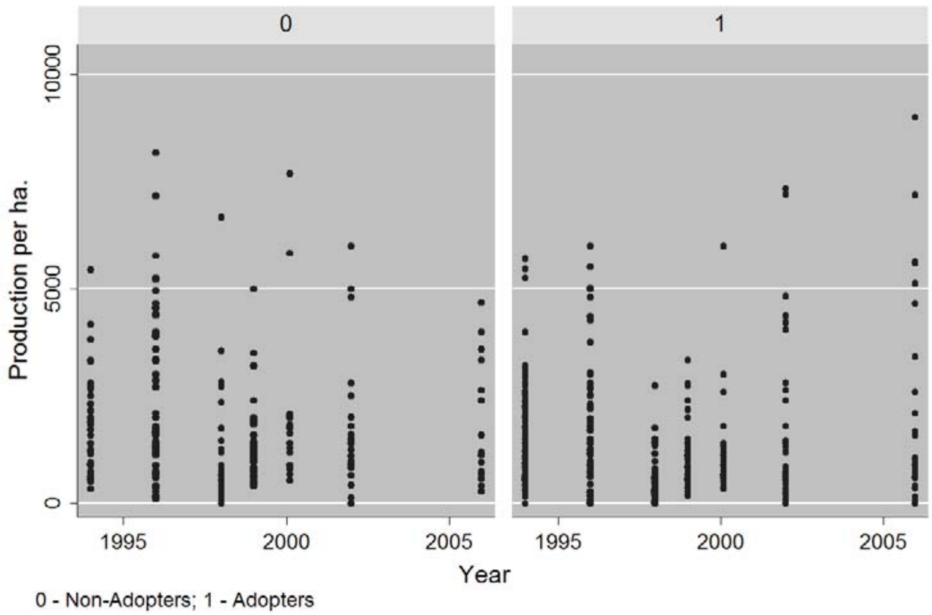
From the earlier discussion, the empirical analysis for the sub-sample of corn farmers needs to account for the high plot attrition. Two tests were done. First was a simple test for the possibility of attrition bias based on observables along the lines of Becketti, Gould, Lillard and Welch [BGLW] (1988). This test utilizes regression between the production level against inputs and an indicator for attrition. The sample that was used is only for the initial wave (1994 data). The dummy variable for attrition assumes a value of one, if the plot was not used for corn cultivation in any year and plots that were used throughout the survey waves. The second test uses a slight modification on Fitzgerald, Gottschalk, and Moffitt (1998) [FGM] procedure for testing attrition based on observables. This modification involves using information on the last year prior to attrition. The original FGM test utilizes only information on the base year much like the BGLW test.

The modified FGM and the BGLW test (Tables 5 and 6) both reveal that attrition bias may not be a problem for our data. The modified FGM tests further shows that

Table 4. Soil conservation adoption for sub-sample of corn plots

Year	Number of Plots	Number of Plots With Soil Conservation Technology	% Adoption
1994	152	116	76
1996	110	56	51
1998	73	44	60
1999	79	44	56
2000	80	58	73
2002	58	35	60
2006	44	29	66

Figure 1. Production (per ha) trends between soil conservation adopters and non-adopters (1994-2006)



"attritors" estimated coefficients are not significantly different from sample "stayers". All of the interaction terms between attrition and the production inputs are all not significant. Thus, this test shows that attrition, at least based on observables, has no effect on coefficient estimates.

Determinants of Soil Conservation Adoption

The results of the probit regression for the soil conservation adoption decision are shown in Table 7. The following are the definitions for the binary variables in the model:

Table 5. BGLW test for attrition

	Coefficient	Standard Error
ln (Seed Inputs)	0.12	0.11
ln (N)	0.18*	0.08
ln (P)	-0.11	0.09
ln (K)	-0.01	0.09
ln (Man-days of HH Labor)	0.06	0.06
ln (Man-days Hired Labor)	0.20**	0.07
Slope	-0.10	0.11
Watershed	0.10	0.21
Attrition	0.07	0.30
Constant	6.00**	0.49

*significant at 5 percent level; **significant at 1 percent level

Table 6. Modified FGM test for attrition

	Coefficient	Standard Error
Production Inputs		
ln (Seed Inputs)	0.09*	0.05
ln (N)	0.10	0.07
ln (P)	0.002	0.07
ln (K)	-0.02	0.06
ln (Man-days of HH Labor)	0.12**	0.04
ln (Man-days Hired Labor)	0.05	0.04
Interaction With Attrition		
ln (Seed Inputs)	0.03	0.08
ln (N)	-0.04	0.11
ln (P)	0.01	0.11
ln (K)	-0.003	0.09
ln (Man-days of HH Labor)	0.06	0.06
ln (Man-days Hired Labor)	0.03	0.06
Biophysical Variables		
Drought Dummy	-1.25**	0.14
Watershed Dummy	-0.41*	0.18
Slope Dummy	0.01	0.06
Adoption Dummy	0.99**	0.31
Interaction Term Between Watershed and Adoption	0.40*	0.21
Interaction Term Between Slope and Adoption	-0.003	0.06
Mills Ratio	-0.84**	0.12
Constant	6.64**	0.25
Interaction With Attrition		
Drought Dummy	0.54	0.43
Slope Dummy	0.05	0.06

*significant at 5 percent level; **significant at 1 percent level

- Adoption of soil conservation technology (0 – adopters, 1 – non-adopters)
- Tenure security [0 – less secured (shared tenancy, leased, cash rental), 1 – more secured (shared ownership, tax declaration, mortgaged, stewardship, private title, CLT)]
- Steep slope (0 – flat, 1 – moderate/steep slope)
- Location in watershed (0 – lower watershed, 1 – upper watershed).

Variables included in this regression are the variables used for the second stage of the yield determination function, except for tenure, which is the over identifying variable. Tenure was the instrumental variable because it is assumed that the more secured the tenure, the higher is the probability that the farmer will adopt soil conservation (Rola and Coxhead 2002). Households with more secured tenure would also tend to be more educated and to seek non-farm jobs.

The education variable was hypothesized to affect corn yields. Probit regressions show that farmers' perceptions on security of their tenure tend to increase the odds of adoption. Farmers also tend to substitute certain inputs for soil conservation. In particular, abundance of family labor tends to increase adoption probability, while seeds tend to lower adoption probabilities. On the other hand, hiring of labor is associated with decreasing odds of adoption. One possible explanation is, hired labor is

Table 7. Probit estimates on propensity to use soil conservation technologies

Variables	Coefficient	Standard Error	Marginal Effects (dy/dx)	Standard Error (dy/dx)
Seed	-0.28**	0.08	-0.10**	0.03
Manure	0.06	0.06	0.02	0.02
Potassium	-0.04	0.06	-0.01	0.02
Family Labor	0.11*	0.07	0.04*	0.02
Hired Labor	-0.13*	0.05	-0.05*	0.02
Drought	-0.60*	0.27	-0.22*	0.10
Watershed	-0.15	0.17	-0.05	0.06
Ethnicity	-0.26*	0.15	-0.09*	0.05
Slope	0.04	0.04	0.01	0.02
Education of HH	0.01	0.06	0.00	0.02
Age of HH	0.00	0.01	0.00	0.00
Tenure	0.43**	0.17	0.15**	0.06
Lagged Variables				
Seed	0.11	0.08	0.04	0.03
Manure	0.04	0.06	0.01	0.02
Potassium	0.01	0.06	0.00	0.02
Family Labor	-0.10	0.06	-0.03	0.02
Hired Labor	0.03	0.05	0.01	0.02
Adoption	2.15**	0.16	0.71*	0.04
Year Dummies				
1996	-1.04**	0.25	-0.39**	0.09
1999	-0.62*	0.26	-0.23*	0.10
2000	0.52*	0.28	0.16*	0.07
2002	-0.67*	0.28	-0.26*	0.11
2006	-0.62*	0.32	-0.24*	0.13
Constant	-0.27	0.54		
LogLikelihood	-210.90			
% Correct Predictions	91%			

*significant at 5 percent level; **significant at 1 percent level

more prone to moral hazards and requires more management and supervision. Another explanation is farmers tend to substitute labor hiring for soil conservation measures. Instead, adopting farmers can hire more labor to maintain the productivity of the farm under the threat of soil erosion.

Likewise, abundance of planting materials reduces the odds of adoption. Again, the plausible explanation is, instead of maintaining soil nutrients through soil conservation measures, alternatively, farmers can apply intensive seeding or planting to maintain production levels.

The positive coefficient of the lagged adoption variable shows an inertia in adoption. This implies that adoption in the previous period increases the probability of current adoption and shows the irreversible nature of most soil conservation technologies in the uplands of Lantapan. In this sense, farmers are "locked" into these technologies. In terms of the marginal effects, the most influential determinant of adoption probability is lagged adoption. This is not surprising in light of the irreversible nature of the technologies. The figures also imply that, approximately, only 30 percent of adopters are able to reverse their adoption. On the other hand, security of tenure increases the probability of adoption by 13 percent.

Determinants of Corn Yield

The second-stage estimates are shown in Table 8. Among the non-adopters, the variables that are positively and statistically influencing yields are potassium use, family labor, education of household heads, and lagged seeds use. Those which are negatively and statistically influencing yields are incidence of drought (the El Niño year), location of the watershed (the upper watershed plots have lower yields), slope (the steeper the plot slope the lower the yields) and lagged potassium use.

For the adopters, the variables influencing corn yields that are positive, and are statistically significant are seeds, hired labor and education. Yield was affected by drought but in a more intense manner. Furthermore, yields were not affected by the location on the watershed nor the slope. The latter can be the result of the soil conservation practices.

Results show that there is no self-selection for both adopters and non-adopters. Likewise, tests show no evidence for a time varying inefficiency term. Despite this, the signs of the coefficient for the inverse mills ratio is plausible. Adopters are those who would have a higher yield than the mean; while non-adopters are those that would have lower than average yield if they adopted soil conserving measures. Lagged adoption also is not a significant determinant of yield levels, however, they also have plausible signs. They indicate that for non-adopters, lagged adoption (or non-adoption) tend to result in lower yield. This may be capturing the soil decumulation effect of continued corn production. The positive sign for the adopters is likely capturing the soil accumulation effect brought about by soil conservation.

The input variables also have the expected signs, however, not all of the input variables affect yield levels. For non-adopters and adopters alike, the quantity of seed used increases production. This means that the availability of planting materials significantly affects corn production in the uplands of Lantapan. Unlike adopters, however, the lagged effect of input use affects the production levels of farmers with no soil conserving structures in their plots, which is true for potassium, seed, and hired labor usage. Potassium use seems to increase production in the short-run, but tends to decrease it in the medium-term. The net effect,

Table 8. Results of stochastic frontier estimation

Variables	Non-Adopters		Adopters	
	Coefficient	Standard Error	Coefficient	Standard Error
Seed	0.11	0.07	0.14**	0.06
Manure	0.02	0.05	0.04	0.03
Potassium	0.07*	0.03	0.02	0.03
Family Labor	0.09*	0.05	0.06	0.04
Hired Labor	0.04	0.04	0.08**	0.03
Drought	-0.31*	0.18	-0.99**	0.16
Watershed	-0.27*	0.14	0.10	0.12
Ethnicity	-0.20	0.13	-0.06	0.10
Slope	-0.06*	0.03	-0.03	0.03
Education of HH	0.09*	0.04	0.08*	0.04
Age of HH	0.00	0.01	0.00	0.00
Inverse Mills Ratio	0.22	0.37	-0.29	0.35
Lagged Variables				
Seed	0.13*	0.06	-0.03	0.05
Manure	0.02	0.05	-0.04	0.03
Potassium	-0.09*	0.04	0.05	0.03
Family Labor	0.09	0.05	0.04	0.04
Hired Labor	0.04	0.04	-0.01	0.03
Adoption	-0.39	0.45	0.24	0.41
Year Dummies				
1996	0.46*	0.22	0.23	0.18
1999	-0.04	0.18	-0.23	0.15
2000	0.07	0.24	-0.43**	0.15
2002	0.12	0.20	-0.22	0.17
2006	-0.08	0.23	-0.28	0.19
Constant	6.90**	0.49	6.36**	0.53
Other Parameters				
M	-1.14	4.32	-709.76	
σ^2	1.36	2.03	362.72	1.43
Γ	0.78	0.33	1.00	0.00
σ_u^2	1.06	2.03	362.29	1.43
σ_v^2	0.30	0.04	0.42	0.04
LogLikelihood	-210.90		-417.80	

*significant at 5 percent level; **significant at 1 percent level

however, is that the accumulation of potassium tends to decrease production. This could be a sign that soil in Lantapan is rich in potassium, thus, decreasing marginal productivity of this micronutrient can be observed across time. For both adopters and non-adopters, hired labor is also an important input. What is quite surprising is that family labor does not affect production levels.

Another common factor for both sub-samples is education. The positive coefficient shows that the higher the educational status of the farmer, the higher is the corn production. This variable might be capturing the managerial skills of the farmer. Finally, note that for non-adopters, geophysical variables such as slope and watershed location adversely affects production. That is, without soil conservation measures in place, plots in steeper slopes and the upper watersheds will have lower outputs. However, for plots with soil conservation measures in place, these variables have no effect on production. This might allude to the fact that locational disadvantages in upland production are eliminated by soil conservation measures.

Treatment Effects on Adopters and Non-Adopters

The treatment effects model calculates the counterfactuals for the treated (adopters) and untreated (non-adopters), by comparing these counterfactuals with the frontier or optimal production measures yielding the average treatment effects (Table 9).

The ATT and ATU of adopters and non-adopters are both positive. The gain from adoption (ATT), however, is significantly lower than the gains from non-adoption (ATU). What is evident is that both adopters and non-adopters have chosen rationally their respective current states. Both have productivity gains as compared to what they would have had if they changed their current state.

We then looked at the average treatment effects before and after the severe drought which plagued the country in 1998. Before 1998, the average treatment effect for the adopters and non-adopters were still both positive, and the gains from non-adoption are greater. However, for adopters, the gain from adoption before 1998 was greater than after 1998. This explains why many farmers adopted early in the panel and supports the contention that adoption rate is diffused because non-adopters are still gaining despite not changing their current practices.

There is a more interesting trend that can be gleaned from the Table 9. We can see a contrast between the changes in the gains in production between adopters and non-adopters after 1998. For adopters, there was a drastic decrease in production gains which means that, although it was still rational for adopters not to change their state, the rationale for doing so is weaker. On the other hand, there was a modest increase in gains for non-adoption. Two important and interesting points can be deduced from these findings. First, soil conservation technologies

Table 9. Average treatment effects for treated (adopters) and untreated (non-adopters)

Treatment Measure	Whole Data (kg/ha)	Before 1998 (kg/ha)	After 1998 (kg/ha)
Average Treatment Effect on Treated	238	507	79
Average Treatment Effect on Untreated	1420	1432	1453
Difference	-1182	-925	-1374

hamper farmers' ability to adapt to severe natural calamities that occur with very small probability. Considering that most technologies are irreversible, farmers become less flexible in their land-use decisions in the presence of soil conserving technologies. Again, farmers are locked into a specific land use configuration. Second, if farmers cannot adjust their decisions and there are declines in productivity gains, then, there are productivity costs associated with soil conservation adoption. This is a less explored dimension in soil conservation studies. Lastly, soil conservation technologies, at least in Lantapan, do not seem robust against calamities like drought.

CONCLUSIONS AND RECOMMENDATIONS

With the accelerating urbanization and industrialization in the lowlands, the upland is the potential food basket of the Philippines. Therefore, more upland technology development, which is both productivity increasing and resource conserving, will have to be pursued. Available data however, reveal that investment in R and D in the uplands is low, about 0.2 percent of total agricultural R and D investments. These research investments are also found to have equity impact because upland farmers generate improved productivity from adoption of these measures.

Our results suggest that adoption of soil conservation measures may have a positive effect on yield, however, these measures may also allow for yield declines in drought years. The factors that affect the adoption of these conservation measures include tenure and availability of family labor. This implies that asset reform programs in steep slope areas being pursued by the government have sustainable outcomes. Family labor played a significant role in the adoption of soil conservation techniques, which means that attractive non-farm labor opportunities may negatively affect sustainability goals (Rola and Coxhead 2002). Adopters of the technology use lower inorganic inputs. However, adopters could suffer productivity losses, in reaction to climate shocks, such as drought, because some soil conservation techniques (such as agro-forestry) are irreversible, in the short-term.

There are at least three policy measures that can maximize the gains of the research investments in developing conservation farming techniques, particularly on soil.

First is the need to provide the enabling environment for farmers to adopt soil conservation measures. Tenure is critical for adoption. Asset reform in the uplands should be continued and intensified. Likewise, a tenured farmer, especially the highly educated one, can seek non-farm incomes, and pursue labor-saving farming activities. The expected shift in farm activities would be to plant fruit trees and other perennials such as coffee, to avoid annual crop-based soil erosion. A necessary condition would be favorable expected market prices for these soil-conserving commodities.

Second, agriculture extension should inform farmers about agricultural productivity effects of conservation farming. In the past, the field personnel of the Department of Environment and Natural Resources (DENR) promoted the planting of perennials. The Department of Agriculture (DA) promotes conservation farming systems for natural resource conservation. In the future, and with more evidences becoming available, the DA can capitalize on the agricultural productivity, aside from sustainability effects of soil conservation practices.

Third, introducing conservation measures that encourages farmer's flexibility in the face of erratic weather patterns should also be considered. There may be a need to provide public intervention, to soften productivity losses of those who incur irreversible damages as a result of the adoption of soil conservation, in times of unfavorable climatic conditions. These measures could be in the form of subsidies for seeds, and green credit schemes for adopters.

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