Chapter 9

Soil Conservation Adoption and Yield Risk: Evidence from Upland Farms in Bansalan[7]

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LAND DEGRADATION and soil conservation are important economic and environmental problems throughout the developing world (Anderson and Thampapillai 1990; Blaikie 1985; World Bank 1992). In response to declining yields and off-farm damages, substantial effort has been directed at finding soil conservation measures that are appropriate for low-income hillside farmers. Studies from both experimental trials and farmers' fields demonstrate that given sufficient time, soil conservation measures can reduce rates of soil erosion, increase crop yields, and provide a favourable return on a farmer's investment (Lal 1990; Lutz et al. 1994; Partap and Watson 1994; Shively 1998). However, the impact of soil conservation measures on income risk is an issue that has received little attention to date. In response, this chapter presents a framework for examining the impact of soil conservation adoption on yield risk, and reports empirical findings from a study of hillside farms in the municipality of Bansalan, Davao del Sur.

Understanding the impact of soil conservation on yield risk is important for two reasons. First, production risk has important implications for the adoption of agricultural technologies (Just 1974; Just and Pope 1979; Feder 1980; Feder and O'Mara 1981). The risk characteristics of a soil conservation technology are therefore likely to influence patterns of adoption. For example, Shively (1999) shows how risk-exposure helps to explain patterns of soil conservation adoption by low-income farmers. Second, since soil conservation measures are widely promoted for use on low-income farms, their performance has important implications for farmer welfare.

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The soil conservation method analysed in this chapter is contour hedgerows. Contour hedgerows are defined as a spatially zoned agroforestry practice (Kang and Ghuman 1991). Comprehensive reviews of hedgerows are provided by Young (1989), Kang and Wilson (1987), and Lal (1990). They are widely promoted as an effective and low-cost method of erosion control for conserving annual crop cultivation on steep fields. Hedgerows are constructed as permanent vegetative barriers, typically grasses or densely spaced shrubs, planted across the width of a field in rows and spaced 5–10 metres apart. The barriers restrict soil and water movement, and annual crops are grown in alleys between the hedgerows. Contour hedgerows have been widely promoted and adopted by farmers throughout Asia, Africa, and Latin America (Partap and Watson 1994). Nitrogen-fixing species are sometimes used to form hedgerows, and their trimmings are applied to crops as green manure to enhance nutrient recycling. This practice can enhance soil fertility and reduce the need for commercial fertilisers (Cosico 1990; Rosecrance et al. 1992). However, since steeper slopes generate higher rates of soil loss, hedgerows must typically be more closely spaced on steep fields to control soil erosion. As hedgerow spacing intensifies, crop area declines, and competition between alley crops and hedgerows for light, nutrients and water may become severe (Garrity et al. 1995; Nair 1990; Nair 1993; Rosecrance et al. 1992). Thus while more intensive use of hedgerows may increase their long-run performance, more intensive use also increases their opportunity cost.

From the perspective of production risk, hedgerows have the potential to mitigate yield variability. Hedgerows can improve moisture retention during low rainfall periods and can reduce overland water flow and associated crop damage during high rainfall periods. It therefore seems possible that hedgerows could stabilise yields overall and also trim the left-hand tail of the yield distribution. If so, the risk-reducing properties of hedgerows would reinforce recommendations for their use. The analysis presented below is designed to test empirically the hypothesis that hedgerows mitigate yield risk.

A Model of Soil Conservation, Yields, and Yield Risk

Consider a model of agricultural production that relates agricultural inputs to yield, accounting for the fact that yield variance may also depend on technology, levels of input use, or other features of production. Alternative functional forms are available for investigating a hypothesised relationship between inputs, outputs, and production risk. The approach used here follows Just and Pope's (1979) general recommendations for a functional form that imposes as little structure on the risk properties of the arguments as possible. The production function is:

$$g = g\left(x,\theta,z\right) + h\left(x,\theta,z\right)\varepsilon . \tag{1}$$

where x, θ, and z represent inputs, a hedgerow indicator, and plot characteristics, respectively, and ε represents a production shock. This additive specification permits increasing, decreasing, or constant marginal risk. A functional form for $g(\ )$ is determined via specification tests reported below in Section 3. Assumptions maintained throughout the analysis include:

$$E\left(\varepsilon\right) = 0; V\left(\varepsilon\right) = \sigma; E\left(g\right) = g(x); V(g) = h^2\left(x\right)\sigma;$$

$$\text{and } \frac{\partial E\left(g\right)}{\partial x_i} = g\left(x_i\right); \frac{\partial^2 E\left(g\right)}{\partial x_i} = g_{ii}\left(x_i\right); \frac{\partial V\left(g\right)}{\partial x_i} = 2hh_i\sigma .$$

To proceed, let $u = y - g(x, \theta, z)$ and let $\hat{u}$ denote the residual from a regression of observed yield on factors of production. With $u^2 = [y - g(x, \theta, z)]^2$ define $v = \hat{u}^2/s^2$ (where s^2 is the sample yield variance). Below, regressions are used to examine the relationships between v and factors hypothesised to influence yield variance. Note that $\hat{u}$ will include measurement error, as well as covariate and idiosyncratic shocks. The latter may include differing environmental outcomes among farms, conditional on farmer behaviour. For now, these limitations in $\hat{u}$ as an indicator of pure yield variability are accepted, although an attempt is made to control for farmer specific factors in the empirical analysis below. In general, correct specification of the stochastic component in equation (1) is necessary for obtaining consistent and efficient estimates of the deterministic component of the equation.

Analysis is conducted at the plot level. Yield per hectare is measured in kilograms of grain and is assumed to depend on the per-hectare rates of application of fertiliser and labour, as well as on the choice of technology. Variables used in the analysis are divided by the area actually occupied by crops (that is, net of area occupied by hedgerows, if any). Both traditional plots and hedgerow plots are included in the analysis.

To account for the impact of soil conservation measures on yields and yield variability, a binary indicator of hedgerows and a continuous measure of the share of land in hedgerows are included in the model. The latter variable measures the intensity of hedgerow use on a parcel, that is, the percentage of the plot area devoted to hedgerows. It is included under the assumption that an increase in hedgerow intensity may influence yield. From another perspective, introducing this variable in conjunction with a binary indicator of hedgerow presence allows both the overall impact of hedgerows on yield and the marginal impact of additional hedgerow intensity on yield to be examined. In addition, because the ability of hedgerows to maintain or enhance fertility may improve over time, a variable measuring the age of hedgerows at planting time (in years) is also included.

Harvest data used in the analysis span a calendar year. Thus the impact of timing on harvests must be considered. For example, seasonal variations in rainfall onset or amount may introduce seasonal variations in yield that are systematic in the sample. To account for this, the data are partitioned into two groups, corresponding to first and second planting periods. These groups are distinguished via a binary indicator, identified as second cropping in the regressions. Harvests that occurred between April and October (wet season) are labeled first cropping; those that occurred between November and March (dry season) are identified as second cropping. Lower second cropping (dry season) yields are expected.

Given that the relative ages of fields differ in the sample, and that the age of a plot may provide some evidence regarding the degree to which the soil's inherent fertility is exhausted, a variable is also included in the model to account for the amount of time the field has been in use. This variable is measured as the number of months of prior use of the parcel at planting time. This variable has been adjusted to account for intervening fallow periods, but likely overestimates the actual number of months the plot has been continuously cropped. The relationship hypothesised is that older plots will have lower yields. Finally, to improve upon months of use as an indicator of land quality, cumulative soil loss is estimated for each plot and from this the imputed value of soil depth is included as an explanatory factor. The regressor measures soil depth at planting time (in mm).

Data and Testing

Data

Production data, including inputs levels and harvested amounts were collected by trained enumerators during the period November 1994 to March 1995. Data for this study include 89 plots that were drawn from a sample of 115 upland farms in Bansalan Municipality, in the province of Davao del Sur. The survey site and farming practices in the area are described by Garcia et al. (1995). For this study, the sample of plots were stratified by hedgerow age. Plots and areas occupied by hedgerows were measured using a forward bearing, compass and tape method. Parcel measurements were checked numerically for closure; all errors fell within 5% of measured area. Both hedgerow and traditional (non-hedgerow) plots are included in the analysis.

Soils on the sample plots are sandy clay loams of volcanic origin, and ranged in pH from 5 to 5.5. More than 80% of land area in the sample was above 18-degree slope, at elevations ranging from 500 to 1200 metres above sea level. Corn production in the area at the time of the survey was characterised by two, or sometimes three croppings per year, short fallows, moderate use of animal traction, and limited application of commercial fertiliser. Hedgerows were typically constructed using double-rows of *Desmodium rensonii* and *Flemengia macrophylla*. At the time of the survey the oldest hedgerows had been in place for seven years. To calculate the estimate of soil depth on each parcel a measure of cumulative soil loss was imputed for each plot as a sigmoidal function of months of use and the presence or absence of soil conservation. Plot-specific soil losses were combined with village-specific estimates of initial soil depths drawn from a 1991 soil survey of the area (Latada et al. 1994). The rate of soil loss is based on experimental data from the area as reported in MBRLC (undated) and procedures reported in Shively (1998).

Sample means of variables used in the regressions are reported in Table 9.1. To summarise these descriptive data, 40% of the plots in the sample had hedgerows, and these hedgerows were 4 years old on average at the time of the survey. Among the hedgerow plots, 12% of the parcel was occupied by hedgerows on average. The average yield from hedgerow plots (1437 kg/ha) was higher than the average yield from traditional plots (1266 kg/ha), and the average yield during the second cropping period (1068 kg/ha) was significantly lower than the average yield during the first cropping period (1670 kg/ha).

Figure 9.1 is a frequency distribution of yields for the sample, which are approximately log-normally distributed. Yields range from 0 to just over 3000 kg per hectare. The frequency distribution includes harvests from both first and second croppings, as well as harvests from hedgerow and traditional plots. It is worth noting that the only plots that experienced large catastrophic losses (e.g. harvests below 200 kg/ha) were traditional plots. Table 9.2 disaggregates and reports average yields on both an observed per hectare basis (including hedgerow area) and an effective per hectare basis (corn area only), by cropping season.

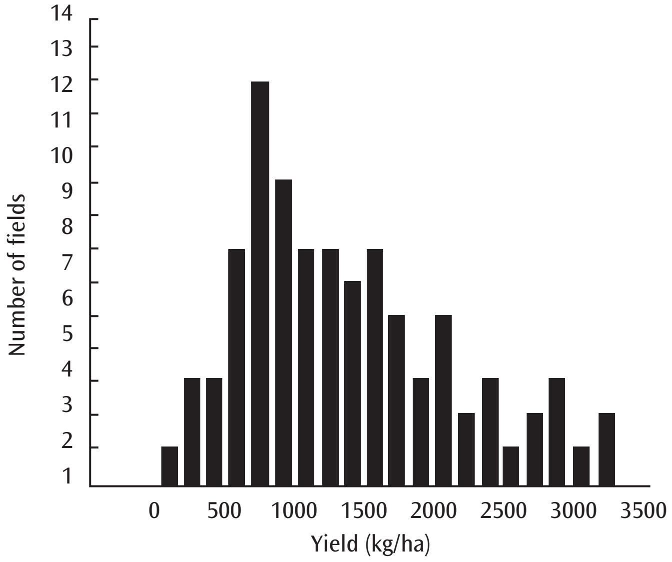

Figure 9.1 Frequency distribution of yields in Bansalan, 1994.

Experimental plot yields from MBRLC (undated) are presented for comparison. In general, hedgerow plots appear to outperform traditional plots on both an effective and observed basis, although in part these differences reflect the fact that hedgerow plots received greater amounts of labour and fertiliser on average than traditional plots. The average plot had been in use for approximately 7 years at the time of the survey. Average remaining soil depth was estimated as approximately 850 mm.

Testing for Functional Form and Heteroskedasticity

A range of possible functional forms are available for estimating the mean equation of a production function. A log-linear Cobb-Douglas model was justified on the basis of a specification test. The test, following MacKinnon, White, and Davidson (1983), assesses the significance of the estimate of the coefficient *a* in the model:

$$g = x'b + a\left[lng - ln\left(x'b\right)\right] + e \qquad (2)$$

where *g* represents yield, *x* is a vector of independent variables, *b* is a coefficients vector, and *e* is a vector of regression residuals.

Patterns of coefficient significance were similar in linear and log-linear regressions, but based on the specification test the linear model is rejected in favour of the log-linear model at a 95% confidence level. A fully specified translog production function performed poorly with these data, although the signs and estimated magnitudes of regression coefficients were broadly similar to those reported for the log-linear Cobb-Douglas model.

The presence of heteroskedasticity in yields was confirmed by the results of diagnostic tests for conditional variance in the yield regression. To test for heteroskedasticity in yields the procedures suggested by Breusch-Pagan (1979) and Glesjer (1969) were used. These diagnostic tests examine the null hypothesis of homoskedasticity in the yield function against an alternative hypothesis of heteroskedasticity. The tests require that one regress transformed residuals from a base regression on independent variables of the mean regression. Residuals used in the tests were obtained from a regression of the equation:

$$g = x'b + e \qquad (3)$$

where variables are defined as in equation (2). The Breusch-Pagan test is a Lagrange multiplier test using squared residuals, while the Glejser test uses the absolute value of the residual. These tests were applied to the data using two subsets of the independent variables. The first set consisted of labour, fertiliser, and a dummy variable for second cropping. The second included these variables as well as soil depth and the hedgerow indicators. The tests and test results are reported in Table 9.3. To summarise, the Breusch-Pagan test allows acceptance of the null hypothesis of homoskedasticity in both instances, but the Glejser test recommends rejecting the

Table 9.1. **Sample means for selected production variables in Bansalan.**

	Average per hectare				Average per effective hectare			
	All plantings	Second planting	Non-hedgerow	Hedgerow plots	All plantings	Second planting	Non-hedgerow	Hedgerow plots
Yield (kg/ha)	1335	1068	1266	1437	1409	1130	1266	1619
Labour (days/ha)	326	334	267	412	352	366	267	477
Fertiliser (kg/ha)	136	141	130	145	146	151	130	170
Time used (months)	83	85	90	117	83	85	90	117
Slope (degrees)	26	26	25	27	26	26	25	27
Soil depth (mm)	850	847	838	867	850	847	838	867
% of plots with hedgerows	0.39	0.40	-	1.0	0.39	0.40	-	1.0
% of land with hedgerows	0.05	0.06	-	0.12	0.05	0.06	-	0.12
Hedgerow age (years)	1.48	1.60	-	3.80	1.48	1.60	-	3.80
n	89	50	53	36	89	50	53	36

Table 9.2. **Observed corn yields for hedgerow plots and non-hedgerow plots.**

	Experimental plots		Farmers' plots	
	Observed yield	Effective yield	Observed yield	Effective yield
First planting	n.a.	n.a.	1670	1770
Second planting	n.a.	n.a.	1070	1130
Traditional plots	1910	1910	1270	1270
Hedgerow plots	1480	2880	1440	1620
All plots	1700	2400	1340	1410

Source: Experimental plots, MBRLC; (undated) Farmers' plots, Bansalan survey (figures are rounded).

null hypothesis. Greene (1990) argues that the Glesjer test is more powerful than the Breusch-Pagan test within the specific context of the chosen regression model. Therefore, the null hypothesis of homoskedasticity is rejected.

Table 9.3. Tests of heteroskedasticity in corn yield regression.

Independent variables	Test		
	Breusch-Pagan	Glejser	Critical value
Labour, fertiliser, second cropping dummy	4.32	9.22	7.82
Labour, fertiliser, soil depth, second cropping dummy, hedgerow dummy, hedgerow share	6.52	18.21	12.59

Note: The test statistics are distributed chi-square with degrees of freedom equal to the number of independent variables. Residual regressions contained a constant term in all cases.

Results

Results from four jointly estimated mean and variance regressions are reported as models 1–4 in Table 9.4. The regressions were estimated by maximum likelihood under the assumption of Gaussian errors. Dependent variables in the variance regressions are the squared residuals from mean regressions. For all models the coefficient estimates in the mean regressions are similar in sign, magnitude, and significance to those estimated using Ordinary Least Squares (OLS) under the assumption of homoskedasticity. In most cases point estimates are individually significant at the 95% confidence level.

Table 9.4. Maximum likelihood estimates of heteroskedastic corn production functions.

Mean equation: dependent variable is natural log of corn yield per hectare				
Independent variables	1	2	3	4
Constant	4.3481 (0.4746)	3.7797 (0.6091)	4.2480 (0.3933)	3.7277 (0.4123)
Log of labour (person-days per hectare)	0.3443 (0.0562)	0.3669 (0.0549)	0.2558 (0.0334)	0.3434 (0.0423)
Log of fertiliser (kg per hectare)	(0.0736) (0.0214)	0.0624 (0.0208)	0.0187 (0.0122)	0.0533 (0.0087)
Log of soil depth (mm)		0.1012 (0.0626)	0.1702 (0.0529)	0.1002 (0.0519)

Note: The inverse Mill’s ratio is derived from plot-level adoption equations reported in Table 9.5. Asymptotic errors are in parentheses.

Table 9.4. (cont'd) Maximum likelihood estimates of heteroskedastic corn production functions.

Mean equation: dependent variable is natural log of corn yield per hectare				
Independent variables	**1**	**2**	**3**	**4**
Period of use(months)	-0.0003 (0.0003)			
Second cropping (0,1)	-0.4589 (0.1034)	-0.5757 (0.0939)	-0.5637 (0.0546)	-0.4840 (0.0544)
Hedgerows (0,1)		-0.2387 (0.1771)	-0.2686 (0.1934)	0.4767 (0.1003)
Hedgerow share (0,1)		-1.6343 (0.6727)	-1.5881 (0.8805)	-2.7360 (0.9451)
Hedgerow age (years)		0.0448 (0.0364)	0.0485 (0.0370)	0.0211 (0.0129)
Inverse Mill's ratio from adoption Probit (0,1)				-0.1227 (0.0643)
Constant	1.1151 (0.3477)	-0.0982 (0.2821)	0.2099 (0.1613)	-0.3327 (0.1316)
Log of labour (person-days per hectare)	-0.0844 (0.0375)	-0.0826 (0.0313)	-0.1021 (0.0216)	-0.0310 (0.0136)
Log of fertiliser (kg per hectare)	-0.0275 (0.0143)	-0.0206 (0.0124)	-0.0088 (0.0032)	0.0048 (0.0035)
Log of soil depth (mm)		0.1250 (0.0278)	0.0574 (0.0195)	0.0650 (0.0250)
Period of use(months)	-0.0011 (0.0002)			
Second cropping (0,1)	0.10522 (0.0658)	-0.0189 (0.0399)	0.0645 (0.0151)	0.0284 (0.0157)
Log of slope(degrees)		0.1123 (0.0313)	0.1372 (0.0263)	0.1212 (0.0236)
Hedgerows (0,1)		-0.1203 (0.0477)		-0.2624 (0.0577)
Hedgerow share (0,1)			1.9790 (0.7171)	2.9212 (0.8308)
Inverse Mill's ratio from adoption Probit (0,1)				0.1198 (0.0237)
Log-likelihood	-88.90	-83.90	-72.88	-63.06
n	89	89	89	89

Note: The inverse Mill's ratio is derived from plot-level adoption equations reported in Table 9.5. Asymptotic errors are in parentheses.

Results from the mean equations for all models indicate that labour and fertiliser contributed positively to output. Hypotheses of constant returns to labour or fertiliser are rejected in the Cobb-Douglas model in favour of the one-sided alternative of decreasing returns to input use: labour and fertiliser each contributed positively to output, but at a decreasing rate. Similarly, decreasing returns to scale are indicated for combined inputs. In elasticity terms, a 1% increase in available labour is associated with a 0.3% increase in corn yield at the mean. For fertiliser, results indicate that a 1% increase in available fertiliser is associated with a 0.06% increase in corn yield. The marginal impact of an additional kilogram of fertiliser is approximately 0.5 kg of corn per hectare at mean application levels. Given prevailing prices of fertiliser and corn in 1994 (7 pesos ($0.28) and 5 pesos ($0.20) per kilogram, respectively), the regressions indicate that the economic benefit of additional fertiliser application was positive at levels of fertiliser application below 50 kg/ha, but likely negative above that level. In part this pattern reflects the relatively high reliance on native seed which exhibits poor nitrogen response. All regressions clearly indicate that controlling for input use and other factors, second-cropping yields (dry season) were statistically lower than first-cropping yields (wet season) and that an additional month of cropping reduces corn yield by about 1 kilogram per hectare.

Model 2 replaces months of continuous cropping with estimated soil depth. Results indicate that soil depth is positively correlated with corn yield, and that a 1% reduction in soil depth was associated with a 0.12% reduction in corn yield — about 2 kg/ha at the mean. Higher order terms for soil depth consistently failed to indicate either increasing or decreasing rates of yield decline associated with changes in soil depth. In a model (not reported) that included a fertiliser-soil depth interaction term one could not reject the hypothesis that fertiliser served as a substitute for soil depth for the range of outcomes observed.

Models 2–4 include three regressors that measure the impact of hedgerows on corn yield. These three are typically both individually and jointly significant at the 95% confidence level. Results show that as the share of land in hedgerows rises, effective yield falls. However, the mere presence of hedgerows is positively correlated with yield, and this benefit appears to increase over time. At sample means (12% of area and four-year-old hedgerows), the reduction in yield due to loss of cultivated area (approximately 300 kg) is roughly compensated by the benefits of hedgerows (roughly 350 kg). However, more intensive hedgerow use is associated with a net reduction in yield, particularly during early years of adoption. Because hedgerow pruning is generally erratic among farmers in the sample, and because the hedgerow technology itself is new and unfamiliar, this result may indicate that shading or disruptions in farmer practices are occurring. Furthermore, some competition between hedgerows and corn, either for water or for soil nutrients, may be occurring. Unfortunately, neither hypothesis can be tested using the sample data. In fact, if pruning and mulching were performed regularly, shading would be reduced and soil moisture content might be increased, potentially raising yields in the alleys. This underscores the importance of farmer practices, rather than the technology itself, in generating outcomes.

Turning to the variance regressions, not surprisingly, the models indicate that labour is a risk-reducing input. The models also show that fertiliser is a risk-reducing input on upland farms. This finding, which is repeated across most of the reported models, contrasts with findings from lowland agricultural studies that find a positive correlation between fertiliser use and production risk. For example, Roumasset (1976) argues that the means of lowland rice yield distributions consistently increase with nitrogen application, but that the variances in these distributions increase in some settings and decrease in others. In particular, when nitrogen was applied during the dry season it significantly reduced yield variance. Since upland corn is grown under rainfed conditions, a similar pattern may be appearing here. As Figure 9.2 shows, the nitrogen response of corn is somewhat greater, and more wide ranging, during the upland wet season than during the dry season. Lower conditional yield variance during the dry season is a natural byproduct of this relationship.

Model 1 also indicates that second cropping yields were somewhat more variable than first cropping yields. Although the coefficient estimate is not significantly different from zero at standard test levels in this model, the pattern that is established here is strengthened in models 3 and 4. Older plots also appear to be associated with lower yield variance. This result is consistent with the fact that newly opened parcels tend to be on steeper and less stable land. Plot slope, for example, is negatively correlated with plot age in the sample.

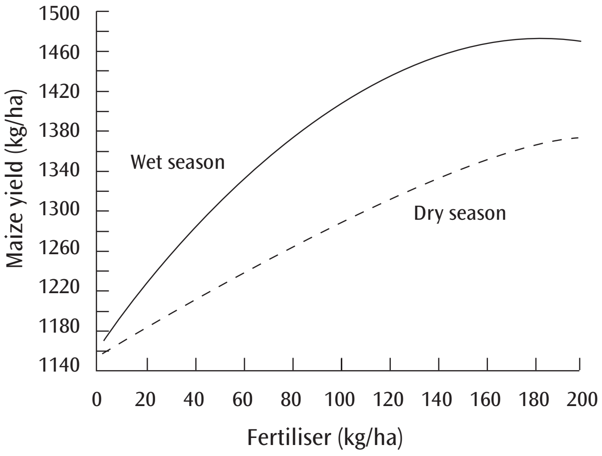

Figure 9.2. Nitrogen response in upland corn.

Model 2 uses soil depth rather than parcel age in the variance regression. Results indicate that prior soil loss reduces yield variability. Figure 9.3 graphs this predicted relationship between soil loss and yield variance. The figure includes upper and lower bounds on yield (defined as mean yield +/- one standard deviation). Patterns suggest that soil loss may reduce the upper tail of the yield distribution and thereby compress the yield distribution downward. Model 2 also introduces a binary hedgerow indicator in the variance regression. The estimated coefficient indicates the overall impact of hedgerows is a slight reduction in yield variance. Model 3, in contrast, uses a measure of hedgerow intensity in the variance regression and suggests that hedgerow intensity is positively correlated with yield variance. Models 2 and 3 both show that yields are more variable on more steeply sloping fields, a finding that is robust to inclusion of soil depth and parcel age in the variance equation.

Model 4 attempts to reconcile the ambiguity regarding hedgerows and risk exhibited in the variance equations of models 2 and 3. Model 4 indicates that the overall presence of hedgerows on a parcel is associated with lower yield variance, but that the marginal effect of hedgerow intensity is an increase in yield variance. In fact, the results suggest that the mean-increasing benefits of hedgerows over time are partially offset by increases in yield variance vis-a-vis traditional plots. Nevertheless, hedgerows are valuable in so far as they afford protection against catastrophic losses.

The mean and variance equations of model 4 also include a measure of latent farmer characteristics in the form of an inverse Mill's ratio. As is well known, estimation of production functions without regard to stochastic features in the maximisation process can produce simultaneous equation bias in parameter estimates. Correction for this potential bias depends on the nature and sources of

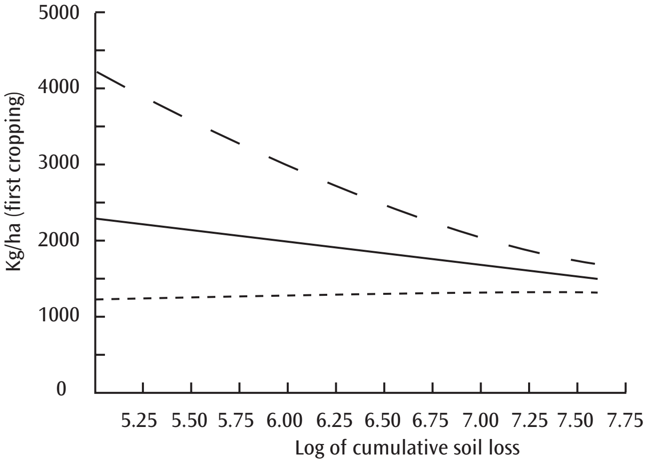

Figure 9.3. Yield and conditional yield variance with hedgerows.

stochasticity. If disturbances are unknown at the time inputs are chosen, then these disturbances cannot enter into the maximisation process (or the first-order conditions), and hence estimation of the production function independent of the factor demand equations appears reasonable. This is the reasoning employed by Zellner et al. (1966) and de Janvry (1972). In contrast, if decision-makers understand the sources of risk, then one potential solution is to estimate jointly the production function and the factor demand equations.

In the current context, we investigate an alternative explanation, namely that latent (and unobserved) farmer characteristics may be correlated with production outcomes. In order to test this hypothesis, a Probit model is used to predict the probability of hedgerow adoption on a plot using a range of household and plot characteristics. The results of this Probit model, which includes as explanatory variables available labour, ownership, soil depth, age, and opportunity cost are reported in Table 9.5. Using this Probit regression, a measure of self-selection into the sample was generated for each household. This inverse of the 'Mill's ratio' is a monotone decreasing function of the probability an observation falls into the sample (Heckman 1979). In the current context, it measures the degree to which yields are influenced by the same unobserved factors that determine hedgerow adoption. The yield and variance equations of model 4 both incorporate this measure to account for latent farmer characteristics in the production function. Production results presented earlier are invariant in sign and magnitude to the inclusion of the inverse Mill's ratio in the mean and variance equations. Results indicate that, controlling for plot-specific factors, farmers exhibiting characteristics associated with hedgerow adoption tend to have lower corn yields and higher yield variance, on average than those who do not exhibit these characteristics. That is, a hypothesis that hedgerow farmers perform no worse than non-hedgerow farmers is rejected for this sample. Inclusion of the inverse Mill's ratio in the variance regression strengthens the power of hedgerows in explaining yield variance.

Discussion

Analysis shows that soil conservation measures have the potential to increase yields and can reduce yield variance slightly. However, evidence also clearly indicates that hedgerows initially reduce effective yields, and substantially reduce observed yields. This argues against their use in short planning horizons, although in the long run the highest effective yields are attainable only through more intensive use of hedgerows. Based on sample data, the break-even point for contour hedgerows (in terms of yield) is found to be approximately 7 years.

The analysis supports the hypothesis that hedgerows are variance reducing. Furthermore, variance around the yield trajectory decreases over time when hedgerows are in place. However, the analysis also shows that yield variance increases as hedgerow intensity rises. Including an inverse Mill's ratio in the variance regression strengthened the power of hedgerows in explaining yield variance. The results suggest that yield variability on hedgerow plots may reflect underlying characteristics of hedgerow adopters or unobserved features of the land that they use. This pattern may also reflect extension efforts in the area that have targeted hedgerows to resource-constrained households.

Table 9.5. Results of Probit analysis of soil conservation adoption.

Independent variable	Coefficient estimate (standard error)
Constant	1.1722 (1.9255)
Farm size (ha)	0.1666 (0.0821)
Available household labour per hectare (person-days per hectare)	0.0021 (0.0011)
Proportion of cultivated area with secure tenure (0,1)	1.2737 (0.6700)
Plot size (ha)	-0.9187 (0.5200)
Soil depth of plot (mm)	-0.0028 (0.0014)
Period of continuous cropping on plot (months)	-0.0162 (0.0084)
Ratio of initial cost of adoption on plot to total household corn availability	-0.4498 (0.1663)
Value of log-likelihood function	-48.71
Percentage correct predictions	0.65
n	89

Note: Asymptotic standard errors are presented in parentheses. Likelihood ratio test for regression with constant only is -60.1.

To illustrate the empirical findings on the impact of hedgerows on yields and yield variance, Figure 9.4 illustrates a 10-year trajectory for effective yield and an approximate lower bound on yield (1 standard deviation below the mean). The *x*-axis in Figure 9.4 corresponds to time and the *y*-axis corresponds to the hedgerow share.

Figure 9.4 illustrates several important empirical findings. First, the underlying tendency is for yields to decline as a parcel becomes older. Hedgerows can dampen or reverse this decline, but they initially reduce effective and observed yields. This recommends against their use over short or greatly discounted planning horizons, and helps explain why low-income farmers are reluctant to adopt hedgerows.

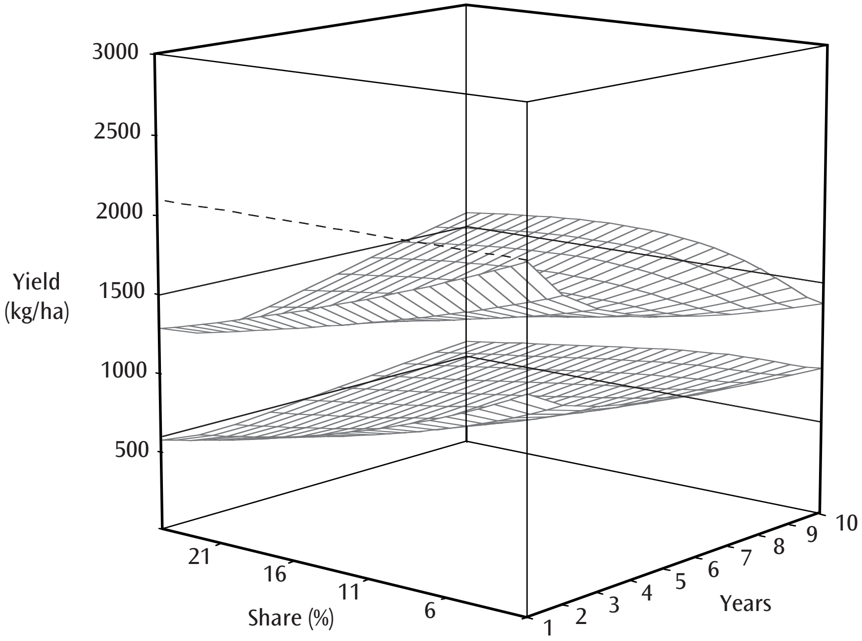

Figure 9.4. Trajectory surface for corn planted with hedgerows.

Second, as hedgerows increase in age, their soil-conserving and yield-enhancing properties improve. The increase in yield depends on hedgerow intensity: more intensive use of hedgerows increases effective yields. The maximum effective yield after 10 years (exclusive of hedgerow area) is estimated as 1650 kg/ha, and would be achieved with a 15% hedgerow share (corresponding to hedgerow spacing of approximately 5.5 m). By comparison, the maximum per-hectare yield (inclusive of hedgerow area) is estimated as 1450 kg/ha, and would be provided by an 8% hedgerow share (corresponding to spacing of 10 m).

Third, hedgerows reduce yield variance. The lower bound on yields rises with more intensive hedgerow use, which suggests that hedgerows provide protection against downside risk, especially risk of yields falling below 500 kg/ha. However, as the intensity of hedgerow use rises, overall yield variability increases. This suggests that yield variability due to crop-hedgerow competition or management difficulties may arise when hedgerows are used more intensively. These results are robust to inclusion of measures of parcel slope in the regressions.

Conclusion

This chapter examined the impact of soil conservation measures on yields and yield risk. A heteroskedastic production function was used to test the hypothesis that contour hedgerows mitigate yield risk using data from corn production on hillside farms in Bansalan. Regression analysis was used to show that hedgerows can dampen or reverse the rate of reduction in yields on farmers' fields. However, evidence clearly indicates that hedgerows initially reduce effective yields, and substantially reduce observed yields.

Regarding the main investigation of the chapter, namely the influence of hedgerows on production risk, the analysis supports the hypothesis that hedgerows are variance reducing. Furthermore, variance around the yield trajectory decreases over time when hedgerows are in place. However, the analysis also shows that yield variance increases as hedgerow intensity rises. These results should be of value to those who are interested in both the practical application of soil conservation strategies in low-income settings, and also those who wish to consider broader welfare issues related to resource conservation by low-income farmers. Future work should extend this analysis to other settings and focus on further distinguishing the factors explaining yield variance, including technology, plot, and farmer-specific effects.