LAND CONDITION, CROP PRODUCTIVITY, AND THE ADOPTION OF SOIL CONSERVATION MEASURES

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ABSTRACT

Attempts to achieve socially-optimal levels of soil conservation require information about the on-farm benefits of conservation programmes, and the importance of these benefits relative to other factors that influence adoption. We attempt to assess whether and by how much soil conservation increases the profitability of farming in a given region, and then to integrate this result into an analysis of what has influenced the adoption of recommended measures. The study region in New South Wales, Australia, is characterised by serious soil erosion and intensive government programmes of soil conservation.

Yield increases following adoption of conservation measures were estimated from response functions. These increases provided a variable in the probit analysis of the three stages in the adoption process (perception of an eroded condition, recognition of a problem worth resolving, and the final decision to adopt). Other factors in the adoption analysis covered land condition, farmer characteristics, farmer motivations, further economic variables and institutional programmes. Adoption of the measures significantly increased wheat yields, and increased farm profitability in 41 of the 50 farms. The probability of adoption proved likely to increase with the expected yield increase, the availability of the institutional programmes, the farmers rating as an investor, and the income flexibility offered by the livestock carrying capacity of the farm.

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Determination of a socially-optimal level of soil conservation, and the design of policies to ensure that on-farm implementation of conservation measures contributes to that optimum, constitute the soil conservation poblem. The many facets of this problem range from questions of practical technique, timing and location, to issues of market failure. Clearly however, any resolution of the problem requires information about the on-farm benefits of technically feasible measures and the relative importance of these benefits.

Implementation may require establishing incentives for farmers to undertake conservation, and exploring the ways in which policy instruments modify these incentives (Seitz and Swanson). Rausser supports an emphasis on the farmer's role, but also highlights the relationships among the important soil-resource variables because these influence productivity over time. McConnell concludes that farmers tolerate erosion because the extra income from conservation generally fails to cover the costs of the change in practices. As he argues later (1986), his competitive market model may capture the essentials of real decisions but, following Kiker and Lynne, a full description would also recognise other influences on the decision to adopt. Any review of incentives and implementation must therefore recognise the complexity of the adoption process and the range of relevant factors, which must include land conditions, farmer perceptions and characteristics, farmers economic and non-economic motivations, as well as government policies and incentives.

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Empirical studies of the adoption of soil conservation measures have focussed on the relative strengths of some of these factors. For example, Ervin and Ervin investigated variations in the number of conservation practices actually adopted, relative to farmer perceptions, erosion potential and the existence of a cost-sharing programme. Taylor and Miller examined the influence of the farmers perceived needs, and potential persuasion toward new practices, and measured both these explanatory variables through Likert attitude scales. The rate of adoption of minimum tillage, by ownership size and erosion hazard classes, was examined by Lee and Stewart.

A useful extension of this kind of research would be an integrated study of the financial profitability of conservation practices and the set of factors that promote adoption. Such an approach might successfully identify the separate influence of the different kinds of factor. Accordingly, the goal of this paper is to investigate the set of factors that influence the adoption of soil conservation practices.

In addition to the work of other researchers, we were motivated to undertake this analysis by two paradoxes in farmer behaviour in a cropping region of New South Wales, Australia. In this region, there is serious soil erosion and an intensive government programme to combat it. For other research purposes, we had gathered information from 50 of the 70 farmers who purchased land between 1979 and October 1985. The first paradox concerned the lack of local information on increases in crop productivity that might follow soil conservation. Despite this, 29 of the 50 had adopted intensive conservation measures, and so the sample appeared to be over-adopters relative to the state of information. The second paradox concerned potential gains from conservation. Our early research indicated substantial economic gains from soil conservation to 41 of the sample. Following the economic paradigm of choice, the farmers appeared to be substantial underadopters relative to likely on-farm gains. Our specific objective was therefore to try to identify what was influencing adoption in addition to profitability, and to contrast the relative importance of the different kinds of influence. We were able to measure the influences of land condition, personal characteristics, personal motivations, profitability, income levels, and the institutional programmes.

To set the context for the whole analysis, the nature of adoption decisions is reviewed as the first part of the conceptual framework. Theoretical models of the adoption process, and the crop yield/land condition response, comprise the remainder of the framework. Data collection is then discussed in terms of the study area and variables to be measured. The analysis begins with estimates of a crop-response model. These results then provide a key variable for the probit analyses of the adoption process, where one probit model is estimated for each stage of the process. The calculations of the potential profitability of soil conservation are contained in the appendix.

THE CONCEPTUAL FRAMEWORK

Nature of adoption decisions

The adoption of innovations has received exhaustive study, much of which Rogers reviews while updating his own important work in the area. Research into diffusion of agricultural innovations and new environmental practices rests on this body of literature and often extends it quantitatively (see for example, Turner, Eppersen and Fletcher; Pampel and Van Es; and Taylor and Miller).

Conceptual models of adoption vary in their details, but most recognise a multi-stage decision process. Indeed, Kennedy's general model for agricultural innovations rests on the three stages of (a) recognition of a problem and search for innovations, (b) awareness and mental acceptance of a new practice, and (c) adoption or non-adoption of the practice. Despite difficulties with interdependencies and political dimensions, he concluded that such models were generally relevant but usually needed refinement for particular studies.

Ervin and Ervin successfully test a three-stage model (perception of the degree of erosion, decision to adopt, and actual quantity of effort) of the adoption of practices in Missouri. A three stage process was also modelled by Taylor and Miller for the adoption of measures to control pollution of Black Creek in Indiana. Their measures included familiar conservation practices such as grassed waterways, holding ponds and contour farming, although their stages were slightly different (knowledge of the innovations, persuasion about them, and the decision to adopt).

To fully recognise behaviour, any model of the adoption process must explicitly include motivation. Implementation of soil conservation practices will differ with social and economic variables as well as the erosion hazard, argue Earle, Rose and Brownlea. The income motive, expressed as increases in total farm income, proved the most useful overall influence on adoption in their sample of 115 farmers in Queensland. The stewardship motive, of passing to the future a fully-productive resource, may be important to many landholders. As Van Kooten and Furtan footnote in their review of issues in Canada, stewardship is almost always reported as a reason for adopting conservation practices and economics as a reason for rejecting them. Taylor and Miller found that persuasion toward the conservation project most influenced the use of new practices in their study area. Their persuasion variable explicitly included the farmer's desire for general pollution control, and the clearly-motivational benefit to those involved. Explanatory variables will of course vary with location and practice, but motivation should always be a dominant factor.

A model of the adoption process

Even this brief review indicates the usefulness of multi-stage models as representations of the adoption process in agriculture. The conceptual model of Figure 1 provides a framework within which to organise the present research on what influences the adoption of soil conservation practices. The model follows Ervin and Ervin although their last stage, quantity of conservation effort, has been redefined as the decision to resolve the erosion problem. As Saliba (1985) argues, such models help to emphasise the separate importance of land, management and insitutional factors, as well as the relationships between them. For simplicity, the model omits the feedback loops that Saliba and Bromley use to characterise changes over time. But Figure 1 expands their decision process to include a problem recognition stage between perception and decision.

Perception of land condition (PERCEP) depends on the exogenous factors of the land itself as well as on the personal attributes of the farmer. Recognition (RECOG) that a problem is worth trying to resolve rests on these initial perceptions, on economic forces, and on the farmers motivation to resolve the problem. The decision whether to undertake soil erosion (FIXIT) rests on both the recognition and perception stages, but also depends on the existence of institutional programmes of assistance. This behaviour could be modelled by the following system of structural equations.

(1) PERCEP = f(Land factors, personal factors)
(2) RECOG = f(PERCEP, other personal factors such as motivation, economic factors)
(3) FIXIT = f(RECOG, institutional factors)

Equations (1) and (2) recognise the possibility that some personal characteristics may influence PERCEP rather than RECOG -- and vice versa. Equations (2) and (3) presume that both recognition and decision stages depend on economic forces and that the same economic forces influence both.

If all three stages were resolved simultaneously, the system should be estimated simultaneously. If all three are resolved sequentially and in the same decision process, the system should be estimated sequentially. In other circumstances, separate estimation of each of the three models is appropriate. These circumstances include, (a) the fixit or decision stage may occur one or two years after the recognition stage -- as in the present research, (b) the separate effects of the factors at each stage may be of interest -- as apparently it was to Taylor and Miller, and Ervin and Ervin, or (c) perhaps just one stage in the process is to be analysed -- as in Earle, Rose and Brownlea. For separate estimation, the stages may be specified as follows.

(4) PERCEP = f(Land factors, personal factors).
(5) RECOG = f(Land factors, personal factors, economic factors
(6) FIXIT = f(Land factors, personal factors, economic factors, institutional factors)

The variables PERCEP, RECOG and FIXIT are all conveniently and logically defined as binary variables. The farmer either does or does not perceive that his land is in a conserved condition (PERCED = 1, and 0 respectively). He does or does not recognise any erosion as a problem worth resolving (RECOG = 1, and 0 respectively), and similarly he either does or does not adopt measures to fix up the problem (FIXIT = 1, and 0 respectively).

In each case, the farmer is essentially choosing between two events, (E) and (not E). The general model to explain participation based on this binary choice is:

(7) $P_n = F[B'(Z_{1n}-Z_{2n})]$

where P_n is the probability that event one will be chosen in observation n, and F is a cumulative distribution function. The vector of K coefficients is represented by B', while the Z's represent K-vectors of data for observation n. If the individual does participate in event E, data describing participation are in Z_{1n} otherwise they are in Z_{2n}. The Z's can measure any attribute of the participation status, or any transformation of an attribute. If F is the cumulative normal distribution, if the equation is linear in its parameters, and if individual observations are to be analysed, then the probit method is the appropriate estimation procedure. In this method, the participation decision is modelled by a linear criterion function.

(8) $I_i = a + bX'_i + e_i$

where I_i is the binary choice variable measured at 1 (for participating in the event) or 0, X_i is a vector of attributes (or independent variables), and e_i is the random disturbance. Parameters a and b are, of course, to be estimated.

The probability of E_i occurring is greater for larger values of the index I_i, so the model of equation (8) can be transformed into a monotonic relationship between the value of I_i and the probability of the event E_i.

(9) $\text{Prob}\ (E\ I_i) = \text{prob}\ (I_i^* \leq I_i) = F(bX'_i)$

where F(.) is the cumulative distribution function, X. Theoretically, the farmer will choose E only if $I_i \geq I^*$, where I^* is the threshold value of the random index which reflects the underlying attributes.

Equation (9) sets the observable parameters (X_i, I_i) in the full context of the general model of binary choice. Parameters a and b are generally estimated through maximum likelihood procedures. When the sets of observations are statistically independent, and when the function of independent variables (equation 8) is distributed normally, the maximum likelihood estimates of the parameters are distributed normally and have the properties of consistency and efficiency. Since the b_i parameters are normally distributed, hypotheses about them parameters can be tested with the t-statistic.

Probit analysis has been widely used in this way to investigate participation in various activities and to assess the impact of extension programmes (see, for example, Huang and Rauniker; Lane, Kushian and Ranney; Thompson and Eiler; and Turner, Epperson and Fletcher).

A model for the yield/land condition response

The relationship between changes in land condition and changes in agricultural output is a prime concern of this research and the potential yield increase is of course an important economic factor in the RECOG and FIXIT functions.[1] The underlying response model, and the nature of possible land condition variables, must therefore be explored in some detail.

Both the quantity and the characteristics of the land input influence the quantity of production. For a given property, or a given amount of land, crop output can be expected to vary with several characteristics such as soil depth, fertility, organic matter, and potential for cultivation. In principle, these characteristics can be substituted one for another, and for the quantity of land, labour and capital in the production process.

Consider a potential purchaser of land who wishes to produce a given output of wheat. His labour input, skills, technology and capital are given. He will consider the characteristics of the land that he believes will influence production. For example, he could purchase an eroded property with a high proportion of arable land or a well-conserved property of the same size, but with a lower proportion of arable land.

His choices lie along an isoquant where the inputs (or characteristics) are arability (X_1) and conservation/erosion status (X_2). In applying this model to grazing, Barlowe interprets X_1 as per cent of land suitable for forage production and X_2 as intensity of the necessary conservation practices (where contour farming is least intense and terracing is most intense).

A general expression for this response function is:

(10) $Y = f(X_1, \ldots, X_n)$

where Y denotes the quantity of output, and Xi are the total set of inputs.

The selection of the variables X_i for the characteristics of the land is, of course, of some interest. One obvious choice for a cropping property is the proportion that is arable land and another must concern the conservation/erosion status of the property.

Conservation/erosion status has been measured or defined in various ways. A direct definition is annual soil loss, for given conditions of slope, soil type, and climate, and was used or suggested by Heady and Vocke, McConnell, Crosson and Stout, and Burt. Proxies for erosion status have included residual depth of topsoil, and for conservation/erosion status, the proportion of the property with conservation measures in place (Drynan, Hodge and Watson). Other proxies for this status also could include the proportion of land that still needs treatment, and the costs of the remaining necessary treatment. Whatever the variable(s) used to measure this status, they must (a) directly influence crop output, (b) be susceptible to direct change by management, and, of course, (c) be measurable.

Thus, our initial response function is

(11) $Y = f(X_1, X_2, X_i, X_j)$

where Y = crop yield per hectare

X_1 = per cent of land suitable for crop production,

X_2 = annual soil loss

X_i = other relevant variables of land condition,

X_j = other relevant inputs.

The direct definition of conservation/status, as annual soil loss, is used first for X_2. Then, following Saliba and Bromley, the use of two other variables is examined to emphasise the role of management. These two concern the percentage of arable land that needs conservation treatment, and the overall costs of treatment.

We would expect decreasing productivity to each input and diminishing rates of substitution between inputs, but we would not necessarily expect a constant elasticity of production per input. We therefore adopt a partial

logarithmic function of the following form,

$$(12) \qquad Y = a + \sum_{k=1}^{n} b_k \text{Ln} X_k + U$$

where Y remains in arithmetic units.

Application of the framework

The responses of crop output to changes in land condition are estimated first by applying the response function of equation (12). The expected increase in crop yield then becomes a variable in the RECOG and FIXIT functions of equations (5) and (6)of the adoption process. The probit method is applied to estimate models for each stage in the adoption process (equations (4), (5) and (6)). Taken together, the response and probit analyses implement the general model of Figure 1 in a step-by-step manner.

DATA COLLECTION

The study area

Manilla Shire in New South Wales, Australia was chosen for study because the Soil Conservation Service of New South Wales has maintained an active soil conservation programme there for some time[2]. The programme has accomplished much, but many conservation works remain to be completed -- according to the Service. The Shire includes the Keepit Soil Conservation Project which was started in 1971 to reduce soil erosion in the catchment of Keepit Dam.

Farm planning is one of the services provided by the Soil Conservation Service (SCS). The Service develops a farm plan which includes recommendations for soil conservation works which directly affect the condition, or degradation potential, of the land. The recommended works lower the degradation potential, and so raise the conservation status of the land to a technical standard set by the service. Upon approval of a plan, an agreement is prepared which details the specific works and the responsibilities of the SCS and the farmer in carrying it out. For farms within the Project, one half of the cost of the works is borne by the SCS, and the landholder is usually eligible for a 15-year loan at 4.5 per cent to cover the remainder. This loan is available to all farmers who meet the eligibility requirements, wherever their farm is located. The farmer's decision to undertake the works should be influenced by whether or not his property was in the Project, because of the greater need for them and because of both, the cost-sharing programme and the greater extension effort devoted to the Project area.

Data were collected simultaneously for the present research and for research into the relationships between land condition, soil conservation and land values. Sales of all properties larger than 40 hectares were identified for the period between 1979 and October 1985 and during this period 154 properties changed hands[3]. Farms purchased by government agencies, properties not used for agriculture, properties solely suited to grazing, and within-family transactions were excluded. Seventy eligible farms were left and the survey included the first 50 farmers with whom appointments could be made. The data are considered to be representative of family owned and operated, mixed crop/grazing farms in the Shire. Indeed, they are considered representative of this kind of farm in the much larger north-west slopes region of the state. The representative farm in the sample is 354 hectares in size, of which 64 per cent is suitable for cropping.

The variables

Adoption process One dependent variable was defined for each of the three stages of the adoption process. The landholders perception of the condition of his land at the time of purchase (PERCEP) was defined as

1=conserved or well conserved, and 0= degraded or very degraded. Data were obtained through the following 5-point rating question. When you bought the land, did you think it was very degraded, degraded, about average, conserved or well conserved? Twenty three of the fifty felt their land was conserved or better and twenty seven rated their land as degraded or worse.

Data on recognition were obtained through the question: did the potential loss of agricultural productivity due to erosion detract seriously from the value of the land at the time of purchase? The variable RECOG was scored at 1 if yes (10 responses) and 0 if no (40 responses).

Local Soil Conservation Service officers provided data on (a) which landholders had already contracted and started the recommended works (17 had started) and (b) which were about to sign the contracts and about to start (12). FIXIT, for the decision to undertake the conservation measures, was coded as 1 = had started or were about to start (29 in all), and 0 = otherwise (21).

Land factors The quantity of soil movement down a 100 metre length of given slope per hectare per year (SLOSS) was taken as the basic measure of the erosive condition of the land. The data were obtained from local applications of the Universal Soil Loss Equation, combined with local experience and the results of local experiment[4]. The figures ranged from 5.0 tonnes on a slope of 0 to 1 per cent, up to 106.4 tonnes on slopes exceeding 10 per cent. (A. Harte, pers. comm). The property is the unit of analysis, so an average slope per property was required[5].

An alternative, field-by-field measure of land condition was available through the farm plans. The total cost of all the recommended conservation works, remaining to be completed at the time of purchase, was calculated in 1984 costs (and expressed as CCOST $ per hectare over all hectares of the purchase). Properties with low erosion potential, a technical condition and standard implicit in the quantity of recommended works, have low values for CCOST and vice versa. This measure of land condition directly reflects conservation/erosion status, and directly enters the recognition and decision stages of the adoption process.

Further, it provides the kind of comparable, field-level or regional-level measure of conservation management that Saliba and Bromley promote.

The local SCS officers estimated the percentage of the arable land on each property that needed treatment with soil conservation works (PCTREATS), providing another measure of overall land condition. For a landholder perception, the farmers were each asked what per cent of the whole property they felt needed treatment when they purchased it (PCTREATL).

Farmers were surveyed for their perceptions on three more aspects of land condition at the time of purchase. ACCESS was the standard of access tracks to homestead, fields, buildings and the property itself. It was coded 1 if the tracks required substantial and carefully-defined repairs every 1 year, 2 if every 2 years etc. SILTRO was coded similarly for the frequency of maintenance to adjacent shire roads due to silting and gullying from the property. The farmers estimated the cost of on-farm conservation works necessary to stop erosion into off-farm water courses (WATERC in $ per ha)[6].

Of these measures of land condition, SLOSS and CCOST are directly related to the biophysical/topographic characteristics of the land. The remainder are explicitly cost-oriented (CCOST and WATERC), directly affect farm operations (ACCESS and SILTRO), directly measure what conservation works are necessary (CCOST),or are direct perceptions of what needs to be done to raise the land condition to some inherent standard (PCTREATS and PCTREATL). Values for the variables SLOSS, CCOST and PCTREATS were assessed by the researchers or SCS professionals. Thus these variables should provide the most consistent measures of conservation/erosion status and so they are used as alternative measures in the response analysis.

The city of Tamworth lies to the south of the study area. Properties more distant from Tamworth tend to be more undulating, to have more rocky outcrops and to have poorer vegetative cover. DTAM, distance from Tamworth in kilometres, was included in the response analysis to capture these biophysical effects.

The percentage of a property suitable for cropping (PCARAB) will influence yield response, so this variable was also included in the response analysis and a positive sign expected.

Personal factors An important factor in the adoption decision is the management skill of the farmer himself, a concept that is inherently difficult to measure. Years in farming (YRSF) was used as one measure. Another was a rating on a 1 to 10 scale by SCS professional officers of each landholder's ability to invest capital to obtain a high yet safe return (BINV). The intensity of the landholders search for a purchase reflects the care in his earlier decision to buy the property. This care may carry through to other decisions so BSCH was included, and defined as the number of properties the landholder said he seriously considered in his search for land.

The landholder's motivations for purchasing and managing the land will influence his decisions, and his recognition of the problem. Each farmer was asked whether he thought that the potential agricultural income and potential capital gain from the property were especially important reasons for purchase (MAGINC, MCAPG). These two variables were both coded 1 if so, 0 otherwise.

A direct motivation for undertaking the recommended cons[illegible]ion works is the expected increase in profit. Actual increases were estimated through the response analysis as the increase in wheat yield (YINC in tonnes per hectare) if the farm plan is implemented.

The importance of the stewardship motive was assessed as follows. Landholders were given a list of 14 potential benefits from soil conservation and asked to select the five that they thought generally gave the greatest benefit to them. One benefit was, "pass on to the future a fully productive resource". The variable MSTEW was coded as 1 if this was selected and 0 otherwise.

Economic factors Relevant economic factors include existing agricultural yields, because these will affect the farmers overall ability to pay for works. WHEAT was the total wheat yield per hectare expected in the next year, as estimated by the farmer. It was recorded as total yield in tonnes divided by the total area of the property. This basic measure of agricultural production was supplemented by STOCK, the total livestock carrying capacity expected in the next year in livestock month equivalents per hectare. STOCK obviously recognises the agricultural potential of grazing land, and partially recognises the potential of arable land to provide fodder crops.

Smaller properties can be managed more intensively, therefore total size in hectares (SIZE) was included in the yield response analysis.
Institutional factors The town of Manilla is central to the area. It is the educational, health and religious centre, and is the headquarters of the local Soil Conservation District and the Keepit Project. Over the years, properties closer to Manilla have had greater access to SCS extension services and SCS plant and machinery, so perhaps less conservation work remains to be done on these properties. Again, more extension advice is currently focussed on the more distant properties, so distance from Manilla (DMAN in kilometres) should partly explain the influence of institutional programmes.

Farms within the Keepit Project are eligible for a 50 per cent subsidy on the cost of the recommended conservation works -- as well as the standard 4.5 per cent loan for the remainder of the cost. This cost-sharing programme recognises the severity of erosion within the Keepit Project at the time the project was established and the incentive provided by the SCS to complete recommended works. Accordingly, INK was defined for location of the property relative to the project (1 = within project, 0 otherwise).

Farmers who have had previous loans, and particularly those who have had previous agreements with the SCS for land within the project, can better assess what the agreements entail. BPAG was therefore defined as 1 = the landholder has had a previous agreement concerning land within the project, 0 = otherwise.

RESULTS

The response functions, for the relationships between land condition and wheat output, provide data for the yield increase variable (YINC) which is subsequently included in the recognition and decision models. The response functions are therefore considered first. Then come the perception, recognition, and decision functions, which have all been estimated by probit analysis. Together they model the adoption process and so they are reviewed together.

The yield/land condition response

The ordinary least squares estimates of equation (12) are reported in Table 1, with one equation for each of the three alternative measures (SLOSS, PCTREATS, CCOST)of land condition. The t-statistics are in parentheses with significance at ( )*** for 1 per cent, ( )** for 5 per cent and ( )* for 10 percent.

The co-efficients on Ln (PCARAB), Ln(SIZE) and Ln(DTAM) remain stable for the different variables of land condition, but Ln (CCOST) in equation (15) is the only significant condition variable.[7] Higher coefficients of determination can be obtained with other transformations of the explanatory variables, as for example the following linear model.

$$
\begin{array}{llllll}
(16) & \mathrm{WHEAT}=1.085 & +\ 0.016\ \mathrm{PCARAB} & -\ 0.0003\ \mathrm{SIZE} & -\ 0.010\ \mathrm{DTAM} & -\ 0.119\mathrm{Ln}\ (\mathrm{CCOST}) \\
 & & (6.0)^{***} & (1.3)^{*} & (1.5)^{*} & (1.5)^{*}
\end{array}
$$

$R^2 = 0.554$, $\bar{R}^2 = 0.515$, $F = 14.026$ for 4,45 degrees of freedom.

Nevertheless, the general logarithmic form of equation (15) is conceptually superior and statistically satisfactory. The significant and negative sign on Ln (CCOST) indicates that decreases in the quantity of necessary conservation works are associated with increases in wheat yields.[8] Apparently then, increases in the amount of necessary conservation works are associated with decreases in wheat yield.

The expected yield increases, following increases in the soil conservation works, can be calculated from equation (15). Farmers tend to undertake all the recommended works on the farm plan, or none at all. The mean wheat yield of the study farms was 1.07 tonnes per hectare, and the logarithmic mean of CCOST was $52 per hectare. If all of these works are undertaken, the value of WHEAT will rise by [0.150 x Ln (CCOST)]. For a property with a CCOST of $52, the yield increase is 0.593 tonnes [0.150 x Ln(52)] per hectare.

Table 1

Alternative functions for the yield/land condition response

Variables	Equations 13	 14	 15
Ln (PCARAB)	0.448 (3.9)***	0.489 (4.7)***	0.507 (5.0)***
Ln (SIZE)	-0.107 (1.4)*	-0.115 (1.5)*	-0.094 (1.3)*
Ln (DTAM)	-0.521 (1.4)*	-0.525 (1.4)*	-0.646 (1.8)**
Ln (SLOSS)	-0.089 (0.8)		
Ln (PCTREATS)		0.068 (0.8)	
Ln (CCOST)			-0.150 (1.6)**
Constant	2.148	1.511	2.653
R^2	0.448	0.409	0.433
$\bar{R}^2$	0.356	0.356	0.383
F	7.768	7.780	8.602
Degrees of freedom for F-test	4,45	4,45	4,45

Farmers will be motivated to undertake soil conservation works when they anticipate a profit, and the profit depends upon the yield increase. A major variable for the recognition and decision stage models is therefore the economic factor of yield increase (YINC), calculated as [0.150 x Ln (the particular property value of CCOST)]. The use of increase in yield, as a proxy for increase in net income, avoids the problems of estimating crop prices and selecting discount rates.

The variable YINC is calculated from CCOST and each of these variables is used in separate probit models of the adoption process. Mathematically, a response to YINC could therefore be a response to CCOST. But behaviourally, farmers can readily translate their perceptions of the erosion status of their land to a cost of required works (CCOST), so CCOST is included in the PERCEP models. Subsequent discussions with neighbours and SCS officers may give the farmers some notion of the magnitude of likely yield increases so YINC was used in the RECOG and FIXIT models.

The adoption process

The results of the probit analyses, for each of the three stages in the adoption process, are presented in Tables 2 and 3. The likelihood ratios show that each set of coefficients as a whole is significantly different from zero, and three of the four sets are significant at better than 1 per cent. The null hypothesis, that there is no relationship between the dependent variable and its set of explanatory variables, is clearly rejected in each case. The numbers in parentheses are t-statistics. Consider now in turn the models for each stage in the process.

Perceptions of land condition Perceptions had been coded as 1 if the landholder reported his property to be conserved at the time of purchase, and 0 if he reported it to be eroded. The three personal factors (BINV, BSCH, YRSF) contributed little in Model 1 (Table 2), so Model 2 was estimated with the land factors alone. The most influential variables in both models are CCOST, WATERC, and PCTREATL. These variables measure, respectively, the cost of the recommended conservation works, the landholders estimate of the costs of on-farm works to prevent off-farm silting and gullying of water courses, and the landholders estimate of the per cent area of the property that required treatment with conservation works. The signs on these three variables indicate that conserved properties (PERCEP=1) are perceived as likely to have low CCOST and low PCTREATL but a high WATERC. These perceptions follow expectations for the objectively-determined CCOST and, the observable PCTREATL. But the positive influence of WATERC may seem, initially, to be counterintuitive. Generally, a badly-eroded farm would lead to more silting and gullying of off-farm water courses. However, PERCEP was coded from the farmers beliefs about land condition as he felt that condition would affect him. Silting and gullying of off-farm watercourses hardly affect him directly and WATERC may well be reflecting his perceptions of the effects of slope, soil type or some other characteristic of the land. The correlation coefficient between SILTRO and WATERC was -0.31, below our arbitrary multicollinearity threshold of 0.40. In retrospect, the a priori sign on WATERC may be hard to predict.

Two of the measures of land condition (ACCESS and SILTRO) have no significant influence on the perception index. The quality of access to fields, homesteads and the properties themselves, varied widely between properties and poor access imposes direct costs on landholders. The lack of significance of ACCESS is therefore surprising, although that for the externality of SILTRO might be expected.

There is some evidence that farmer perceptions and the perceptions of officers of the Soil Conservation Service are in agreement. The variable CCOST is derived from professional judgements of the SCS officers on what works remain to be completed. It is a significant determinant of PERCEP. Farmer perceptions and decisions seem therefore to be directly associated with those of the Service.

Variables ACCESS, SILTRO, WATERC and PCTREATL all refer to perceptions of the land at the time of purchase. The recognition and fixit models refer to a rather later time (between one and four years) and so these variables are not used in the RECOG and FIXIT models.

Recognition of a problem The recognition equation (Table 3) is the least significant of the probit models -- although it's significance still exceeds five per cent. The signs indicate that farmers, who were likely to believe that the potential loss of agricultural productivity was a serious problem (RECOG = 1), were those who had spent the lowest number of years farming (YRSF), who were classified as better investors (BINV), who appeared to pursue to the stewardship motive (MSTEW) and who had actively sought capital gain (MCAPG). The potential increase in wheat production (YINC), the likely production levels without soil conservation works (WHEAT and STOCK), and the income motivation appear to have little effect on recognition.

Fixing up the problem In contrast to the recognition function, YINC was highly significant in the FIXIT results while years in farming (YRSF) was insignificant. Apparently, soil conservation works are more likely to be undertaken on properties where the accompanying yield increases are high, and the distinction between established and new farmers ((YRSF) has no effect on this probability.

The significant, positive/signs on WHEAT and STOCK suggest that increases in the total farm income promote the probability of adoption. The significance of STOCK, the total livestock carrying capacity next year, further suggests that security of income through the opportunity to diversify into livestock production promotes adoption.

The stewardship motive (MSTEW) and likely yield increase (YIMC) are each significant, but in different models. Apparently, those who say they adhere to the stewardship motive are more likely to recognise the existence of an erosion problem -- but not more likely to fix it up (equations 18, and 19). The expected yield increase does not appear to affect the probability of recognising a problem -- but it appears to be the most significant factor in actually undertaking conservation.[9]

All three institutional variables (DMAN, INK and BPAG) have significant effects on the probability that farmers will actually undertake soil conservation. Works are more likely to be undertaken when properties are in the Keepit Project, presumably because of the cost-sharing programme and the especially-active extension programme for the project. However, buyers who have had previous agreements are less likely to fix up their land condition -- and conversely buyers who have not had previous agreements are more likely to undertake the works.[10]

Following Huang and Raunikar, the derivatives of the FIXIT probability function were calculated with respect to the significant independent variables, and calculated at the variable means. These show the change in probability for a given change in the variable, ceteris paribus. A ten per cent increase was selected as the given change and the results were as follows.

YINC	+	0.383	WHEAT	+	0.067
BINV	+	0.197	INK	+	0.035
DMAN	+	0.137	BPAG	-	0.013
STOCK	+	0.097			

When all variables were set at their means, the probability for FIXIT was 0.404. The derivatives show that yield increase is the most influential variable -- as would be expected for a rational profit-motivated farmer. BPAG is the least influential of the significant variables.

Sequential probit models If the PERCEP, RECOG and FIXIT variables had been measured for a common time period, the system of equations (1), (2) and (3) could have been solved sequentially. Values of PERCEP from equation (1) could be data for the PERCEP variable in equation (2), and then values of RECOG from equation (2) could be data for the RECOG variable in equation (3).

The FIXIT model (Table 3) uses the same set of variables as the RECOG model, plus the three institutional variables. So sequential estimation of equation (3) from equation (2) would be consistent. But the RECOG model of Table 3 uses YINC, whereas the estimated PERCEP models of Table 2 use CCOST, which is different from but mathematically related to YINC. Further, the variables PCTREATL is the variable which most clearly measures average land condition in the perceptions of the landholder. Accordingly, for sequential purposes equation (1) would be most simply estimated as:

(20) PERCEP = f(PCTREATL, BINV, BSCH, YRSF)

The models for RECOG and FIXIT would follow from this, and the set of estimated sequential equations was as follows.

Table 2 Perception functions derived by Probit Analysis

	Equations	
	16	17
Explanatory Variables	Model 1	Model 2
Land Factors		
CCOST	-0.014 (2.1)**	-0.014 (2.5)***
ACCESS	-0.004 (0.7)	-0.004 (0.8)
SILTRO	0.003 (0.5)	0.004 (0.7)
WATERC	0.041 (2.0)**	0.035 (1.9)**
PCTREATL	-0.054 (2.0)**	-0.052 (2.0)**
Personal Factors		
BINV		0.150 (0.5)
BSCH		0.004 (0.2)
YRSF		0.029 (1.7)**
Constant		0.776
0.867		
Likelihood ratio	22.576	19.169
Level of significance	0.01	0.01

Table 3 Recognition and Fixit Functions derived by Probit Analysis

Explanatory Variables	Equations 18 RECOG	 19 FIXIT
Personal factors		
BINV	0.674 (1.7)**	0.578 (1.7)**
BSCH	0.044 (1.2)	0.029 (0.7)
YRSF	-0.054 (2.4)**	-0.001 (0.1)
MAGING	0.269 (0.5)	0.567 (0.9)
MCAPG	0.714 (1.4)*	0.513 (0.9)
MSTEW	1.653 (1.6)*	-0.440 (0.5)
Economic factors		
WHEAT	0.259 (0.6)	0.624 (1.5)*
STOCK	-0.059 (0.9)	0.119 (2.1)**
YINC	3.176 (1.2)	6.499 (2.5)***
Institutional factors		
DMAN		0.094 (2.1)**
INK		1.352 (1.4)*
BPAG		-2.236 (1.4)*
Constant	-6.156	-8.863
Likelihood ratio	18.404	33.986
Level of significance	0.05	>0.01

$$(21)\qquad \text{PERCEP} = 0.331 - \underset{(2.4)^{**}}{0.031}\ \text{PCTREATL} - \underset{(0.8)}{0.180}\ \text{BINV} - \underset{(0.3)}{0.008}\ \text{BSCH} + \underset{(1.8)^{**}}{0.026}\cancel{\text{Y}}\ \text{YRSF}$$

Likelihood ratio = 11.015 Level of significance = worse than 0.10.

$$(22)\qquad \text{RECOG} = -3.679 - \underset{(1.3)^{*}}{0.450}\ \text{PERCEP} + \underset{(0.7)}{0.334}\ \text{MAGINC} + \underset{(1.4)^{*}}{0.657}\ \text{MCAPG}$$

$$+ \underset{(0.7)}{0.481}\ \text{MSTEW} + \underset{(0.1)}{0.059}\ \text{WHEAT} - \underset{(0.5)}{0.026}\ \text{STOCK} + \underset{(1.1)}{3.114}\ \text{YINC}$$

Likelihood ratio = 11.469 Level of significance = 0.05

$$(23)\qquad \text{FIXIT} = 0.080 + \underset{(1.9)^{**}}{0.582}\ \text{RECOG} + \underset{(1.4)^{*}}{0.038}\ \text{DMAN} + \underset{(2.1)^{**}}{1.458}\ \text{INK} - \underset{(0.9)}{1.033}\ \text{BPAG}$$

Likelihood ratio = 15.689 Level of significance = better than 0.01

The coefficients on PERCEP in equation (21) and RECOG in equation (22) are significant. The significant coefficients in equations (21) and (22) approximate those of their respective models in Table 2. However sequential estimation has offered no new information, and equation (21) both appears not to have a useful level of significance as a whole.

CONCLUSIONS

The analysis can now be interpreted in terms of the profitability of on-farm conservation measures, and the factors that promote their adoption in the study region. These conclusions may help to explain the apparent paradoxes of farmer behaviour, namely over-adoption relative to the state of information but under-adoption relative to likely econmomic gains.

The response analysis indicated that adoption of conservation measures which reduce CCOST, does significantly increase wheat yield and the appendix indicates that these increases appear to earn at least 10 per cent on 41 of the properties. The managerial measure of land condition (CCOST) was straightforward to measure, is a direct measure of conservation/erosion status, and proved an important variable in the models. As such it may have more widespread use.

The major determinant of the final decision to resolve the problem (the FIXIT stage) was the economic factor YINC, the likely increase in wheat yield after adoption. The arithmetically-related CCOST, measuring land condition, was a major determinant of PERCEP, and the measures of farm income (WHEAT and STOCK) were significant determinants of FIXIT. The importance of these variables supports the role of the market paradigm in the adoption process, particularly in the key stage of actually resolving the problem.

Nevertheless non-economic factors are important too and these may explain why adoption was not followed in all profitable cases. Those persons with more years in farming (YRSF) may in fact recognise erosion as less of a problem -- according to their reported information. Previous experience with agreements (BPAG), which may reflect personal factors such as age, seems to make adoption less likely -- <u>ceteris paribus</u>.

The institutional factors help to explain the adoption rate in the study area. The area contained the Keepit Soil Conservation Project which, as included as the variable INK, significantly increases the likelihood of adoption. Apparently the Soil Conservation Service has had a positive effect because its Keepit programme does increase the likelihood of the adoption of soil conservation measures.

FOOTNOTES

1. While research is in progress, there is no published work which establishes whether soil conservation increases crop yields in New South Wales.

2. A shire is an administrative unit of government, roughly equivalent to a county in the United States of America.

3. Those who adopted conservation practices (FIXIT = 1) could conceivably be those who purchased land early in this six-year period. To test for this, we compared the time of purchase for adopters and non-adopters. The mean was September 1982 for the former and October 1982 for the latter, and there was no statistical difference between these means.

4. The Universal Soil Loss Equation was derived from, and so only really applies to, conditions in the Upper Midwest of the United States (Bromley). Not surprisingly, local SCS officers expressed some reservations about its use to estimate soil loss in New South Wales. As the analysis turned out, SLOSS proved a poorer determinant of wheat yields than CCOST.

5. While we estimated these average slopes from topographical maps, as carefully as possible, more detailed fieldwork might have given more precise figures.

6. The correlation coefficient between the two monetary variables of CCOST and WATERC was 0.083. The cost of these particular on-farm conservation works was estimated by farmers, instead of Service officers, because the variable WATERC was to be related to farmer perception.

7. The correlation coefficient between Ln(PCARAB) and Ln(SLOSS) is -0.437, rather above our abitrary multicollinearity threshold of 0.400. The properties of the coefficients in equation (13) may therefore be doubtful, and the coefficient of 0.448 on Ln(PCARAB)may capture some of the effects of Ln(SLOSS). All other correlations between independent variables in Table 1 are less than 0.280.

8. Cross-sectional analyses, such as this, imply that the increase in wheat yields would be "instantaneous". In fact, there may be a delay of one or perhaps two seasons.

9. These differences suggest a slight amendment to the Van Kooten/Furtan hypotheses. Stewardship is one of the reported motives in recognising a problem, but economics is the reason for resolving it.

10. Our field experience suggests that this result may reflect landholders age, rather than poor experience with previous agreements. Landholders who had previous agreements (BPAG = 1) are more likely to be older and so perhaps less likely to invest in the future through soil conservation.

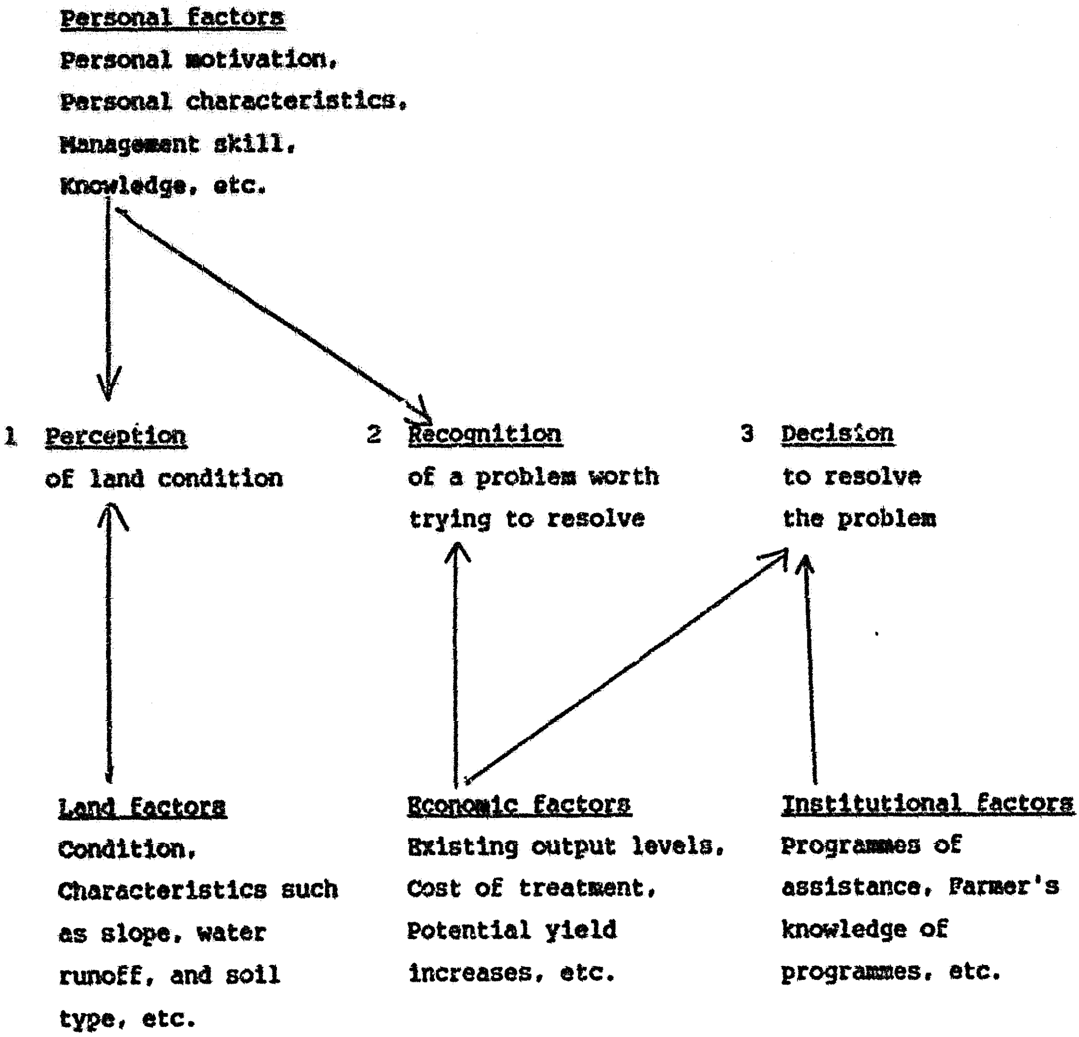

Figure 1 Three stages in the process of adoption of soil conservation practices.

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APPENDIX

Profitability of soil conservation

The basic framework for estimation of profitability has been summarised by Lee and Stewart, and Walker. In simplest terms, the net present value (NPV) to the individual farmer from the adoption of soil conservation works is calculated as follows.

NPV = (discounted value of yield increases) - (discounted value of the cost of conservation works) - (net cost of any changes in practices)

Farmers in the study area follow substantially the same crop production techniques with or without the conservation works, so the last item in the equation is effectively zero. The cost of conservation works per hectare per farm is of course CCOST. Local experience suggests a conservative works life at 12 years, if maintained at the level of one half of the original costs every four years.

The yield increases can be estimated from equation (15). Since all of the recommended works are undertaken or none at all, the yield increase is given by XINC = 0.150 Ln (CCOST). Five per cent approximates the real social rate of discount and 10 per cent is a minimum estimate of a farmers real opportunity cost of capital. The net present values for the range of values of CCOST is now summarised.

Land Condition as CCOST $ per ha	Net present values	
	At 5 per cent	At 10 per cent
10	365.72	299.06
50	267.32	139.68
100	163.52	13.90
150	67.32	-102.61
190	-5.48	-190.91

The break-even land conditions, those with a net present value of $0, are represented by a CCOST of $187 at 5 per cent, and by $106 at 10 per cent. The former break-even point would include 49 of the 50 properties, while the latter would still include 41 of them. The break-even land condition for a discount rate of 20 per cent is represented by a CCOST of approximately $61. Twenty-six properties have CCOST levels lower than this threshold, hence these 26 can be expected to earn a real rate of return of 20 per cent -- a not-inconsiderable return.

The level of CCOST on the most-eroded property is $190, only $3 per hectare above the social threshold. For simplicity, potential increases in land value at the end of the time horizon were not assessed, and several external benefits have not been valued. So it may well be socially efficient to undertake conservation works on all 50. There is some doubt whether owners of the nine most-eroded properties would themselves be motivated to undertake the works because their financial return is less than $0.