CHOICES OF SOIL CONSERVATION METHODS ON KWAZULU-NATAL COMMERCIAL SUGARCANE FARMS

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A Principal components analysis and multiple regression techniques are used to analyse heterogeneity in 53 KwaZulu-Natal sugarcane farmers soil conservation decisions. Minimum tillage and construction of water carrying terraces are the most common methods used, whereas trash mulching is least commonly practised. Results indicate that farmers' demands for soil conservation, their demands for other attributes of soil conservation practices and interactions between practices are important to explaining their choices. Intra-farm variation in use of soil conservation methods is small relative to inter-farm variation. Education programmes, provision of information, and improving farmers' technical soil conservation skills have implications for aggregate soil conservation adoption, whereas the types of information provided, fire insurance programmes and soil conservation subsidies have implications for the combinations of practices adopted.

INTRODUCTION

Understanding farmers' soil conservation decisions is important for assessment of soil conservation policy options. However, a review of empirical research suggests that agricultural economists understanding of these decisions is poor : The statistical fit of estimated models tends to be poor and results show little consistency between studies. A critical analysis indicates that these studies ignore useful economic information. In particular, attributes of soil conservation practices other than their soil conserving properties and interactions between soil conservation methods tend to be overlooked. In this study multivariate techniques are used to analyse heterogeneity in KwaZulu-Natal commercial sugarcane farmers' soil conservation decisions to assess factors affecting farmers' soil conservation decisions. The authors are unaware of any other multivariate analyses of farmers' soil conservation decisions. Results are pertinent to the soil conservation policy arena.

THEORY

The movement towards soil conservation is generally accomplished by the adoption of a combination of m, $m = 1,2,..,M$, management practices which result

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in benefits of reduced erosion. This decision environment may be represented in a probabilistic choice system, which is analogous to a conventional econometric specification of a demand system. Through application of the hypothesis of random utility maximisation, a multivariate qualitative response probability model of individuals decisions may be derived such that $P(I/b,s) = F(\alpha x_i)$ which specifies the probability of choosing the *n*th, *n* = 1, 2, ..., N, bundle of soil conservation management practices, given that I is the choice set ; the decision maker has characteristics s; and x_i is a vector related to the relative attributes of the *i*th bundle, characteristics of the decision maker and his (her) background economic environment (McFadden, 1981). If $M \geq 2$ then the adoption decision is inherently multivariate, and attempting univariate modelling excludes useful economic information contained in interdependent and simultaneous adoption decisions (Dorfman, 1996). Hence, adoption decisions are related not only to the farmer's demand for soil conservation, but also his demands for the other attributes of these practices and how interactions between practices affect the perceived distributions of these attributes.

STUDY POPULATION

The study population of South African commercial sugarcane farmers is appropriate because soils in sugarcane growing areas are prone to erosion, hence soil conservation management systems are essential on sugarcane fields (Platford, 1987). There are five decisions pertinent to infield soil conservation of sugarcane fields (adoption of minimum tillage, stripcropping and trash mulching, choice of terrace bank type, and spacing of terrace banks) (Platford, 1987) for which farmers are afforded autonomy (McFarlane & Maher, 1996). Platford (1987) provides technological information relating use of these methods of conserving soil to achieved infield soil conservation efficiency on sugarcane land.

Soil conservation structures require substantial capital investment and are designed to reduce in-field velocity of runoff. Spacing between these terraces in a field is important. Water-carrying terraces, but not spillover roads, also convey run-off at an acceptable velocity to suitable discharge points. Chemical minimum tillage, which uses glyphosphate instead of ploughing to kill the old crop, is carried out prior to replanting (on average every 12 years). Trash mulching and strip cropping, on the other hand, are carried out at harvest (every 12-18 months). Because trash mulching reduces soil temperature it reduces ratoon vigour and is thus a less viable option in relatively cold areas and at altitudes higher than 400 metres above sea level. Strip cropping not only improves soil conservation, the horizontal field layout also create fire-breaks (Platford, 1987; McFarlane & Maher, 1996 and Anonymous, 1996).

The data are based on a stratified random sample consisting of 53 large scale commercial sugarcane farmers in the Eston, Sezela and Mzimkulu sugar mill areas of KwaZulu-Natal, South Africa. The sample was drawn from a list of growers obtained from the South African Cane Growers' Association. Farmers were interviewed on their farms during May and June of 1996.

METHODOLOGY

Techniques commonly used to model adoption decisions of multiple technologies that can be applied in various combinations include multinomial qualitative response models e.g. Caswell & Zilbermann (1985) and Dorfman (1996) and simultaneous equations systems eg. Smale & Heisey (1993) cited by Dorfman (1996). Because some, but not all, 'intensiveness of use' management decisions are qualitative in nature (e.g. spacing of terrace banks is not) neither technique is suitable for this analysis. Other multivariate approaches include principal components analysis (PCA) and factor analysis (FA). FA has been used by Raniyar & Goode (1992), amongst others, to model farmers' technology adoption decisions. The central aim of both techniques is to reduce the dimensionality of a data set while retaining as much as possible of the variation present in the data set. This reduction is achieved by transforming to a new set of variables, the principal components (PC's) or factors respectively, which are (usually) orthogonal, and which are ordered so that the first few retain most of the variation present in all of the original variables (Jolliffe, 1986:115). Elicited PC's (factors) may subsequently be used as dependent variables in regression analysis to identify factors affecting adoption of these groupings of practices.

Both techniques may be thought of as trying to represent some aspect of the covariance matrix (or correlation matrix) as well as possible. Whereas PCA concentrates on the diagonal elements of the covariance matrix, in factor analysis the interest is on the off-diagonal elements. Consequently, for a given set of data, the number of factors required for an adequate factor model will be no larger, and may be strictly smaller, than the number of PC's required to account for most of the variation in the data. However, independent decisions cannot be captured as a 'single variable' factors but can be captured in 'single variable' PC's (Jolliffe, 1986:122-4). Because explaining adoption of 'independent' soil conservation practices, and not only groupings of practices, is important to explaining soil conservation decisions, PCA is used in lieu of FA.

Adoption of minimum tillage, strip cropping, terraces and trash mulching on the jth field of the ith farm, are captured in the dummy variables $MINTIL_j$, $STRIPCROP_j$, $TERRACE_j$ and $TRASH_j$ respectively, which equal one if the practice is adopted, otherwise zero. The relative effect of the chosen VI on soil conservation efficiency is captured in the variable $VERTINT_j$, defined using Platford's (1987) nomograph as the actual panel vertical interval divided by the range of recommended vertical intervals for that slope. Consequently, $VERTINT_j$ is negatively related to the contribution of terrace spacing to soil conservation and is conducive to relative analysis. These variables reflect 'intensiveness of adoption' of the respective soil conservation measures for the *j*th field of the *i*th farm. Following Ferrer & Nieuwoudt (1998) observations were replicated to encompass both relatively steep (*j* = S) and average gradient (*j* = A) fields with respect the topography on each farm to incorporate information on 'extensiveness of adoption' of each soil conservation measure. Although some authors suggest that PCA should only be done on continuous variables, Jolliffe (1986:200) contends that correlations on which PC's are based are still valid for discrete variables provided that the possible values of the discrete variables have a genuine interpretation, and variables should not be defined with more than two possible values.

RESULTS AND DISCUSSION

Table 1 reports frequencies of adoption of the soil conservation practices on 'average' (*j* = A) and 'relatively steep' (*j* = S) fields. Construction of water-carrying terraces and adoption of minimum tillage are most common, whilst few farmers practices trash mulching. All practices have a higher incidence of adoption on 'relatively steep' slopes and there were no occurrences observed where a soil conservation practice was adopted on an 'average gradient' field that was not also adopted on the farms relatively steep fields. Considerable heterogeneity in adoption of soil conservation practices is evident, ranging from none to all practices adopted within fields.

Table 1: Frequencies of adoption of soil conservation practices by commercial sugarcane farmers (n=53) (June, 1996)

Soil Conservation Practice	"Average' gradient fields		'Steep' gradient fields	
Minimum tillage	21	(39.6%)	42	(79.2%)
Strip cropping	16	(30.2%)	25	(47.2%)
Water-carrying terraces	31	(58.5%)	39	(73.6%)
Trash mulching	3	(5.7%)	8	(15.2%)

The principal components analysis elicited four PC's with eigenvalues greater than one, denoted $TECH_s$, *s* = 1, 2, 3 and 4 respectively, accounting for 72.4 percent of the variation in the data. The eigenvalues and eigenvectors of these

PC's are presented in Table 2.

$TECH_1$ is positively related to intensiveness and extensiveness of whole farm soil conservation adoption, and hence indexes farmers' demands for whole farm soil conservation. Low factor loadings of the $VERTINT_j$ variables may reflect respondents' relative difficulties in assessing the partial effect of VI's on soil conservation (Ferrer & Nieuwoudt, 1998). This PC indicates that on average respondents regard the soil conservation practices as compliments and not substitutes in soil conservation management. Although differences in farmers' demands for whole farm soil conservation are the primary source of variation in their soil conservation decisions, $TECH_1$ accounts for less than 28 percent of the variation in the data, indicating that other factors are also important.

Table 2: Principal components describing heterogeneity in commercial sugarcane farmers' soil conservation decisions (June 1996)

	Principal Component			
Variable	$TECH_1$	$TECH_2$	$TECH_3$	$TECH_4$
$VERTINT_A$	-0.099	**0.762**	-0.281	**0.309**
$VERTINT_S$	**-0.358**	**0.548**	0.233	**0.399**
$MINTIL_A$	**0.695**	0.105	**-0.399**	-0.106
$MINTIL_S$	**0.481**	-0.051	**-0.387**	**-0.439**
$STRIPCROP_A$	**0.577**	0.184	**0.677**	-0.044
$STRIPCROP_S$	**0.585**	0.265	**0.590**	-0.214
$TERRACE_A$	**0.577**	**-0.529**	0.137	**0.495**
$TERRACE_S$	**0.629**	**-0.425**	-0.205	**0.478**
$TRASH_A$	**0.486**	**0.613**	-0.221	0.234
$TRASH_S$	**0.521**	**0.454**	-0.112	-0.175
eigenvalue	2.76	2.04	1.37	1.07

$TECH_2$ captures variation in farmers' propensities to adopt soil conservation works (capital intensive, long term investments) relative to trash mulching and strip cropping (time intensive management practices at harvest). It is expected that farmers with greater financial (management time) constraints are less (more) likely to prefer in soil conservation works relative to trash mulching and strip cropping. $TECH_3$ indexes farmers' relative propensities to adopt minimum tillage relative to strip cropping. This variation is ascribed to possible incompatibilities of the two practices : adoption of both within the same field increases risk of spray drift of glyphosphate onto young cane. Because strip cropping is fire risk reducing, it is expected that farmers with formal fire insurance are less likely to implement strip cropping programmes.
$TECH_4$ reflects variation in farmers' use of soil conservation works and indexes

farmers' propensity to use water-carrying terraces relative to reduced spacing of terrace banks as a soil conservation strategy. This substitution of practices is likely to be related to physical land and soil characteristics: firstly, relatively narrow panel widths, which are more likely on land relatively prone to erosion, may impede infield operations; secondly, adoption of water-carrying terraces is more likely to be necessary on land that is relatively prone to erosion, and finally, adoption of minimum tillage only on relatively steep slopes is more likely on farms that are generally less prone to soil erosion.

Regression analyses were conducted to relate the $TECH_s$ to farmers' personal, farm, farm business, and institutional characteristics. Personal variables include EDU, the farmer's years of formal education; $RISK_1$, an index positively related to the farmer's absolute risk aversion (elicitation of this variable is described in Ferrer *et al*, 1998); and SKIL, the farmer's own assessments of his technical skills in implementing soil conservation, measured on a lykert-type scale where 1 is poor and 5 is excellent.

Farm and farm business characteristics include hectares of sugarcane farmed (CANE); the farm debt-asset ratio (DBASR), the proportion of the principle farm decision maker's time spent in off farm employment (OFRT); the farmer's off farm income not attributable to employment (UI); the percentage gradient of a relatively steep field on that farm (SLOPE); whether soil erosiveness was classified according to Macvicar (1973) as being highly erodible (ERSV = 1, otherwise zero); whether the farm has a SASEX land use plan (LUP); whether the farm is below an altitude of 400 metres (COAST = 1, otherwise zero); whether implementation of the farm's soil conservation plans is not yet completed (ACTV = 1, otherwise zero); and MINEP, the farmers' assessment of the proportion of his land that does not have potential for serious erosion problems.

Institutional variables considered include $INFO_1$, an index positively related to use of non extension information sources; $INFO_2$ an index positively related to use of media information (radio, television, magazines, newspapers) relative to other sources of information; $INFO_3$, an index positively related to use of extension information; and purchase of fire insurance for sugarcane from a commonly used insurance brokerage ($FINS_1$ = 1; otherwise zero); or any other brokerage ($FINS_2$ = 1; otherwise zero). The estimated regression equations for $TECH_1$, $TECH_2$ and $TECH_3$ are reported in equations 1,2 and 3, where *, **, and *** indicate statistical significance at the 10, 5 and 1 percent levels of confidence respectively. The regression on $TECH_4$, however, was not statistically significant and is not reported. This may be attributed to the long-term nature of soil conservation works and consequent separation of observed farmer and farm business characteristics from those at the time of the observed decision.

$$TECH_1 = -4.49^{***} -0.53^{***}ACTV + 0.86^{***}COAST + 0.18^{***}EAU + 0.27^{**}INFO_3 +0.57^{***}SKIL + 0.41^{***}ERSV$$
$$df = 38 \quad F=13.8^{***} \quad R^2 = 0.685 \quad adj\ R^2 = 0.64 \quad ...(1)$$

$$TECH_2 = 1.81^{**} - 0.31^{**}RISK_1 + 0.28^{**}INFO_2 - 0.63^{**}LUP - 1.3E\text{-}05^{**}UI - 0.052^{**}SLOPE + 1.22^{***}COAST - 7.5E\text{-}02\ EAU$$
$$df = 37 \quad F = 4.76^{***} \quad R^2 = 0.474 \quad adj\ R^2 = 0.375 \quad ...(2)$$

$$TECH_3 = 0.79^{*} - 0.64^{**}ACTV + 9.8E\text{-}03^{***}MINEP - 0.62\ FINS_1 - 1.8^{***}FINS_2$$
$$df = 40 \quad F = 7.69^{***} \quad R^2 = 0.435 \quad adj\ R^2 = 0.378 \quad ...(3)$$

Equation 1 accounts for 68.5 percent of the variation in the data. Results, including goodness-of-fit statistics, bear striking similarity to the regression equations explaining conservation adoption in Ferrer & Nieuwoudt (1998).

Farmers who are have more education, use more information from extension sources, have better technical skills, and who are more aware of the need for soil conservation (those with highly erosive soil types and those who farm at the coast where topography tends to be relatively steep) demand more soil conservation. The ACTV coefficient reflects the lag between soil conservation decisions and achieved soil conservation adoption due to the long term nature of implementing soil conservation.

Equation 2 accounts for almost 50 percent of the variation in $TECH_2$. Results indicate adoption of land use plans, education, risk aversion, steep topography, reduced financial constraints and relatively less use of media information sources encourage greater use of soil conservation structures relative to trash mulching and strip cropping. Results also reflect that trash mulching is a less viable option inland and suggest that farmers consider adoption of soil conservation works to be relatively less risky than adoption of strip cropping and trash mulching.

Equation 3 accounts for only 43.5 percent of the variation in $TECH_3$. However, the overall regression is statistically significant and the estimated coefficients are all statistically significant. Results indicate that adoption of strip cropping is less likely if fire insurance is purchased. This relationship is less strong if $FINS_1$ equals 1, suggesting that insurance premia from this insurance brokerage more accurately reflect the fire risk reducing properties of strip cropping programmes. The positive relationship between MINEP and adoption of strip cropping confirms *a priori* expectations that strip cropping is adopted not only for its soil conserving properties but also because it reduces fire risk. The ACTV variable coefficient reflects the long-term nature of implementing strip-cropping programmes.

CONCLUSIONS AND POLICY IMPLICATIONS

Although farmers' demands for soil conservation are the primary source of variation in their soil conservation decisions, this accounts for less that 30 percent of observed heterogeneity. Within the residual variation, variation is identified in farmers use of a) soil conservation structures relative to trash mulching and strip cropping; b) minimum tillage relative to strip cropping; and c) water carrying terraces relative to reduced terrace spacing within fields. Intra-farm variation in soil conservation practices is small relative to inter-farm variation. Relative attributes of these practices and interactions between these practices explain these natural groupings.

Policies of education, provision of information through extension, and programmes to improve farmers' technical skills for soil conservation are likely to improve aggregate conservation adoption amongst commercial sugarcane farmers. Policies may also affect farmers choices of soil conservation practices. Increased adoption of land use plans, education and reduced financial constraints (e.g. soil conservation subsidies) will promote adoption of improved soil conservation works, whereas, increased provision of media information on soil conservation is likely to encourage adoption of strip cropping and trash mulching. Results indicate that the demand for strip cropping is derived not only from the demand for soil conservation, but also the demand for fire insurance. It is important that formal fire insurance risk premia accurately reflect the value of reduced fire risk attributable to stripcropping or fire insurance programmes will negatively affect soil conservation on sugarcane farms.

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