THE ADOPTION OF MINIMUM TILLAGE IN THE CENTRAL WHEATBELT OF WESTERN AUSTRALIA: PRELIMINARY RESULTS

Bryan J. Gorddard

Agricultural Economics
School of Agriculture
The University of Western Australia
Nedlands, W.A. 6009

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INTRODUCTION

A vigorous debate has developed in the 1980's over extension policy for environmental practices in agriculture. While the basis of these arguments can be traced to the classic exchanges between Griliches (1960, 1962), Havens and Rogers (1961) and Brandner and Straus (1959), a study by Pampel and van Es (1977) suggested that factors associated with the adoption of commercial practices (defined as "profitable") were different from those associated with conservation ("unprofitable" practices).

The assumption that conservation practices were intrinsically unprofitable, and that adoption-diffusion approaches were therefore irrelevant to the practice of conservation extension has become entrenched in branches of the sociological and environmental literature. More recently, the perceived futility of information and education in changing environmental practices has stimulated legislative approaches to land use (Bradsen 1990). This has been despite the methodological limitations of the original study and subsequent findings that both economic and information variables are involved in the adoption of environmental practices (Nowak 1987). A closely related problem is the generally low predictive validity of virtually all models of conservation adoption, with coefficients of determination commonly less than 0.3 (Ervin and Ervin 1982, Rahm and Huffman 1984). This is in marked contrast to models of the adoption of "commercial" practices where R^2 values of 0.5 to 0.8 are common (Rogers, 1983).

There has been surprisingly little critical analysis in the literature of the validity problems in the oft-cited conservation-adoption models, more so given the extent of public investment in the extension of conservation practices. The most common approach to the study of conservation-adoption has been the application of adoption-diffusion theory, usually relating the adoption of a practice to a range of socio-economic variables (age, education, farm size, extension use, resources, etc.), (Rahm and Huffman 1984, Earle *et al*, 1979).

A second class of studies has focussed on farmers' perceptions of environmental problems usually in addition to socio-economic variables (Ervin and Ervin 1982, Green and Heffernan 1987), often including structural constraints to adoption. Unfortunately neither class of model is particularly useful for extension practitioners, even when their questionable validity is admitted. This is primarily because such models lack a theoretical basis for the role of information in human learning about new practices. Lindner (1987) points out that the adoption process is essentially one of learning, firstly about the existence of an innovation, and then about the likely impact of the innovation upon the farmer's welfare. That is, the farmer seeks and uses information about the characteristics of the practice, how they might express themselves on the farmers' paddocks, and their expected effects on the family's total welfare. In this neo-Bayesian model of adoption, information is presumed to impact upon the farmers' subjective beliefs about the traits of the innovation and their expected consequences on the farm, relative to the performance of the present practice. Such a model admits that a technology is valued in terms of its overall impact on welfare or subjective expected utility, which includes, but is not restricted to, relative profitability. Therefore, models which specify the subjective beliefs of farmers and relate these to behaviour have potential value for extension practitioners since they offer the prospect of targetting information and extension activities at specific beliefs and adopter categories.

MODEL DEVELOPMENT

The research was based upon a recent predictive model of human behaviour which has given reliable results in a wide range of social situations: the "theory of reasoned action" of Ajzen and Fishbein (1980). Examples of its applicability to environmental issues may be found in Kantola, Syme and Nesdale (1983) and Kantola, Syme and Campbell (1982).

The basic model takes the form:

$$BI = Ab + Sn$$

where $Ab = \Sigma\ Bb \cdot Ei$ and $Sn = \Sigma\ Bj \cdot Mj$

and BI = Behavioural intention; Ab = Attitude to the behaviour; Sn = Subjective norm; Bb = Behavioural beliefs; Ei = Outcome evaluations; Bj = Normative beliefs; and Mj = Motivation to comply.

The model proposes that a person's behaviour can be predicted with some confidence from a knowledge of that person's belief set, attitude, subjective norm, and behavioural intention with respect to a specific behaviour. Correlations reported in the literature (Ajzen and Fishbein, 1980) between these components vary in the range 0.6 to 0.95.

The model further proposes that change in behaviour can be brought about by providing information directed at behavioural and normative beliefs.

The basic Fishbein model was tested at Northam, Western Australia, in 1989 on a range of conservation practices (Gorddard and Nash 1990). The basic model showed acceptable predictive validity ($R^2 = \cdot 33$ to $\cdot 55$) for three of five practices (minimum tillage, early seeding of wheat, and lupin-wheat rotations, but was less successful for the use of herbicides and paddock selection for cropping. Farmers' beliefs and attitudes towards herbicides were in conflict with their use of herbicides in conservation cropping systems, as also reported by Cary, *et al* (1989) for Victorian farmers.

Further analysis, and the work of Lynne *et al* (1988) suggested that the model might be improved by re-specification in the form -

B = f (Bb, Ab, Sn, Bc, Rp)

where Bb = behavioural beliefs
Ab = attitude to the behaviour
Sn = social norm
Bc = behaviour constraints
Rp = risk preference
B = behavioural index

giving an 'expectancy value' model not unlike the SEU model in economics.

Behavioural beliefs (Bb): The belief set was specified to include:-

Health and safety: from machinery use
Health and safety: from herbicide use
Herbicide residues in water
Herbicide residues in soil
Herbicide damage to farm trees
Wind erosion
Water erosion
Soil structure
Wheat yield
Net income from wheat
Trafficability of soils
Smoothness of paddocks
Weed resistance to herbicides
Insect damage
Pasture regeneration
Soil fertility

Questions were presented on a seven-point, bipolar scale indicating a range of possible outcomes from the use of three cultivation practices. These were: (1) Direct drilling:- no cultivation in the year of sowing, other than the seeding operation itself. (2) Reduced cultivation:- one cultivation only, prior to the seeding operation. (3) Conventional tillage:- more than one cultivation prior to seeding. Particular care was taken with the definition of cultivation method, given problems reported elsewhere (Cary *et al*, 1989). Extensive pre-testing indicated that farmers preferred a verbal/descriptive scale to numerical categories used in the earlier model. Farmers were asked to indicate the chances out of 100 that they might experience each outcome, so that a form of subjective probability distribution was elicited for the effect of each cultivation technique on each belief. In the case of water erosion, a set of photographs was used to elicit an expected frequency for each level of erosion with each cultivation method, for a specified soil type/land class.

Attitude to behaviour (Ab): Attitude was assessed using the semantic differential (Osgood *et al*, 1957) as used by Ajzen and Fishbein (1980). This elicits a person's overall, affective evaluation of a specified behaviour.

Social Norm (Sn): The perceived social pressure, towards or against the behaviour, was elicited using the original Ajzen and Fishbein (1980) technique, with a restricted list of significant others.

Behavioural Constraints (Bc): Ajzen (1988) extended the original model to incorporate "perceived behavioural controls". These are the external factors perceived by the person to be controlling a behaviour - obvious examples would be a legal obligation or lack of a market. Three sets of potential constraints were presented using a scale of "strongly agree - strongly disagree". Set 1 dealt with machinery and cultivation constraints, Set 2 with herbicide and spray-effectiveness factors, while Set 3 included safety factors. It was hypothesized that the machinery and safety constraints would differ across cultivation types and soil types.

Risk Preference (Rp): Ervin and Ervin (1982) and Lynne *et al* (1988) provided equivocal evidence that risk attitude may be related to the adoption of conservation practices. Accordingly, levels of actual insurance behaviour against fire and hail, and subjective probabilities of loss were elicited, plus levels of public liability and personal accident insurance cover, with a view to estimating the Pratt coefficient from observed behaviour, as per Anderson *et al* (1977). Risk attitude was also estimated by the sum of variables for the levels of public liability and personal accident insurance taken out by the respondent.

The Dependent Variable: The majority of adoption studies have applied a bivariate, adopt/not adopted dependent variable to cross-sectional data.

Early studies were analysed using relatively crude, non-parametric techniques although recent work has applied multi-variate methods, and the use of logit, probit and tobit analysis has dominated in the economics literature. These approaches to adoption are limited by the static, bivariate representation of an essentially dynamic, continuous process (Lindner 1987). A further difficulty lies in the qualitative application of an innovation, as skill and experience accumulate (Nowak and Korshing, 1985). The use of time lags to discovery, first trial and adoption (Lindner *et al*, 1982) to generate a continuous dependent variable is conceptually attractive, but suffers from recall problems with older technologies. The present study uses a bounded dependent variable - the proportion of total crop sown with each technique in 1990. Also tested is a "behavioural index" which weights the levels of present use with an "intention" factor for the next season.

Behaviour was specified using a combination of written descriptions, and photographs of major land classes in the region (soils, vegetation and slope).

THE STUDY AREA

The study area comprised 14 shires in the central wheatbelt of Western Australia. This area includes over 1100 agricultural holdings. Rainfall varies from 350 to 450 mm, and the major soil-vegetation-landform complexes are common across the region.

SURVEY TECHNIQUE

The sampling frame was defined as all farmers, with a minimum farm area of 400 ha, who planted wheat in 1990. Leased properties and ownership changes in the last two years were excluded. The frame of 952 farmers was checked for recent changes in ownership and for multiple ownership, before a random sample of 150 was drawn, stratified on a shire basis, representing 16% of the population.

Farmers were interviewed on-farm, using questions presented with a portable microcomputer, supported by photographic and written information. Six farmers either declined to be interviewed or were unavailable, producing 144 usable responses.

RESULTS

The proportion of wheat sown in 1990 using the various techniques is shown in Table 1. This was converted to a Behavioural Index via an arbitrary weighting factor derived from responses to the question on intended change to cultivation practice in 1991.

All variates were calculated from the ratio of the raw scores for [Reduced Cultivation + Direct Drilling : Conventional Cultivation] thus providing a measure of perceived relative advantage over the conventional method. Data were fitted in both raw and normalised form, with similar results. The normalised form is presented here.

Correlations between the variables (Table 2) range from negligible to 0.52. Multiple regression results for the original Ajzen and Fishbein model are given in Table 3, with an adjusted R^2 vale of 39.3. The revised model, incorporating risk and using the sums of normalised scores for Behavioural and Constraint beliefs, is presented in Table 4. The coefficient of determination improved to a modest .45 in the modified model (Table 4), and the regression was significant at the $p \leq 0.001$ level.

The belief sets were then partitioned, in the case of Behavioural Beliefs on the basis of (1) health, safety and "conservation" items and (2) "production" items (yield, income, fertility, weed resistance, insect incidence, etc.) and for Constraint Beliefs into sets based on (i) machinery and practical issues, (ii) spray efficiency factors and (iii) safety issues. Table 5 examines this reduced set of "behavioural" and "constraint" beliefs. While more detailed analysis of the belief sets is clearly required, this preliminary classification improved the model, with an adjusted R^2 of .51.

Reduction of the complete belief set, using a best subsets routine, suggested that the most important Behavioural Beliefs were -

* Net income from wheat
* Health and safety from herbicide use
* Herbicide residues in water supplies
* Herbicide effects on farm trees
* Soil structure
* Soil fertility

and that the Constraint Beliefs dealing with

* Herbicide efficiency, and
* Safety

were always significant.

Beliefs shown to be important in an earlier study in an adjacent district (Gorddard and Nash, 1990), such as expected effects on pasture regeneration, paddock smoothness and insect problems, were seldom significant in the models.

Table 1

Present Use of Conventional Cultivation, Reduced Cultivation and Direct Drilling for Wheat.
Number of farmers and level of adoption as % of total wheat sown in 1990.

	Practice					
Level or Use	Conventional		Reduced		Direct	
% Crop Sown	Number	%	Number	%	Number	%
Nil	23	16	41	28.4	85	59.9
1 - 20	21	14.5	16	11.1	22	15.5
21 - 40	24	16.7	24	16.7	14	9.9
41 - 60	24	16.7	25	17.4	10	7.0
61 - 80	11	7.6	21	14.6	3	2.1
81-100	41	28.5	17	11.8	8	5.6
TOTAL	144	100%	144	100%	142	100%

Table 2

Correlations between Behavioural Index, Attitude, Social Norm, Behavioural Beliefs and Constraint Beliefs.

Behavioural Be..ef	Behavioural Index	Attitude	Social Norm
Health - Machinery	.16	.25	.17
Health - Herbicide	.30	.23	.04
Herbicide Residual -water	.25	.16	.14
Herbicide Residual -soil	.28	.24	.12
Herbicide on Trees	.40	.43	.16
Wind Erosion	.19	.24	-.01
Water Erosion	.05	.16	.04
Soil Structure	.48	.51	.29
Yield	.49	.49	.39
Income	.52	.49	.19
Trafficability	.21	.19	.11
Smoothness	.14	.12	-.07
Weed Resistance	.01	.04	.05
Insects	.11	.08	.01
Pasture	.33	.43	.06
Soil Fertility	.48	.49	.21
Behavioural Constraint			
1. Cultivation	-.45	-.48	-.26
2. Spray	-.33	-.34	-.14
3. Safety	-.14	-.23	-.09

Table 3

Multiple regression of Behavioural Index on Attitude, Social Norm and Constraint Beliefs

Variable	Coefficient	SD	Significance Level ($p \leq$)
Attitude	1.31	0.18	.000
Social Norm	74.4	38.5	.05
Constraint Beliefs	-9.96	6.54	.13
Constant	-2.37	26.06	.93
Durbin-Watson Statistic	1.90		
R^2 adjusted	39.3		

Table 4

Multiple regression of Behavioural Index on Attitude, Behavioural Beliefs, Social Norm, Constraint Beliefs and Risk

Variable	Coefficient	SD	Significance Level (p ≤)
Bb	55.88	16.06	.001
Ab	.90	.22	<.001
Sn	54.5	37.39	.148
Bc	-7.29	-1.09	.28
Rp	4.92	27.12	.85
Constant	-48.16	29.46	.10
Durbin-Watson Statistic	1.90		
R^2 adjusted	44.9		

Table 5

Multiple regression of Behavioural Index on Attitude, selected Behavioural Beliefs, Social Norm and Risk

Variable		Coefficient	SD	Significance Level (p ≤)
Attitude		.76	.20	.000
Bb:	Net Income	132.54	68.65	0.56
	Soil Structure	236.6	115.1	.042
	Tree damage	424.3	294.8	.15
	Health	220.3	218.9	.316
	Residues - Water	222.9	151.8	.14
Social Norm		45.56	35.55	.20
Bc:	Spray: Effectiveness	-2.15	.68	.002
	Spray: Safety	3.79	1.15	.001
Risk		29.93	25.66	.28
Constant		-48.16	29.46	.10
Durbin-Watson Statistic		1.97		
R^2 adjusted		51.3		

The estimation of risk was confined to a relatively crude risk index based on the level of public liability and personal accident insurances purchased, yet its inclusion invariably improved the models. Calculation of the Pratt coefficient from actual and elicited data on hail and fire insurance behaviour (Anderson *et al*, 1977), has presented computational problems and is not reported here.

DISCUSSION

Data analysis is in an early stage, but the proposed model appears to represent a marked improvement in predictive validity over the original Ajzen and Fishbein version. The adjusted R^2 values are modest, yet better than found in most previous studies of the adoption of conservation practices.

As in most previous studies of this type, attitude to the behaviour as measured by the semantic differential, proved to be highly significant.

The inclusion and partitioning of the Constraint Beliefs appeared worthwhile, and indicated that many farmers saw factors such as herbicide reliability and the practicality of existing protective gear as important constraints on their use of reduced cultivation. Further analysis of the belief sets by district may be of interest to extension managers and practitioners in the region.

The data clearly indicate the importance of profitability and health and safety issues in the use of reduced cultivation.

Concerns about herbicide residues in water and soil and the impact of herbicides on farm trees were also common. The lack of consistent significance of the wind erosion and water-erosion variables was unexpected, but may be due to the different incidence of the two erosion sources on sandplain and heavier soil types, which may appear with further analysis.

Normative factors were relatively insignificant at the present level of analysis.

Risk preference was included in the model on both theoretical and empirical grounds but the crude estimate used was never significant. The estimation and elicitation of risk attitude presents a number of problems, not the least of which is the elicitation of subjective probabilities for rare events, yet the elicitation of insurance behaviour and associated probabilities proved to be relatively straightforward, and may offer a practical means of estimating risk preference in the field if the mathematics prove tractable.

The models tested appear to suffer from inadequate specification of the dependent variable, with a large number of cases at "NIL" use. Application of the weighting for behavioural intention did little to improve matters, and further analysis with the Poisson distribution may be warranted.

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