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BARRIERS TO THE ADOPTION OF CONSERVATION TILLAGE IN WESTERN AUSTRALIA

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ABSTRACT

The use of minimum tillage offers both economic and conservation advantages to farmers in the central wheatbelt of Western Australia. In 1990, 84% of farmers in this region had adopted some form of reduced cultivation on some part of their wheat crops, but only 6% were using direct drilling for the establishment of their entire wheat crops. Beliefs, attitudes and perceived constraints to the adoption of reduced and zero tillage were elicited in a longitudinal study of 146 farmers over 1990-91.

Beliefs which best discriminated between adopters and non-adopters of zero tillage (direct drilling) were dominated by expected yield and income effects, and by factors relating to the safety and residue aspects of the herbicide use. Machinery problems were important constraints to the adoption of zero tillage on heavier textured soils, in addition to some problems with herbicide reliability. The implications of these results for the targeting of information in extension programs are discussed.

BACKGROUND

Agriculture in the cereal belt of Western Australia is based on annual crop species (cereals and legumes) grown on some 30 to 50% of the farm, in rotation with annual, legume-based pastures for sheep and cattle production. These areas receive an average of 350 to 450 mm of annual rainfall, mostly during the winter growing season from May to October.

The Western Australian Department of Agriculture estimates that some 0.75 million ha of land in the Agricultural Region is affected by water erosion (sheet, gully and rill), and considers this to be a substantial underestimate. Virtually the entire 6.0 million ha of land cropped annually in Western Australia is considered susceptible to sheet and rill erosion, and the overall cost of water erosion to the community has been estimated at $21.3 million per year (Select Committee into Land Conservation 1990).

The need to increase the rate of adoption of remedial and preventative practices has led to a major extension program to change the crop establishment techniques used by farmers from multiple tillage to direct drilling or reduced cultivation systems, in association with stubble retention, and improve paddock selection by concentrating cropping on land classes with low risk of degradation and high production capability.

A previous evaluation of this program revealed some unexpected associations between farmers' beliefs and the nonadoption of reduced tillage (Gorddard and Nash 1990). Farmers with little or no reduced tillage held negative beliefs about the effects of reduced tillage on yield, crop income, paddock smoothness and on pasture regeneration. They also held strong negative beliefs about the effects of herbicide use on their health, crop yield and weed resistance to herbicides. A clear conflict was found between the need to use herbicides for conservation tillage, and concerns about the impacts of these herbicides. The generality of this study was affected by the small, self-selected sample (n=35) and by some respondents being on the fringe of the main cropping zone.

Some problems with model specification and elicitation were also evident. It was decided to repeat and extend the study in a more rigorous fashion in the adjacent cereal-growing region, under funding from the National Soil Conservation Program, during 1990-92. Some preliminary results from this research are reported here.

INTRODUCTION

The Adoption of Conservation Practices

A vigorous debate has developed in the 1980s over extension policy for environmental practices in agriculture. The basis of these arguments can be traced to the classic e xchanges between Griliches (1960), Havens and Rogers (1961) and Brandner and Straus (1959), over the extent to which the rate of adoption of innovations could be explained by relative economic advantage. The debate was rekindled by Pampel and Van Es (1977) who 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 some conservation practices were intrinsically unprofitable, and that traditional extension approaches were therefore irrelevant, has become entrenched in branches of the sociological and environmental literature (Napier *et al.* 1984). Other studies have attempted to predict the adoption of conservation practices from behavioural models which incorporate farmers' perceptions of environmental problems in addition to socio-economic variables, including institutional constraints to adoption (Ervin and Ervin 1982, Green and Heffernan, 1987, Earle *et al.* 1989, Sinden and King 1990). A common 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). 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), which suggests that there are chronic mis-specification errors in the conservation models.

More importantly, these models have not been particularly useful for extension practitioners, even when their questionable validity is admitted, because, with the possible exception of Lynne *et al.* (1988), they do not make provision for the role of information in human learning about a new practice, and in decisions to adopt or reject that practice. Lindner (1987) points out that the adoption process is essentially one of learning, firstly about the existence of a new practice, 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 these characteristics might express themselves on the farmers' paddocks, and their expected effects on the family's total welfare. In this model of adoption, information is seen 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. 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 targeting information and extension activities at the specific beliefs held by the various adopter categories.

Model Development

This research is based upon a 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 *et al.* (1982 and 1983).

The basic model takes the form

$$BI = Ab + Sn \quad (1)$$

where $Ab = \sum Bb \bullet Ei$ and $Sn = \sum Bj \bullet Mj$

and BI = Behavioural intention

Ab = Attitude to the behaviour

Sn = Subjective norm

Bb = Behavioural beliefs

Ei = Outcome evaluations

Bj = Normative beliefs

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. Behavioural beliefs incorporate the strength and direction of a set of salient beliefs held by a respondent about the impacts of the behaviour on his/her welfare. Normative beliefs are a measure of perceived social pressure on the respondent to perform the behaviour, weighted by the person's motivation to comply. Correlations reported in the literature (Ajzen and Fishbein 1980) between these components vary in the range 0.6 to 0.95.

The model requires that the behaviour be precisely specified, and that all beliefs, attitudes and norms be focussed on the perceived consequences to the respondent of using that practice on his/her farm. Elicitation requires the respondent to state whether they think that the practice would have positive, negative or nil effects on their welfare.

Ajzen (1988) extended the original model to incorporate perceived behavioural controls, or behavioural constraints. These are the external factors perceived by the person to be controlling a behaviour. Obvious examples would be a legal obligation or the lack of a market. Further analysis (Gorddard and Nash 1990), 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) (2)

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

This specification gives an 'expectancy value' model not unlike the SEU model in economics (Lynne *et al.* 1988).

Ervin and Ervin (1982) and Lynne *et al.* (1988) provided equivocal evidence that risk attitude/preference may be related to the adoption of conservation practices. This is consistent with a decision theoretic approach to choice under uncertainty (Anderson *et al.* 1977).

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

The representation of behaviour presents particular difficulties in models of the adoption process, with the majority of adoption studies applying a bi-variate, adopt/not adopted dependent variable to cross-sectional data. A further difficulty lies in the qualitative application of an innovation, as skill and experience accumulate (Nowak and Korshing 1985). The present study attempts to address some of these issues.

METHOD

The model was tested using data generated from a stratified, random survey of farmers in the central wheatbelt of Western Australia.

The Study Area

The study area comprised 14 shires in the central wheatbelt of Western Australia, immediately to the east of the area studied by Gorddard and Nash (1990). The area includes over 1 100 agricultural holdings, producing 22% of the State's wheat (ABS, 1987-89). 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 individually managed farms, with a minimum farm area of 400 ha, on which wheat was planted in 1990. The sampling unit was specified as the person who had the major responsibility for decisions in the cropping program in 1990. Wholly leased properties and those whose ownership had changed in the last two years were excluded. The frame of 952 farmers was also 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 in August 1990, 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.

The same farmers were re-surveyed in October 1991, when their actual cultivation practices in 1991 were recorded, together with their attitudes, beliefs and behavioural constraints. The second survey included 132 of the original sample, with three farmers declining to be re-interviewed and the remainder being unavailable during the survey period, either because they had relinquished farming or were travelling outside the district.

Variables

The Dependent Variable

The present study uses two dependent variables—the Behavioural Intention (BI) for 1991, recorded in July 1990, and the Actual Behaviour (B) as observed in 1991.

The BI was generated by weighting the B in 1990 with the farmer's intended percentage change in cultivation practice in the next year. Hence the present level of use is incorporated explicitly into the dependent variable, in contrast to the Fishbein model which takes account only of the intended change. This approach is similar to that of Bentler and Speckart (1979) in recognising the role of past behaviour as a determinant of present behaviour for repeated or habitual practices. Cultivation methods were defined as the following

Direct Drilling (DD)
No cultivation in the year of sowing, other than the seeding operation itself.

Reduced Cultivation (RC)
One cultivation only, prior to the seeding operation.

Conventional Cultivation (CC)
More than one cultivation prior to seeding. Both dependent variables were elicited as the actual area of wheat planted with each of the three cultivation practices. An index was then generated for each, where BI and B were continuously distributed as $-2 \leq BI (B) \leq 2$ with scores of -2,+2 representing 100% of wheat sown with Conventional Cultivation and Direct Drilling, respectively. Behaviour was also specified in terms of land class, to account for possible cultivation differences between major soil types. These were specified using a combination of written descriptions and photographs of the major land classes in the region based on soils, vegetation and slope.

Independent Variables

Behavioural Beliefs (Bb)

The belief set was specified to include the expected effects of using DD, RC and CC on the following

Health and safety from machinery use	HLTHMACH
Health and safety from herbicide use	HLTHHERB
Herbicide residues in water	WATRES
Herbicide residues in soil	SOILRES
Herbicide damage to farm trees	NATTREES
Wind erosion in crops	WINDEROS
Water erosion in crops	WATEROS
Soil structure	SOILSTRU
Wheat yield	WHTYLD
Net income from wheat	NWINCT
Trafficability of soils	BOGGING
Smoothness of paddocks	SMOOTH
Weed resistance to herbicides	RESWEED
Insect damage	INSECTS
Pasture regeneration following the crop	PASTREG
Soil fertility	SOILFERT

The list of salient beliefs was generated through discussion with local extension officers, and refined further during a similar study in an adjacent district (Gorddard and Nash 1990). Questions were presented on a seven-point, bipolar scale indicating a range of possible outcomes from the use of the three cultivation practices. 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. The land class was also specified with a set of colour photographs.

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, effective evaluation of a specified behaviour on a seven-point Likert scale.

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, including spouse, parents/relations, friends/neighbours and professional advisers.

Behavioural Constraints (BC)

Three sets of potential constraints were presented using a Likert scale of 'strongly agree–strongly disagree'. The constraints are outlined below

Availability of water for spraying	WATERAV
Fully set up for Conventional Cultivation	SETUPCC
No decent spraying equipment	SPRAYGEAR
My machinery is unsuitable for Direct Drilling on Hillside Soils	MACHUS
Crops sown with herbicides will miss out on the organic market	ORGANIC
Penetration and point wear prevent Direct Drilling	PENETRAT
No seeding machinery on the market suitable for Direct Drilling	MACHNA
People who use herbicides should be tested and licensed	TESTLIC
Reduced tillage leads to dependence on the chemical industry	DEPEND
'Sprayseed®' does not work reliably under my conditions	SSNR
'Roundup®' does not work reliably under my conditions	RUNR
Hillside and heavy soils MUST be worked up and renovated every few years	RENESSEN
Overdraft limit restricts spray purchases	ODLIMIT
Heavy stubbles make sprays ineffective	STUBBLE
Sealed/pressurised cab or ute is essential	SEALCAB
Protective gear available at present is not practical	GEARNP
Residues will one day be found in grain and sales will be affected	RESGRAIN
Conventional Cultivation for crop establishment is essential	CCESTAB
Conventional Cultivation is essential in some seasons	CCSEAS

Risk Preference (RP)

Risk attitude was estimated by the level of public liability and personal accident Insurance taken out by the respondent in 1990-91, as a percentage of farm assets.

Data

Scores on Attitude, Behavioural Belief, Constraint belief and Social norm scales were summed to provide a simple, total score for each respondent on each of these variates, as per the original Ajzen and Fishbein (1980, 1988) models. Scores on the individual items in each of these groups were used in the more detailed models. An index was constructed for each independent variable to capture the respondents' perceived relative advantage for DD, RC and DD [(DD score + RC score)- CC score)]. All scores on the psychological independent variates were normalised prior to analysis.

RESULTS

The proportions of wheat sown in 1990 and 1991 using the various cultivation techniques are shown in Table 1, and the percentage of farmers adopting these methods is presented in Table 2.

Table 1 The use of conventional cultivation, reduced cultivation and direct drilling for wheat (percentage of total wheat sown in 1990 and 1991)

	% of Wheat Sown in	
Practice	1990	1991
Conventional cultivation	39	20
Reduced cultivation	45	55
Direct drilling	16	25
Total %	100	100
n	144	132

Table 2 The use of conventional cultivation, reduced cultivation and direct drilling for wheat in 1990 and 1991 (percentage of farmers and their level of use)

Level of use (% wheat sown)	Practice					
	Conventional cultivation		Reduced cultivation		Direct drilling	
	1990	1991	1990	1991	1990	1991
Nil	16	62	28	24	60	55
1–40	31	13	28	11	25	26
41–80	24	11	32	31	9	14
81–100	29	14	12	34	6	5
Total	100		100		100	

n = 144 (1990): 132 (1991)

There is an apparent increase in the use of both RC and DD in 1991, both in terms of area sown and number of farmers using these practices. In 1991, 80% of the wheat crop was sown using some form of reduced tillage, as against 61% in 1990. In 1991, 62% of farmers had no conventional tillage on their farms compared with 16 percent in the previous year. However, only 5% of farmers were using DD on their entire crop, and 55% had no DD on their farms in 1991. There appears to have been an increase in the use of RC, with a corresponding decrease in CC between 1990 and 1991. The number of farmers using some level of DD rose from 40 to 45%, and the percentage of wheat sown with DD increased from 16% to 25% between 1990 and 1991.

The apparent sharp increase in the adoption of DD/RC in 1991 may be an artefact of seasonal variability and the rigorous definitions of DD, RC and CC. The 1990 season began much earlier than usual, and farmers in this region were faced with the problem of controlling large, early-germinated weeds on paddocks intended for crop. Conversely in 1991, the season did not start until late May, so that early cultivation for weed control and early seeding was not possible. Farmers then used less cultivation than normal, and many were observed to direct drill crops that would otherwise have received at least one prior cultivation, and to rely on post-seeding weed control with herbicides.

The relationship between intended and actual behaviour and behavioural beliefs, attitudes, constraint beliefs and perceived social pressures, using rank order correlation, is presented in Tables 3 to 5.

Correlations between behaviour and the main psychological variables in the model are $0.33 \leq t \geq 0.62$. Signs of the major coefficients are all positive, as expected, so that the adopters of DD and RC tend to hold positive beliefs and attitudes towards these behaviours, and vice-versa for the non-adopters. Similarly for the Social Norm, where the perceived social pressure from, and motivation to comply with, a range of significant others is positively related to use of DD and RC, thus suggesting that both positive and negative social pressures are important for the adopters and non-adopters respectively.

Behavioural Beliefs (BB)

The BB most obviously correlated with behaviour are those to do with expected effects on Yield, Net Wheat Income and Soil Fertility and Soil Structure on all soils, plus Pasture Regeneration on Hillside soils (Table 3). Coefficients for Health and Safety (herbicides), Herbicide Residual, Wind and Water Erosion and Herbicide Damage to Trees were = 0.2. Beliefs about Health and Safety (machinery), Trafficability of Soils (bogging), Weed Resistance to Herbicides and the Smoothness of Paddocks showed no clear relationship with behaviour. Neither Wind Erosion nor Water Erosion were strongly correlated with behaviour. Signs were positive, except for Insect Damage (all soils) and Weed Resistance. The sign and level ($\tau = -0.30$) for Insect Damage suggest that users of DD/RC believe that these problems (INSECTS) are worse under DD/RC overall, but not on the 'hillside' soils.

Table 3 Spearman correlation coefficients for attitudes, behavioural beliefs and the social norm in 1990 and behaviour in 1991 (n = 142)

Behavioural Beliefs	Attitude	Social Norm	Behavioural Intention for 1991	Actual Behaviour in 1991
HLTHMACH	.16	.07	.06	-.01
HLTHHERB	.18	.22	.22	.07
WATRES	.10	.14	.22	.19
SOILRES	.14	.11	.26	.23
NATTREES	.33	.27	.24	.13
WINDEROS	.31	.22	.24	.16
WATEROS	.39	.07	.17	.18
SOILSTRU	.47	.29	.27	.35
WHTYLD	.62	.49	.47	.46
NWINC	.56	.48	.40	.38
BOGGING	.14	.06	.04	-.003
SMOOTH	.09	.03	.12	-.06
RESWEED	-.01	-.04	.09	.07
INSECTS	-.21	-.30	-.17	-.15
PASTREG	.29	.12	.15	.13
SOILFERT	.50	.38	.33	.33
Total behavioural beliefs	.62	.35	.40	.33
Attitude	-	-	.59	.51
Social norm	-	-	.56	.50

Behavioural Constraints (BC)

The BC's concerned with machinery and with spray-efficiency factors were more strongly correlated with all categories of behaviour than were the safety and environmental factors (Table 4). Of the 'mechanical' factors, the most important were beliefs that it is essential to use CC on heavier soil types (CCESTAB), and that these soils must be cultivated (RENESSEN). Problems associated with existing machinery were also related to behaviour (SETUPCC, MACHUS, PENETRAT, and CCSEAS). Herbicide-related factors centred on the reliability of the 'knockdown' herbicides, with $.3 \leq r \geq 4$ for SSNR and RUNR, suggesting that users of DD/RC perceived fewer problems with reliability than low or non-users. Safety constraints were generally less important than machinery factors but, of these, concerns about the possibility that residues would be discovered in grain at some future time (RESGRAIN) seemed to be the most important. ORGANIC was not strongly correlated with behaviour.

Table 4 Spearman correlation coefficients for constraint beliefs in 1990 with behavioural intentions for 1991 and actual behaviour in 1991

		Wheat on All Soils (n = 142)		Wheat on Hillside Soils (n = 101)	
		Behavioural Intention for 1991	Actual Behaviour in 1991	Behavioural Intention for 1991	Actual Behaviour in 1991
1	WATERAV	.03	.06	.01	.13
2	SETUPCC	.28	.37	.23	.34
3	SPRAYGEAR	.18	.17	.22	.19
4	MACHUS	.23	.21	.27	.18
5	ORGANIC	.03	.02	.07	.08
6	PENETRAT	.25	.29	.25	.24
7	MACHNA	.12	.26	.06	.30
8	TESTLIC	.11	.03	.06	-.10
9	DEPEND	.27	.11	.18	-.03
10	SSNR	.25	.23	.36	.16
11	RUNR	.32	.38	.41	.38
12	RENESSEN	.36	.35	.42	.26
13	ODLIMIT	.10	-.04	.12	.07
14	STUBBLE	.24	.19	.27	.05
15	SEALCAB	.14	.07	.16	.05
16	GEARNP	.01	-.06	-.04	-.12
17	RESGRAIN	.28	.18	.34	.13
18	CCESTAB	.53	.44	.57	.43
19	CCSEAS	.31	.30	.33	.18
	TOTAL P.B.C.	.44	.40	.48	.36
Set 1	Machinery Factors (2, 3, 4, 6, 7, 12, 18, 19)	.47	.49	.49	.42
Set 2	Spray Related Factors (1, 9, 10, 11, 13, 14)	.34	.28	.43	.27
Set 3	Safety & Environmental Factors (5, 8, 15, 16, 17)	.16	.06	.17	.02

Socio-economic Variables

Correlations between behaviour and a range of socio-economic and psychological variables are presented in Table 5.

Coefficients for Age, Experience, Education and Level of Managerial Control are relatively small, and in several instances the signs are unstable. Variables which appear to be related to behaviour include Area (positive), Equity (negative), Liabilities (positive) and Membership of Technical Groups (positive) and Risk preference (negative).

The level of information-seeking activity on cultivation methods, and especially on health and safety matters, have small coefficients with signs in the expected directions..

Table 5 Spearman correlation coefficients for attitude, social norm, constraint beliefs, behavioural intention (all soils) and socio-economic variables

	Attitude	Social	Perceived Behavioural Controls	Behavioural Intention	Actual Behaviour in 1991
Age (years)	.08	-.02	.16	.05	-.11
Experience (years)	-.03	-.11	.02	-.01	-.16
Education (years)	.12	.22	.08	.11	.24
Management Control (%)	.03	.01	.09	-.13	.24
Membership of Technical Groups (No.)	.43	.58	.31	.43	.45
Membership of Conservation Groups (No.)	.09	.20	.06	.18	.17
Arable area (ha)	.34	.50	.28	.28	.34
Equity (%)	-.31	-.24	-.16	-.27	-.46
Liabilities ($)	.34	.35	.24	.32	.48
Risk Preference	-.21	-.23	.06	-.22	-.21
*Information Search - Health	.03	.05	.02	.01	.07
*Information Search - Cultivation	.17	.25	.18	.11	.17

*Elicited on a 5-point Likert scale.

Regression Analysis

The relationship between behaviour and the psychological and socio-economic variables was explored further with multiple regression, using the TOBIT estimator. TOBIT permits more accurate model estimation where the dependent variable is censored, as in this case (Maddala 1983). That is, the dependent variable (behaviour) is censored at both its upper and lower limits, as it cannot be observed beyond these points using the present method of elicitation. This is because an elicited response of 'NIL' use may be obtained both from subjects who have been developing positive attitudes towards DD/RC, and who may be about to adopt, and by those who hold extremely negative attitudes and may never adopt. Similarly at 100% use, some subjects may have only recently reached this level yet others may have adopted the practice some years earlier, and would therefore be expected to have much greater experience, and therefore different attitudes to the practice.

The Models

Interpretation of these results requires attention both to the significance of the associations and to their signs. A significant, positive relationship suggests that high adopters hold beliefs that DD/RC will have beneficial effects on that item, and (conversely) that low or non-adopters believe that DD/RC will have negative impacts, and therefore that the item is a possible barrier to adoption.

Table 6 **Multiple regression (TOBIT with upper and lower censoring) of behavioural intention for and actual behaviour in 1991 (all soils) on attitude, social norms, constraint beliefs and risk preference (n = 129)**

VARIABLE	Behavioural Intention			Actual Behaviour		
	Co-efficient	S.E.	Significance Level (p Ü)	Co-efficient	S.E.	Significance Level (p Ü)
Constant	1.67	.79	.04	-1.68	.89	.06
Attitude	22.02	5.74	.000	19.76	6.21	.001
Social Norm	9.92	4.85	.04	10.19	5.30	.05
Constraint Beliefs	0.98	.34	.004	0.62	.37	.09
Risk Preference	-0.17	.11	.13	-0.16	.12	.21
SIGMA	.97	.06	.000	1.06	.07	.000
Log Likelihood			-169.43			-182.40

Results for the modified Fishbein models are presented in Table 6. Attitude, Social Norms and Constraint Beliefs were all positively associated with both Behavioural Intention and Actual Behaviour, and Risk preference was negatively related to both. Attitude, Social Norm, and Constraint Beliefs were significant at the $p \leq 0.10$ level or better in both models, confirming the predicted relationships with behavioural intention and actual behaviour. Risk preference was not significant. The addition of the variate for total Behavioural Beliefs was not significant, as predicted by Ajzen and Fishbein (1980), and is omitted from the models. This is consistent with the original Ajzen and Fishbein model, which maintains that Attitude reflects a person's overall evaluation of the set of Behavioural Beliefs.

The relationship is further explored in Table 7, where Behavioural and Constraint Beliefs are each decomposed into the factors found (by a best sub-sets routine) to be most significantly related to behaviour. In Table 7, it is clear that Attitude is interacting with both the Behavioural and Constraint Beliefs, with the possible exception of SOILRES, HLTHHERB, and ORGANIC, so that variates such as WHYTYLD are not significant in the presence of Attitude.

In the absence of Attitude and Social Norm, the relative importance of the detailed beliefs is more apparent, with WHTYLD, HLTHHERB and SOILRES become significant (at $p \leq .10$). Among the Constraint Beliefs, ORGANIC and RENESSEN remain significant in the absence of Attitude and Social Norm but the significance of CCESTAB and MACHUS increases. When Constraint Beliefs were considered as the sole explanatory variables, CCESTAB, RENESSEN, ORGANIC and RESGRAIN were each significant. Risk preference was not significant in the presence of Attitude and appeared to be interacting with Attitude, Social Norm and the Behavioural Beliefs.

Table 7 Multiple regression (TOBIT with upper and lower censoring) of behavioural intention for 1991 (all soils) on attitude, behavioural beliefs, constraint beliefs and risk preference (n = 129)

VARIABLE	Co-efficient	S.E.	Significance Level (p 0)	Co-efficient	S.E.	Significance Level (p 0)	Co-efficient	S.E.	Significance Level (p 0)
Constant	-5.45	1.53	.000	-4.60	1.54	.003	-1.75	.37	.000
Attitude	17.22	6.56	.009	-	-	-	-	-	-
Social Norm	3.32	4.87	.49	-	-	-	-	-	-
Behavioural Beliefs:									
WHTYLD	1.92	4.67	.68	8.84	4.30	.04	-	-	-
HLTHMACH	-6.04	4.55	.18	-6.07	4.72	.20	-	-	-
HLTHHERB	21.81	7.51	.004	22.53	7.73	.003	-	-	-
WATRES	7.74	5.23	.14	7.41	5.30	.16	-	-	-
SOILRES	14.17	6.83	.04	13.82	7.02	.05	-	-	-
WINDEROS	5.87	9.15	.52	9.22	9.39	.32	-	-	-
SMOOTH	3.42	4.18	.41	6.22	4.16	.13	-	-	-
SOILSTRU	1.49	6.03	.80	3.48	6.16	.57	-	-	-
Constraint Beliefs:									
CCESTAB	3.02	2.86	.29	5.94	2.78	.03	8.99	2.85	.002
RENESSEN	6.52	2.93	.02	8.47	2.97	.004	8.64	3.16	.006
RESGRAIN	4.86	3.48	.16	5.21	3.61	.15	6.39	3.89	.10
SETUPCC	3.00	2.47	.22	2.65	2.54	.29	4.06	2.63	.12
ORGANIC	-5.73	2.18	.008	-6.40	2.21	.004	-5.95	2.40	.01
SSNR	-0.90	2.44	.71	-0.36	2.53	.88	2.24	2.57	.38
RUNR	2.26	2.77	.41	1.81	2.84	.52	3.34	3.00	.26
ODLIMIT	-1.92	2.21	.38	-3.17	2.26	.16	-2.30	2.41	.34
MACHUS	0.23	2.05	.91	1.84	2.06	.37	2.40	2.23	.28
RISK	-0.09	.11	.40	-.15	.12	.20	-.32	.12	.009
SIGMA	.86	.06	.000	.90	.06	.00	.99	.07	.000
Log likelihood		-154.63			-159.59			-173.40	

DISCUSSION

While of some theoretical interest, a realisation that variables such as attitude, social pressure and demographic factors are related to the adoption of conservation tillage, is *per se* of limited value to extension practitioners or to policy makers in the conservation area. This is due to the difficulty in incorporating this knowledge, in any practical or specific way, into extension programs in the field. The most important factors which discriminated between adopters and non-adopters were beliefs about

- wheat yield and income effects of reduced cultivation
- the necessity for cultivation on heavier-textured soils
- machinery problems in crop establishment on heavier-textured soils
- investment in existing machinery that is unsuitable for DD/RC
- concerns about herbicide residues in soil, and future unknown risks of residues in grain
- health and safety concerns arising form herbicide use
- problems with the reliability of knockdown herbicides.

The barriers to adoption of conservation tillage in this region seem to fall into two distinct categories, which appear to be statistically independent. These are — (A) economic-technical areas (yield, machinery and related factors), and (B) health, safety and non-market factors.

The measure of Risk preference is relatively crude (Table 5), but the negative sign does support the findings of Lynne *et al.* (1988), Napier *et al.* (1984) and Ervin and Ervin (1982) that risk-seeking behaviour is related to the adoption of new practices. This suggests that the non-adopters of DD/RC tend to be relatively more risk averse, carry less debt per farm, belong to less groups, are older, have less formal education, and enjoy a greater level of managerial control on their farms than do high-level adopters.

The effect of social factors is less clear, but the positive sign for the Social Norm suggests that social pressures are consistent with, and reinforce, behaviour. Implicit in these results is the fact that there are farmers in the region who have adopted DD/RC on all or most of their cropping programs and who hold positive beliefs towards many of the factors identified here as 'constraints'. Presumably these farmers have overcome these problems, and their experience should be of interest both to other farmers and to the local extension service, yet the data suggest that this cross-fertilisation may not occur through the normal social networks.

The variates that were not significant in the models also merit attention. These suggest that the adopters of DD/RC are not convinced of the positive impacts claimed for DD/RC on factors such as Soil Fertility, Soil Structure, Wind and Water Erosion.

CONCLUSIONS

Barriers to the adoption of conservation tillage in the central wheatbelt of Western Australia may be classified into two groups on the basis of the behavioural and constraint beliefs held by adopters and non-adopters. Group A factors include several beliefs about the yield effects, the practicalities of reduced tillage and change-over costs, while Group B contains a set of beliefs about the health and residual effects of the routine herbicide use that is associated with present systems of reduced tillage.

Adopters of conservation tillage were carrying higher levels of debt and were more risk-seeking than non-adopters. The change in economic circumstances from 1990 to 1991 may partly explain the significance and direction of beliefs about overdraft limits and spray purchases, suggesting that non-adopters perceive increasing financial barriers to the change-over to conservation tillage.

Some implications for extension policy and practice are outlined below

- The existing beliefs about DD/RC held by adopters are significantly different levels of use of DD/RC by non-adopters should be targeted specifically at these beliefs.
- These beliefs are shared and presumably reinforced in the social networks of both adopters and non-adopters.
- Non-adopters are not satisfied that yields can be maintained under DD/RC, nor that heavier soils can be cropped without cultivation. Indeed they tend to believe that these soils must be cultivated for 'renovation'. Closely related are beliefs about the suitability of existing machinery for DD/RC on these soils.
- Extension needs to review the evidence supporting the use of Direct Drilling, in particular, on the heavier 'hillside' soils, as only 5% of farmers are currently planting all their crop on these soils with DD. Farmers are having practical problems in reducing tillage on these soils, and further research and development in the machinery area, preferably involving the farmers, is clearly required.
- Concerns about the health and residual effects of the herbicides used in conservation tillage need to be addressed by the public and private-sector extension services. The negative beliefs expressed in this study, while more extreme with non-adopters, were also present amongst the adopters.
- Beliefs about the effects of DD/RC on soil structure, soil fertility and water erosion were ambiguous, and reflect a great deal of uncertainty, and a need for better information about these effects under local conditions.
- The reliability of the knockdown herbicides, especially glyphosate, may also require attention, especially in years such as 1990 when there is an early break to the season.
- Socio-economic factors are of limited relevance for extension and policy. Level of debt does not appear to be a barrier to adoption, but the willingness to bear risks and to incur debt are both positively related to adoption. Credit limits may be becoming a factor in restricting the purchase of herbicides by low adopters.
- The study does confirm the work of Nowak (1987) that both economic-technical and non-market factors are important in the adoption of conservation tillage. This implies that, to be effective, extension ought to focus on providing information and encouraging network activities which address the specific beliefs held by adopters and non-adopters in both market and non-market areas.

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