Modelling the adoption of environmental management practices by farmers

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Abstract: The adoption of environmental management practices (EMPs) is a complex process, with various expressions at the enterprise, regional and industry levels. The social literature has identified individual, social and resource characteristics that determine the capacity and willingness of people to adopt EMPs. This paper presents a model of the adoption behaviour of farmers, which is based on empirical data. The data were compiled from a landholder survey in the Burdekin river catchment in North East Queensland. The data document socio-economic characteristics of farms and farmers, and levels of implementation of EMPs on properties. The paper summarises various statistical models that have been developed to explain adoption of EMPs in the non-irrigated areas of the Burdekin river catchment. It provides a discussion of the findings in the light of adoption theory. This study identifies, in accordance with the adoption literature, financial capacity and education as key drivers for the implementation of environmental management practices by farmers.

Keywords: *Natural resource mangement; Adoption; Modelling; Landholder survey; Burdekin catchment*

1. INTRODUCTION

There is a large body of literature investigating the propensity of landholders to adopt environmental management practices (EMPs). Yet many of the relationships between 'adoption' and landholder or farm characteristics are complex and/or tenuous (Cary et al. 2002). Despite the fact that some empirical studies have found significant correlations between the characteristics of landholders/farms and the adoption of EMPs (a summary of which is provide in Table 1) there is no widely accepted theoretical model of human adoption behaviour.

This paper makes a contribution to the adoption literature by modelling the empirical relationship between socio-economic variables and the degree of implementation of NRM practices in the Burdekin river catchment.

Table 1: Individual and business-related indicators of adoption (BRS 2001)

Type of Indicator	Anticipated relationship/Linkage to adoption	Direction of expected impact (positive/negative)
Individual Attributes		
Age of property manager/owner	Desire to remain on property, Environmental attitudes	Negative
Formal education	Skills, Environmental attitudes, Desire to remain on property, Information	Positive
Participation in recent training	Skills, Environmental attitudes, Information, Pressure to Adopt	Positive
Years of management experience	Skills, Habit	Ambiguous
Membership of Landcare	Environmental attitudes, Skills, Pressure to adopt, Decision support	Positive
Farm family with dependent children	Financial capacity, Desire to remain	Positive
Business Related Attributes		
Property Management plan	Skills, Information	Positive
Family members working on property	Pressure to adopt, Decision support	Positive
Employment of non-family labour	Financial capacity, Skills	Positive
Total farm family income	Financial capacity, Security	Positive
Farm family off-farm income	Financial capacity	Positive
Farm cash income	Financial capacity, Desire to remain, Security	Positive
Farm profit at full equity	Desire to remain	Positive
Farm equity ratio	Financial capacity, Security	Positive

Data for this investigation were collected during a survey of landholders in the Burdekin Dry Tropics (BDT) region. The survey was part of a broader study into social and economic issues of natural resource management (NRM) in the BDT – funded by the BDTNRM Board (Greiner et al. 2003).

The primary purpose of the survey was to 'scope' a broad range of NRM issues. Amongst other things, it collected information on: the socio-economic status of landholders and farm businesses; the extent of implementation of NRM practices across the catchment; perceived landholder impediments to further implementation; and landholder preferences and attitudes towards a range of different NRM policies. The breadth of information collected in this survey, therefore provides unique insights into the link between socio-economic variables and the propensity to adopt EMPs in the Burdekin Dry Tropics.

2. METHODS

The Burdekin river catchment is comprised of four sub-catchments: the Upper Burdekin; Belyando-Suttor; Bowen-Broken; and the Lower Burdekin. A questionnaire mailed to the landholders for completion prior to a telephone interview formed the basis of the survey. To ensure representation across those areas, the sample was geographically stratified and selection within sub-catchments was randomized. In total, 170 landholders were asked to participate in the survey (Table 2) and 82 questionnaires were completed.

Table 2: Response to landholder survey

Sub-region	Mail-out	Completed surveys	Response rate (%)
Upper Burdekin	45	23	51
Belyando-Suttor	41	20	49
Bowen-Broken	25	14	56
Lower Burdekin	69	25	36
Total	170	82	48

Most properties in the Lower Burdekin grow (irrigated) sugarcane, while those in the other catchments are largely grazing properties. The two areas face different NRM issues, and have different options for EMPs. This analysis focuses exclusively on the adoption of EMPs among the 57 grazing properties surveyed in the 'Upper' / dryland catchments. All dryland sub-catchments were grouped together in the analysis. This assumes relative homogeneity of management systems and farming structures across the sub-catchments.

The aim of the research reported here was to investigate the empirical relationship between the degree of implementation of selected EMPs (the response variates) and the socio-economic characteristics of landholders and farms (explanatory variables). Table 3 and Table 4 describe the variables in detail and give a summary of valid samples.

Table 3: Explanatory variables for adoption analysis

Name	Type	Description	Missing value	Valid N
Age	Numerical	Range from 1-6, equal 10 years from 20-80 years	1	56
Higher education	Categorical: Yes/No		0	57
Equity = 100 -Mortgage	Numerical	Percentage of property equity	15	42
Family full time equivalent workers	Numerical	Number of family working on the farm	6	51
Family successor for farm	Categorical: Yes/No	Family member continuing farming on property	0	57
Freehold	Categorical: Freehold or Leasehold	Property on freehold or leasehold	0	57
Income	Numerical	Mid point of total income	15	42
Off farm income	Numerical	Percentage of income from outside the farm	4	53
Management Plan	Categorical: None, Either, Both	Environmental management plan and Property management plan	0	57
Ownership	Categorical: Owner or Manager	Property managed by owner or manager	0	57

Table 4: Missing values and valid number of samples (N) for response variables

Response variable	Factor levels[1)] and N	Valid N	Missing	Total N
Pasture monitoring	None: 9 Partial: 14 Overall: 32	55	2	57
Paddock spelling (area periodically retired from grazing)	None: 6 Partial: 21 Overall: 27	54	3	57
Fodder crops	None: 27 Partial: 14 Overall: 1	42	15	57
Cell grazing	None: 37 Partial: 5 Overall:3	45	12	57
Biological pest control	None: 15 Partial: 23 Overall: 15	53	4	57
Improved riparian vegetation	None: 20 Partial: 19 Overall: 7	46	11	57
Fencing remnant vegetation	None: 35 Partial: 10 Overall:1	46	11	57
Installing remote stock water points	None: 26 Partial: 18 Overall:1	45	12	57

1) Implementation levels were recorded as None - no implementation, Partial - implemented on part of property, Overall - implemented across the property

As shown in Table 3 there are five categorical variables that could potentially occur in 48 different combinations. A fully orthogonal model would therefore require 48 data sets, each measuring the relationship between the response variable and the other explanatory variables (age, income, equity and off-farm income) and each – preferably – with replicates. The data set described here is considerably smaller than that, generating an intriguing analytical challenge.

Specifically, the small sample size and the relatively large number of ‘missing values’, meant that there were few degrees of freedom for analysis. To minimize this problem, non-factorial missing values and invalid responses (such as those indicating that equity was 0%) were replaced with means. Other missing values were deleted (case wise).

The relatively few degrees of freedom also restricted the number of explanatory variables, which could be used. Consequently, only a subset of those surveyed was included in the model. The subset was selected on the basis of:

1. Importance. This included the variables identified in the literature as important for adoption of EM practices;
2. Degrees of freedom ‘consumed’ by the variable (eg. one cardinally measured variable versus an ordinal variable requiring 3 different ‘dummy variables’ for adequate representation); and
3. Potential problems with multicollinearity. For example, significant correlation occurred between ‘age’ – ‘experience’ (Spearman's R =0.8, $p<0.01$). Further analysis of ‘experience’ was omitted, as was ‘tenure’ (freehold, leasehold, both) because the variable freehold (1=yes, 0=leasehold) translates into tenure by combining farming properties that have freehold and leasehold as properties with freehold.

This subset of variables formed the basis for the selection of variables through modelling procedures as outlined in the following section.

2.1. Modelling procedures

Each environmental management variable (response variable) was analysed using three different models: a multinomial with AIC forward and backward selection (Model 1); a binary with AIC forward and backward selection (Model 2); and either a binomial or a quasibinomial (depending on dispersion) using a deviance ratio test for – forward – variable selection (Final model). More specific details are as follows:

Firstly, a multinomial model was used to describe the relationship between the three different ‘levels’ of adoption ('none', 'partial', and 'overall') and the socio-economic variables. This analysis resembles a linear discriminant function analyses (LDA) in that it estimates equations that best predict *a priori* response categories. Unlike the Gaussian error based LDA, which is unsuitable for nominal response variables, the multinomial model uses a multinomial error distribution with the logit link function and is a choice method for multicategorical response variates (eg Venables and Ripley 2002, Harrel 2001).

Secondly, the response variables were re-coded into binary responses. Rather than indicating whether an EMP was used in some parts of the property, all parts or none, the re-coded response simply indicated whether the EMP was used at all (‘yes’ or ‘no’). Although this approach does not allow one to differentiate the extent of EMP implementation, it increases the number of observations in the combined categories, thereby reducing the error of the estimates.

Both models 1 and 2 used Akaike's information criterion (AIC) for variable selection through a combination of adding and deleting (*ie.* stepwise) selected variables. This resulted in retaining variables for a model with the lowest AIC (Venables and Ripley 2002; Burnham and Anderson 2001).

Finally, binomial models with over or under-dispersion were re-estimated using a quasi-binomial distribution (Venables and Ripley 2002), and a more detailed analysis of the "Paddock Spelling" (used on most properties), "Riparian vegetation improvement" (used on 56% of properties) and "Fencing off remnant vegetation" (used on less than 2% of properties) was undertaken. Here, the three-factor response variable "Management Plan" was reduced to a dichotomous variable (Plan – yes/no), so as to increase the degrees of freedom.

Validation of the final model incorporated assessment of dispersion (based on residual deviance and degrees of freedom ratios) and goodness of fit test using χ^2 or F tests (binomial and quasibinomial models respectively). Deviance ratio tests are more stringent than the AIC criterion and quasibinomial models do not calculate a likelihood, so AIC is not feasible (Venables & Ripley 2002). This stringent testing is also more suitable given the restricted sample size.

This paper presents the discrimination ability (correct classification rate) of the multinomial and binomial models as an indicator of model fit, because a classification rate is easily calculated and intuitive. However, this measure requires careful interpretation as correct (or incorrect) classification depends on the cut-off rate at which a predicted probability is categorised (Harrel 2001). In this case predicted probabilities of more than 50% are used as the positive response.

3. RESULTS

A summary of results is presented in Table 5. The correct classification rate of Model 1 and Model 2 for each explanatory variable ranges from 63% to 96%.

In the final model, three response variables were selected for detailed examination: "paddock spelling", "improve riparian vegetation" and "fencing remnant vegetation". For these models independent variables, which passed the deviance ratio tests, and their direction of influence on the response variable are listed.

Farm income was found to exert a positive influence on paddock spelling – ie. the higher the income the more likely was the landholder to spell paddocks. Increases in equity were associated with a decreased likelihood of paddock spelling. Landholders were also less likely to spell paddocks if they owned the property (rather than managed it for an absentee owner), had a family successor or had freehold (as opposed to leasehold) title on the land.

The final model predicts that landholders with higher education and/or with a 'management plan' are more likely to make 'improvements' to riparian vegetation than those without. Higher levels of farm equity were negatively associated with improvements to riparian vegetation.

The model found a negative association between the number of family members working on the farm, and the likelihood that landholders will fence off riparian vegetation.

4. DISCUSSION

The models presented here were developed to describe a data set that had not been designed to test adoption theory. Rather, the data were collected as part of a scoping review of NRM implementation in the Burdekin catchment. The predictive power of the models are consequently restricted by:

- Small sample size; and
- Unequal number of data points for the different variates (non-orthogonal design).

Nevertheless, the analysis is consistent with the findings of Cary et al. (2002) in that it confirms that: (1) different factors and socio-economic variables are associated with adoption; and (2) that there are few statistically significant explanatory variables for each EMP. The analysis is also consistent with some of the conclusions of the BRS (2001), where it was noted that landholders must have both the 'capacity' and the 'motivation' to adopt EMP.

For example, the analysis found that landholders with higher education and/or higher income (ie those with 'capacity') are more likely to spell paddocks and/or improve riparian vegetation than those with less capacity. This is consistent with findings of the BRS (2001).

Table 5: Summary of environmental adoption practices modelling. Variables in grey indicate the focus of subsequent discussions.

	MODEL 1: Multinomial (AIC criteria)	MODEL 2: Binomial (AIC criteria)	FINAL MODEL (based on more stringend deviance test and using quasibinomial if under/over dispersion)
Response Variable	**Discrimination ability**	**Discrimination ability & dispersion**	**Variables selected (direction)**
Pasture monitoring	63%	84% Under-dispersed	Quasibinomial None
Paddock spelling	72%	96% Under-dispersed	Quasibinomial Equity (-) Freehold (-) Income (+) Family Successor (-) Owner (-)
Fodder crops	71.5%%	84% Under-dispersed	None based on quasibinomial
Cell grazing	87%	82% Under-dispersed	Quasibinomial None
Biological pest control	64%	83% Under-dispersed	Quasibinomial Higher education (+)
Improving riparian vegetation	74.8%	71.8%	Binomial Equity (-) Management Plan (+) Higher education (+)
Fencing off remnant vegetation	77.2%	72%	Binomial Number of family members working on farm (-)
Installing remote stock water points	64.5%	65% Over-dispersed	Quasibinomial None

The analysis also found that landholders with property plans (management, environmental or both) were more likely to improve riparian vegetation than those without. This is again consistent with the BRS (2001) who found that having either a property and/or an environmental management plan was positively correlated with EMP implementation. Cary et al. (2002) found no relationship between the presence of farm plans and the preservation/enhancement of areas of conservation value. However, that study only considered farm plans, whereas this model considers both management and environmental plans, meaning that the studies are not strictly comparable.

The analysis also raises the issue of impact on title on implementation of EMPs. The model revealed that 'freehold' properties were less likely to use paddock spelling than others. This may be a result of leasehold land carrying environmental management obligations – hence establishing an *a priori* link between tenure and 'motivation' to adopt.

At first glance, the negative link between equity and adoption (paddock spelling and improving riparian vegetation) is surprising because higher equity indicates better financial capacity and would therefore suggest higher adoption rates. Cary et al. (2002) also found that that the relationship between equity and adoption was not as predicted. They suggest that there may be confounding effects associated with high equity and speculate that landholders with high equity in their properties may be more risk averse and thus less inclined to adopt what they might perceive to be risky resource management technologies.

Another explanation might be that the variable 'equity' captures only one aspect of farm equity; it describes the degree to which a farm is debt-free in relative rather than absolute terms. Landholders on low-value properties could have low absolute levels of equity that correspond to high equity ratios (eg 95% equity in a $30,000 property) while landholders of high-value properties could have high absolute levels of equity that correspond to low equity ratios (eg. 50% equity in a $1m property). It is not inconceivable that wealthier properties might tend to have less equity, making it difficult to establish the link between equity and adoption.

Another interesting model result is that properties, which were managed by the owners and/or had a family successor and/or had a larger number of family members working on the property were less likely to adopt EMPs than others. This is not as would have been expected on the basis of Table 1. Adoption literature specifically links family-orientated characteristics with 'desire to remain' on the property long-term and therefore increased adoption of EMPs.

The model results, while based on a small sample, suggest the possibility of other confounding effects associated with family and ownership and the need for more careful analysis of the adoption behaviour of landholders. It is possible that there is an important link between financial capacity and family orientation, which is spuriously related to adoption.

5. CONCLUSIONS

This paper presents an opportunistic analysis of the implementation of EMPs gleaned from a NRM scoping survey of landholders in a large catchment.

Although the analysis was limited by the small sample size, the correct classification rate of the models indicates that the approach was indeed appropriate. Results relate well with other empirical studies.

The analysis raises important questions about the role of title, family characteristics and ownership in the adoption behaviour of landholders and identifies the need for further research.

The analysis confirms that financial capacity and education are key drivers for implementation of EMPs in the Burdekin catchment. This has important policy implications for NRM of grazing land in the BDT, and elsewhere. It emphasizes that 'capacity' in the form of (a) knowledge and therefore motivation, and (b) financial ability is a necessary condition for adoption. However, there are additional conditions that influence the likelihood of adoption, which have so far not been adequately addressed in adoption research.

Another important area of further research is the distribution of costs and benefits of a variety of different EMPs in terms of public versus private and short-term versus long-term benefits and costs. It is unlikely in the current policy context that landholders will invest in the implementation of EMPs, which generate predominantly public benefit, unless there is public support for such on-farm investment. Further research could provide invaluable information to those charged with developing, implementing and funding NRM policy.

Finally, the landholder survey upon which this paper is based collected information on a much broader range of variables in relation to the implementation of EMPs, including impediments to implementation and policy approaches to support implementation. Further analysis of these aspects can provide additional information to decision makers and contribute to the understanding of adoption behaviour.

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