One Model or Three: Integrating Social and Biophysical Scientific Models

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Keywords: *Catchment management; behavioural modelling; social network analysis; integration.*

EXTENDED ABSTRACT

Researchers and practitioners in the field of natural resource management (NRM) have a plethora of simulation models and other tools at their disposal. Modellers themselves are often confronted with the need to make trade-offs between "the demands of a general theoretical approach and the descriptive accuracy required to model a particular phenomenon" (p.4, Pyka and Grebel, 2003). As efforts are made to conduct integrated assessments, the tension in this area is exacerbated because of the complexity of system interactions and range of disciplinary perspectives. One approach that is proffered as providing substantial promise for incorporating the human dimension in participatory NRM is agent based modelling.

Agent-based models (ABM) enable individual agents or groups to 'behave' according to a set of rules or constraints. In multi-agent simulations, real-world patterns such as land use/land cover change, resource use or afforrestation patterns are emulated. Companion modelling attempts to better emulate system outcomes by using informants to characterise the 'behaviours' of agents in a role playing game. While these techniques may provide insight into the impact of decisions in constructed environments, practitioners acknowledge the significant effort required to characterise or program agents or groups of agents so that an adequate representation of adaptation processes occur. As stated by Bousquet and Le Page (2004) "the challenge has been to develop a new approach focusing more on the interactions between ecological and social components and taking into account the heterogeneity of these components" (p.315).

In this paper, we describe an alternative approach to participatory NRM that utilises an interactive modelling/partnership methodology that avoids the complexity of trying to characterise human behaviour in a computer system. The case study is drawn from our experiences in the Central West of New South Wales in Australia, with the Partnerships and Understanding Towards Targeted Implementation project (PUTTI). PUTTI is a partnership project between Catchment Management Authorities (CMAs), landholders, the broader community and researchers at CSIRO. It draws on the strengths of several complementary analytical techniques to develop a process that integrates across scale (individual farm to catchment) to identify and target the drivers that influence people's land management practices. Each approach provides insight into the dynamics of the decision-making processes of landholders, their social networks, and the underlying motivations and factors that influence the way they manage their properties. A change program for sustainable land management will be developed in close partnership with the community and the CMA.

In the first phase, a scoping study has informed the development of a survey carried out with dryland farmers in the Bell and Cudgegong sub-catchments. Structural equation modelling is used to develop a preliminary model of the key drivers influencing their land management practices. In the second modelling activity, selected respondents from the behavioural survey are interviewed and social network analysis used to determine the nature and extent of the contacts they use to gain information about farming practice and related issues. Finally, we intend to work with colleagues involved in modelling of key biophysical processes operating at the regional to local scale to conduct workshops with the catchment community in ways that utilise the social systems and networks and targets the key behavioural drivers. All stages involve in-depth individual and group discussions (shed meetings) with landholders and others to explore and gain a greater understanding of the meaning of the empirical data. All project activities including the modelling will feed into a change program developed in close partnership with the community and the CMA that aims to achieve sustainable land management practices.

1. INTRODUCTION

Since 2001, the Australian Government has supplemented Landcare efforts through bilateral agreements with all State and Territory Governments (except for the ACT). A regional model for the delivery of natural resource management (NRM) has been adopted in the belief that "strategic landscape-scale change is most effectively achieved where communities have a sense of ownership over planning and investment decisions, and are therefore prepared to make the investments in time, resources and better practices to achieve good outcomes. The importance of the community ownership principle, especially at the regional level, reinforces the biophysical importance of the region as a basic unit for NRM programme delivery" (Keogh et al, 2006).

Across Australia 56 NRM regions have been established under the National Action Plan for Salinity and Water Quality (NAP) and the Natural Heritage Trust (NHT). In NSW, the primary mechanisms for delivery of NAP/NHT priorities are the thirteen statutory Catchment Management Authorities (CMAs). Each body has developed Catchment Action Plans, Investment Strategies and Annual Implementation Plans that include catchment and management targets that align with State level targets. Incentive programmes are offered to landholders to assist them undertake works to improve catchment health. There is a strong assumption within these programmes that individual landholders or groups of farmers will readily utilise the funding opportunities and implement improved management practices on their properties. Moreover, the aggregated result will be enhanced environmental outcomes at the regional level.

Implementation of the new regional delivery model constitutes a significant challenge for CMAs. It is well recognised that the focus on local level environmental stewardship activities such as the Landcare program has not had a significant impact on the increasing rate of land degradation in Australia (CSIRO Land and Water, 2003). Although these programs have increased awareness of environmental issues particularly at the local scale, there is a need for more widespread adoption of improved land management practices to achieve catchment scale amelioration of landscape condition. Regulatory measures or incentive programs alone are not sufficient to encourage landholders to adopt better practices given the constraints imposed on them by limitations in financial and human resources, and confusion regarding the feasibility and practicality of technical solutions (Cary and Webb, 2001).

Furthermore, while all farmers have a stake in managing their properties in a sustainable way, tighter margins may drive landholders to seek productivity gains that in turn inadvertently impose pressure on agricultural landscapes. This is particularly the case in periods of extended drought as experienced in many areas of Australia over the last six years.

The Partnerships and Understanding Towards Targeted Implementation project (PUTTI) is designed to bring together the experiences and knowledge of landholders, natural resource managers, the broader catchment community and scientists to achieve changed land management practice and contribute to overall catchment management. It draws on complementary analytical techniques and systematic social investigation to:

- identify the factors that influence the decision making processes and behaviours of rural landholders;
- identify barriers to the adoption of sustainable practices;
- develop a program of attitudinal change with catchment managers and communities to support the adoption of modified practices and contribute to the achievement of natural resource management objectives at the sub-catchment to catchment scales;
- develop indicators to assess progress and evaluate 'on-ground' impacts over the course of the project and for the longer term.

It is realistic to suggest that Agent Based Modelling may be of value in reaching these objectives. Agent-based models (ABM) are in a simplistic sense, computer-based models that enable the study of emerging features through the interactions of deliberative (intentional) agents or adaptive (reactive) agents with a set of objects in their environment. Individual agents or groups 'behave' according to a set of rules or constraints. In multi-agent simulations (MAS) emerging features may emulate real-world system level patterns such as land use/land cover change, resource use or afforrestation patterns. Companion modelling attempts to better emulate system outcomes by using informants to characterise the 'behaviours' of agents in a MAS or role playing game. While these techniques may provide insight into the impact of decisions in constructed environments, practitioners acknowledge the significant effort required to characterise or program agents or groups of agents so that an adequate representation of adaptation processes occur. As stated by Bousquet and Le Page (2004) “the challenge has been to develop a new approach focusing more on the interactions between ecological and social components and taking into account the heterogeneity of these components” (p.315).

With this challenge in mind, we describe an alternative approach to participatory NRM that utilises an interactive modelling/partnership methodology that avoids the complexity of trying to characterise human behaviour in a computer system. The case study is drawn from our experiences in the Central West of New South Wales in Australia, with the PUTTI project. PUTTI is a partnership project between Catchment Management Authorities (CMAs), landholders, the broader community and researchers at CSIRO. Over the course of the project, PUTTI will extend into three catchment areas in NSW.

The project is focussed on practices related to dryland farming and is implemented through a staged approach. Stage 1 (Scoping) involves unstructured interviews with community members to understand landholder attitudes, beliefs and values relating to farming practices and decision-making. Stage 2 consists of a comprehensive survey of landholders to collect further data and identify the key factors that influence land management practice. During stage 3, a change program for sustainable land management will be developed in close partnership with the community and the CMA. We describe progress in the first two stages conducted in the Central West of NSW in the Bell and Cudgegong sub-catchments.

In order to achieve it’s aims PUTTI draws on the strengths of several complementary analytical techniques to develop a process that integrates across scale (individual farm to catchment) to identify and target the drivers that influence people’s land management practices. Each approach is encapsulated in a model. The models provide insight into the dynamics of the decision-making processes of landholders, their social networks, and the underlying motivations and factors that influence the way they manage their properties.

2. METHODOLOGY

The first two models correspond with components of the PUTTI project as it is currently implemented while the proposed Model 3 would enhance the process and effectiveness of the change program.

2.1 Model 1: Land Management Behaviour

A preliminary model of the main factors that influence land management practices has been developed using structural equation modelling. A complete report can be found in Porter et al. (2007).

To develop the survey used to collect the data, semi-structured interviews were conducted with 79 members of the catchment community in a scoping study. Areas covered included the management of pasture, weeds, crops, soil, stock and vegetation as well as information sources and types. The interviews proved to be a rich source of contextual anecdotal material as well as informing the questionnaire. An hypothesised model of landholder behaviour was developed building on this material, the previous experience of the research team and an extensive literature review.

The hypothesised model involved 16 latent variables including for example, farm size; the age, experience level, qualifications and degree of community engagement of farmers; their perceptions of barriers to change, environmental condition, and effectiveness of their practices; their use of formal written farm plans; their belief in science and technology and their trust in and influence of information sources. A comprehensive questionnaire to measure these variables was used in a telephone survey of 407 dryland farmers in the Bell and Cudgegong sub-catchments. The questionnaire included the following

- Background information relating to farming/property details – including farming activities, property size, years in farming, and property ownership.
- Trust in and influence of sources of information and advice.
- Roles in and views of the community.
- A series of attitudinal statements.
- Perception of the environmental condition of the wider farming region and individual properties.
- The existence of farm plans.
- A range of questions on weed management, soil management, perennial pasture management, native vegetation management and stocking rate management.

Having identified the key behavioural drivers, a series of shed meetings are currently being held with small groups of specifically selected landholders to better understand the nature of these drivers, how they can be influenced, and how these may relate to the effectiveness of the CMA’s incentives programmes.

2.2 Model 2: Social Networks

A further component of the research involves data collection and analysis to understand the networks that landholders use to gain information about farm management and the value that they place on that information. Initial data collected through the behavioural survey has provided some insights, and has informed the design of the social network research.

In this component, several waves of personal interviews will be conducted using a snowball approach. Participants for the initial wave are drawn from respondents in the behavioural survey while those involved in the subsequent waves are drawn from their referrals. The exercise will be repeated throughout the course of the study. While the behavioural modelling is complete for the Central West, the social network analysis is still in its early phases.

2.3 Model 3: The Biophysical World

Finally, when the behavioural drivers are fully understood and the social networks identified, we suggest that a decision support system could be effectively integrated in the change process.

The intention is to provide landholders with an opportunity to assess the potential impact of different land management practices on their properties, their local area and on the region or catchment as a whole. Additional funding is required to support this component. As an alternative, a reduced program of activities that does not rely on a full suite of fully functional simulation models may be used in a pilot program to demonstrate the feasibility and utility of the approach.

3. THE MODELS

3.1 Model 1: Land Management Behaviour

As described above, based on a hypothesised model of predictive factors of land management behaviours (see Porter et al., 2007), a telephone survey was developed and implemented in two sub-catchments in the Central West.

LISREL 8.72 software (Joreskog et al, 2000) and Robust Maximum Likelihood Estimation were used to create an initial exploratory structural equation model. The final simplified model can be seen in Figure 1. The model shows the resultant latent variables only and the relative strength and significance of pathways. All the pathways are statistically significant, with relatively larger effects shown as thick red arrows, relatively moderate effects as thinner blue arrows, and relatively weaker effects as thin green arrows. The co-efficients on the paths indicate the strength of the relationship (either positive or negative) between the independent variables and the dependent variable (Land Management Practices). The model shows that four latent variables had significant direct relationships with Land Management Practices – *Innovator*, *Farm Plan*, *Perceived Effectiveness* and *Perceived Cost Barriers*.

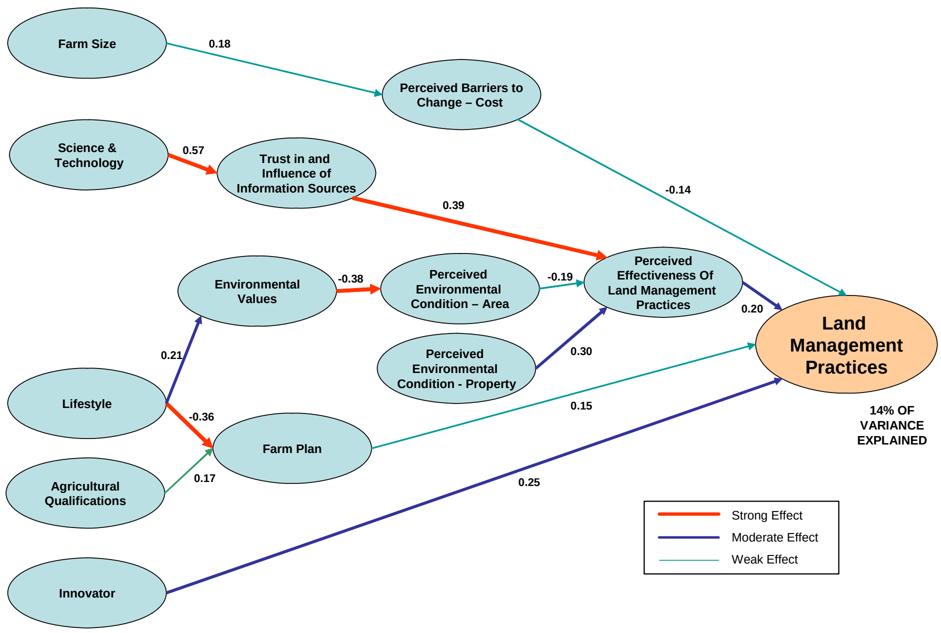

Figure 1. Simplified Estimated Structural Equation Model for Land Management Practices

Although the other latent variables did not have a significant *direct* effect on Land Management Practices, they all imparted a mediated influence through their direct relationship with other variables.

The model accounted for 14% of the variance that while not large, reflects the complexity of real-world social and NRM settings. The land management behaviour and its overall goodness-of-fit indices (see Table 1) were adequate given the exploratory nature of the model, there being two more stages in the study to refine and replicate the model.

The Chi-Square was significant at the .05 level indicating that the model could not reproduce the relationships among the indicators observed in the sample within a .05 level of significance. The chi-square statistic is known to be upwardly biased in samples of 200 cases or more (Hair et al, 1995). Consequently, a number of other goodness-of-fit measures to test the overall fit of the model were applied. The Root Mean Square Error of Approximation (RMSEA) measure was well within the suggested standards, and although the GFI and CFI were slightly outside of recommended values (Kline, 2005) they were acceptable given this exploratory stage.

Table 1. Model fit indices for the initial structural equation model

Fit Statistics	Obtained Value	Recommended Value
Chi-square (df)	1660.26 (730), $p < .05$	$p > .05$
CFI	0.86	≥ .90
GFI	0.80	≥ .90
RMSEA	0.06	≤ .08

Perhaps some of the most interesting findings of this analysis were the variables that did not emerge in the model given what might have been expected from the hypothesised model. *Age* was a key variable that would be expected to be a predictor, as was *succession planning* and *social norm.* This was not the case. However, the preliminary model does provide clear directions for the variables that need to be targeted in a change program. Of particular note is the relationship between *Science & Technology* and *Trust in and Influence of Information Sources* and *Perceived Effectiveness of Land Management Practices*. Also of interest is the role of the *Farm Plan* and the *Innovator*. Understanding these key variables and relationships is an important next stage in the project.

In-depth discussions are being held with the farmers to further clarify the relationships and key variables and a change program will be designed based on these discussions. It is, however, at this stage that the next two models can be of considerable assistance. Firstly, knowledge of the social networks will be invaluable in change implementation and information dissemination. Secondly, a biophysical model and interaction with trusted scientists could provide an excellent means by which the farmers could test alternative outcomes of land management practices that are promoted for sustainability.

3.2 Model 2: Social Networks

As indicted earlier, a number of questions were included in the landholder survey relating to who farmers spoke to when they were making key farming decisions, who came to them for advice and what roles they played in their communities. These were preliminary questions for scoping the methodology and data collection for the social network analysis. However, they also facilitated the conduct of some exploratory analysis and provided early insight into advice seeking and land management behaviours. Figure 2 below shows the network diagram of six sources of advice (shown by coloured dots) and the level of sustainable land management practices (the larger the dot, the better the land management practice). At this stage, it would be incorrect to read too much into the analysis as it is exploratory and more systematic analysis is required.

Black:	some family
Brown:	agribusiness, agronomists, family (some other farmers)
Red:	agronomists, government departments, family
Royal Blue:	other farmers, family, (some agronomists, government departments)
Pink:	family, financial/legal
Grey Blue:	multiple family

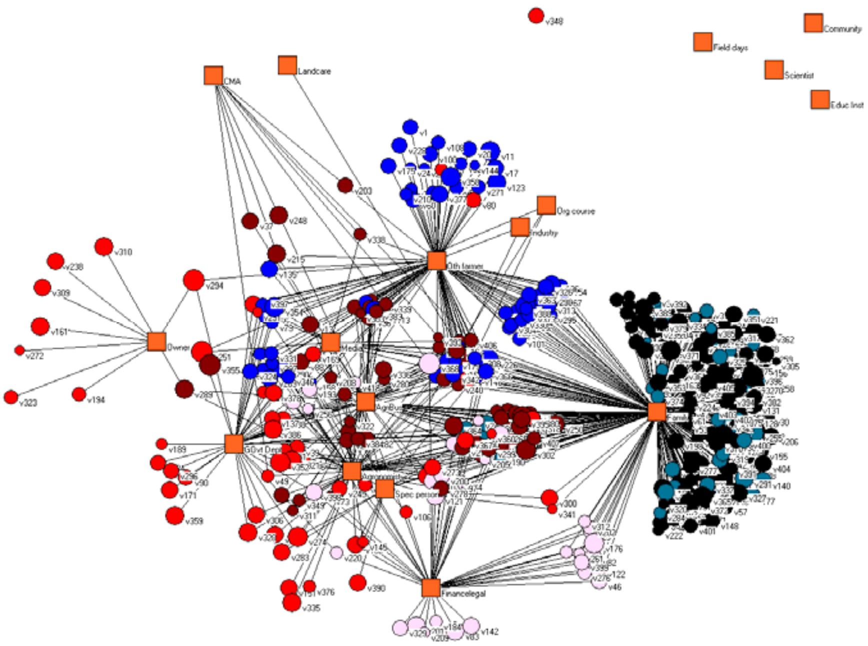

Figure 2: Preliminary network diagram of "if you are making a key decision on your property, who do you talk to?" with "land management behaviour".

The key point of interest here is the importance of the role and influence of family, and also of other farmers. However, those who relied on family members were less likely to be practising sustainable land management. This is particularly interesting in terms of linking into trusted sources of information. If this finding continues after the specific network analysis, it does indeed create a challenge for addressing the key behavioural predictor variables. If the people less likely to be performing sustainable land management practices mostly keep to their family members for advice of what to do on the farm, ways of addressing the development of useful farm plans or increasing perceptions of the effectiveness of sustainable practices will not be readily obvious. However, linking with the *innovator* farmers may provide a lead.

3.3 Model 3: The Biophysical World

Key to all this is the role that the biophysical scientist can play as a trusted source of information, especially in relation to debate about the effectiveness of land management practices. It is likely that this will best be done in small groups or families where farmers can test different combinations of practices to see what could happen on their properties. The final social network analysis will dictate the most effective groups for this. However, a simple, fast and effective decision support system would be of greatest use here. Unfortunately, the project is yet to secure funding for this aspect.

4. CONCLUSIONS

This paper has provided a very brief overview of what is occurring as part of the PUTTI project and what needs to occur to systematically address partnered behavioural change in regard to increasing sustainable land management in dryland areas. It is highly participative, while trying to take the guesswork out of what key areas are likely to bring about greatest change, and how to link into the ways in which the community functions.

We argue that this is a viable alternative to current ABM approaches with all their inherent limitations of design in trying to include human behaviour and decision making with land management. Instead, this project seeks to include the components from the ABM, but in a separate, iterative and real world setting. While the different models each provide key information and directions, it is the farming community that provides the data, and assists in interpreting the results, and how best they can be influenced to reach agreed outcomes. In this way, we are working with knowledge of "what is" and instigating change that the farmers are an integral part of.

We do not expect that change will happen quickly, but hopefully this approach will provide an informed basis to increase the likelihood of success.

5. ACKNOWLEDGMENTS

The PUTTI project is a collaborative research initiative between CSIRO and the Central West Catchment Management Authority funded by the Australian Government's National Action Plan for Salinity and Water Quality / National Heritage Trust Program. The authors gratefully acknowledge the contribution and collaboration of our colleagues at the University of Melbourne. Similarly, we acknowledge the significant contributions made by all members of the ARCWIS team to the research undertaken through the PUTTI project and the findings reported in this paper.

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