Producer Behaviour in a Systems Model of Integrated Catchment Management

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ABSTRACT: *The complexity of Australia's agricultural systems and the wide range of problems that rural areas currently face makes coordinated policy development difficult. This paper reports on a project that is using systems tools to develop an integrated catchment model to assist in this policy coordination problem. The focus here is on how an economic model of farmer behaviour can be adapted to permit systems analysis of the effects of a range of policy tools on a range of social, economic and environmental outcomes.*

Keywords: Systems modelling, integrated catchment management, household production model.

INTRODUCTION

The INSIGHT project is developing the ability to analyse agricultural and resource policies at the regional level. Based in the Lachlan catchment in NSW, the project is developing a systems model of how agriculture interacts with the natural and social systems surrounding it. The objective of the project is to provide regional policy makers with a clearer understanding of the systems they are managing, allowing them to explore what futures different policy choices may lead to, and where conflicts among policy mechanisms and goals may exist. To do this, the project is developing a model of natural resource problems currently facing the region. This provides a balanced view of the combined social, economic and environmental impacts of different change processes and policies.

The purpose of this paper is to describe the dryland farming sub-model, with an emphasis on producer decision making. The dryland farming sub-model is central to an integrated view of the catchment. Farming activities directly link production and environmental outcomes, while many of the social impacts of concern are direct or indirect consequences of on-farm decisions. As a result a range of social and environmental policies with overlapping influences affect dryland farming systems. This paper presents a framework for modelling the combined effects of different types of policy tools on the range of social economic and environmental outcomes.

The decision model is an application of the household production theory designed to take account of how a farmer's social and financial position affect the relative priorities of generating short term income, maintaining the productive capacity of the farm, and conserving ecosystems.

First I provide an overview of the INSIGHT project and the state of natural resource management in the Lachlan Catchment. Following this is the motivation for a systems approach to the problem of catchment management. The farm decision sub-model is then described. The ability of this model to provide integrated analysis of a range of policy tools is then demonstrated by examining three policy options aimed at preserving native ecosystems. Finally the issues involved in integrating this farm level into the regional level are discussed.

THE INSIGHT PROJECT: APPLYING SYSTEMS TOOLS

The Lachlan Catchment in central New South Wales faces a range of natural resource and social problems. Over clearing of remnant vegetation threatens native biodiversity, and has upset the water cycle resulting in mobilisation of stored salt to soil surfaces and into rivers. There are also related issues of soil degradation and acidification. Demand for water use has also increased over time, putting pressures on riverine environments, groundwater supplies and water users. At the same time significant social adjustment pressures have arisen at a time when the continual decline in farmers terms of trade has been exacerbated by a severe and persistent fall in the price of wool. The most evident social adjustments are concentrations of populations in large urban centres at the expense of smaller town and farming families.

The INSIGHT project is using the ideas from systems thinking to assist catchment managers develop a coordinated approach to dealing with these problems. The process has involved mental mapping exercises with various community groups to improve understanding of the different aspects of the problems and to tap local and specialist knowledge. A second stage involves the development of systems models that can help analyse the links among these different issues and improve understanding of the working of the system. Since these models are aimed at improving understanding as well as providing analysis of broad policy directions, a premium is placed on developing relatively simple and transparent models, that can be readily revised.

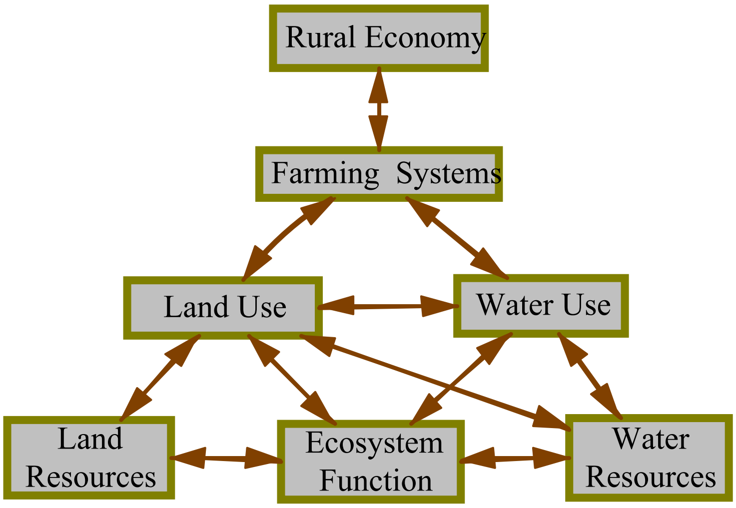

Figure 1: An overview of the INSIGHT model structure.

Figure 1 indicates the scope of issues covered by the project. It illustrates that there are tight dependencies among all aspects of the system. It also suggest that four levels of modelling are required, starting at the bottom with strict biological and physical model, then integrating the impacts of different land and water use options, then examining how farmers will chose among resource use options, and finally examining the social implications and determinants of these choices.

The large number of feedbacks, the importance of the dynamic behaviour of the system, and the need for an integrated perspective on the processes makes a systems approach a natural for this problem. The next section discusses three aspect of the system where links and feedbacks are particularly significant.

THE NEED FOR A SYSTEMS APPROACH TO RESOURCE MANAGEMENT

Integration of biophysical systems

It has long been argued that integrated management is needed to tackle the range of environmental problems facing Australian agriculture. The interconnectedness of the problems is well illustrated by the common trio: salinity, soil degradation, and loss of native biological diversity. Some potential solutions, such as revegetation with native species, can help combat all three problems. While farm level agricultural systems are being designed to exploit these complementarities, many of the important impacts of these problems, such as salinisation and loss of biodiversity, occur at a regional level. Integrative regional level modelling of the range of environmental problems can assist regional planners develop a coherent vision of how the system might change over time, and develop a regional management strategy. Such a strategy would involve determining the approximate type, location, magnitude, and timing of resource use interventions.

The importance of human behaviour in the system

The role of social factors in determining natural resource outcomes is also becoming more widely appreciated. However Malcolm(2000) identified this topic as a major gap in our current policy analysis tool kit. This is not just a matter of recognising that a trade-off exists between environmental goals and other objectives. It also means recognising that a range of people make these decisions, and that their decisions will depend on their social, economic, and environmental situation.

The need for coordinated policy development

Finally, the present crisis in environmental and natural resource degradation coincides with a period when declining rural services and financial problems for farmers are pressing rural problems. The close links between social and environmental outcomes means that social and environmental policies cannot be considered in isolation. Binning and Young(1997) argue that effective policy development requires, amongst other things, the use of a wide range of policy tools that are well coordinated. Possible adverse interactions among policies is also a major concern of Lachlan catchment managers. Binning and Young identify three groups of policies:

1. Extension and Motivation
2. Security: regulations, codes of practice.
3. Financial: Incentive instruments.

One objective of this project is to develop the ability to jointly analyse the impacts of all three types of policy tools.

Integrated biophysical modelling, linking social and environmental systems, and integrated policy analysis are therefore three key elements that need to be considered in developing a balanced approach to catchment management.

DEVELOPMENT OF AN INTEGRATED MODEL OF DRYLAND FARMING

This section outlines the major social and environmental variables requiring analysis that are connected to dryland farming. A major challenge in building a useful systems model for integrated catchment management is to control the complexity of the model. The discussion therefore focuses on the essential elements of the system, the links among them and how to develop a conceptual framework for systems analysis.

The links between farming and social processes

At the farm level, social indicators of interest include the distribution of farm income and wealth, and the rate of change in farm ownership and farming enterprises. The impact of changing rural services and infrastructure on farmer welfare is also of concern. The location of farms relative to services centres is also of interest.

At a community level, most social issues result from the flow-on effects of changes in farm input use, production, employment and on farm populations. Changes in these factors can result in significant changes in the structure of rural communities.

Social factors that may affect farm management include the availability to earn off farm income, management skills, farm size, the age and wealth of the farmer, and farmers long term goals. These factors may affect both the choice of farming system and the decision to enter, expand, or exit farming.

The need to jointly analyses these features imposes several specifications on the model. In order to examine the welfare distribution issues, a model will need to examine a number of different farms. Spatial issues need to be considered, such as the location of farms relative to service centres, and the position of farms in the biophysical environment. Finally to capture the flow on effects of changing farming practices requires modelling the quantity and value of farm inputs and production

The links between farming and the environment

The land intensive nature of agriculture put it at the frontier of humans interactions with natural systems. The need for integrated modelling of these interactions has been discussed and the specific of the biophysical model are outlined below. Modelling however requires a framework for measuring the range of benefits and costs of farming-environment interaction.

Benefits from the environment that are derived indirectly, after being transformed via production processes and markets, are typically studied under the heading of sustainability. The primary focus is the ability of these resources to continue delivering a stream of goods. Concern about maintaining benefits that are not traded or transformed generally come under the heading of conservation. Here the environment itself, more than the derived benefits is valued. This distinction is made here because the different types of benefits are treated very differently by our markets and institutions. It should be noted however that the source of these benefits are closely related, the same biological and physical processes underpin them.

Conceptually we can measure the preservation or degradation of the productive capabilities of an environment reasonably easily. Here the measure of sustainability is the decline in annual output, given constant levels of applied inputs and conservation benefits.

More significant difficulties exist in attempting to measure and model conservation outcomes. Part of the difficulty lies in defining what exactly is valued about the environment, while a second problem is the limited knowledge we have about how farming impacts on the functioning of ecosystems. Practical approaches to developing objective targets for conservation, such as the focal species approach of Lambeck (1997) provide useable measures, however they are at best rough indicators of what features of the environment may be valued in the future.

This model measures environmental outcomes by comparing them with predetermined environmental states that have been subjectively assessed as likely to achieve a certain level of species preservation. This has the limitations mentioned above but represents a simple and transparent measurement method. A further problem is the difficulty of measuring conservation outcomes at the farm level, as opposed to a regional scale, where species loss and other indicators can be measured. This raises the issue of how farmers value the contribution of their land to regional conservation goals. These issues are discussed in the next section.

Biophysical Model specifications

Indices of the following physical variables are used to model how agriculture interacts with the environment:

1. The water balance and water cycle, including ground water levels and water run off.
2. The acidity of the soil.
3. The physical and organic properties of the soil.
4. The mobilisation of salt.
5. The area, fragmentation, and condition of native vegetation.

Though these variables are not valued in themselves, they are key state variables determining productive and conservation outcomes. This project requires a model of how the state of these variables change over time, interact with each other and relate to production, conservation and farmer behaviour. Physical interaction among the variables can be captured relatively simply using this state variable approach, however developing catchment scale biophysical models that are realistic enough to permit valid analysis is a major hurdle to soft systems analysis of natural resource problems. Our approach is to combine an understanding of the basic physical principles of these change processes with available data on the distribution of the problems. The emphasis is on the potential interactions among the different processes and the relative importance of these changes in different areas. It should be emphasised that despite the complexities of the biophysical system and the difficulties in developing realistic biophysical models, the behaviour of the human part of the system is equally if not more important in deciding the future of the system.

A MODEL OF FARMER BEHAVIOUR FOR INTEGRATED POLICY ANALYSIS

This section develops a model of producer decision making that incorporates the social, economic and environmental influences and outcomes. The model is based on household production theory[1], an approach that recognises that production decisions are not separable from household consumption decisions. Modelling both aspects of the farmer decision making (production and consumption) is necessary in order to incorporate the complete range of policy effects. In addition, the household production model is a useful framework for analysing the links among the various farm enterprises and characteristics. As many farm characteristics that were previously unvalued, such as carbon uptake and biodiversity, are becoming important in their own right, this feature is particularly appealing.

This application emphasises several links between farmer production behaviour and consumption preferences.[2] The household characteristics considered to affect production and resource management decisions include:

1. Farmers preferences for on-farm environmental amenity.
2. Household financial constraints and off farm labour possibilities.
3. Farming household preferences for current verses future income.
4. Household preferences for maintaining productive farming capacity.

Various farm household and farm characteristics may affect these preferences. For instance, we can speculate about what may increase a households preference for current income. Household wealth, size and age are some possibilities. Similarly farmers preferences for preserving productive capacity may depend on how much longer

[1] See Deaton and Muelbauer (1980) for a review.

[2] Typically economic models assume that perfect competition ensures farmers are efficient and therefore profit maximisation determines producer behaviour. This argument is not compelling in this instance for several reasons. The thinness of land markets, the importance of human capital in farm productivity and the variation in producers labour opportunity costs, long delays in adjustment processes, and different valuations and uncertainty about the future all mean that productive behaviour may be significantly affected by other influences than enterprise profitability.

the family intends to farm, which will depend on farmers age and potential heirs. It is difficult to measure and quantify some of these effects, however, if the framework is to permit integrated policy analysis, it is important that the potential influence of these variables can be included in a logically consistent manner.

The next step in developing the model is to specify the dimensions over which household preferences are defined. For the purposes of this model, households are assumed to have consistent preferences defined over:

1. Current year income.
2. Preservation of the farm resources productive capacity.
3. Conservation outcomes affected by farm management.

Numerous studies have pointed to the overriding importance of financial considerations in determining farmer behaviour. While it may be disputed that preference for conservation outcomes are a strong determinant of farmers behaviour, this model emphasises environmental amenity for several reasons. First environmental outcomes are of central importance in this analysis. Some environmental management changes require minimal costs, farmer conservation preferences in these situations could be highly significant. Second, lifestyle farms are becoming a significant land use, especially close to large population centres. This may not translate into increased conservation, however it is likely that outcomes besides profitability are important on these farms. Finally changing preferences captures changes that arise from activities that raise awareness of environmental issues and change communities environmental ethics.

The model specifies how farmers evaluate the technical production possibilities in light of these preferences in order to make decisions. Figure 2 illustrates this conceptual framework. The diagram focuses on the choice between the production of current income, and preserving the farm natural asset base for production in the future. The shape of the production possibility set indicates that there is a physical trade off between production today and preserving land for future production, however the bowed shape of the frontier indicated that there are synergies from producing both outputs together. Production on the shaded frontier is said to be efficient, that is on this frontier, it is not possible to produce more current income without giving up future production.

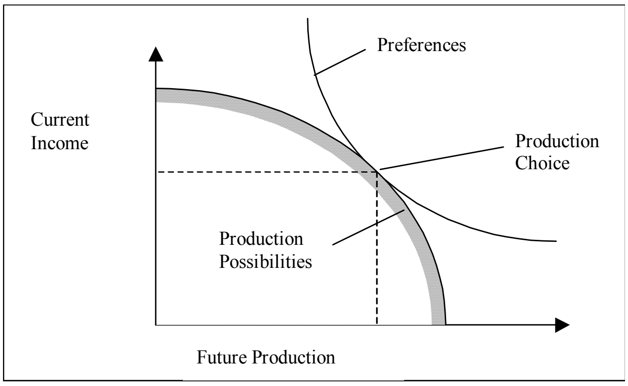

Figure 2: The farm decision model

The curve marked preferences indicates pairs of current income and future production outcomes that the farmer would be equally happy with. The slope of the curve indicates the rate at which the farmer is prepared to trade one for the other. The shape of this curve reflects the idea of diminishing marginal utility: At lower incomes the farmer is less prepared to trade current income for future production. Indifference curves that are higher and further right are preferred to lower once. The farmer therefore chooses the production point that attains the highest possible curve, resulting in the choice indicated in the diagram.

Uses of the model

One purpose of developing this model was to allow analysis of the three types of policy levers identified by Binning and Young(1997). To illustrate, consider a range of policies aimed at increasing revegetation. A financial incentive such as a subsidy for revegetation work would change the shape of the productivity frontier, making it relatively less expensive (in terms of current income) to achieve conservation outcomes. The resulting substitution will result in potentially trading some current income for conservation. Educational programs may change the preferences of farmers, perhaps by increasing their awareness of degradation problems, or they could affect farmers understanding of production set by raising awareness of the productive benefits of vegetation. As an example of analysing regulations,consider the impact of vegetation clearing restrictions on farmer welfare and behaviour. Modelling behavioural changes simply involves comparing the pre and post regulation choices of sustainability, current income and conservation. Modelling the impact on farmers welfare of the regulation is more difficult, however upper and lower bounds of this impact can be calculated by observing the production choices made before and after the introduction of the regulation.

None of these analyses are particularly novel, however this specification of the household production model provides a unifying framework. By specifying calibrated models of the production frontier, it is possible to generate plausible analysis of the likely effects of policy changes.

Regional Level Modelling of the Dryland Farming System.

There are several conceptual and practical issues involved in scaling a farm level model up to regional level. Some economic variables that can be considered fixed when a farm is viewed in isolation are variable when the combined effects of all farms are considered. Local labour markets, feed markets, and specialty crops, are examples of markets where local prices can be influenced by supply conditions.

Farmer entry and exit becomes a significant issue both for potential land use and population changes. Variables likely to influence entry and exit decisions are closely related to the social variables already discussed. Since indebtedness is a major cause of farmer exit, exit behaviour also needs to be linked with the model of the distribution of farmer wealth.

The regional level of the impacts of conservation and salinity control also make scaling up difficult. Group efforts to coordinate conservation work, such as landcare, can perhaps be captured by modelling regional changes in preferences and costs of conservation, as district level grant and land care schemes take effect.

A practical consideration is that the quality of spatial data tends to be inconsistent. The importance of overlaps of different variables in determining outcomes needs to be balanced against data quality when specifying models of how farms are spread over the land scape.

CONCLUSIONS

The need to simultaneously evaluate the impacts of changes on a range of social economic and environmental variables, the complex links and feedbacks among the different biophysical and social systems, and the importance of considering a wide range of view points, make systems thinking a potentially powerful approach to catchment management. The complexity of the system however means that simply general and interconnected sub-modules are required.

This paper described a simple economic model of behaviour that can be embedded in a systems model of regional agriculture. The household production model emphasises that it is the interactions between physical possibilities and the preferences of producers that determine production and land management choices. This framework, permits integrated analysis of the range of policies that affect dryland farming systems and subsequently systems analysis of the associated economic social and environmental outcomes.

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