Explorative Modelling of the Links Between Social Change and Natural Resource Policy

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Abstract: CSIRO Sustainable Ecosystems is constructing a spatially explicit modelling system called INSIGHT capable of exploring the implications of land use policy alternatives under plausible price and climate scenarios for the next 20 years. In this paper we report on the structure of the economic and social aspects of the model and illustrate how it can be used to analyse the connections between resource issues and social issues. The prototype model consists of agricultural production point models linked to a spatial hydrological model simulating the implications of various types of land use for stream flows and salinity. A model of farmer decision making allocates land to different uses based on a weighting of three indicators: economic performance, agricultural sustainability and conservation outcomes. Three different farm types are defined that differ in size, preferences and restrictions on production options. A model of farm adjustment driven primarily by demographics reallocates land among the three farm types. Farm population, employment and production link farm activities to a model of regional employment and population adjustment. The model is designed to explore the extent to which policies in the natural resource area may affect rural communities and the implications of rural adjustment for the management of natural resources within the catchment. Its use is illustrated by modelling the potential system-wide impacts of investment in improved pasture productivity.

Keywords: Simulation; Integrated catchment modelling; Socio economic modelling

1. INTRODUCTION

The INSIGHT project aims to build a spatially explicit modelling system capable of exploring land and water policy alternatives against plausible price, cost and climate scenarios for the next 20 years. The purpose is to provide natural resource policy makers with insight into how the catchment behaves as a system. The relevant system was defined by potential users to include environmental, economic and social issues. A high priority is to provide a balanced and integrated overview of these different aspects and their potential interactions. The approach is being trialled in the Lachlan catchment in central NSW.

This paper reports on the social and economic aspects of the INSIGHT model, and illustrates how the model can be used to explore the potential social impacts of natural resource policies. The full INSIGHT model is outlined in Gorddard and Walker [2001]. Details of the biophysical components are provided in White et al. [2001].

Section 1.1 describes a framework for integrating social factors into the model. The model is described in two parts, the first looks at population demographics, employment and migration. The second looks at social influences on farmer decision making. We use the model to explore the potential impacts of development of profitable perennial pasture systems.

The Lachlan Catchment covers about 84,700 square km - around 10% of the NSW State. There are a wide range of natural resource issues in the catchment. Over-clearing of native vegetation in the past continues to threaten the survival of native species [Reid, 2000], especially when combined with the sustained pressures from grazing and introduced species. Replacing native vegetation with annual cropping and grazing systems also altered the water balance in the catchment. This resulted in increased river flows, but also in increased groundwater recharge and the subsequent mobilization of salt to the surface and into the river system. Soil degradation issues include acidification, dryland salinity, declining soil structure and sodicity. Diversion of water and modified river flow regimes for human use affect the ecology of riparian zones and important wetlands along the length of the Lachlan river.

Farmers, towns and communities are affected by the combined impact of these issues, and the policies that target them.

1.1 Social Issues in NRM Policy

There are perhaps two types of interactions between social and natural resource issues that require modelling.

The first category, social impacts, looks at the impact that changes in the natural resource base, changes in natural resource use and changes in natural resource policy have on individuals and communities. The modelling of social impacts focuses on rural population and demographics. There are several reasons for this.

While population growth, aging and movement are not in themselves indicators of social health, they underpin issues such as regional employment, workforce adjustment, training needs and the provision of services such as health care. In addition many of the more intangible social impacts, such as community coherence, are due to the rate of adjustment. Modelled population adjustment therefore can serve as a proxy for many social impacts.

The second category of interaction focuses on how characteristics of communities and individuals influence the way in which policy affects natural resource management. This includes NRM policies as well as policies aimed at other issues.

Social variables influence the effectiveness of NRM policies in at least three ways. The difficulty in defining, measuring, and monitoring sustainability or biodiversity outcomes means that property rights are difficult to define and enforce. Incentive and regulatory mechanisms are therefore difficult to implement without land owner goodwill. As a result, policies such as Landcare have focused on raising awareness, changing attitudes, and facilitating action at the local level. The ineffectiveness of many policies in achieving the desired magnitude of change in behaviour is, possibly, due to constraints on farmer ability to respond. Constraints include reduced borrowing ability due to debt loads, and limited management experience with alternative farming systems [Barr and Cary, 2000]. Finally the owners of rent-generating productive land are not forced by the market to either sell or produce efficiently if they are prepared to trade some of the potential rents for non-market rewards. Lifestyle factors, and not simply production efficiency, may therefore determine the behaviour of debt-free farmers.

2. RURAL POPULATION

Paterson [1975], in a study of rural migration found that population movements in rural areas were attributable to five main factors: distance from capital city, tourism, factory production, mining and broad scale crop production. Garnaut et al. [2000] found that the dominant industry sectors in many country towns of Australia were still agriculture and mining and their related servicing and processing industries.

The ABS [1987] surveys of internal migration found that the highest mobility rate occurs amongst those aged 20-24 followed by the 25-29 year olds. Bell [1992] found that workers in agriculture displayed the lowest rate of mobility of all industry sectors. However, Bell concluded that the structural transformation of industry (reflected in declining employment in both manufacturing and agriculture) is of fundamental importance to understanding out-migration.

NSW Urban Affairs and Planning [Culpin et al. 2000] projected accelerating inland population losses due to the existing demographic structure of the population in these areas.

2.1 Modelling Regional Population Trends

Three sub-models, labour supply, labour demand and population, are used to simulate regional population growth [Smyth, 2001].

The population sub-model calculates the number of persons in each 5 year age-sex cohort on an annual time step for each statistical local area (SLA).

The labour supply sub-model calculates the total workforce in an SLA, together with the potential new workforce entrants from the school leaver population. It assumes the existence of a stable workforce with no leakage (other than the change in the participation rate), which is topped up by new school leavers. The school leavers may enter the workforce after year 10 or after year 12, dependent on the school retention rate. As there is no tertiary education facility within the catchment (excluding distance education and TAFE), there is a leakage of school leavers for higher education.

The total labour supply is also affected by retirees and the farm consolidation process. The percent of farmers remaining in a district on retirement from farming is assumed to depend on the size of the non-agricultural labour force.

The labour demand sub-model calculates the total labour requirements for each SLA. It is based on the regression model of Paterson [1975]. However, it disaggregates several sectors. Regression analysis was used to estimate the relationship between the total labour demand in each sector and other population, production and service related variables. The sectors are community services, health and education, retail, wholesale, manufacturing, agricultural production, mining and other service jobs.

A simple labour market sub-model calculates the surplus of labour supply over available jobs and attributes an age-sex propensity for unemployed persons to migrate, based on the national average [ABS, 1987]. It does not consider part-time work, the under-employed, structural unemployment or skill requirements. Nor does it take into account job skills, training requirements, or wages.

3 FARMER ADJUSTMENT AND DECISION MAKING

The farm model explores the joint issues of farm adjustment and the influence of social variables on farmer decision making. The model specifies three farm types: lifestyle, small family and agri-business. They differ in size, on-farm labour, management ability, entry and exit behaviour and farming objectives. The difficulty of defining empirically useful farming types [Vanclay et al., 1998] means that the construction is not empirically validated. Its use is to explore which social factors might be important in affecting farmers' management of natural resources, their response to policy incentives, and the catchment scale effects of these changes.

3.1 Farm Adjustment

Farmers' ages are tracked over time using a cohort model. A base selling rate is specified for each farm type, and the propensity to sell increases with age. In addition a maximum retirement age is specified. Selling of agribusiness farms is unaffected by owner age. Base rates of sale are calibrated such that retirement sales plus the base rate equals current farm sales rates.

Land sold by the three farm types is pooled and reallocated to the different farm types according to a buying sub-model. The default assumption, representing the farm consolidation process is that agribusiness farms buy most land. The option exists to permit a large proportion of lifestyle farm buyers near population centres.

This model does not include land prices, or the impact of the farmer's financial situation on the sales decision. Future versions will need to include these relationships in order to assess how policies that affect farm income influence farm adjustment.

3.2 Land Use Decision Making

The farm decision making model is based on household production theory [Deaton and Muelbauer, 1980]. This approach recognizes that production decisions are associated with household consumption decisions, it also permits the consistent modelling of a wide range of influences on farmer decision-making. The model defines the set of feasible production options, which may include multiple outputs or, equivalently, multiple attributes of the production process. Household preferences determine the choice of production options and subsequently household resource allocation and consumption decisions.

In this application farmers are assumed to have defined preferences that are a function of: a) the net present value of production; b) on-farm environmental amenity derived from the area and condition of native vegetation; and c) maintaining the productive capacity of on-farm natural resources, or in other words sustainable production. Constraints included are the management ability of the farmer and the availability of on-farm labour.

A subroutine is used to calculate the impact of current activities on the value of future production. For each land use option in year t, the resulting state of the system in year t+1 is used as a starting point to run the system for 20 years under a constant land use strategy. This strategy uses standard grazing until it becomes unprofitable. The resulting future benefits or costs are then used in the simulation run to determine the land use choice. Land use decisions that result in future costs or benefits are the removal of productive land for revegetation, investment in fencing of native vegetation (which has a positive influence on vegetation condition and possibly future productivity), and agricultural land use options that affect the rate of soil acidification.

On-farm environmental amenity is measured by the area and condition of native vegetation. The value that farmers place on this may reflect amenity value, or their desire for on-farm conservation for its public good value.

Sustainability of production is measured by the change in potential production assuming fixed amounts of applied inputs. The production potential is derived from the crop production model. This implies that substitution among different kinds of natural capital is considered acceptable in achieving sustainability goals; however, substitution of off-farm inputs for natural capital is not.

The model calculates the value of the utility function for a range of options and selects the utility maximising option. The number of options is small; they represent significantly different land use strategies. Each option consists of two decisions, an agricultural land use decision and a native vegetation management decision. Agricultural land use options are intensive, standard and conservation-orientated cropping and grazing packages. Each package specifies inputs such as fertiliser and labour, and a productivity factor, specifying the expected yield relative to standard technology. The vegetation management decision is to choose one of three conservation strategies; these are "do nothing", "fence remnant vegetation", or "revegetate 2.5% of the land area".

The farm decision model is designed to explore the trade-offs between profitability, sustainability and conservation. The key questions to ask about this component are 'to what extent are the goals complimentary or competitive?', and 'what implications might these interconnections among farmers' objectives have for their response to policy changes?'.

The model is being used to explore these questions in the context of farmers' responses to incentive payments for nature conservation. The preliminary results indicate that the flow-on consequences of incentive payments for conservation are minimal. That is, they do not significantly affect farm income, river flows or salt loads, or regional employment. To demonstrate the model's ability to explore the systemic impacts of a policy option, the next section looks at the potential impacts of new agricultural technologies.

4. MODELLING POLICY IMPACTS

In this section we use the model to explore the implications of a policy that invests in increasing the productivity of deep rooted perennial pasture systems for dryland wool production in the high rainfall areas of the Lachlan catchment. Pastures in the high rainfall areas of the catchment are predominantly over-sown and fertilised native pastures, and improved pastures based on perennial grasses [Hill and Donald, 1998]. Improved pastures represent a significant financial investment and require intensive management to maintain. Degradation results in a decrease in the proportion of perennial species [Kemp and Dowling 2000], and is a widespread problem in this region as a result of sustained low wool prices. Increasing the productivity of improved (perennial) pastures is one mechanism for increasing their profitability and therefore encouraging adoption. Potential benefits are improved profitability and decreased rates of salinisation.

To explore these issues three grazing options are defined. The base grazing system consists of degraded pastures with a large percentage of annual plants. Two improved grazing strategies are defined, the first uses pastures based on perennial grass in conjunction with high input of fertiliser, intensive management and high stocking rates. A third strategy corresponds to improved native pastures: a low yielding but low cost native perennial system.

Figure 1 presents summary results from two model runs based on these options. The base scenario (labelled 'current' and represented by the thin line marked with a x) projects the consequences of the model's base assumptions into the future. The 'newtec' scenario includes the effects of a boost in the potential productivity of the perennial grasses in the high input system by 50 percent.

Several factors drive the time trends in the base scenario results. The improved pasture options are unprofitable on the majority of lifestyle farms as they lack the required management input. Therefore as the area in lifestyle farms declines over time, the area of intensive pasture increases. This increase is partly at the expense of the base grazing system and partly at the expense of cropping. Cropping occurs more frequently on the lifestyle farms as it is relatively more profitable when the high input grazing system are not feasible. The changing productivity of land over time, due to rehabilitation of native vegetation and declining soil pH, also influences the timing of a the change to improved pasture. The decline in agricultural employment over time reflects the farm consolidation process and the associated

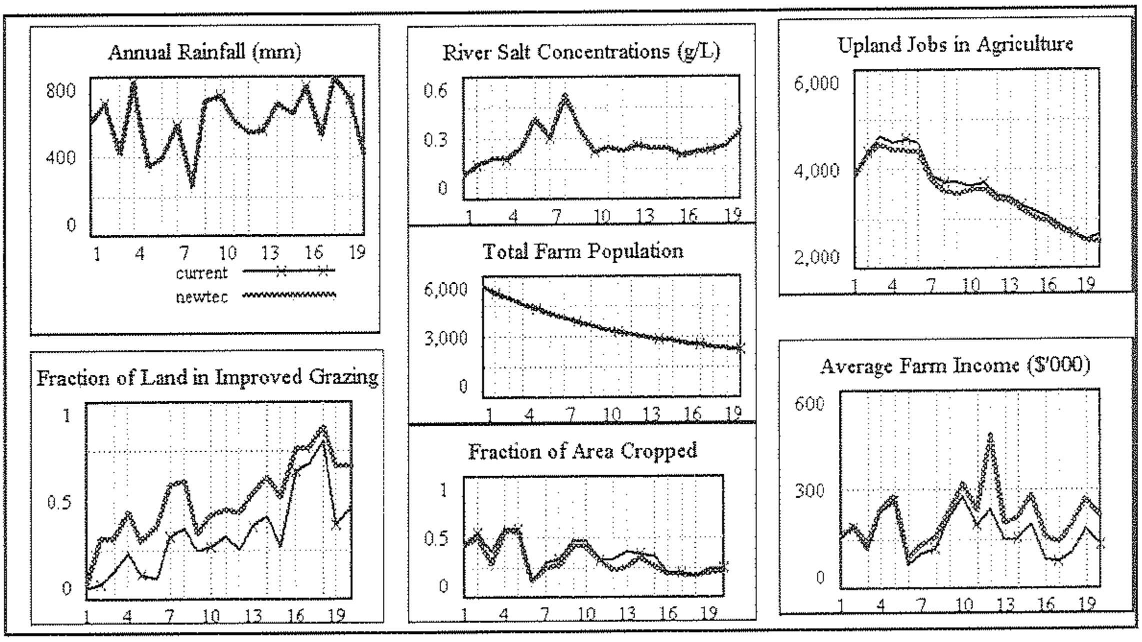

Figure 1. Catchment scale impacts of increased productivity of perennial pasture.

decline in cropping which is relatively labour intensive.

The availability of the new higher yielding perennial grazing system represented by the 'newtec' scenario causes several changes. First, the area of improved pasture increases rapidly soon after introduction. A second effect is additional substitution of the perennial pasture system for cropping. This effect is relatively small, and reflects the fact that (remaining) cropping is limited to fertile soils in areas where it remains the most profitable option. This change also drives the additional decline in agricultural employment.

Employment opportunities in the rest of the economy (not shown) follow a similar trend, moderated by the relative importance of agriculture to the economy in the different regions. Other impacts of this new technology are a reduction in stream flows and salt loads. The net effect on river salinity concentrations is minimal. This results from the new technology being used across sub-catchments and underlying geologies, averaging its impacts across high salt and high water yielding areas.

The new technology causes no change in the conservation of native vegetation. Some potential mechanisms that may cause an effect, such as the increased wealth of farmers, are not included, while others such as the potential for the new technology to increase the productivity advantage of increasing animal shelter turn out to have a minimal impact.

5. DISCUSSION

The predictive power of the model is low, key issues are ignored and models of most components would need to be far more detailed and refined to claim predictive power or realistic representation of mechanistic processes. However, the results illustrate the ability of the model to raise a balanced range of issues for consideration in evaluating policy options. The specific results about say the rate of farm adjustment, and of the redistribution of land among different land use options, are best seen as starting points for informed discussion about the merits of a particular policy. The presentation of the systemic impacts would ideally help focus the debate on the critical aspects of the system. More specialised knowledge is required at this point in the decision making process, whether it be about the social impacts, the hydrology, or farm profitability.

In addition to raising and prioritising issues in a systematic manner, the results also put specific changes in context. For instance, the impacts of the investment in technology on employment in rural areas are small relative to trends arising from the farm consolidation process and comparable to the shocks due to climate variability.

The learning applications of the model have been emphasised. The model's success in assisting learning will depend on several factors. First the model results must be driven predominantly by plausible and realistic mechanisms, rather than the simplifying model assumptions. This appears to be the case for the issues explored so far; however, we expect the depth and breadth of the model may be found wanting as it is applied to other issues.

Second, the user must be able to identify the drivers of trends and change in the model. The causal tracking features of the Vensim® simulation package work well for this; however, an intimate knowledge of the model is perhaps necessary to interpret these outcomes correctly. The complexity of the model must also be controlled to permit understanding of model behaviour. The model is yet to be field tested as a learning tool. No doubt other issues such as the user's comfort with the model assumptions, the suitability of the model to the questions of interest, the way the model is used and the way questions are framed will all affect the value of the exercise.

The final paper in this series, van Ittersum and Gorddard [2001], discusses applications of the model in more detail.

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