Applying Systems Thinking to Catchment Management

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ABSTRACT: *Participative planning processes are being used to examine and determine appropriate strategies for the Lachlan catchment in central NSW Australia. However the inter-related impacts of planning decisions are not easy to unravel. A systems simulation modelling tool is being developed to allow the exploration of alternative environments and strategies.*

This paper examines the adaptive approach and discusses one sub-system in the model. This sub-system deals with the socio-economic issues that may be impacted by planning decisions. The regional implications for the population living in the catchment in terms of existing and future infrastructure, and its likely viability under differing scenarios is the issue of interest for this sub-system.

Keywords: Conference, systems thinking, system dynamics, adaptive management, catchment management.

INTRODUCTION

The Lachlan Catchment, covers an area of approximately 84,700 square km or around 10% of the NSW State. Central to the catchment is the Lachlan River, the waters of which are in demand for town water supply, mining, irrigation and other urban, agricultural and industrial uses. This usage is additional to that required by the natural ecosystem. Dryland and river salinity are major issues in the catchment that require careful management. The NSW government has adopted a community based approach to the socio-economic assessment of water management plans.

The INSIGHT project, a joint project between CSIRO Wildlife & Ecology, NSW Dept of Land and Water Conservation, NSW Agriculture and the Bureau of Resource Sciences, has as its objective, the development of a tool to facilitate the integration of the social, economic and environmental analysis.

Questions that require these integrative analyses are:

- how might the use of water for flushing flows, as opposed to the impact of allowing further increasing stream salinisation, impinge on other water dependent activities in the Lachlan.
- what is the impact of re-vegetation for salinity control likely to be on rainfall run-off, and what would be the consequences for other water users if it resulted in a significant reduction in water availability.
- What is the likely impact on town populations, employment and infrastructure if water trading moves large quantities of water from the central part of the Lachlan to the bottom of the catchment,

These questions, and others like them, assume increasing importance when it is realised that the major water storage for the catchment (Wyangla Dam) is in the upper part of the catchment and yet some of the largest areas of good productive soils are in the bottom of the catchment (Figure 1), where irrigated agriculture is expanding.

INSIGHT, although an integrative model, is being developed in sub-modules. This paper discusses the development of the regional socio-economic sub-model..

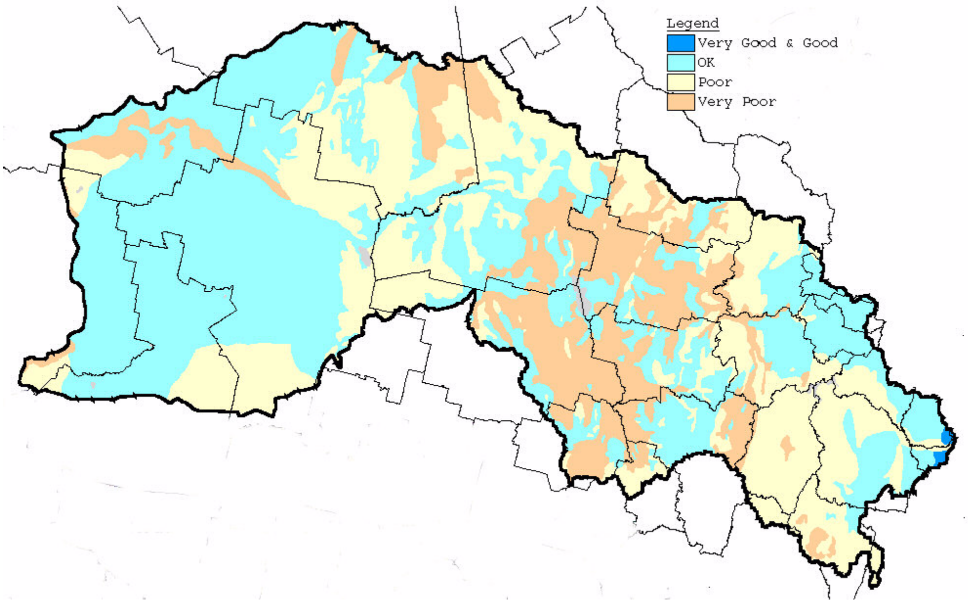

Figure 1: Soil Quality of the Lachlan

SYSTEMS MODELLING
The Modelling Requirements for Adaptive Management

Senge et al. (1994) listed five key components of Systems Thinking as: (i) team learning, (ii) mental models, (iii) personal mastery, (iv) shared vision, (v) systems tools.

Having regard to this, workshops with industry and government identified key requirements that the INSIGHT project must address for adaptive management in a catchment context as:
Team Learning: Establishing learning processes with potential users, Highly transparent interactive gaming structures, High level human intervention and learning, A dynamic system
Mental Models: Adopting systems thinking concepts to represent interactions, Using procedures for displaying uncertainty, Causal tracking and alternative views
Systems Tools: Core simulation modelling system with multiple views, Maximum use of existing models, Maximum use of existing data sources

Team Learning: Learning Processes with Potential Users

The Lachlan Catchment Management Committee (CMC) has the overall responsibility for the catchment. Individual issues such as water or vegetation are referred to other Committees by the CMC. The Lachlan River Management Committee (RMC), for example, is responsible for reviewing and making recommendations on the river flow management regime. NSW Government Departments have adopted a service provider mode of operation and bodies such as NSW Agriculture (NSW Ag) and the Department of Land and Water Conservation (DLWC) service these Committees.

The Committees have, and are refining, a vision of where the Lachlan could be in 20-30 years. Our goal is to mesh into this vision to enable the assessment from integrated social, environmental and economic pathways.

Learning processes were therefore established with potential users of INSIGHT by:

- Establishing a Steering Committee for the project comprised of staff from both of these departments (NSW Ag & DLWC)
- Establishing regular presentation and exchange meetings with the Lachlan Catchment and River Management Committees. The members of thses committees have been appointed on the basis of their experience (mining, agricultural, conservation, science and urban administration, aboriginal and community issues etc.) and so are well equiped to provide direction for this project and comment on details of it.

- Project staff making transects of the catchment, and holding discussions with representative segments of the major land and water users within the catchment as well as town administrations and service industries, in order to better understand the driving forces within the catchment.

A key component of the project is to ensure that the input data is transparent; that is, all users can see the model assumptions and the input data. This has been accomplished by:

- Using Excel spreadsheets for data input. The Vensim simulation package has been used to create a simulation application that interfaces to the Excel spreadsheets.
- The use of slide bars for the major policy levers and list-selection boxes for such things as "typical" rainfall year . This allows easy trialling of various scenarios by users in much the same way as a business "flight simulator". Policy levers were identified in conjunction with the service departments and the RMC

In the main, the levers proposed do not relate directly to the socio-economic part of the model, except for changes to community water profiles which effect water demand (such as Tourism event promotions which cause peak loads on water demand) or water quality. The central question at issue is what the impact of different river flow regimes are on the catchment given a particular rainfall regime, having regard to other policy decisions, such as re-vegetation and the priority areas where re-vegetation should be encouraged. And so the levers generally relate to the production sub-model which impacts on the socio-economic model via the effect on the various production sectors, agriculture, mining, manufacturing and tourism (Figures 3 and 4).

Mental Models: Active Learning

As part of the system development process, workshops were held to elicit perceptions from the Committees, and other members of the community, and scientific personnel on the relevant variables that were important in their decision making process so that they could be incorporated into the systems model. The workshops further elicited from participants what they believed were the likely interconnections between the variables. These "mental models" were progressively built up as System diagrams similar to Figure 2.

Causal tree analysis (Figure 3) was used in the workshops to clarify the perceived structure of the system and to identify possible sub-models such as the socio-economic one. The system diagrams were sketched out on white boards and transferred to a computer for the causal tree analysis during the

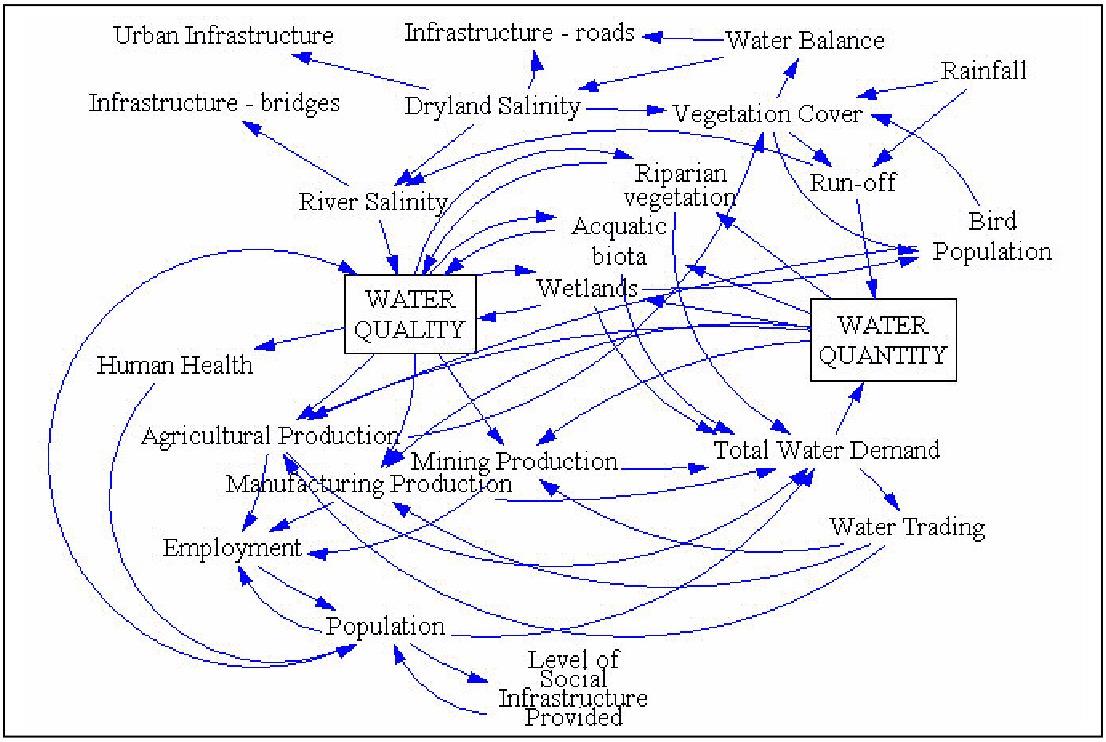

Figure 2: A system diagram derived from variables identified in the consultations

workshop so that participants could readily identify whether they believed they had satisfactorily described the system and the relevant variables. These diagrams helped guide the development of the system dynamics model. In addition, the software allows the use of "reality check" statements solicited from people in the catchment to further validate the model. The incorporation of these is on-going;

System Tools: Aids to Learning

High level human intervention assists the system learning and is achieved by the simulation aspect of the model, which allows rapid generation of scenarios, step simulation with intervening policy changes and a graphical output medium allowing comparison of simulation runs resulting from different policy frameworks.

These are features of the simulation package being used for the project. Sensitivity graphs may be displayed for any of the variables in the model. Examples of the causal tracking are shown in Figures 3 and 4, however these causal trees may also be displayed in strip graph form over time, allowing the visual tracing of effects through the tree. Because any of the data or policies may be changed during the running of the model in step mode, it will satisfy this last requirement, that of a dynamic system.

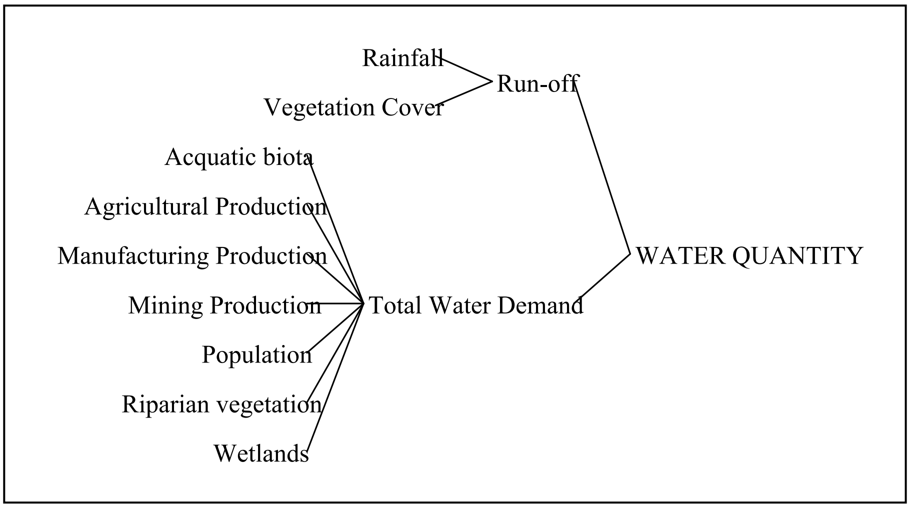

Figure 3: Causal Tree for Water Quantity – an Identified Issue of Concern (simplified for presentation)

Maximising use of existing data and models, the data used to drive the socio-economic model is largely that from the Australian Bureau of Statistics. The town location data used was from the Australian Survey and Land Information Group gazetteer. Data on "representative" water use profiles for different types of farms is currently being collected by the NSW Department of Agriculture, one of the participants in this project.

The socio-economic aspects of interest were identified readily from the causal trees (Figure 4) as being those pertaining to population, employment, human health and the amount of social infra-structure.

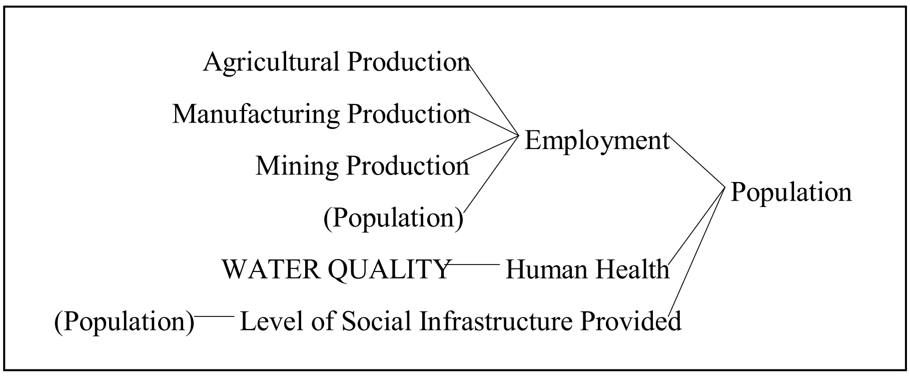

Figure 4: Causal Tree Diagram for Population simplified for presentation purposes

Looking at previous models, the most detailed study of population in Australia was probably that undertaken by the National Population Inquiry (Borrie, 1975) and in that same year an extensive study on internal migration was published by John Patterson (1975) for the Cities Commission. The driving factors were found to be agricultiural production (in the form of cropping), mining production, manufacturing production and a tourism factor, (this was corroborated by Garnaut et. al. 2000). The variables in this model appeared to be highly applicable to the Lachlan Catchment model and work is proceeding on implementing a form of this in a system dynamics model.

Patterson examined the influence of many factors (including distance), but did not include in the model technological change (eg impacts of IT on service sectors). Since 1975 there have been numerous changes to rural economies, the most significant affecting the Lachlan catchment are:

- The development of the wine industry
- Expansion of irrigated agriculture
- Increase in horticulture
- Improved transport network, tarred roads and better cars significantly reducing travel times
- Increase in farms with off-farm income
- Female workforce participation rate

The effect of this last factor cannot be under-estimated. Between 1964 and 1973 (both in the period of Patterson's study) the female workforce participation rate rose from 33.4% to 40.5% (Borrie, 1975). Since that time it has continued to rise to 46.1% (1985), 49.4% (1988), 52.1% (1991), 53.2% (1994), and 53.7% in 1998 (Australian Bureau of Statistics, 1999).

THE SOCIO-ECONOMIC SUB-MODEL DEVELOPMENT

Population patterns

The age-sex composition of the population, a function of natural birth and death processes together with internal migration patterns, is central to the socio-economics. 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. An glance at the demographic profiles (Figure 5) for the Statistical Local Areas (SLA's) gives some indication of what is happening.

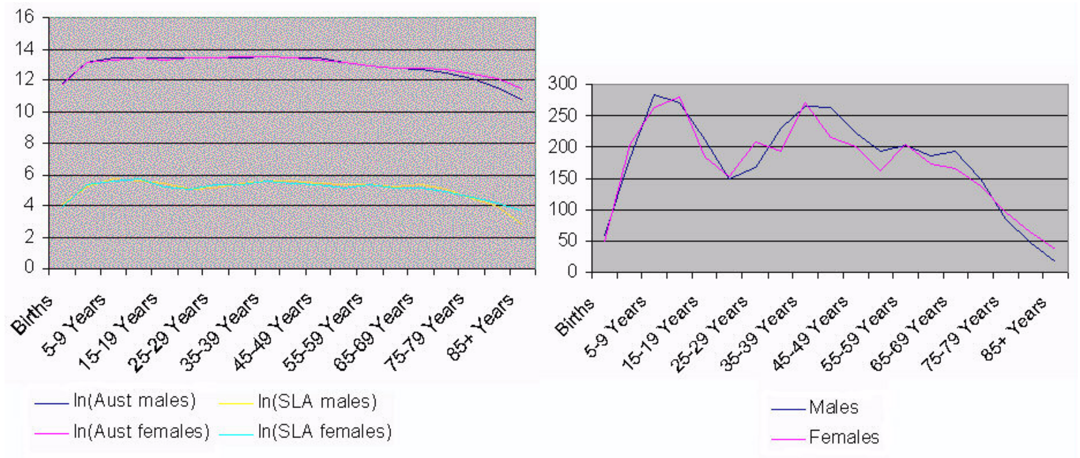

Figure 5: 1996 Population. Left hand graph shows population for Australia and for the Bland SLA on a natural log scale. The right hand graph shows the raw data for the Bland SLA.

There is a pronounced dip for both the males and females in the 15-29 age group in the Bland Shire as they leave school and seek employment and further educational opportunities. This has already been remarked upon (Lachlan Shire Council, 1999), and is general across all local government areas in the catchment. This loss of the highly fertile age groups has a definite effect on the demography shown in more detail in the right hand graph (Figure 5).

The increase in the female workforce participation rate has already been remarked upon. However another important factor for the model to consider relates to where this participation occurs. A perusal of the difference between the major male and female employment categories by industry shows that female employment is more dependant on auxiliary services to the main economic driver (agriculture). As such their employment would be more susceptible than males to population movements, productivity growth due to technology change and centralisation and rationalisation of services due to the reduced travel times now possible (increased tar roads and better motor vehicles). In discussing labour mobility, the Australian Bureau of Statistics (1999) noted that persons working in Agriculture, forestry and fishing were most likely to stay in their current job for the full year (92%).

The local government areas in the Lachlan vary considerably in the importance of the various sectors to their economy. Some are far more highly diversified and so may be more resilient to a downturn in agricultural production. However even in Cowra, much of the manufacturing is agri-business related. Garnaut et al. (2000) noted that the dominant industry sectors in many country areas of Australia are still agriculture and mining and their related servicing and processing industries.

Other factors included

Tourism and retirement have been considered in regional models (John Patterson Urban Systems, 1975). From the early work on growth centres that Patterson's work was associated with, natural transport corridors were identified as a requirement for the success of growth centres.

With the Lachlan, the central place concept received some credence from a transect of the Catchment. Anecdotal evidence was received that visits to saleyards and doctors were used as opportunities for shopping in a non-local town. The local newspapers carry reports of the local sporting competitions that involve towns as disperse as Dubbo, Coonabarabran, Coolah, Mudgee, Naromine, Wellington, Parkes, Forbes, Cowra, Canowindra, Tullamore and Yeoval. McDonalds and the lake at Lake Cargelligo were perceived as attractors.

The role of central places and transport corridors (road and rail) and movement due to retirement are being tested for inclusion in the model. This latter factor, raised in consultations, receives further credence from the differing population profiles of local government areas for this age group relative to the Australian profile.

Current Status

The structure of the socio-economic aspects of the model has been agreed and is being tested, the data paths are being defined and the reallity checking statements are being assembled to assist in the validation of the model.

CONCLUSION

The socio-economic sub-model will be linked to the other sub-models (agricultural production, re-vegetation, salinity, etc.) currently under development. Because this is an exercise in adaptive learning, the process is on-going. The systems modelling is using off-the-shelf Systems Tools to refine the Mental Models of the participants in a Team Learning situation. The success will be gauged by the degree of acceptance of the fully developed model.

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