Land Use change for Salinity Management: A Participatory Model

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Abstract: This paper describes the use of spreadsheet models to help farmers and their advisors to make decisions on land and water use to manage dryland salinity. Salinity management requires an understanding of catchment data and processes. Modelling forms part of the process of understanding the catchment and the turning of data into useable information for salt management. The TARGET project is a NSW government pilot program to support integrated catchment management in selected catchments in New South Wales. A major feature of the program is the simultaneous progress of research and implementation of salinity management measures in a context of adaptive learning. The research described here took place at the same time that extension staff and cooperating farmers were planning and implementing salt management procedures. The dual focus of the project meant that communication was of central importance and this affected the type of modelling carried out. Because of time and data constraints the development of an integrated model of the biophysical and economic system, including spatial and temporal feedbacks, would have had limited value. Instead a partial model was developed that reflected the financial consequences of land use changes and was which was transparent to farmers. The biophysical feedback mechanisms and the external costs and benefits that they imply were external to the model and based on subjective analysis by experts in the field. The paper presents selected analytical results and shows that modelling that is accessible to farmers can best assist salinity management in a context where farmers, advisors, scientists and economists are working together.

Keywords: Salinity management; land use; farm management, spreadsheet model.

1. INTRODUCTION

One of the biggest challenges in model building is working with policy makers, extension staff and farmers in ways that build confidence and contribute to change in policies and farm practices.

The aim of the modelling in this case was to assist policy makers and farmers in making on-farm investment decisions to manage salinity in the catchments of the Lachlan and Macquarie Rivers in New South Wales (NSW) in the Southeastern part of Australia.

This paper describes the process of building a model to analyse the financial consequences of current farming practices and proposed management actions and presents some results from the analysis.

The project involved simultaneous research and implementation over a period of several years. The more usual approach is to do research first then implement the findings but financial and political considerations prevented this. In the event, the approach worked well, because the practical experience of the extension team in the first year agreed with the findings of the modelling team. This led to improved project implementation in the second and subsequent years.

1.1 Context of the modelling

An assessment of salt trends in the Murray-Darling Basin by Williamson et al. [1997] highlighted the severity of salinity problems confronting the Central West Region of New South Wales (catchments of the Macquarie, Lachlan and Castlereagh Rivers). For example, it was predicted that the Macquarie River at Narromine would be unfit for human consumption 30 percent of the time by 2020, and 55 percent of the time by 2050.

Significant efforts will be required to halt or reverse salinity and water quality problems. In many cases, a change at an individual farm level is unlikely to result in much change to what is usually a regional scale problem. According to Hajkowicz et al. [2001] effective solutions may require changes to land use practices and production activities over whole catchments or drainage basins.

In some cases the benefits of management actions accrue to the broader community (eg. biodiversity benefits). This externality in benefits may lead to market failure unless the community is willing to compensate farmers for the costs incurred in protecting, for example, biodiversity.

The *Tools to Achieve Landscape Redesign Giving Environmental Economic Targets Project* (TARGET) is a cornerstone project of the NSW Salinity Management Strategy. A major objective of the TARGET project is to facilitate large-scale land use change in catchment areas that have been identified as being major contributors to Murray-Darling Basin salinity by providing community funding and support.

The TARGET project was funded as part of the National Heritage Trust Murray-Darling 2001 program with joint funding from the Commonwealth of Australia and the State Salinity Strategy in New South Wales.

Management of the TARGET project is the responsibility the Department of Infrastructure, Planning and Natural Resources (DIPNR) in NSW. DIPNR proposed a number of on-farm management actions to target natural resource and environmental hazards, primarily salinity, in each of four selected sub-catchments. Advisory and financial support was provided to farmers in the selected catchments to implement the suggested management strategies.

The selected strategies were largely no-regrets actions which have low cost, if implemented, and include increased use of native, perennial and saline pastures, establishment of farm forestry and saline forestry plantations, increased use of conservation farming practices, intercropping and, increased fencing off of waterways and of remnant vegetation.

2. MODELLING ISSUES

2.1 Farm level models

Modelling of systems can be carried out at a variety of levels or scales. In the farm and natural resource modelling context, the key levels are field or paddock, farm and catchment or region.

The farm is the common management unit for agricultural land use. It is mostly at this level that economic, social and management variables are included in models.

Salinity modelling at the catchment level is particularly important for assessing the implications of hydrological processes beyond the individual farm.

The modelling needs of the project are at farm and catchment level; a representative farm model was adopted to meet these two needs. That is, the model uses a single reference farm to represent the farms in a catchment.

In any group of actual farms, each is likely to have a different resource limitation. For example, one farm may be short of land, another short of capital and a third short of labour. These limitations help to determine the cropping and management decisions for each individual farm. In the case of a representative farm however, these differences are evened out, which may bias the representation of decision-making. This aggregation error is a technical problem with using an average farm that needs to be acknowledged but is unavoidable except under highly restrictive conditions described by Buckwell and Hazel [1972].

2.2 Time structure

Some models represent a single period while others simulate large numbers of periods. Multi-period farm management models typically are run over 20 to 30 years. This is important for long-term investments such as tree crops and to take account of gradual changes often associated with natural resource processes, for example, changes to watertables and salinity levels.

Integrated economic and hydrological models may define different periods for different systems; for example, hydrogeological data may be daily and income data annual. This can be complex to model and have heavy data needs if, for example, daily rainfall over a period of years is to be included.

2.3 Modelling approach

Oliver et al. [2002] reviewed the existing salinity management models in Australia. These included mathematical programming models, simulation models and spreadsheet models.

An example of a mathematical programming approach is the MIDAS family of models, which are whole-farm, profit maximising linear programming models developed in Western Australia. MIDAS models use detailed biological and economic relationships to analyse interactions between enterprises on farms. Pannell [1996] has used MIDAS in salinity research in Western Australia. This type of model was considered to be too complex and too location specific to be ideal for the TARGET project.

Simulation models attempt to reproduce the structure of decisions and feedback in farming and natural systems and are usually based on a specific simulation language. Researchers with a natural science background often prefer simulation models because they allow relative freedom to represent environmental processes in reasonable detail. In general, simulation models take better account of biological and hydrological feedbacks than either mathematical programming or spreadsheet models.

The Australian Bureau of Agricultural and Resource Economics (ABARE), in cooperation with the MDBC and CSIRO, developed a simulation modelling framework that incorporates the relationships between land use, vegetation cover, surface and ground water hydrology and agricultural returns Bell and Heaney [2000]. This model is however based on a large catchment overview that was unsuitable for the small specific sub-catchments used for the TARGET study.

The development of spreadsheet systems such as Excel has made it relatively easy to develop models capable of calculating or solving a variety of financial and statistical functions. Although spreadsheet models are relatively easy to build they often have a relatively short operational life. An example is the FARMULA model, developed in Western Australia and used in a number of salinity analyses by Morrissey et al. [1996]. This model has not been redeveloped since 1996 and is no longer operational.

The workings of spreadsheets are easy to understand and allow relatively quick construction of models. These attributes can be helpful for extension work or where the model is to be used for practical catchment planning. A simple spreadsheet model can facilitate communication and open up discussion that might be inhibited by more technically sophisticated modelling approaches.

Because of these advantages, and the fact that no other models could be used without significant adaptation, the project team concluded that a spreadsheet model should be built from scratch for this project.

2.4 Representative farm

The farm model uses a constructed representative farm to compare costs and returns from each selected management action. This representative farm has been constructed to be broadly representative of properties with salinity management problems in the catchment without breaching the confidentiality of any individual farmer.

The physical characteristics of the representative farm (such as farm size, crop/pasture areas and enterprise types) are based on the results of the producer profiles studies and discussions within the whole project team. The main enterprises used by a majority of respondents were incorporated into the representative farm. Livestock and crop enterprises used by a minority of producers were not included.

Some of the financial characteristics (such as debt level and capital expenditure on plant and improvements) were derived from the producer surveys. Enterprise specific information, particularly variable costs, was based on published gross margin data such as that in NSW-Agriculture [2002]. Forestry information gathered by Hall [2002] was also drawn on.

3. THE TARGET MODEL

3.1 The team approach

A model is a representation of ideas and hypotheses about how a system works. In an integrated modelling system the modeller attempts to incorporate all the information known to the researchers in the model.

Integrated models offer the promise of solving the salinity management problems of a catchment in a single operation. However, they are expensive in both time and data requirements and may become a 'black box' system that is not well understood or trusted by farmers or catchment managers.

Our approach was to use the shared understandings of the multidisciplinary research team as the background to development of one or more simpler numerical models. In TARGET the modelling is an integral part of a process of research and application to control salinity in specified catchments.

This approach allowed use of a straightforward farm management model without attempting to model the biophysical interactions endogenously. The multidisciplinary team as a whole took responsibility for the integration of the modelling.

The modelling team used the judgement of other team members with relevant expertise to take account of the biophysical and social aspects of salinity management in the catchments. There was very limited biophysical data, at farm level, in most of the catchments studied. The farm sustainability survey also found a number of non-financial impediments to salinity management including strong preferences for particular farming systems and family situations. These issues were taken account of in the specification of actions to manage salinity that were restricted to those that were acceptable to farmers and were expected to have the desired biophysical effects.

The project structure relevant to the modelling is shown in figure 1. The Department of Infrastructure, Planning and Natural Resources (DIPNR) have a continuing relationship with both farmers and catchment managers and a strategic role in the research. DIPNR appointed a Project Board that included departmental officers and farmers to supervise the research and ensure that it was integrated with departmental and community aims.

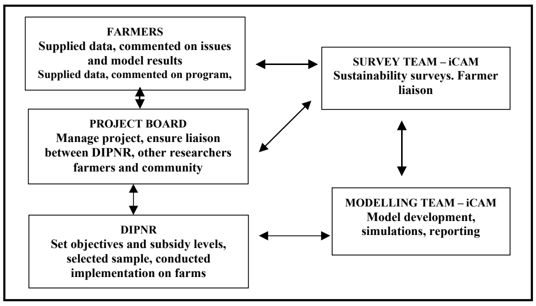

Figure 1. Integrated Team Modelling approach

The Integrated Catchment Assessment and Management group at Australian National University contracted the modelling and survey teams. The survey team included a farm management economist and a hydrogeologist. It was found that involving both disciplines in the farm interviews led to valuable mutual understanding that benefited the modelling and was appreciated by the farmers.

The team visited farmers selected for the survey by DIPNR to investigate their sustainability as well as collect data needed for the model. Sustainability was based on an assessment of the stocks and flows of key sub-systems identified by Watson et al. [2003]. This survey provided farm data for the modelling that was based on the actual catchments studied and could be related back to actual farms. This relating had to be done through the survey team because of farmers' sensitivity to their private data being known to others, including DIPNR. This sensitivity limited their access to the model.

The modelling team, who were also responsible for the survey processing, were briefed on their task by the survey team and DIPNR officers. There was a continuing interaction between the teams, the Board and DIPNR as the model was developed and validated.

The analysis was determined by DIPNR, the survey team and the modellers, in consultation with the Board, with the aim of analysing strategies which DIPNR was encouraging as part of the implementation phase. Farmer feedback on the analysis during the surveys and in Board discussions also influenced the analysis and so the modelling process.

For example, the areas of tree planting for each catchment and strategy were determined by the whole team. This team included farmers, through the Board and surveys, and DIPNA officers, implementing the salinity management programs. In this way the analyses were expected to be realistic and relevant to actual management.

3.2 Model structure

The TARGET model was developed as a multi-enterprise, multi-period, whole-farm analysis tool with an emphasis on 'what if' types of analysis. Most financial inputs (eg. prices and costs) and production inputs (eg. yields, lambing rates) can be readily varied on a yearly basis.

The spreadsheet model consists of seven main worksheets that accommodate a broad range of farm enterprises including a cattle enterprise, two sheep enterprises, up to six broadacre winter crops, fodder crops and fodder production, up to four pasture types and two forestry enterprises. There are also two ancillary worksheets comprising sheep and cattle stocking rate assumptions.

The cattle worksheet, for example, calculates opening and closing numbers by stock category (eg. steer) as well as by age group. Sales, purchases, joinings, births and deaths can be adjusted on a yearly basis if required. The worksheet also calculates total stock sales revenue as well as sales revenue by age group and category. In addition the worksheet calculates up to nine categories of variable costs, total variable costs and costs by age group and category. The other enterprise worksheets are similar in their coverage.

The physical summary worksheet is linked to the cattle, sheep, crop/pasture and forestry worksheets and summarises totals for sheep and cattle numbers, DSEs, crop, pasture and tree areas on a yearly basis over 40 years as well as providing an internal consistency check to ensure maximum areas and stock numbers set by the user are not exceeded.

The financial results worksheet is linked to the cattle, sheep, crop/pasture, forestry and overhead/capital worksheets and summarises sales revenue and total variable costs for each livestock, crop/pasture and forestry enterprise. It also provides a yearly cash flow budget over 40 years. This whole farm cash flow budget shows income from each enterprise as well as other sources, variable costs for each enterprise, overhead and capital costs and calculates NPV ands yearly cumulative debt level.

Most of the enterprise production coefficients, input costs and prices can be varied on a yearly basis to allow the researcher to take account of feedback from environmental degradation over time as well as test the sensitivity of the model to key variables.

The model's analysis period extends to 40 years in order to account for long-term enterprises such as farm forestry. The analysis viewpoint is effectively that of a property manager looking forward into the future. That future will include uncertainty with respect to prices, weather and government policies; therefore, the actual outcomes will not necessarily correspond to the expectations now held. Uncertainty is not internal to the model, like the hydrological issues it is discussed as part of the team approach.

4. RESULTS AND DISCUSSION

The economic analysis used to evaluate the profitability of each management action is the Net Present Value of cash flow on the farm over the analysis period. Six salinity management actions were selected for the analysis:

- Increase perennial pastures to reduce accessions to groundwater by replacing crops or annual pasture,
- Plant saline pastures to use saline areas,
- Fencing of remnant vegetation for conservation,
- Fencing of waterways for conservation,
- Establishing farm forestry to reduce accessions to groundwater and so reduce the spread of salinity,
- Establishing saline agroforestry to use saline land and draw down groundwater in discharge areas,

Selected results are shown in Table 1 for one of the four catchments studied. The others showed similar results. Most of the management actions considered would reduce the Net Present Value of cash flow compared to a continuation of current land use into the future. However, with the exception of farm forestry and fencing waterways, all actions produced farm incomes within one percent of the base scenario. These results include the effect of assistance to farmers under the TARGET program. Planting more perennial pasture was the only activity predicted to increase farm incomes.

Table 1 Modelling results for Warrangong catchment

Salinity mitigation measure	% change in Net Present Value
Increase perennial pasture area	0.2
Increase saline pasture area	-0.1
Fence-off remnant vegetation	-0.5
Fence-off waterways	-1.1
Establish farm forestry	-7.7
Utilise saline agroforestry	-0.1

The results presented in table 1 take no account of the environmental benefits that may flow from implementation of any of the management options. The low cost of most of the proposed actions means that the benefits of most of the management actions would not need to be large to make them worth adopting.

The results of the study were presented to the Board, to DIPNA, to the farmers in each catchment and to a two-day workshop open to the public. The surveys and modelling were accepted as providing valuable information about the costs of salt management procedures. Individual farmers did not however interact directly with the model at any of the meetings.

The income losses predicted for most of the proposed actions to manage salt suggest that they would be unattractive to farmers. This was consistent with the experience of DIPNR officers implementing the measures in the field, who found a low level of interest in many of the proposed actions.

Although the representative farm analysis showed that most of the activities were marginal or unprofitable, individual farmers were prepared to carry out particular practices. This reflected both personal preferences for risk and enterprises and the different financial structures of individual farms that were not reflected in the representative farms used for modelling because of aggregation error.

After the first year of the project, DIPNR decided to alter their approach away from a general offer of financial assistance, towards a tender system. Farmers are asked to tender for carrying out specific management activities within a particular sub-catchment. This change in policy was only partly the result of the modelling but the modelling results contributed to the outcome.

5. REFERENCES

Bell, R and A Heaney, *A Basin Scale Model for Assessing Salinity Management Options: Model Documentation*, ABARE Technical Working Paper 2000.1, 2000.

Buckwell, A and P Hazel, Implications of aggregation bias for the construction of static and dynamic linear programming supply models, *Journal of Agricultural Economics* 23(2) 119-24, 1972.

Hajkowicz, S, T Hatton, W Meyer and M Young, *Concepts of Landscape Redesign: A Discussion Paper*, CSIRO Land and Water, Glen Osmond, South Australia, 2001.

Hall, N, *Forestry Economics for the Lachlan and Macquarie Catchments*, Integrated Catchment Assessment and Management (iCAM) Centre, Canberra, 2002.

Morrissey, H, R Van Hilst, B Watson and M Oliver, *Jojoba: Farm Level Analysis and Market Assessment*, ABARE report prepared for the Murray-Darling Basin Commission, Canberra, 1996.

NSW-Agriculture, *Farm Enterprise Budget, 1st X Lambs*, Sydney, 2002.

Oliver, M, N Hall and W Watson, *Farm Economic Analysis Models: Scoping Study*, iCAM client report 2003 TARGET 10, Integrated Catchment Assessment and Management (iCAM) Centre, ANU, Canberra, 2002.

Pannell, D, Lessons from a decade of whole-farm modelling in Western Australia, *Review of Agricultural Economics* 18 373-83, 1996.

Watson, W, R Evans, J Powell and M Oliver, *Macquarie and Castlereagh Catchment Report*, Report no 2003 TARGET 14, Integrated Catchment Assessment and Management (iCAM) Centre, Australian National University, Canberra, Canberra, 2003.

Williamson, D, G Gates, G Robinson, G Linke, M Seker and W Evans, *Salt Trends. Historic trend in salt concentration and saltload of stream flow in the Murray-Darling drainage division*, *Dryland Technical Report*, 1, *Murray-Darling Basin Commission*, Canberra, 1997.