The Murray-Darling Basin Irrigation Futures Framework (IFF?)

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Abstract Integrated modelling frameworks are becoming increasingly valuable for exploring the behaviour of large ecological, environmental and management systems around the world. These framework systems, which may have few inherent models, facilitate the integration of various models or analysis tools into a single coherent framework. The Irrigation Futures Framework (IFF?) is an integrated scenario modelling framework linking biophysical, production and socio-economic models for exploring future conditions in irrigation regions of the Murray-Darling Basin. A biophysical component simulates surface and subsurface water and salt movement to evaluate soil salinity, waterlogging and salt export from the catchment. Linked to the biophysical component is a production component, which using production functions determines the potential detrimental effects of salinity and waterlogging on agricultural production. An economic component quantifies the financial performance of farms in the region. The flow-on effects of irrigated agriculture to the rest of the economy are estimated using Input-output (I/O) analysis. The framework allows us to explore both complex spatial and temporal information. Twenty year scenarios being developed identify the impact of a range of factors on the biophysical resource base, agricultural production and socioeconomic structure of irrigation regions. Scenarios include, for example, the implication of 'Do-Nothing' scenarios, changes in spatial distribution of soil salinity levels, effects of increasing salinity on agricultural production, impact of drainage programs, alternative landuse and mix of activities, water market reforms and the impact of industry development.

Introduction

Integration framework systems, are not well known or understood in Australia. These tools have few inherent models, but facilitate the integration of various models or analysis tools into a single coherent framework; they provide the 'glue' to form complex modelling systems from many diverse sources [Malafant and Fordham, 1997]. Such tools are being used to explore the behaviour of large ecological, environmental and management systems around the world.

The aim of the framework approach is to determine the best options for integrating environmental, resource, ecological sustainable management, heritage, economic and social analyses for use in planning, conservation and industry development. Specific objectives of the framework concept are to develop an information system which:

- integrates the outcomes of any analyses being developed by different technical agencies or user groups;
- is portable to enhance consistency in analyses;
- permits greater transparency and, hence, adds credibility;
- is flexible to changes in approach which may be adopted by different user groups;
- is capable of comparing real world spatial, environmental, resource, economic and social implications of different resource use options; and
- includes a user friendly interface for the interactive examination of and experimentation with a range of scenarios [Malafant and Fordham, 1997].

Modelling frameworks are becoming increasingly valuable tools, allowing land managers and policy makers to integrate and evaluate resource information and make more informed decisions.

Integration Toolkit

The Irrigation Futures Framework (IFF?) (Figure 1) has been developed using Whatif?, an integrated scenario modelling system. Whatif? facilitates the integration of various support tools, models or decision support systems into a single coherent framework. The Whatif? object-oriented modelling package follows the design approach outlined by Gault et al. [1987], which features the tight integration of user, models and simulation framework. An important feature of this modelling approach is 'workshopping' or stakeholder analysis. This involves specialists/ stakeholders/clients from a variety of disciplines coming together to develop the framework components and linkages of the system. This is an iterative task, with not only the design, but also the construction and component validation changing as the user explores the system behaviour. Whatif? provides a structured set of tools for groups of experts to interact, express their ideas and apply concepts to achieve resolutions in the debate of economically and ecologically sustainable resource issues. Whatif? allows the future to be explored by examining the driving processes in the system and their interrelationships, rather than trying to forecast the future by extrapolating data measured from past activities [Fordham and Malafant, 1995].

The Whatif? tools consist of three main components : TOOL (Tool On Object Language), an interactive coding language for manipulating data objects; SAMM (Scenario And Model Manager), allows for the management of the framework and the creation of scenarios which are composed of sets of variable instances or objects; and Documenter, a text and graphics system for preparing structural and relationship diagrams and for preparing framework documentation.

Application

The irrigation industry in the southern Murray-Darling Basin is facing a complicated future: the costs of irrigation are going up; water trading is being expanded; producers are facing increasing competition on both domestic and foreign markets; and environmental problems, caused by rising watertables and nutrient run-off are increasing. A number of urgent policy decisions must be made by resource managers and regional communities to provide a framework for the future shape of sustainable irrigated agriculture. Soundly based information on the implications of these decisions is fundamental to the development of successful programs and policies.

The Irrigation Futures Framework (IFF?) (Figure 1) links biophysical, production and socio-economic models for exploring future conditions in irrigation regions [Fordham and Malafant, 1995].

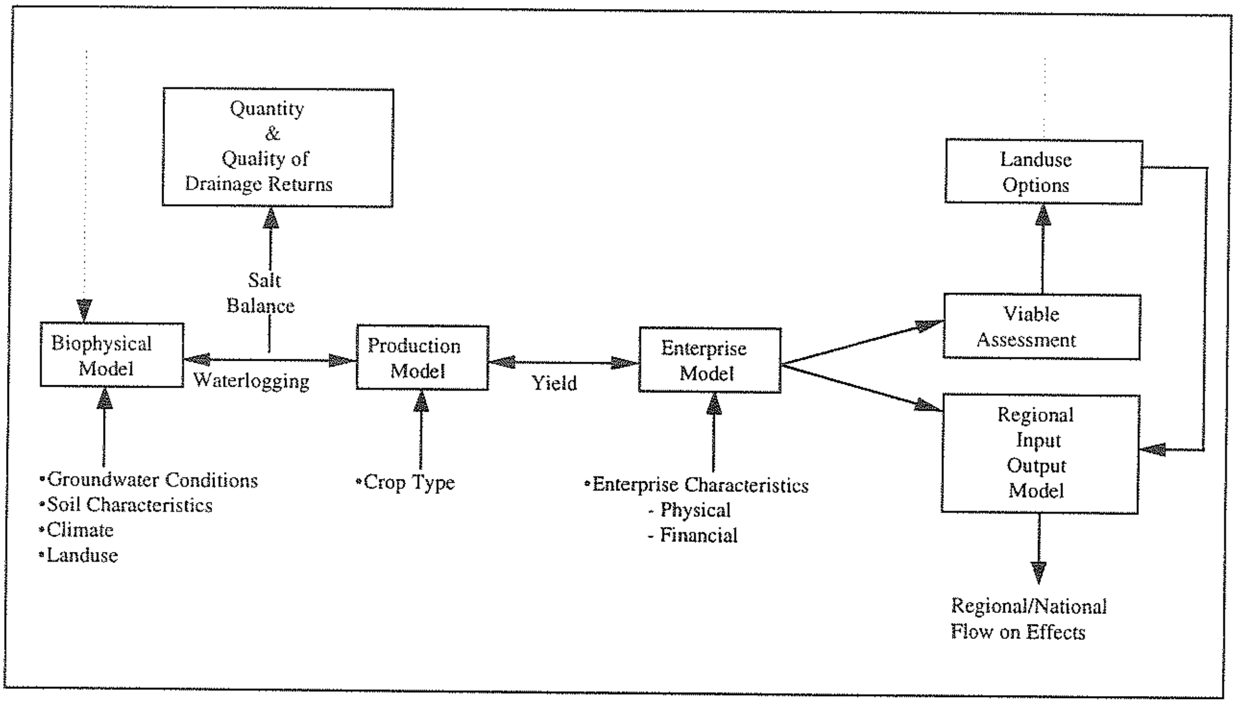

Figure 1. The Irrigation Futures Framework (IFF?) diagram showing the four main components, linkages, feedback, outputs and data requirements.

The study area, a 3000 ha catchment in northern Victoria, has shallow water tables of variable salinity; land use is predominantly dairying on irrigated perennial and annual pastures.

The biophysical component consists of hydrological models, which study surface and subsurface water and salt movement to evaluate salinity, waterlogging and salt export from the catchment. The soil water and groundwater model simulates a coupled surface water and groundwater system using a lumped conceptual model for one-dimensional movement through the unsaturated zone, and a distributed model to simulate two-dimensional groundwater flow. A second hydrological model evaluates soil salinity and regional salt loads from irrigation areas. Salt movement through the profile is simulated using a mass balance approach, with a separate conceptual formulation used to generate salt export along the drainage lines [Beverly et al., 1997].

Linked to the biophysical component is a production component, which using production functions, determines the potential detrimental effects of salinity [Maas and Hoffman, 1977] and waterlogging [Maher et al., 1996] on agricultural production. An economic component quantifies the financial performance of farms in the region using the Farm Management Analysis models described by Young and Dowell [1992].

The flow-on effects of irrigated agriculture to the rest of the economy are estimated using Input-output (I/O) analysis. These effects are those generated by the use of purchased inputs, labour and capital in irrigated agriculture and the marketing and handling of the production from irrigated agriculture [Powell et al., 1985]. Inter-relationships between main sectors in the regional economy can be identified.

The framework components integrate models operating at four spatial and two temporal resolutions. Spatially, models operate at fine scale grids (100m x 100m), fields (hectares), farms (10's of hectares) and regions (1000's of hectares). There are approximately 2400 cells in the finite difference grid covering the 3000 hectares. The temporal scales are day and year.

Results

Preliminary results from the development of twenty year scenarios are presented for the study area. Figures 2 (a) Rainfall and 2(b) Irrigation show examples of daily input data used for scenarios. Figure 2(c) shows typical daily watertable patterns for a particular field in the catchment; the watertable level fluctuating in response to rainfall and irrigation. During a normal irrigation season ('baseline' or 'do-nothing' scenario B) the watertable is close to the surface (0.00 metres) dropping off during the winter periods. Under a 'zero irrigation' scenario (no irrigation in the catchment) watertable levels are much lower (Z). Figure 2(d) shows the patterns of soil salinity for a field in the catchment for various scenarios: 'baseline' (B) indicates the soil salinity profile for a low salinity soil over the twenty year period; soil salinity falls under the 'zero irrigation' scenario (Z); soil salinity increases with an increase in salinity of the irrigation water from 0.3ec (dS/m) to 0.6ec (S); for this field, soil salinity is unchanged from the 'baseline' under a scenario where 25% less irrigation water is available per farm (B).

Figure 3 shows the annual pasture yields and corresponding gross margins for scenarios for a selected farm in the catchment: 'baseline' (B); 'zero irrigation' (Z); increasing irrigation water salinity to 0.6ec (S); 25% less water availability (L). Production and returns to the farmer fall as salinity increases and as water becomes less available and landuse changes from irrigated to dryland pastures. For these scenarios, apart from water costs, the cost structure of farms remains the same.

Figure 4 shows the direct and indirect impacts of irrigated agriculture on the local economy in terms of final demand and flow-on for output, income, value added and employment. Figure 4(a) shows for the baseline scenario: output from the study area dairy (irrigation) industry over a twenty year period (D); output from other sectors due to the dairy (irrigation) industry (ie. flow-ons) (O); total output for the region due to the dairy (irrigation) industry (T). Figure 4(b) shows total income, 4(c) total value added and 4(d) total employment for the region for the various scenarios: 'baseline' (B); 'zero irrigation' (Z); 0.6 ec irrigation water salinity (S); 25% less irrigation water (L). Flow-ons to the local economy reflect falling returns to farmers as salinity increases and as the amount of irrigation water available declines.

Discussion

The framework allows us to explore both complex spatial information - the field, farm and regional results - as well as complex temporal information - daily and yearly. In these integrated applications,

scenarios add an extra dimension to the information that also needs to be communicated to the decision maker [Fordham et al., 1997].
Although the framework is being developed for three study areas, the design and models are applicable to any irrigation catchment. A framework can be used to integrate the best and most appropriate of existing models and data for a project [Malafant and Fordham, 1997]. Not only are sources and forms of spatial and temporal data highlighted, but also where data and methods are lacking.

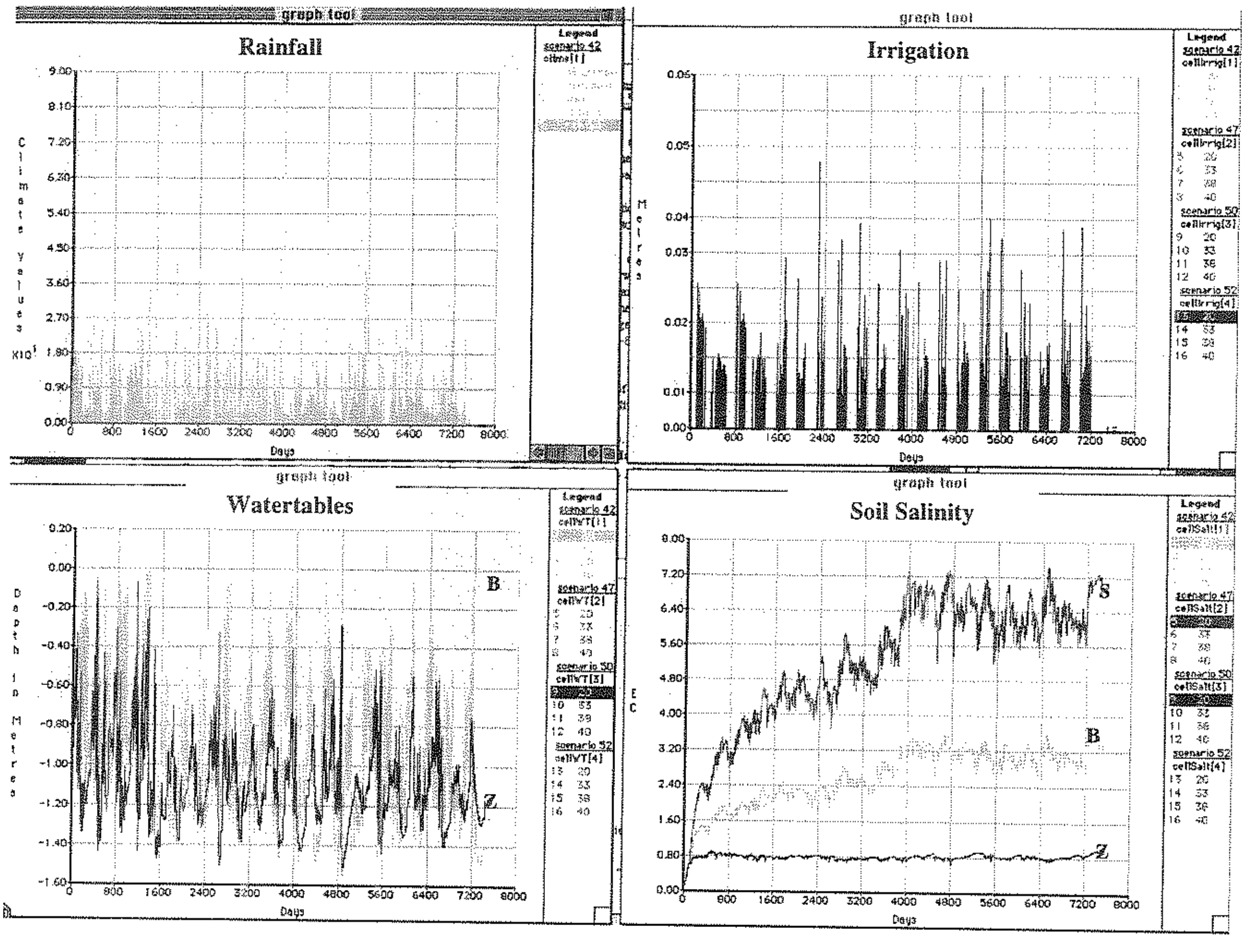

Figure 2. Field level Scenario output from IFF?

The software and framework design are flexible; as new research and/or models become available they can be integrated into the framework. The system's object-based construction allows an application developed for a small area or limited issue to be expanded as part of a larger system, building on what has already been assembled.

Development of the framework by a group of people with experience in the individual components of the system and with knowledge of local conditions ensures that the best available knowledge is exploited and that outcomes are realistic and feasible [Grayson et al., 1993]. The development of these frameworks must be seen as an iterative task, with not only the design, but also the construction and component validation changing as the user explores the system behaviour.

The design approach adopted by the Whatif? framework does not inherently implement optimisation strategies, rather optimisation is just one possible scenario. The lack of global optimisation or equilibrium constraints can lead to scenarios which are inconsistent or socially unacceptable - tensions. Integrating individual components into a complex framework may lead to little intuitive knowledge of the overall system behaviour even though we may understand the behaviour of individual components. The user can resolve these tensions by exploring alternative scenarios or the user may exercise choice and accept scenarios where tensions still exist.

The application framework can be used for identifying the likely impact of policy and program options at regional and Basin levels on the biophysical resource base, agricultural productivity and socio-economic structure of irrigated regions over the next 20 years. The preliminary results illustrate how scenarios can be used to explore various policy options. Decision scenarios allow the policy or decision maker to anticipate and understand risk and to discover new options for action. Well documented scenarios provide a way of exploring alternative futures, and can support informed debate of the policy decisions built into the scenarios and the resolution of their tensions [Fordham and Malafant, 1995].

The framework is being developed for policymakers, regional resource management organisations and community groups to enable a more informed basis for decision-making. It will also be a useful awareness-raising and educational tool that allows difficult concepts and technical information to be presented in an easy to understand form.

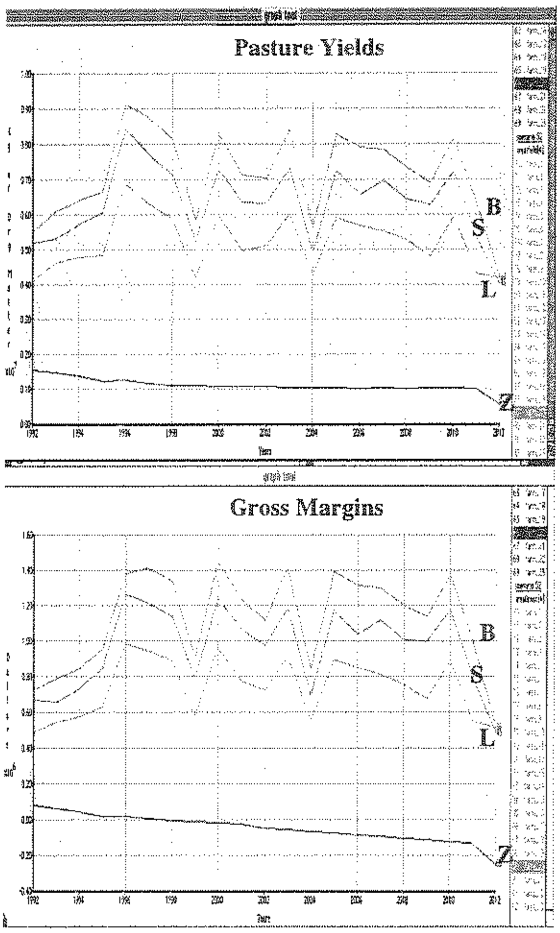

Figure 3. Farm level information from IFF?

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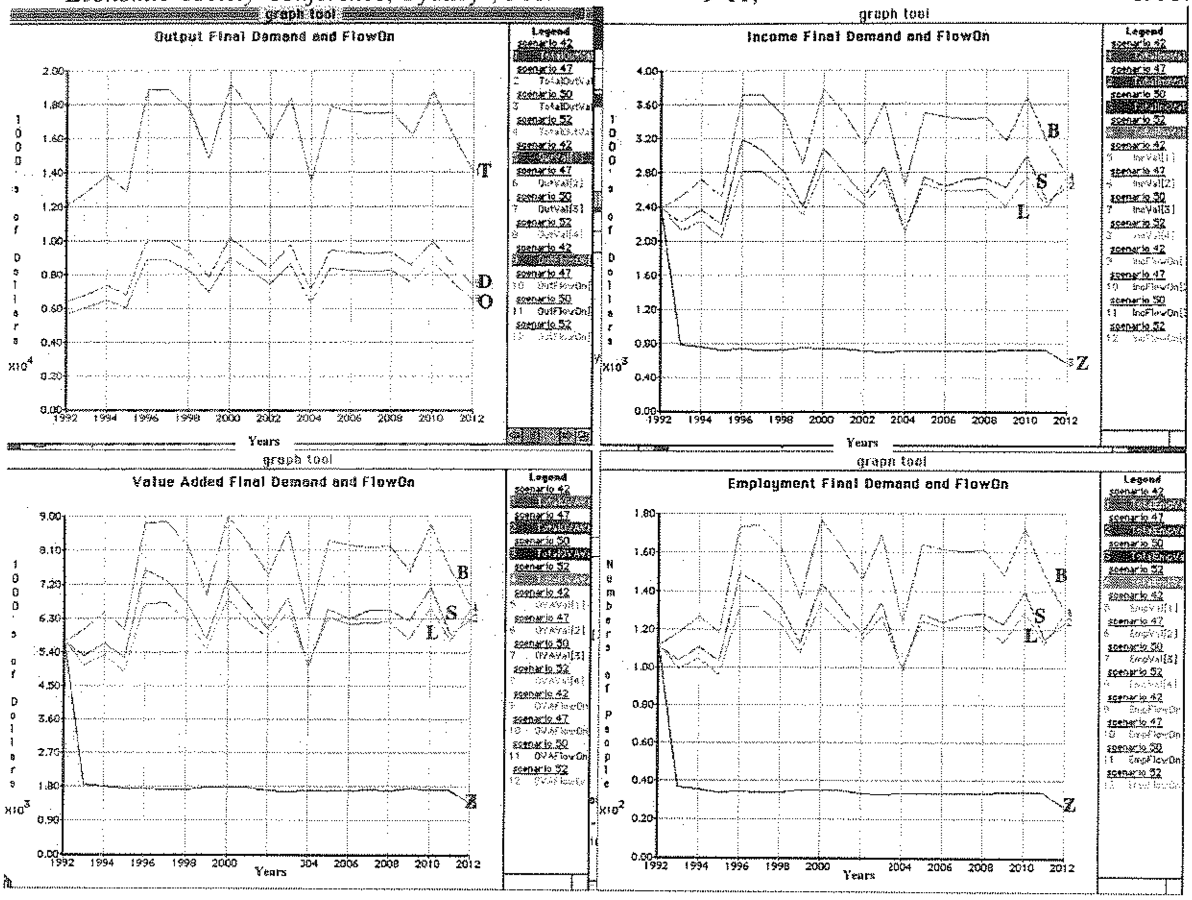

Figure 4. Regional level information from IFF?