Systems Framework for Integrated Regional-Scale R&D Projects

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Abstract: Natural resource management (NRM) is an important component of sustainable regional development. Research in support of NRM needs to address a wide range of issues involved, from small-scale biophysical to large-scale planning issues. Such research is by default multi-disciplinary, including biophysical, ecological, economic and social lines of inquiry – as well as their integration. The recently initiated Ord-Bonaparte Program (OBP) is an example of an integrated R&D program in support of NRM. It covers the Ord-Bonaparte region in the East Kimberley, Northern Australia. Projects within the OBP investigate a wide range of NRM, planning and policy issues that reflect the various natural resources and their uses and related issues. This work is undertaken in partnership with a diverse range of stakeholders. One key challenge of the OBP lies in developing a systems framework that (i) enables the integration and interpretation of the various disciplinary research activities and (ii) facilitates the implementation of its outputs and translation into outcomes for sustainable regional development. This paper discusses how such a systems framework may operate.

Keywords: Integration, natural resource management, regional-scale, multi-disciplinary, modelling

1. INTRODUCTION

Tropical Northern Australia is rich in natural resources, including minerals, land and water as well as terrestrial and marine biodiversity. It is sparsely populated with only 255 thousand people – or 1.4 per cent of Australia's population – living across an area of 1.78 million square kilometres of land – or 23 per cent of Australia's surface area [Johnson et al., 1999].

Commercial development opportunities and proposals include expansion and intensification of grazing, new irrigation, aquaculture, fishing, mining and tourism projects. There is little scientific knowledge available that would enable an assessment of the long-term implications of such developments specifically in the ecological and social domain and broader economic context.

Development of natural resource use in the southern parts of Australia has happened largely unregulated and in the absence of scientific data and understanding. Various resource degradation issues have emerged at a large scale as a direct consequence. Northern Australia has the opportunity to learn from the lessons of the South and develop its resources in a long-term sustainable manner.

This paper describes an integrated research and development approach aimed at supporting sustainable development in Northern Australia. It elaborates on how integration and modelling, specifically, can make a contribution to sustainable development.

2. AN R&D APPROACH TO SUSTAINABLE DEVELOPMENT

This section introduces a research-and-development program that is set up to support long-term sustainable natural resource management at the regional scale. It is philosophically, operationally and methodologically grounded in the concepts of systems analysis and integration.

The science provided within the R&D approach is embedded in a partnership approach with stakeholders. It aligns with a paradigm shift in NRM away from 'autocratic' or 'interactive natural science based' NRM towards 'collaborative

natural- and social-science-based management", [Mullner et al., 2001].

2. 1 The Ord-Bonaparte Program

Land and Water Australia and CSIRO are the major funding agencies of a new R&D initiative entitled the Ord-Bonaparte Program [CSIRO 1999]. The aim of the OBP is to underpin NRM, planning and policy with the knowledge of how natural and human systems function and inter-relate at the catchment and regional scales.

The Ord-Bonaparte region was chosen as 'case study region' because of its diversity and significance of natural-resource based industries, the renewed natural-resource development interests in the region, the diverse social fabric of the regional community, and the fact that there are already participation and management processes in place to support the implementation of research outcomes.

If lack of information is a key factor in bad development decisions, then sound data and knowledge are the necessary condition for sustainable development. A series of sufficient conditions have to be fulfilled so that information actually translates into sustainable development. They include [Johnson et al., 1999]:

- Effective databases containing baseline and monitoring data in bio-physical, ecological, social and economic domains;
- Effective tools for data interrogation such as decision-support systems and geographic information systems;
- Synthesis and integration of the information;
- Analysis of resource management and planning institutions and processes.

2.2 Catchment-scale Level of Inquiry

The OBP aims to address integrated natural resource planning and management issues and as such its natural spatial reference is of bioregional definition, comprising catchments and their coastal and marine impact areas. The Ord catchment is about 80,000 square kilometres. The hydrological catchment boundaries are not congruent with what can be called the limits of the 'social catchment' relevant to the study, characterised by administrative boundaries and the social, cultural and economic activities and linkages of the approximately 12,000 people living in this region. The area of the social catchment is about three times the size of the actual Ord River catchment, extending approximately 300 kilometres east-west and 750 kilometres north-south, and covering some 250,000 square kilometres of land.

The catchment focus of the OBP is intended to provide a systems context for natural resource management. In a biophysical sense, this means considering flows from the top of the catchment right through to the coastal and marine environment. Questions of relevance here include, e.g., the effects of changes to grazing regimes in the upper parts of the catchment (around Halls Creek) to surface water runoff and sediment loads, with potential down-stream effects on irrigation-water supply, the lower part of Ord River and adjoining coastal and marine environments of the Cambridge and Josef Bonaparte Gulfs.

In a socio-economic sense, the regional focus enables an involvement of all relevant stakeholders – including the large Aboriginal population, an assessment of management impacts beyond the immediate user groups or industries implementing changes. Including flow-on and indirect effects provides the opportunity for a comprehensive assessment of alternative management and development options. It also allows for institutional arrangements such as government boundaries and agency responsibilities to be analysed in the NRM context.

2.3 Systems Analysis

Natural resource management at the regional scale provides a challenge for everybody involved as it encompasses several dimensions or layers of complexity.

- There are multiple natural resources to consider including land, fresh water, landscape, terrestrial, coastal and marine biodiversity.
- There are multiple uses of these resources through grazing, tourism, recreation, Aboriginal land uses, irrigation, aquaculture and fishing. Uses may be complementary or competing for resources.
- There are a series of natural resource management and resource development agencies at federal, state and regional level with statutory obligations for the management of natural resources in the region. Their interests and responsibilities may be complementary, overlapping or conflicting.
- There is a wide range of interests and aspirations within the regional community to be considered, specifically those of a large Aboriginal population, as well as interests of the people of Australian at large.

These dimensions define natural resource management as a complex system. A 'systems approach' is needed to track the web of causal relationships within the system and offer solutions to systemic problems. Systems analysis, based on general systems theory [Ashby, 1956], offers a way of conceptualising and analysing the complexity of natural resource management by looking at the entirety of a problem in its specific context with all its 'hard' scientific and 'soft' social dimensions and doing this with the aid of models [eg. Checkland, 1981; Grant, 1998].

The benefits of applying a systems approach to environmental and natural resource management applications have been outlined comprehensively and compellingly by Holling [1978] and Walters [1986].

2.4 Integration

Conceptually, systems analysis is directly complementary to, even largely congruent with 'integrated modelling and assessment' or 'integration'. Both approaches aim to support rational decision-making in the face of complexity and enable the comparison of alternative options in the light of their possible outcomes.

From a more operational viewpoint, systems analysis may be seen as relating more to the understanding of how complex systems function whereas integration may be seen as applying and interpreting that knowledge within a specific context.

The use of the term 'integration' can relate to one or several aspects including: the integration of issues, disciplines, methods, models, scales of consideration, and stakeholder concerns. The integrative intent of the OBP is very ambitious in that it sets out to achieve integration across all those aspects.

In the modelling literature, integrated modelling usually refers to an approach whereby models from different scientific disciplines are coupled, taking into account the major internal dynamics of a system, their interactions and the relevant external forces [Bronstert, 2001].

There is increasing demand for integration all over the world, specifically in areas of environmental impact assessment of resource use and the assessment of tradeoffs among stakeholders for the effects of water and land use decision in catchments and regions. This is reflected in an increasing number of integrated studies and models, with the bulk of applications related to water management [eg. Krol et al., 2001; Staudenrausch and Flügel, 2001] and assessment of climate change [eg. Pahl-Wostl et al., 2000; Alcamo, 1994].

While integration is not new, there is no 'hard core' of integration science. There are no standard methods, approaches or models for integration. A Journal entitled *Integrated Assessment* was launched in 2000 to provide a better forum for the exchange of ideas in a cross-disciplinary context.

2.5 Structure of the R&D Program

The systems analysis and integration philosophy is reflected in the structure of the OBP. The program is made up of five 'sub-programs' which reflect areas of research centred around key natural resources and their management. They are entitled;

1. regional resource futures,
2. sustainable rangeland systems,
3. integrated water resource planning and management,
4. sustainable coastal and marine systems, and
5. Aboriginal planning for 'country'.

Nine research 'themes' cut across the five sub-programs to provide methodological focus. The themes are called 'biophysical resource inventory', 'process understanding', 'socio-economic data and understanding', 'synthesis and integration', 'participation', 'institutions', 'capacity', 'indigenous social and cultural issues' and 'monitoring and evaluation'.

The 'Regional resource futures' sub-program provides the hub for integration. Its role is to develop methods and tools for integrated regional analysis and program evaluation by bringing together issues-based and disciplinary research undertaken in the other sub-programs in an interpretive and participatory manner.

To fulfil its role, the sub-program is structured into three projects (Figure 1). Each project has specific integrative components.

1. The 'community resource information system' project seeks to establish an easily accessible and user-friendly repository of data relevant to NRM, ie. data already existing and new data gathered by or generated across the OBP.
2. The 'regional futures' project proposes to support the conceptual and quantitative integration of data and process and impact understanding. This is to be done through the design, implementation and application of a series of qualitative and numerical models. The technical aspects of the work are embedded in a consultative and capacity

building process with stakeholders. The following sections of the paper reveal details of this approach.

3. The 'evaluation' project assesses the achievements of all projects within the OBP and the program itself against milestones and objectives and distils 'learnings' from the case study that can inform future integrated R&D efforts.

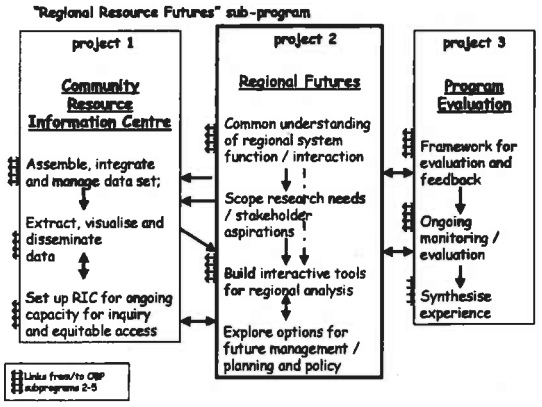

Figure 1. The projects within the "regional resource futures" sub-program.

3. TOWARDS A CONCEPTUAL MODEL OF REGIONAL SYSTEM FUNCTION

This section outlines the participative – conceptual aspect of the integrated analysis proposed as part of the "regional futures" project in the "regional resource futures" sub-program. The objective is to build a common understanding, or systems model, of regional system function. This includes a description of the character of the region – its people, industries, natural environments and institutions – and how the East Kimberley works – explaining inter-relationships between the region's natural resources, their use, the regional economy and community. This qualitative work is complemented by analytical – numerical research which is described in section 4.

3.1 Requirement for a Qualitative, Conceptual Regional Model

Understanding and knowledge, supported by appropriate tools, are essential requirements for managers, planners and decisions makers to make sustainable development happen. Engaging stakeholders and the community right from the beginning in conceptualising integration is part of the strategy to effect learning and common understanding and foster the application and use of tools such as models and expert systems in planning and decision making.

Developing a qualitative model of regional system function provides an important first step. It involves drawing a causal picture of (i) how the community benefits from the various natural resource uses and how they interrelate and (ii) what the management and planning issues are and how decisions impact on various aspects of the system.

The resulting agreed regional framework will:

- guide the various disciplinary research activities across all 5 sub-programs of the OBP,
- enable the disciplinary and issues-based research to be brought together in a consistent format for integrated analysis, and
- provide flexibility to accommodate improved scientific understanding as it becomes available.

3.2 Methodology

The task at hand requires an applied systems thinking approach [Jackson, 2001]. We propose as core method focussed workshopping based on the workshop techniques central to 'participatory action research' [Martin and Sherington, 1997] and 'organisational learning' [Senge, 1990]. A series of workshops is envisaged to bring together local experts, key OBP researchers and selected (inter)national experts in regional development.

During the initial workshop the issues are being defined and supported by existing data. We hope to define a preliminary (qualitative) systems model upon which we base and prioritise information acquisition activities that provide an overarching integrative systems framework and will help guide the disciplinary research undertaken in other sub-programs. We regard this as pre-condition for successful cross-program model integration later in the program lifetime by ensuring that the models built across various OBP sub-programs and projects are consistent in terms of measurement units, scale and model type, and cover the social, economic and biophysical areas of the OBP.

Importantly, that first workshop is also intended to act as a team-building exercise, which brings stakeholders and scientists together to a 'problem-solving' team [Grant, 1998].

The subsequent workshops will develop the regional systems model further based on data and knowledge forthcoming. The model is basically a communication inferface between stakeholders and researchers all of whom have joint ownership of the model. As such the modelling process is more important than the model itself. The intention is to

hold the workshops in Kununurra, the major urban and administrative centre in the region and have at least the first workshop professionally facilitated to ensure equality of all participants.

4. DEVELOPING TOOLS TO ENHANCE THE INTEGRATION, INTERPRETATION AND DELIVERY OF RESEARCH

The participative-conceptual work outlined in section 3 is complemented by the quantitative – analytical work described in this section. The purpose is to develop a suite of models to facilitate stakeholder access to data and understanding of the Ord-Bonaparte region and enhance interpretation, integration and delivery of OBP research outcomes. We use the term 'tools', which has emerged as the stakeholder-preferred term, synonymous for 'models'.

4.1 Tools for Regional Analysis and Integration

Models are essential in bringing the outputs of the disciplinary subprograms together to deal with the complexity and provide the holistic understanding of the region that the OBP seeks. It is envisaged to develop a suite of tools, the specifications of which will be developed in consultation with stakeholders to maximise relevance and consequently research implementation. We seek to develop a suite of tools rather than one all-encompassing model as we expect that stakeholders want to investigate a wide range of issues and conduct analysis in various ways, and bring different levels of expertise to the investigation.

While the exact specification of the tools are yet unknown, we expect that the tools will, broadly:

- integrate various ecological and biophysical models from the disciplinary sub-programs within the overarching conceptual framework;
- offer insights into the regional economy, its dependencies, trade-offs between different nature-based industries and natural resource uses, externalities and economic incentive instruments; and
- explore social response to change in both quantitative and qualitative terms.

All models will be built into a 'toolkit' to facilitate their delivery and application.

4.2 A Preliminary Structure for the Toolkit

The toolkit proposed here comprises four main components: a user interface, a model management system, a multi-objective modelling engine, and an expert system for interpretation of modelling outputs (Figure 2).

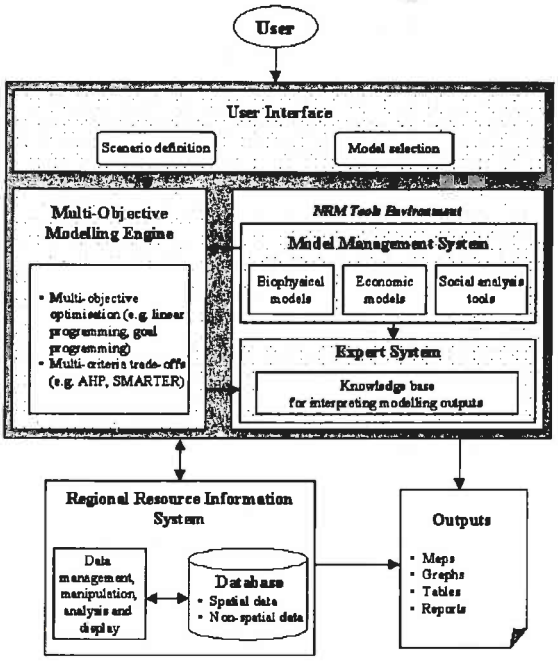

Figure 2. Preliminary toolkit structure.

The model management system contains biophysical and socio-economic models developed in the OBP projects. It also provides functions for selecting, invoking, running, and integrating models. The multi-objective modelling engine is used to explore and evaluate different regional resource use scenarios through multi-objective optimisation or multi-criteria analysis techniques. After a scenario is defined, this modelling engine develops a mathematical programming model using the biophysical and socio-economic indicators generated from the relevant models in the toolkit to determine optimal resource allocation within biophysical constraints and socio-cultural preferences. It can also be used to develop a multi-criteria decision model that identifies trade-offs among regional resource use options based on stakeholder value judgements.

The expert system component provides explanation and interpretation of the models and model results. It shows assumptions, explains the modelling process, provides necessary guidelines for use of models, and interprets and translates information derived by the models to a certain format, which is desired by a certain group of stakeholders.

The user interface provides users with controls for the implementation of the system. This may include managing scenario investigation and

supporting selection of models or tools that seem most useful for an intended application. The toolkit evaluates the effects of the various scenarios on multiple indicators and the tradeoffs among them according to multiple criteria and multiple objectives. This toolkit will be linked to the resource information system (Figure 1), which does not only manage information and data required for modelling, but also provides tools for presenting modelling results in particular forms such as maps.

5. CONCLUSIONS

This paper highlights the key role that modelling plays in a new R&D program designed to support regional NRM. Modelling provides the integrating framework across research in various disciplines and across NRM issues related to various natural resources and associated industries. It also provides the link from research to real-life application of data and understanding by natural resource managers and planners. A toolkit approach is proposed to support this task and accommodate the variety of models and tools to be built during the lifetime of the program. The road to integration and integrated assessment is paved with many challenges [eg. Dahinden et al., 2000; Argent et al., 1999] and great care is required to make this a process that truly supports NRM.

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