A Review Of Models Applicable To 'Our Rural Landscape'

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EXTENDED ABSTRACT

Rural landscapes serve complex and often competing demands of society. They are used by people to generate income (eg. agriculture, mining, and tourism), to provide a living space, to provide quality of life (clean water, recreation, and social activities), and to provide biodiversity. Agriculture has created a new ecology in the rural landscapes of Victoria, and we need a better understanding of the ecology of the landscape and the application of spatial models to provide integrated analysis of current and future agricultural landscapes. The conflicts and trade-offs between different land-uses complicate land-use decisions. We need a greater understanding of the consequences of land-use change to ensure the agricultural use of Victorian landscapes is productive, ecologically sound and has positive social outcomes. As a first step in seeking an integrated approach we reviewed models applicable to analysing issues for Victorian agricultural landscapes.

This paper describes a work in progress: a review of social, economic, and environmental models applicable to landscape analysis, and the 'mapping' of these models to two chosen landscape analysis frameworks. The two frameworks were identified through a review of landscape analysis literature: an Australian framework proposed by CSIRO (which we refer to as the Hajkowicz framework); and an American framework developed at Harvard University (which we refer to as the Steinitz framework). Both are conceptual frameworks that complement each other and address issues associated with landscape change and planning.

Models were selected and reviewed by discipline scientists and classified into three domains with associated sub-domains. The three principal domains used were Social/Economic, Biophysical, and Generic/Integrative.

The Hajkowicz and Steinitz frameworks are very different, yet comprehensive frameworks for landscape analysis. The approach to 'map' models to the frameworks has been adopted to place each model in context with the wider body of knowledge of landscape analysis and planning. The Hajkowicz framework consists of three main components that address: how a landscape is valued; the physical and social processes that supply landscape values; and the institutional response required ensuring correct functioning of landscape processes. The Steinitz framework classifies models based on six levels of modelling that serve a landscape planning hierarchy: representation, process, evaluation, change, impact and decision. 'Mapping' models to the Hajkowicz and Steinitz frameworks provides a means to bring order into a complex multi-disciplinary area and, when used in the context of a particular question, serves to identify gaps in our ability to analyse the landscape. A matrix was used to represent the relationship between the model and the component/s of the frameworks to which the model applied.

This review will enable us to develop a decision-support system where we can search and choose a suitable model to answer a particular landscape question. By linking the models and questions to a single landscape analysis framework, we improve our ability to link the right model to the right question. This in turn will support the development of an ecoinformatics database linking landscape questions to models for solutions and reports based on data availability and capacity for those models to be used in any part of Victoria.

1. INTRODUCTION

Rural landscapes serve complex and often competing demands of society. They are used by people to generate income (eg. agriculture, mining, and tourism), to provide a living space, and to provide quality of life (clean water, recreation, and social activities). Agriculture has created a new ecology in the rural landscapes of Victoria, and we need a better understanding of the ecology of the landscape and the application of spatial models to provide integrated analysis of current and future agricultural landscapes.

A fundamental problem in landscape analysis and planning is that there is no single approach that can guide non-specialists through the complex array of issues that need to be resolved in agricultural landscapes. The conflicts and trade-offs between different land-uses complicate land-use decisions. With the vision to guide the future agricultural use of Victorian landscapes for triple-bottom line outcomes (i.e. economic, social and environmental benefits), we aim to improve and support land-use decision-making for agricultural landscapes. To do this, we need a greater understanding of the consequences of land-use change to ensure the agricultural use of Victorian landscapes is productive, ecologically sound and has positive social outcomes. To be able to provide land managers and land-users with the tools to improve their decision-making, models that describe landscape processes are being reviewed.

Rather than a review that simply acts as an inventory of models, we are 'mapping' qualitative and quantitative models to two landscape analysis frameworks. A review of landscape analysis literature identified the frameworks. We are not attempting to produce an integrated model, but, simply, to place each model in context with the wider body of knowledge of landscape analysis and planning. 'Mapping' models to the frameworks also provides a way for synergies and knowledge gaps to be identified. The frameworks are designed to address the social, economic, biophysical and institutional issues of landscape change. The frameworks may act as the scaffolding for decision-support systems. We may discover that the frameworks require adaptation to address agricultural landscape issues. The development of a decision-support system is in the preliminary design stages, but the precursor to a decision-support system is obtaining a complete understanding of models for landscape change.

2. MODEL DOMAINS

All aspects of agricultural landscapes and their ecosystem services were addressed by breaking the models into three domains:

- Social/Economic;
- Biophysical; and
- Generic/Integrative.

Within the Biophysical and Generic/Integrative domains, several sub-domains were identified (Table 1).

Table 1. Domains and sub-domains of models reviewed.

Domain	Sub-domain
Social/Economic	
Biophysical	Ecology
	Soil & Water/Hydrology
	Solid Earth Processes
	Hydrogeology
	Agricultural Production
	Environmental Pollution & Nutrient Flow
	Land-use Change
Generic/Integrative	Planning Support Systems
	Visualisation
	Decision Support Systems
	Risk Assessment
	Climate Change

Within each domain and/or sub-domain, numerous model types were described. For example the Social/Economic domain where models of population projection, shift-share analysis, industry cluster analysis and community engagement, were reviewed. Similarly, for the Ecology sub-domain, model types such as ecosystem processes, vegetation dynamics, vegetation representation and biodiversity planning were reviewed.

3. HAJKOWICZ FRAMEWORK

The Hajkowicz framework was developed for the Australian landscape by Stefan Hajkowicz and colleagues from the Policy and Economics Research Group in CSIRO Land and Water Division (Hajkowicz et al. 2003). This framework was found to be useful for 'mapping' models due to its broad, yet comprehensive, and conceptual nature. The Hajkowicz framework was designed for use at a range of scales and for a range of users including scientists, policy advisers, farmers and community groups. The multi-disciplinary development team for this framework had skills in geography, GIS, economics, hydrology, soils and planning. The conceptual framework identifies the underlying landscape-scale processes that drive natural-resource condition and the fundamental principles of strategic institutional responses. These are assembled into an integrated conceptual framework for planned landscape change (Hajkowicz et al. 2003).

There are three components to the Hajkowicz framework (Figure 1), and for each component several attributes are addressed:

(i) Component 1 - how is the landscape valued? Eg. Resilience, water quality and quantity, biodiversity, aesthetics, income.

(ii) Component 2 - what are the physical and social processes that supply landscape values? Eg. Community dynamics, water balance, nutrient balance, ecosystem health and biodiversity, economic and market dynamics.

(iii) Component 3 - what is the institutional response required ensuring correct functioning of the landscape? Eg. Institutional tools and incentives, sharing investments costs, predictive modelling of landscape response, identifying drivers of land-use change.

There are feedback loops throughout the framework so that changes in community values, political pressures or scientific understanding can be accounted for at any stage.

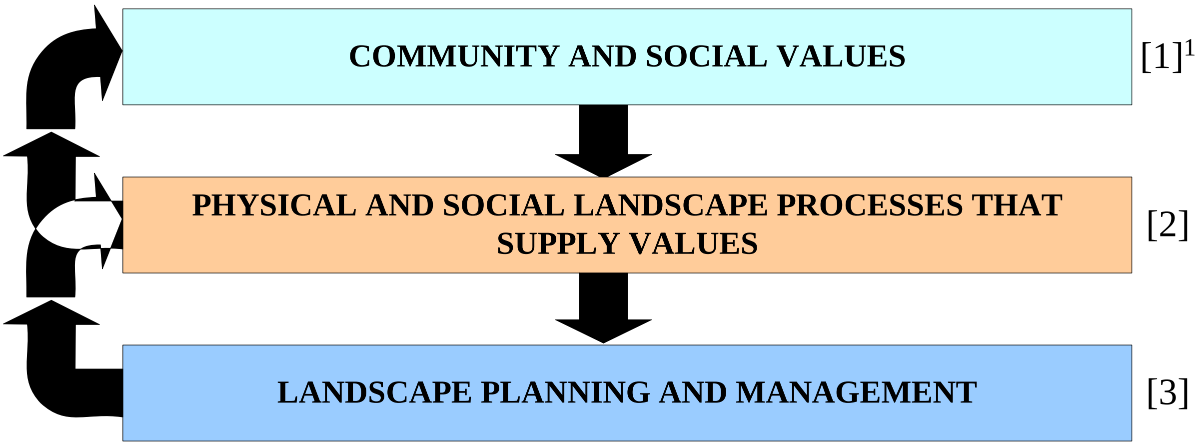

Figure 1. The Hajkowicz procedural framework (adapted from Hajkowicz et al. 2003 p. 49).

[1] Numbers in [brackets] correspond to the component of the framework referred to in Table 2.

4. STEINITZ FRAMEWORK

Carl Steinitz trained as an architect and planner and is one of the earliest pioneers in the use of Geographic Information System (GIS) for analysis and modelling. Steinitz designed a framework for understanding and organising the landscape planning process (Steinitz 1993). The framework is essentially a classification system that identifies and orders the main purposes of models according to the type of question/s they address. The process of landscape analysis and decision making is guided by a deceptively simple flow chart represented in Figure 2. This flowchart needs to be 'passed through' at least three times in any landscape planning exercise. Firstly, the framework is passed downwards to define the context and scope of the landscape questions; secondly, upwards, to specify the project methodology on how to answer the questions; and thirdly, downwards again, to carry the project

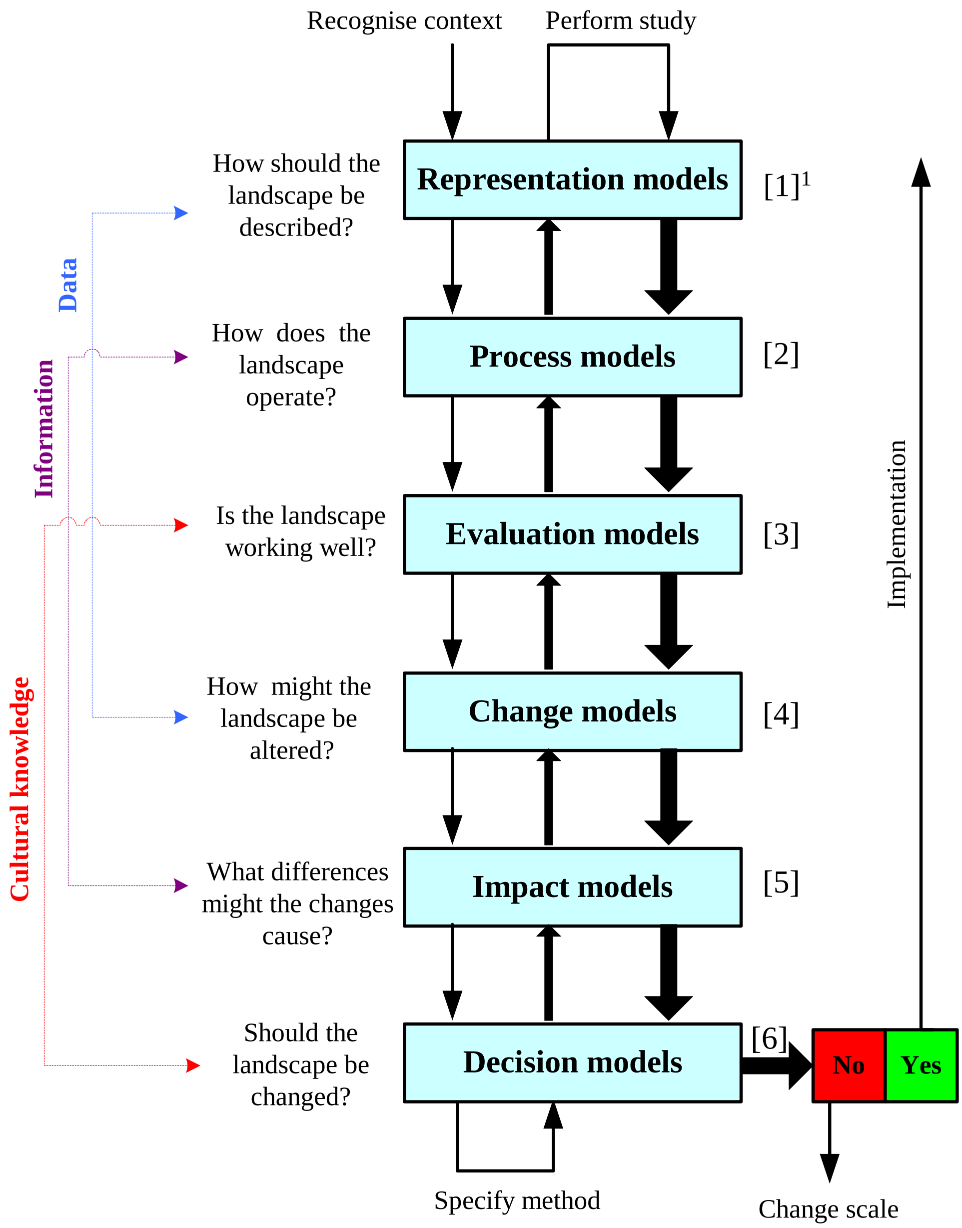

Figure 2. The Steinitz framework for landscape planning (Steinitz 2000).

[1]Numbers in [brackets] correspond to the component of the framework referred to in Table 2.

forward to implementation. Steinitz states that a “no” at any level in the framework demands changes at prior levels. Analysis of a landscape question should continue until a positive “yes” outcome is achieved, however, a “do not proceed” conclusion may also be a positive outcome, depending on the question (Steinitz 1993). Each question, as shown on the left-hand side of Figure 2, is related to each model type (named inside the boxes numbered 1 to 6). By repeating the process over time and scale, the framework provides the organisation for a complex study.

5. MAPPING MODELS TO FRAMEWORKS

The task to ‘map’ models to the Hajkowicz and Steinitz landscape analysis frameworks is currently being completed. The end of 2005 will see the report and associated databases of models and end-user questions completed. A matrix was developed for the review to allow for rapid assessment of how a model, or a type of model, ‘maps’ to the Hajkowicz and Steinitz frameworks.

Table 2 provides an example of the matrix for ecosystem process models classified according to their contribution to the Hajkowicz and Steinitz frameworks and their spatial scale. A similar matrix was compiled for each domain and sub-domain identified in Table 1.

The scientists involved in this review have found it easier to allocate models to the Steinitz framework due to its simpler classification system of model types, compared with the Hajkowicz framework. However, to anticipate all possible consequences of land-use change, including the environmental, social, cultural and economic consequences, it is necessary to 'map' models to the Hajkowicz framework also. Models do not necessarily fit easily into one component of each framework in the matrix (Table 2) therefore the models are shown to have a relationship with more than one component of each framework.

6. DISCUSSION

We have embarked on an ambitious task to synthesise diverse landscape analysis models and tools into a single analytical framework (NB. not a single model). We believe that by doing this we will ultimately make things simpler, yet more complete, for decision-makers and planners seeking appropriate tools to answer landscape questions. In pursuing this goal we have been attracted to the two over-arching frameworks of Steinitz and Hajkowicz et al and we have attempted to fit models into these frameworks, and even to fit these frameworks into each other. This is complex and testing conceptual work for those who would be happier concentrating their efforts in a discipline for which they have been trained and in which they have gained, often

Table 2. Matrix relating ecological models of ecosystem processes to the Hajkowicz framework (Hajkowicz et al. 2003) and Steinitz framework (Steinitz 1993).

Type	**Model**	**Hajkowicz**			**Steinitz**						**Scale**				**Temporally explicit**	**References**
		1	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**point**	**paddock**	**catchment**	**state**		
Ecosystem Processes	Trophic Structure/Food Webs		●			●	●		●			●	●	●		Heal and MacLean Jnr (1975); DeAngelis and Gross (1992)
	NPP Leaf Area Index and Land Cover		●		●	●			●		●	●	●	●		Liu et al. (1997)
	Consumption-Ecological Footprints	●			●		●		●	●				●		Lenzen and Murray (2001)
	Function – Diversity (trophic, taxonomic)	●	●		●	●	●		●			●				May (1973); Tilman (1996); Loreau et al. (2002)

considerable, expertise. One could also question the wisdom of taking two separate ‘complete’ frameworks and trying to match the processes within them. However, the exercise has provided us with some structure, and perhaps even some insight.

Whilst the design and emphasis of the two frameworks are quite different, the frameworks do complement each other. A member of our project team observed that, ‘In every step of Steinitz lies the universe of Hajkowicz’. While this may not be literally true, the statement does serve to draw attention to the iterative and related nature of both frameworks. Even the converse may be true, that in each component of Hajkowicz there is a pathway in Steinitz that can assist in providing context or understanding.

Answering the first question in the Steinitz approach ‘how should the landscape be represented?’ can be simple or complex. Representation of the landscape in GIS can be a simple representation of directly mapped attributes of land, such as a slope, or it can be a classification of land based on the coincidence of several attributes, such as in a land capability map. The latter is still a relatively simple and objective integration of biophysical attributes. Matters of landscape evaluation become more complex when the values held by society are integrated. Brunkhorst et al. (2002) have pursued the spatial integration of biophysical and social values in their ‘eco-civic’ concept of regions. The eco-civic regionalisation of Brunkhorst et al. is a representation model for landscape. Thus it contributes to the first step in Steinitz, although it is, itself, the result of analyses that belong to all of the other steps (understanding the processes, functioning, change dynamics of landscape and the impact of changes in the landscape). Moreover, the eco-civic regional representation fits neatly into the first phase of the Hajkowicz framework, ‘community and social values’.

To explain this further, we need to refer to the principal phases of the Hajkowicz framework given in section 3. The first phase of the Hajkowicz framework, 'Community and Social Values' (Figure 1), consists of landscape attributes such as water quality and quantity, biodiversity, recreation, etc, for which the six questions of Steinitz can be applied. It is appropriate to be asking questions such as "is the landscape working well?" to whether the landscape is supporting recreation, for example. Therefore, the downwards 'pass through' of the Steinitz framework can consider the way the landscape is valued, better defining the community needs for certain landscape attributes using data, information and cultural knowledge provided by the community. The second phase of the Hajkowicz framework considers the fundamental processes that drive landscape change, such as nutrient balance and water balance, and again the six questions of Steinitz could be applied. By considering the physical and social processes and mechanisms of how the landscape operates in the context of questions such as ‘how does the landscape operate?’ and ‘what differences might the changes cause?’ all angles of a landscape change scenario are considered. It is appropriate that the flow of the Steinitz framework 'passes' upwards through these questions when considering the physical and social processes of the landscape. If a decision has been made to change the landscape from a community and social value aspect, then whether this change encompasses a physical change of landscape form and function is a logical question to ask next. Lastly, the final phase of the Hajkowicz framework should be considered. Again, the six Steinitz questions are appropriate for planning and management considerations, such as modelling landscape response, measuring performance, developing incentives and tools, etc. The policy and institutional concepts used to guide landscape change need to be questioned in terms of ‘how should the landscape be described?’ and ‘how might the landscape be altered?’ These questions provide an important reference for ‘before and after’ descriptions of the landscape in question. By applying a defined series of questions to different landscape change scenarios, a prescribed methodology can potentially be developed.

The relationships between the models and the frameworks will be mirrored in a model database. This database will provide: an inventory of the models reviewed; and include comprehensive metadata on model application, spatial scale, input requirements, sensitivity, strengths and weaknesses, etc. The model database will allow for the models to be searched and sorted by how they fit into the frameworks and how they address landscape issues.

In addition, a compilation of end-user questions, the result of analysis of Catchment Management Authorities’ Regional Catchment Management Strategies, in south-west Victoria, have been ‘mapped’ to the Hajkowicz and Steinitz frameworks. This compilation and mapping of end-user questions will be used to serve a more functional purpose for the model review and database, with the ultimate aim of linking questions to model selection.

7. CONCLUSIONS

We believe that if we are to make real progress in landscape analysis and planning we do need to adopt an overall holistic approach. Therefore we have taken the initial steps in our landscape model 'review' and 'mapping' approach. Advances in modelling, particularly in GIS have been considerable, but the promise of modelling is often unrealisable because of missing data or the general lack of integration between different disciplines or issues. We aim to develop an ecoinformatics database, as a decision-support system to search and choose a model or modelling pathway suitable to answer a particular landscape question. The review of models and their relationships to two landscape analysis and planning frameworks will ensure we approach landscape change holistically and with triple-bottom outcomes in mind. Organising the models by the questions they are best suited to addressing provides a conceptual basis for determining what models are needed in an ecoinformatics database. It would be easy, without the work relating models to frameworks, to dismiss or ignore models important for a triple-bottom line approach to landscape questions. We believe that this conceptual approach will result in more efficient and effective response mechanisms to critical natural resource management issues that impact our rural landscapes.

8. ACKNOWLEDGMENTS

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9. REFERENCES

Brunkhorst, D., P. Coop and I. Reeve (2002) Designing 'Eco-Civic' Regions for NRM. Final report on Land & Water Australia UNE 35: Ecological and Social Functions Influencing Governance of Natural Resources. Institute for Rural Futures. Armidale NSW.

DeAngelis, D.L. and L.J. Gross (Eds) (1992) 'Individual-based models and approaches in ecology'. Chapman & Hall, New York.

Hajkowicz, S., T. Hatton, W. Meyer and M. Young (2003) 'Exploring Future Landscapes: a conceptual framework for planned change'. Land and Water Australia, Canberra.

Heal, O.W. and S.F. MacLean Jnr (1975) Comparative productivity in ecosystems – secondary productivity. In 'Unifying concepts in ecology'. (Eds. W.H. van Dobben and R.H. Lowe-McConnell). Dr. W Junk B.V. Publishers, Wageningen. pp. 89-108.

Lenzen M. and S.A. Murray (2001) A modified ecological footprint and its application to Australia. *Ecological Economics* 37, 229-255.

Liu J., J.M. Chen, J. Cihlar and W.M. Park (1997) A process-based boreal ecosystem productivity simulator using remote sensing inputs. *Remote Sensing Environment* 62, 157-175.

Loreau M., S. Naeem and P. Inchausti (2002) 'Biodiveristy and ecosystem functioning. Synthesis and perspectives'. Oxford University Press, Oxford.

May, R.M. (1973) 'Stability and complexity in model ecosystems'. Princeton University Press, Princeton.

Tilman, D. (1996) Biodiversity: population versus ecosystem stability. *Ecology* 77, 350-363.

Steinitz, C. (1993) Geographical Information Systems: a personal historical perspective, the framework of a recent project, and some questions for the future. http://www.gsd.harvard.edu/studios/brc/framework/steinitz.txt Last accessed January 18, 2005.

Steinitz, C. (2000) A framework for PLF. In 'Landscape Futures' (Eds. D. Brunckhorst and D. Mouat). Institute for Bioregional Resource Management, Armidale.