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Collaborative Decision-making Processes for Maintaining Biodiversity: Two Australian Case Studies

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Abstract: There have been many models developed by scientists to assist decision-makers in making socio-economic and environmental decisions. It is now recognised that there is a shift in the dominant paradigm to making decisions *with* stakeholders, rather than making decisions *for* stakeholders. Our paper investigates two case studies where group model building has been undertaken for maintaining biodiversity in Australia. The first case study focuses on preservation and management of green spaces and biodiversity in metropolitan Melbourne under the umbrella of the Melbourne 2030 planning strategy. A geographical information system is used to collate a number of spatial datasets encompassing a range of cultural and natural assets data layers including: existing open spaces, waterways, threatened fauna and flora, ecological vegetation covers, registered cultural heritage sites, and existing land parcel zoning. Group model building is incorporated into the study through eliciting weightings and ratings of importance for each datasets from urban planners to formulate different urban green system scenarios. The second case study focuses on modelling ecoregions from spatial datasets for the state of Queensland. The modelling combines collaborative expert knowledge and a vast amount of environmental data to build biogeographical classifications of regions. An information elicitation process is used to capture expert knowledge of ecoregions as geographical descriptions, and to transform this into prior probability distributions that characterise regions in terms of environmental variables. This prior information is combined with measured data on the environmental variables within a Bayesian modelling technique to produce the final classified regions. We describe how linked views between descriptive information, mapping and statistical plots are used to decide upon representative regions that satisfy a number of criteria for biodiversity and conservation. This paper discusses the advantages and problems encountered when undertaking group model building. Future research will extend the group model building approach to include interested individuals and community groups.

Keywords: GIS; environmental planning; group model building.

1. INTRODUCTION

Traditionally, physical planners and environmental modellers in isolation have undertaken land use planning. However, this resulted in outcomes not acceptable to stakeholders and the wider community. Today the dominant paradigm has moved towards planning *with* the community rather than *for* the community, as advocated by Forester [1999]. This paper examines two Australian case studies, which focus on land use planning and biodiversity issues: i) in urban areas, and ii) in a regional context.

The first case study analysis deploys both geographical information system (GIS) and planning support system (PSS) technologies in developing green system scenarios. The *What if?* PSS tool has been used to elicit decision factors and their weightings of importance from environmental planners within the City of Darebin in order to run and re-run urban green space scenario simulations.

The second case study involved running workshops with a scientific panel to develop an ecoregional classification for the state of Queensland. Visual spatial exploration tools were developed to enable data communication and model exploration. The study aimed to elicit map-based information from experts (mainly ecologists and biologists) on prior probabilities for the distribution of environmental variables that characterized bioregions within a Bayesian modelling framework [Pullar et al., 2004].

This paper discusses the methodology used to formulate the different scaled scenarios, examines the results of urban biodiversity scenarios (case study I) and ecoregional classifications (case study II), and offers directions of how approaches will be refined through the incorporation of further feedback from planners, experts, and the ultimately the community.

2. METHODOLOGY

Miller et al. [1998] have developed a collaborative approach for analysing green systems in the urban context, which integrates suitability analysis with GIS technology for identifying suitable sites for greenway development in the town of Prescott Valley, Arizona, USA. However, there is a paucity of research examining urban green spaces systems in Australia. Our paper incorporates a case study of work in progress, which focuses on the development of a collaborative land suitability approach for developing green systems scenarios for the City of Darebin, Melbourne.

2.1 Scenario Modelling

Spatial modelling is based upon the formulation and evaluation of future scenarios. In the context of decision support systems a scenario can be defined as:

"*A description of the current situation, of a possible or desirable future state as well as of the series of events that lead from the current state of affairs to this future state.*" [Veenklaas and van den Berg, 1994, p99].

PSS are a specialised form of spatial decision support systems (SDSS) focusing on planning (predominantly land use) related decisions. PSS have been described as geo-information tools used to assist in public and private planning processes (or parts thereof) across a range of spatial scales and within a specific planning context [Stillwell, 2003]. In December 2003, the 4th Place Matters - workshop was held in San Francisco, USA. (www.placematters.us). This workshop focused principally on the application of four collaborative PSS tools including:

1. What if?
2. CommunityViz
3. Index
4. Place3S

The workshop enabled participants to explore the application of these PSSs in a charette environment, (a charette is defined as a collaborative hands-on learning experience), to see how planners and community facilitators to formulate different collaborative visions could use them. Direct involvement by the community in the early stages of plan formulation through the interaction of advanced spatial planning tools is an approach which is now being widely applied in urban planning [Synder, 2001].

In formulating the green system scenarios for the City of Darebin case study the *What if?* PSS developed by Klosterman [1999] was used. *What if?* is a collaborative GIS based PSS used to derive land suitability maps, calculate future land use demand, and formulate possible scenarios. In this research only the suitability module of *What if?* was used to formulate urban green system scenarios.

2.2 Approaches to Group Decision Modelling

There are many techniques for group decision modelling, which integrate multiple criteria decision-making and GIS based techniques [Malczewski 1999; Jankowski and Nyerges 2001]. Some of these include the *passive* use of technology where PSS operators observe and model the results of scenarios created by participants using non-technical media such as paper maps and land use stickers. The *passive* scenario modelling approach was demonstrated at the PlaceMatters workshop 2003, where Place3S PSS software, was used in a charette to formulate and evaluate potential development scenarios for a fictitious study area – Edge City, as illustrated in Figure 1.

Figure 1. Place3S passive group decision modelling

Other approaches to group decision modelling may be undertaken using more *active* techniques, which allow the participants to directly interact with PSS software. Such can be the case with the *What if?* PSS, where participants enter their weightings of importance directly into the software and visualise the scenario results immediately after the geocomputational processing is completed. The later, *active* technology approach is utilised in both the case studies presented in this paper.

Generally, the factor weighting and ratings employed in active group decision models need to be determined by informed decision-makers and stakeholders. These individuals and groups may include environment planners and managers from local and state governments, community groups, and the public using formal approaches such as interview, public consultation, and discussions. For example, in Pettit's [2003] land use planning scenarios for Hervey Bay, the local council planners were consulted to determine the appropriate weighting and ratings. This approach was applied in developing preliminary urban green systems scenarios for the City of Darebin. Similarly, when dealing with scientific based decisions there is a need for the input of knowledge by experts in influencing the outcome of a classification. In the ecoregion case study expert knowledge from a panel is used to select model parameters, adjust parameter distributions, and assist in separating structural characteristics of observed data from unstructured random effects. This is explained in detail for the ecoregional analysis in the next section.

3. A CASE STUDY APPROACH

3.1 Urban Biodiversity in the City of Darebin

Green systems such as parks and waterways are an important component of the urban environment. Preserving and enhancing green systems is critical not only for sustaining and improving the quality of life of urban residents but also for conserving biodiversity. In the Metropolitan v 2030 Strategy, the importance of sustainable green systems is expressed in the vision for the city in 2030 in the form of green wedges [DOI, 2002].

The city of Darebin is one of 31 Council comprising metropolitan Melbourne Geographically. Darebin is located between Melbourne's central business district (CBD) and the City of Whittlesea growth area. The City has diverse open space networks that are facing pressure from urban development. Certain areas with environmental and cultural significance in the City of Darebin need to be protected including: native grasslands, waterways (such as Merri and Darebin Creeks), and significant remnant vegetation (such as river red gums at Mount Cooper). Darebin has nearly 0.6 square metres of open space per person, a level comparable to many other inner Melbourne municipalities.

Before the urban green system scenarios were formulated for the City of Darebin a geodatabase was created. Datasets comprising this database includes:

1. Green systems data – open spaces, waterways and water areas;
2. Biodiversity data – flora, ecological vegetation classes, threatened fauna;
3. Cultural heritage data – registered heritage sites; and
4. Planning scheme and land parcel (cadastral) data.

A number of buffering and union GIS operations were performed on these data layers. For example, to accommodate the analysis of suitability of land use by protecting the natural and cultural heritage, green systems, biodiversity, and cultural heritage areas were buffered into 5 zones (0-25, 25-50, 50-75, 75-100, >100 metres) to classify the conservation importance of these areas in sustainable land use. The resultant datasets were used to construct the geodatabase for importing into *What if?*.

A number of urban green systems scenarios were developed to consider the principal of sustainable built environment, and to analyse and determine the supply of land (both quantity and location) suitable for protecting and enhancing the existing green system and biodiversity. Land suitability analysis was undertaken using a weighted linear combination (WLC), multiple criteria analysis (MCA) model, based on the sieve mapping overlay technique [McHarg, 1969]. The MCA model is a simple mathematical procedure which multiplies each decision factor's rating by the overall weighting of importance assigned by the user and then performs an additive operation, combining all suitability factors, to derive a final potential cost surface, also known as a suitability map. By using this simple MCA technique the underlying mathematical model is easily understood by most planners, decision-makers and ultimately the community.

The decision factors have been formulated from a number of spatial datasets listed above using standardised factor values related to buffer distances and weightings determined by priorities in accordance to the existing Darebin Council planning policies. In summary, the land suitability analysis module in *What if?* enabled multiple decision factors to be synthesised in order to determine the relative suitability of different locations for a particular land use ('open space' in this study). Table 1 contains the weightings and rating assigned by the City of Darebin environmental planners used to formulate one of the sustainable urban green system scenarios.

Category		**Considered suitability factors and ratings**							
Factors		Fauna	Flora	Open space	Water features	Heritage	EVC	Land Use	
Factor weight		3	3	3	3	-	-	2	
Buffers (m)	0-25	5	5	3	5	-	-	Park	5
	25-50	5	4	3	4	-	-	bus	2
	50-75	5	3	2	3	-	-	ind	2
	75-100	5	2	2	2	-	-	infra	3
	Outside	1	1	1	1	-	-	res	2

Table 1. Urban Green System Scenario weightings and ratings.

These weightings and ratings, combined with permissible land use conversion values, were used to formulate the urban green space scenario illustrated in Figure 2. This particular scenario is based on a policy of preserving open space, primarily for biodiversity purposes, rather than cultural amenity.

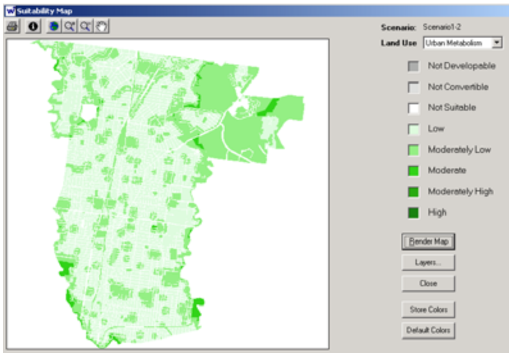

Figure 2. Biodiversity Green System Scenario for the City of Darebin.

3.2 Modelling Ecoregions in Queensland

Ecoregions define recognisable areas that embody broad environmental and landscape structures. Queensland, like most states in Australia, has developed a hierarchical classification of ecoregions for conservation planning, natural resource management and funding allocation. Because of their significance in decision-making and legislation it is essential that ecoregions be defined in an objective and scientifically defensible manner. This lead to a project between the state Environmental Protection Agency and the University of Queensland to develop a ecosystem classification that combined expert (qualitative) knowledge from ecologists and (quantitative) data analysis of environmental data. The resulting classification is described in Pullar et al. [2004]. The main feature of this classification is that qualitative forms of knowledge are interpreted as quantitative data in a rigorous statistical model. Forms of knowledge include rules of thumb, expert advice, scientific publications, or reports. The Bayesian modelling approach supports the inclusion of this knowledge as informative priors, which is balanced with hard data in the model result. The procedure of transforming knowledge into probability statements for informative priors in modelling is called information elicitation. In this case study, information elicitation is carried out through a focused workshop that brings together scientists to define ecoregions. The experts often express their knowledge geographically by describing regions that, in their opinion, characterise a unique pattern of biotic and landscape qualities. For instance, coastal lowland regions with Melaleuca open forest. Through information elicitation we obtain geographical descriptions for ecoregions, and analyse these locations with measurable environmental data, such as climatic, terrain, and soil data. The experts can interactively explore and adjust environmental data distributions and their confidence in these to conform to their opinions of ecoregions. This is transformed into probability distributions and an overall weight is given for this prior information. The Bayesian modelling computes definitions for ecoregions producing outputs as classified maps, uncertainty maps and charts showing the posterior probability distributions.

A GIS application has been written for elicitation of ecoregion classifications. The three main components of the system are: i) an exploratory interface for users to select areas that define ecoregions by querying locations and attributes (biotic and landscape categorical variables), ii) data visualisation tool that allows users to adjust the abiotic variables used to characterise these ecoregions, and iii) a Markov Chain Monte Carlo (MCMC) simulation algorithms that uses a Gibbs sampling technique [Gilks et al., 1996] to classify ecoregions as density mixture distributions. Figure 3 shows an example of an interface for the data visualisation tool. Experts can adjust class breaks of data distribution for several variables to define a model-based cluster corresponding to an ecoregion.

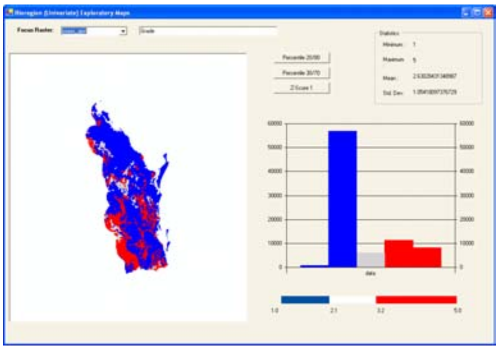

Figure 3. Data visualisation of environmental (abiotic) variables from geographical selection.

4. ADVANTAGES & WEAKNESSES

The land suitability analysis approach to urban green systems scenario modelling has many advantages. It is objective and effective; decision factors can be clearly defined and adjusted according to the objectives. It is transparent as it enables planners, decision-makers and ultimately community members to formulate scenarios by allowing participants to select effective decision factors, assign various weightings of importance to different decision factors, and examine the results by spatial demonstration (suitability maps and reports). Weightings and ratings can easily be adjusted to re-run scenarios based on different policy emphasise.

This type of modelling approach can help to optimise the allocation of additional land to enhance existing green systems in built-up areas such as in the City of Darebin. However, one of the weaknesses of the model is the constraint imposed by jurisdictional boundaries. This means that the formulation of an integrated urban green system is restricted, which negatively impacts on the effectiveness of biodiversity corridors, a critical issue in urban environmental management. For example, Darebin and Merri Creeks flow through three councils – Darebin, Moreland and Banyule. For biodiversity protection of such riparian habitats cross-jurisdictional land use management practices need to be put in place.

Another weakness in the urban green systems scenario modelling approach is it considers the future land use suitability only from the perspective of biodiversity conservation and green systems enhancement. However, in reality many other complex issues need to be considered including social and economic dimensions pertaining to surrounding land uses and values.

The advantages and weaknesses in the ecoregional classification approach are discussed in Pullar et al. [2004]. In this case the output of expert collaboration is to produce a regionalisation that is used as a framework for environmental decision-making. Differences of opinion can arise because certain types of species are seen as endemic to an area, or experts believe an ecological community needs to be identified within a region to remain intact. If there are conflicts in opinion these can be broken down by geographical descriptions to pinpoint where the differences lie. It is generally agreed that this does provide a better way for informing the decision-making process, and the resulting classifications are considered more defensible from an ecological and legal standpoint.

5. FUTURE WORK

In this study, the factor weightings and ratings are only considered from environmental planners from the City of Darebin. However, there is a need to involve stakeholders, and community groups in the selection of model inputs, factor weightings and ratings. This will be explored in future studies.

Further work is required in improving the usability of collaborative PSS systems such as *What if?*. For example work is currently being undertaken to improve the weighting and rating capability of the suitability module through the incorporation of slider bars to enable users to set decision factor trade-offs, as illustrated in Figure 4.

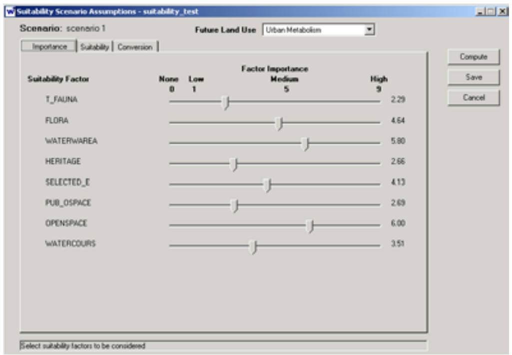

Figure 4. Future enhancements to What if? - slider bar decision factor settings.

6. CONCLUSIONS

One of the current research foci of scenario modelling has been the integration of maps with multiple criteria decision models. Progress in this area has been slow due to a limited role played by maps as decision support tools [Jankowski et al., 2001]. This research examines the application of two modelling approaches, which endeavour to integrate mapping with multiple criteria decision-making techniques.

The urban green systems scenario modelling for the City of Darebin is an example of how GIS and PSS technology can be used to collaboratively preserve and enhance biodiversity in urban areas. Using a collaborative scenario modelling approach, decisions on sustainable land use can be made by potentially incorporating the opinions of different experts, decision-makers, and ultimately the wider community.

It is anticipated that a refined scenario modelling approach will eventually be widely used by planners, decision-makers and the community to assist in achieving the Melbourne 2030 vision. Such a modelling approach could help local councils comprising metropolitan Melbourne to implement an integrated green systems strategy for preserving and enhancing urban biodiversity and conservation.

The ecoregion classification demonstrates a different approach to modelling. The aim is to produce an ecoregion classification based upon environmental data. However, much of the knowledge about ecoregions cannot be readily expressed quantitatively. The case study demonstrates that expert knowledge can be expressed as geographical descriptions, which are transformed into probability measures used in a rigorous statistical model. The use of a Bayesian modelling approach highlights the possibility of combining qualitative and quantitative information to produce model results that include uncertainty values.

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