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Can regional-scale conservation planning influence farm-scale actions?

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***Abstract*:** Major sustainability challenges in agricultural landscapes include the loss of biodiversity, soil erosion from wind and water, and increasing rates of salinity. Other than relatively few exceptions such as the listing or enlargement of nature reserves and the establishment of large corridor plantings (e.g. biolinks in Australia), addressing these challenges generally occurs at the paddock scale through a range of natural resource management policy instruments such as government funded devolved grant and incentive schemes. These schemes typically also include a major in-kind landholder contribution. In Australia this may include schemes such as EnviroFund, BushTender and Landcare in addition to private industry and landholder funded initiatives. The scale of the paddock is generally the scale at which farmers are best placed to visualise, analyse and hence respond with appropriate management actions. Treating these challenges at such scales may also provide paddock scale production benefits (e.g. stock shelter, ecosystem services, wind breaks).

Although decisions regarding on-ground actions are made at paddock scales, ecological restoration priorities such as increasing the extent and quality of native vegetation are often prioritised and planned at catchment scales. For example, catchment management authorities typically develop catchment action plans and related strategies to restore and enhance biodiversity, and these are expressed as quantitative regional targets. A 10% increase in native vegetation extent may be a typical objective for native vegetation restoration. As such there may be a disjuncture between regional imperatives and farm-scale actions. In some instances this is overcome by partially 'scoring' applications for conservation incentive payments by how well the application addresses regional conservation priorities. However, the scoring methods are relatively simplistic and can only be applied when delivering structured incentive programs. They have limited impact when farmers fund their own conservation actions, which based on earlier research in Australia represents a substantial portion of on-ground conservation activities.

We worked with staff from the Wimmera Catchment Management Authority to develop hypothetical maps of their regional revegetation priorities using spatial multi-criteria assessment (MCA) methodologies. The outcomes from the MCA methodology were then presented to key farmers in the Wimmera region of Western Victoria via an interactive workshop, and an additional MCA elicitation process where farmers were asked to weight alternative paddock-scale land use options. Potential actions focused on revegetation activities to mitigate wind erosion and salinity, to provide shelter for stock and for aesthetics. Farmer land use priorities were elicited with and without access to maps of CMA-based regional conservation priorities. Results from this component of the research were elicited via entry and exit interviews, in addition to quantitative data derived using the Analytical Hierarchy Process (AHP) via the farmer MCA workshop. Results highlight that production imperatives drive farmer-led conservation actions and that regional conservation priorities have only limited impact on actions. In addition, results have shown the limitations of applying MCA approaches such as AHP at the scale of the enterprise, rather than the region, owing to interactions between competing land use options.

Keywords: *Multi-criteria evaluation, conservation planning, GIS,*

INTRODUCTION

1. Regional scale conservation planning & multicriteria evaluation

Regional scale conservation planning typically involves natural resource management (NRM) organisations making decisions about competing criteria (or options) limited by the resources available for implementation. Resource limitations mean that a trade-off will exist between the choice of options which can be implemented to achieve particular natural resource management outcomes (e.g. improvements in vegetation condition, reductions in salinity, improvements in water quality, or enhancing species diversity and abundance). However, in most examples of applied NRM decision-making, there is limited reliance on structured decision-making frameworks and tools, and decisions may be based on informal, and non-transparent methods.

There exist a range of decision-making tools which can assist managers to set priorities for possible actions, or to incorporate diverse stakeholder priorities into an aggregate 'preference model'. Approaches can include cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA) (Moffett *et al.* 2005; Gamper *et al.* 2007). In contrast to stakeholder/consensus-based approaches to decision-making there also exists a suite of optimisation methodologies based on mathematical techniques such as integer programming and heuristics to find possible solutions to competing criteria. Malczewski (2004) has labelled these as 'multiobjective' approaches, in contrast to 'multi-attribute' decision-making methods. The former have been applied widely in conservation planning and there is a rich history of their application in Australia. Examples include reserve selection software utilising heuristics such as MARXAN and integer programming approaches (Bryan and Crossman 2008).

For spatially explicit NRM investment planning, these methods are generally coupled with GIS data so that model outputs can be mapped to target the delivery of investments, or to parameterise initial models. This paper pays particular attention to the use of MCA methods for developing maps of regional conservation priorities (revegetation). We focus on MCA methods because of their ability to incorporate stakeholder preferences, their relatively widespread application in NRM decision-making and the transparency they provide decision makers. Hajkowicz (2008) notes that a strength of MCA is that it provides not an answer but rather a process and has likened the methodology to a 'glass box' because stakeholders can gain a detailed understanding of the inputs which have led to a particular decision outcome. These can be reviewed or modified at a later time and they provide a 'transaction history' that documents the decisions adopted to reach a particular end-point.

In this study we apply spatial MCA methods in collaboration with regional NRM staff to develop hypothetical maps of preferred revegetation priorities. We extend these by running an additional MCA priority-setting workshop with farmers to evaluate how farmers respond to these maps, and how revegetation priorities rate against agricultural production priorities. Decisions about agricultural productivity were complemented by maps of paddock yields modelled from precision agriculture data and time-series satellite imagery. In this paper we pay no attention to the methods used to develop yield maps, and rather focus on MCA-based preference elicitation, and the findings from this component of the study.

2. METHODS

2.1. Introduction

The research adopted an MCA process to elicit farmer preferences pertaining to alternative land use options which would also assess how they responded to maps of regional conservation priorities. The research was conducted in collaboration with staff from the Wimmera Catchment Management Authority (CMA), the Birchip Cropping Group (BCG) and famers who had collected precision agriculture data for their crops. An MCA workshop was conducted over three hours in Rapanyup in Western Victoria and facilitated by project staff. The approach follows the broad methodology for catchment planning described in Hill *et al.* (2006) which explores trade-offs between biodiversity, salinity and commodity production through the use of the MCAS-S spatial decision support system (Hill et al. 2005). The Hill et al. (2006) study focussed on identifying areas within the landscape where trees or perennial pastures could be planted to efficiently achieve environmental targets, using priorities identified by NRM personnel. This project follows a similar philosophy but with a focus on incorporating production values and landholder priorities into the land use planning process. Figure 1 provides a project overview and this paper focuses on stages (1), (5) and (7).

2.2. CMA Revegetation Priorities

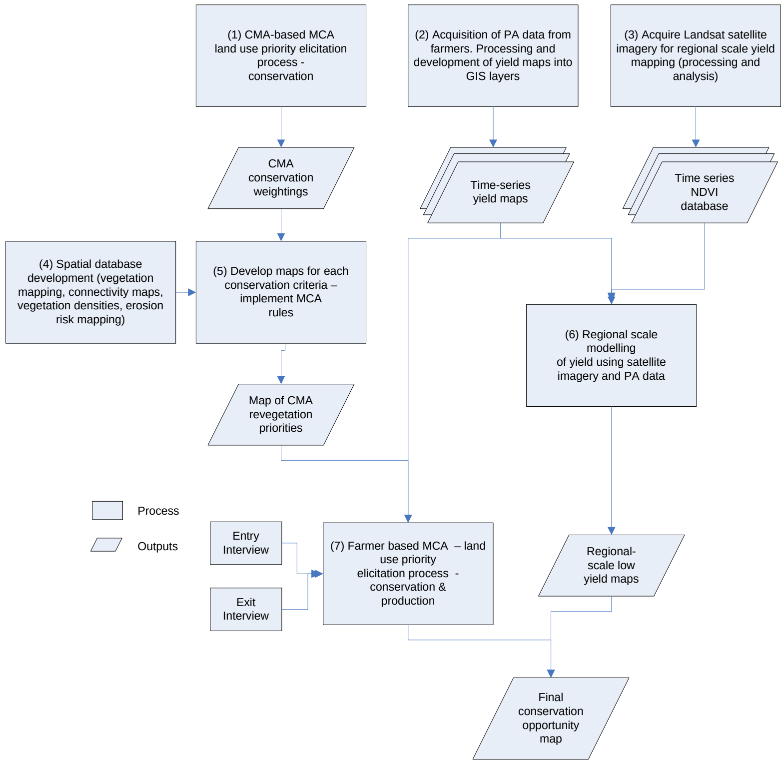

Figure 1 Methods overview – key processes and outputs

Prior to using the MCA preference elicitation process with farmers, there was a requirement to develop a map of CMA revegetation priorities as maps did not already exist. For simplicity, and in consultation with the CMA, this study focussed only on revegetation strategies as improvements in the extent of native vegetation are still a key component of NRM planning in the Wimmera. CMAs in Australia typically develop catchment resource condition targets, and the pathway for achieving these targets are also expressed in written form through catchment action plans and other similar documents. As this study focuses on revegetation, it recognises that there are a number of possible, and sometimes competing, revegetation strategies including improving the extent, representativeness or configuration (linking remnants of a particular size and composition) of native vegetation. Many of these strategies are inherently spatial and therefore they lend themselves well to being mapped to assist with revegetation-focused land use decision-making

To develop a map of revegetation-focussed conservation priorities in the Wimmera CMA an MCA approach was applied to elicit stakeholder preferences via a CMA-based workshop. The Analytical Hierarchy Process (AHP) was used to convert subjective assessments of stakeholder preferences into a suite of final aggregate weights for the competing criteria. Table 1 shows the initial criteria developed in collaboration with CMA staff and an ecological justification for their use in regional conservation land use planning. The AHP process (Saaty 1980) asks stakeholders to conduct a series of pairwise comparisons between pairs of criteria arranged in a matrix (A *x* B). Pairwise comparisons are typically scored on a nine point scale (1-9). AHP is particularly attractive for this study owing to its simplicity in a workshop setting. However, AHP has also received some criticism and in particular critiques have been directed to the ‘rank reversal phenomenon’ whereby the addition of another criteria may invert the relationship between two other criteria (Dodgson *et al.* 2001).

ArcGIS and the Python scripting language were used to spatially implement each criteria (Table 1) as a GIS layer. So for example, for criteria ‘revegetate areas with dense patch distribution’, a high resolution woody vegetation layer was derived from sub-metre resolution aerial photography and a moving window approach was used to identify dense patch distributions. Areas proximal to other vegetation score a value closer to 100 and grid cells further from existing vegetation score values closer to 0. Spatial algorithms were similarly developed for all criteria (Table 1), and where possible using known parameters to maximise the chance of obtaining desired ecological restoration outcomes. Automation of the process via Python was important as criteria parameters may change in the future, or new, higher resolution data may become available requiring one to recreate criteria layers. Obtaining parameters for each criteria from published empirical research remains a major challenge and for any specific case study there may be no accurate parameters. However, where possible we adopted parameters which are based on commonly accepted and tested landscape restoration principles.

Table 1. Conservation criteria used as an input to MCA priority setting exercise.

Criteria	Ecological Justification
Revegetate rare vegetation communities	This rule considers the broader context within which the study area sits by reflecting regional rarity of vegetation types that might be locally common.
Revegetate areas with dense patch distribution; number of patches	Dense patch distribution is an important resource for wildlife; neighbouring patches of vegetation act as 'stepping stones', which enable movement through the landscape (Platt 2002 p. 37).
Revegetate close to large patches	Westphal (2007) found that 'an average patch size of between 780 to 4010ha is needed to maximise species numbers in the Mount Lofty Ranges, South Australia'.
Revegetate close to streams	Bennett et al (2000 pg. 21) "*Give priority to streams and watercourses as 'natural corridors'*. Riparian areas are particularly important resources for wildlife and they introduce other benefits such as improved water quality (Platt 2002 p. 33).
Revegetate enclosed areas	Infill plantings allow existing disparate plantings to be coalesced into a larger area by a block planting filling the void between the disparate plantings. Because of the viable area requirements of some species, infill plantings may transform two non-viable areas into a single viable area.
Revegetate to form corridors	For native mammals Bennett (1990) found that 'The continuity between remnant habits that is provided by a network of habitat corridors is an essential, and critical, component of this conservation strategy'.
Revegetate areas with dense patch distribution; percentage vegetation cover	In a study of the white-browed treecreeper in north-west Victoria Radford (2004) found that *"In agricultural landscapes, most suitable woodland patches within 3 km of an occupied patch were occupied, whereas patches beyond the threshold were vacant"*.
Revegetate to form compact patch shapes	Bennett et al (2000 pg. 17) "*Increase width to reduce 'edge effects'*. Elevated predation rates of (artificial) ground bird-nests were recorded close to forest edges, as opposed to forest interiors, in the Murray Mallee, South Australia (Luck, 1999).
Reduce patch isolation	McIntyre and Hobbs (1999) suggest a set of four states of landscape fragmentation – intact, variegated, fragmented, and relictual. These states are defined according to the percentage of native vegetation remaining in the landscape, i.e. the level of isolation. They suggest that highest priorities for vegetation management and protection should be allocated toward landscapes with the greatest vegetation cover because management actions for biodiversity within those landscapes are more likely to succeed.

Table 2. Wimmera CMA preference weightings

Criteria	Final Weight
Revegetate Rare Vegetation Communities	0.25
Revegetate in Areas of Dense Patch Distribution	0.13
Revegetate Close to Large Patches	0.13
Revegetate Close to Streams	0.22
Revegetate Enclosed Areas	0.10
Revegetate to Form Corridors	0.09
Reduce Patch Isolation	0.07

Table 2 shows the final MCA preference weightings derived from the CMA-based preference elicitation process. CMA preference results highlight that the preferred pathway for achieving conservation outcomes in this landscape is via revegetation of rare vegetation communities (those most cleared since European settlement) and revegetation of stream corridors. Other criteria were perceived as being less important and consequently received lower weightings – in general contributing less than 10% each to the final outcome. Interestingly, whilst improving connectivity between remnant patches is often considered a high priority by NRM agencies, in this case it was not ranked of relative high importance. This may reflect the fact that because much of this landscape is cleared, achieving connectivity goals is recognised as being challenging in terms of available resources. Figure 2 shows the final CMA revegetation priorities mapped across the study area. Spatial priorities are normalised to a range from 0 to 100. Actual suitability scores rarely exceed 80% as it is difficult to find locations in the study area where all criteria are met. Results highlight that as many of the CMA criteria focus on the enhancement and expansion of existing woody vegetation, possible locations for new activities will be proximal to existing vegetation. Hence the spatial priority patterns we see are driven not only by the weight placed on the criteria by stakeholders, but by the initial choice of criteria and how these criteria are expressed in the GIS. In the Wimmera example, the key input to many of the criteria is the high resolution woody vegetation layer and hence we see that high priority areas are proximal to existing vegetation. This does however make intuitive ecological sense if restoration principles focus on enlargement, protection and connection.

3. RESULTS & DISCUSSION

Table 3 shows the final weights applied to different farm-scale land use options derived using an AHP process by five farmers from the Birchip region of Western Victoria via a three hour facilitated workshop in Rapanyup in Western Victoria. The workshop was facilitated by CSIRO project staff and included real-time presentation of modelling results (e.g. CMA revegetation priorities) and contextual GIS data. Results show that when presented maps of proposed ecological restoration activities, they do not weight these highly relative to other farm-scale criteria. Although farmers did not rank the priority highly, verbally and via the exit interviews they did respond in a positive way when presented maps of regional conservation priorities, acknowledging the realistic nature of the ‘spatial plan’. To allow them to weight production imperatives, farmers were provided four conservative production-focussed land use options: keep all production land; keep the best 99 %; keep the best 95%; and keep the best 90%. Farmers ranked ‘keep the best 99%’ under production over ‘keep all production land intact’ acknowledging that there were indeed some opportunities for alternate farm-scale land use options.

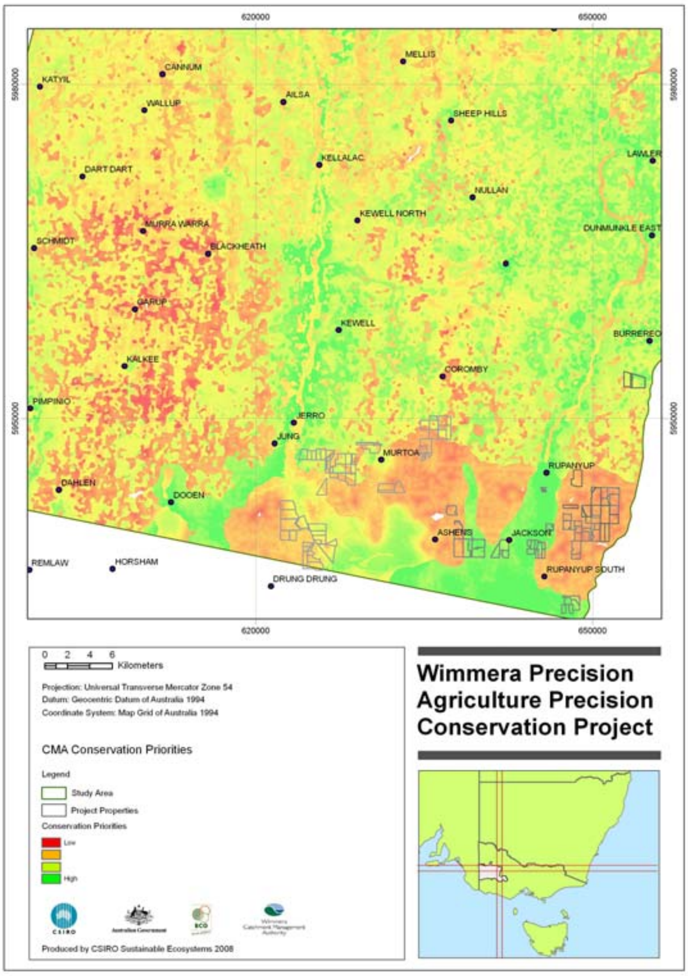

Figure 2 Final Wimmera CMA derived weighted revegetation priority zones

There are good reasons why farmers did not rank regional conservation priority mapping (revegetation) highly. First, farmers may not be likely to consider conservation priorities in their on-farm decision making regardless of the data provided to them, owing to drought-influenced economic imperatives which mean agricultural productivity must be weighted highly.

However, historically farmers in the Wimmera region have demonstrated their willingness to consider conservation and biodiversity priorities in their decision making, though this may be driven by farm scale and personal objectives rather than regional priorities. For example, there are 56 Landcare groups involving around 1600 members in the Wimmera (Wimmera CMA 2008), and a recent study of Wimmera farmers found that those taking part in Landcare training activities were 1.8 times more likely to revegetate, and 2.2 times more likely to fence remnants (Curtis and Byron, 2002). So it is important to consider other reasons why farmers in this particular study were unlikely to rate regional conservation priorities highly.

It is also possible that the land included in this study is considered unlikely to contribute to positive conservation outcomes regardless of the management intervention. Indeed, one farmer mentioned in the workshop that had this study included parts of his farm to the south of the study area, he would be more likely to respond to regional revegetation priority maps in the farmer preference elicitation process. Farmers also agreed that the land in this study was likely to have been sparsely covered with trees prior to introduction of agriculture; hence it is possible that they felt that revegetation was therefore not necessary because degradation due to agriculture was minimal. This also indicates that in future studies we should consider interventions other than simply revegetation such as fencing, retention of coarse woody debris, active regeneration and reducing fertilizer inputs. It is also important to note that this study was undertaken after several consecutive poor production years, which has impacted on farmers' economic wellbeing. This in the short term may reduce the farmers' willingness to consider land use change in favour of conservation or environmental objectives. Where longer term strategies are considered, the opposite may be true. Finally, it is possible that by selecting farmers who had precision agriculture data available, we inadvertently chose farmers who were particularly production focussed and therefore more likely to place high importance on production and economic priorities.

Table 3. Farmer Preference Weightings showing initial weights when farmers did not have access to mapped CMA conservation priorities (initial weights) and a second series of weights (final weights) which were derived after CMA conservation priorities were presented to farmers.

Theme	Criteria	Initial Weights	Final Weights
Agriculture	Keep all production land intact - regardless of yield	.22	.22
	Keep the best 99% yielding land as cropped	.23	.23
	Keep the best 95% yielding land as cropped	.14	.14
	Keep the best 90% yielding land as cropped	.11	.11
Soil Health	Revegetate areas prone to wind erosion	.05	.05
	Revegetate areas prone to water erosion	.03	.02
Aesthetics	Revegetate areas to improve farm aesthetics	.06	.06
Ecosystem Services	Revegetate to provide ecosystem services	.05	.04
	Revegetate for income (farm forestry, carbon credits)	.08	.07
Stream Health	Revegetate to protect creeks & water bodies	.02	.02
Conservation	Revegetate CMA conservation priorities	.02	.02

The attempt to integrate regional scale planning with farm-scale actions via an MCA methodology has also raised a number of spatial planning challenges regarding spatial data suitability, and conceptual issues concerning MCA when applied across multiple management scales (regional to farm). These findings are general in nature and are designed to inform future applications of MCA for NRM priority setting. After running two MCA preference elicitation workshops, once with NRM staff and a second with farmers, it is clear that criteria definition is a major challenge. There are two components to this challenge. The first is the assumption in MCA and AHP that criteria are mutually exclusive. The second is the general inability of MCA to incorporate interactions between criteria.

The generalisations inherent in MCA preference setting may be acceptable at regional scales when knowledge of environmental processes or domain knowledge is limited. However, when applying the same methods at the scale of the farm where farmer domain knowledge is very detailed it is difficult to make generalisations as many exceptions and unique situations arise. For example, farmers may weight revegetation to mitigate wind erosion as more important than production, but only for one paddock on their property. As such incorporating these exceptions is difficult with simple AHP and it may require more sophisticated criteria definition, or a hierarchical approach to defining criteria to better incorporate decision-making scales. From a spatial modelling perspective the use of an MCA framework has also raised the following issues:

- Obtaining accurate ecological parameters as an input to spatially implement criteria for specific study regions is difficult. The choice of parameters can play a major role in how the final spatial MCA-derived land use suitability layer is constructed.

- Spatial data which provides the input into the MCA criteria plays a major role in how the final spatial MCA-derived land use suitability is mapped across the landscape. In this study the primary input layer was a high resolution map of woody vegetation derived from aerial photography. Hence there exists an important interaction between criteria parameters and input GIS data scale and resolution. The inclusion of regional-scale grassland mapping may provide further opportunities to think more broadly about vegetation management.

- In the absence of analytical methods to assess the role of input GIS data and criteria parameters, detailed sensitivity analysis methods should be applied to evaluate the reliability of the final mapped results.

However, options for sensitivity analysis in such studies are limited as generating alternative realisations of input GIS criteria layers can be computationally extremely intensive.

4. CONCLUSION

This research was exploratory as it represents one of the first attempts to couple regional scale priority setting with farm scale planning by assessing whether the provision of maps to farmers could influence farm scale actions. Such thinking is important as regional-scale NRM planning and priority setting can often be conducted independently of production impacts, yet on-ground conservation actions such as revegetation, may often driven by farmers (Seabrook et al. 2008). Moving to a 'pull' philosophy of NRM delivery and away from the traditional 'push' model delivered via grants and incentive payments offers a number of economic benefits to NRM agencies, and may also achieve more effective environmental outcomes as landholders drive the site-scale NRM actions. Based on findings from this study it is apparent that moving to a 'pull' philosophy requires more than just maps of regional conservation priorities and stakeholder engagement needs additional sophistication. For example one approach would be to coordinate a more intensive and more detailed MCA process with farmers, and in concert with domain experts such as ecologists, soil scientists and hydrologists. Finally, any effort to implement 'pull' approaches to farm-scale conservation land use planning also requires effective monitoring to assure landholders that their on-ground actions are delivering effectively to regional-scale targets.

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