Allocating environmental funds amongst competing regions: fairness, efficiency and transparency

S. A. Hajkowicz
CSIRO Sustainable Ecosystems
Brisbane, Australia

Abstract

In Australia, and across the globe, funding for public environmental programs is being increasingly invested through regional community groups. A common policy problem for State and National governments is determining allocations to competing regions. How should the pie be cut? Activities proposed within regions typically far exceed program funding, so prioritisation decisions cannot be avoided. Under such circumstances policy makers need allocation processes that are transparent, perceived as fair and provide best possible social returns. This needs to be achieved with political constraints and limited data availability. This paper explores a technique for supporting fund allocation decisions based on multiple criteria analysis (MCA). The technique is illustrated in Queensland, Australia where a set amount of funding is to be distributed amongst 13 regions to restore degraded ecosystems. It is shown to provide decision makers with an explicit tool for handling complex trade-offs amongst competing environmental objectives.

1 Introduction

The Australian Commonwealth, State and Territory Governments have recently approved a seven-year A$1.4 billion program to address salinity and water quality problems (Australian Commonwealth 2003). The Commonwealth Government has also extended the Natural Heritage Trust program with an additional $1 billion over the next five years (Crowley 2003). This funding will

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deliver environmental benefits through landuse change, tree planting, improved farming practices, habitat protection, better water use and controlling sediments, salts and other pollutants in rivers. It will involve a mix of landscape changes and engineering options.

Much of the on-ground works will be administered through regional community groups. These groups are developing natural resource management plans and securing funds to carry out physical works. Funding of regional groups inevitably introduces the question of allocation. At some point National, State and Territory governments will need to decide how much goes where, given the near-certainty that regional groups would like more funding than is available in total. This dilemma is common to almost all public environmental programs in every country.

In this paper we consider the application of multiple criteria analysis (MCA) techniques to allocate limited funding across a set of 13 regions in Queensland, Australia. The MCA approach helped build a process for allocation that was transparent, fair and efficient. It also helped decision makers assess the latest scientific datasets relevant to fund allocation. By placing weights on competing objectives, decision makers were explicit about their preferences for prioritisation. This held much value as a learning tool in addition to providing a basis for allocation. The approach developed in Queensland has potential applicability in many parts of the world and numerous other environmental programs.

2 Multiple criteria analysis

Multiple criteria analysis (MCA) is a structured framework for investigating, analysing and resolving decision problems constrained by multiple objectives. It is used to appraise a discrete number of alternative options against a set of multiple criteria and conflicting objectives (RAC 1992). The MCA process is generally considered to involve the following stages:

1. Identify objectives. These are statements relating to what decision makers seek to achieve in a particular circumstance. Objectives are distinct from criteria in that they are not necessarily measurable indicators of performance.
2. Identify options. A discrete set of options represent the alternative choices available to the decision maker. Most MCA models will require "either-or" choices to be made, i.e. it is rarely possible to select combinations of options.
3. Identify criteria. Criteria measure the performance of decision options against the decision objectives. For example, water salinity in units of electrical conductivity might be used to measure performance against a water quality objective.
4. Obtain performance measures. A performance measure provides an assessment of an option's performance against a criterion. Performance

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measures are usually obtained from existing datasets, predictive models or expert judgements.

5. Weight the objectives and criteria. Rarely are all objectives and criteria of equal importance in a decision problem. By assigning quantitative and qualitative weights to the objectives it is possible to make important criteria have a greater impact on the outcome than other criteria.
6. Rank the alternatives. A great many algorithms can be applied to rank the options against the criteria. These algorithms make use of the performance measures and the criteria weights to obtain an overall performance score for each option.
7. Perform sensitivity analysis. In this stage weights and/or performance measures in the model are systematically varied to see how they impact the results. This can help account for uncertainty. If a minor variation in one variable has a significant impact on the result, that variable should be subject to further validation.

Generally an MCA problem is represented using an effects table, or evaluation matrix. This contains the performance scores for each option against each criterion. A set of weights is also attached to the criteria. An effects table is generally represented by a matrix of M alternatives and N criteria, as shown below:

		$a_{m=1}$	$a_{m=2}$	$\cdots$	$a_{m=M}$
$c_{n=1}$	$w_{n=1}$	$x_{m=1,n=1}$	$x_{m=2,n=1}$	$\cdots$	$x_{m=3,n=1}$
$c_{n=2}$	$w_{n=2}$	$x_{m=1,n=2}$	$x_{m=2,n=2}$	$\cdots$	$x_{m=3,n=2}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$		$\vdots$
$c_{n=N}$	$w_{n=N}$	$x_{m=1,n3}$	$x_{m=2,n=3}$	$\cdots$	$x_{m=M,n=N}$

In this case we have labeled the criteria as $c_{n=1}$ to $c_{n=N}$, the criteria weights as $w_{n=1}$ to $w_{n=N}$, the decision alternatives as $a_{m=1}$ to $a_{m=M}$ and the performance scores as $x_{m,n}$. The performance scores could be measured in a variety of qualitative and quantitative units. We generally introduce a requirement that the weights sum to 1 and are non-negative.

Once the effects table is completed, our problem is to measure the overall performance of each decision alternative. This first requires defining a transformation function for each criterion. A common transformation is linear, where we define a transformed performance score by:

$$x'_{m,n} = \frac{x_{m,n} - \min x_n}{\max x_n - \min x_n} \qquad (1)$$

when a higher criterion score indicates better performance; and

$$x'_{m,n} = \frac{\max x_n - x_{m,n}}{\max x_n - \min x_n} \tag{2}$$

when a lower criterion score indicates better performance.

Where:

$x'_{m,n}$ = the standardised performance measure for $x_{m,n}$

$x_{m,n}$ = the performance of the mth alternative against the nth criterion in real units of any type;

$\max x_n$ = the maximum performance score under the nth criterion; and

$\min x_n$ = the minimum performance score under the nth criterion

Once we have commensurate units, following the criterion transformations above, we can determine the overall weights-adjusted utility of each option. This can be achieved by assuming additive utility in a process called weighted summation. Here the overall performance of decision alternatives is calculated as:

$$v_m = \sum_{n=1}^{N} w_n x'_{m,n} \tag{3}$$

Where:

v_n = The overall performance of the mth decision alternative; and

w_n = The weight assigned to criterion n.

Through multi-attribute utility theory (Keeney and Raiffa 1993) a great many alternative specifications of this utility function are possible. Sometimes there may be a case for non-linear transformations and the assumption of additive utility may not hold due to inter-criterion dependence. However, for most simple applications of MCA the weighted summation approach satisfies decision maker requirements. It also has the important benefit of being a simple process that can readily be understood by non-technical decision makers.

3 The Queensland fund allocation problem

Fund allocation was between 13 regions across Queensland (see Figure 2). These regions represent a great diversity of physical environments, agricultural production, environmental problems, socio-economic characteristics and institutional structures.

Representatives of these regions attend meetings of statewide assessment panels, with the task of allocating funding. Generally, regional representatives will vigorously promote the funding case for their region. The final fund allocations decided upon by statewide panels will determine to a large extent resources available to regional groups to achieve environmental targets. They will also determine each region's capacity to hire and retain staff. Therefore, there are considerable losses and gains for individual regions.

The statewide panel has, amongst other matters, the task of deciding upon fund allocations between regions. Their task is to identify an allocation that is fair and provides the best attainable level of environmental benefit for Queensland. This is usually undertaken through a series of meetings, some of which may last for 2-3 days. A process of negotiation and arbitration is used until the group reaches a consensus decision.

4 Decision criteria In Queensland

The decision criteria were identified through an iterative process involving consultations with the panel and assessments of natural resource datasets with statewide coverage. Effort was made to be inclusive, rather than exclusive, covering as many potential criteria as possible. It was expected that in allocation decisions some of the criteria would be assigned zero weighting, i.e. removed from the decision problem. This approach also resulted in some overlap between criteria, although redundancy was avoided where possible.

The decision criteria were presented in hierarchical form, with the overriding objective stated at the top, sub-objectives on the next level and specific criteria at the fingertips (see Figure 3). Almost all the criteria are accompanied by statewide datasets, although there are areas of missing data for water quality. Collectively the criteria could be used to define funding priority. Decision makers primarily weighted the criteria shown in italics. In the MCA model it was also possible to weight the criteria at the very fingertips of the hierarchy.

All of the criteria relate to the asset value of resources within a region, or threats from some degrading process. Together threat and asset value are used to define funding priority. Criteria on problem tractability, i.e. how easily and cheaply the problem could be solved, were also sought but few data were available.

5 Data aggregation and sources

Spatial data relating to the criteria were available across Queensland at different resolutions. Some data, for example, was available on a 1km2 grid covering the State, whilst other data was assembled by catchment boundaries. This created a spatial data aggregation problem. A method was needed to transfer data from many different levels to the 13 funding regions shown above. In principle, so long as data was being transferred from coarser to finer levels of detail it was being appropriately interpreted. To move from coarse level data to fine scale regions would mean placing artificial accuracy on base data.

The transfer of data from one set of regions to another was handled using a raster approach, whereby all data was transferred to an intermediary 1km2 statewide grid then re-aggregated to the 13 funding regions (see Figure 4). Designing the database in this way made changes to funding regions a relatively easy exercise; aggregates could be quickly recomputed for any regional framework. The MCA effects table, upon which the standardisation and weights adjustments were performed, was always at the aggregate level for the 13 regions. In other words, there was no attempt to define funding priority on the 1km2 grid then aggregate to regions. This would represent inappropriate data handling.

Much of the data was derived from Australia's National Land and Water Resources Audit. This was a AUD$52 million project to collate natural resource information on water quality, water quantity, soil conditions, agricultural profitability, biodiversity, community well-being and many other indicators. Much of this data was provided in mapped form, often at fine levels of detail. These rich datasets allowed information to be sourced for the criteria presented above.

6 Applying the model

The multi-criteria fund allocation model was presented to decision makers in a spreadsheet, tailored using customised program code (see Figure 5). It allowed decision makers to interactively specify criteria weights and view fund allocations. This way decision makers could see the trade-offs between competing prioritisation objectives. In the meetings many alternative weighting scenarios were tested. The default position placed equal weight on all criteria, with the subsequent fund distribution shown in Figure 5. As weights were changed the model instantly recalculated the fund distribution. This tool was used in meetings using an overhead projector.

By showing numerous criteria weighting scenarios to decision makers, the funding attractiveness of the regions became clearer. For example, when 100% weight was place on one criterion, e.g. population, the results showed a very skewed distribution of funding. Modification of the weights helped assure decision makers that the model was not inherently biased.

Not willing to adopt outright the results of MCA, it was suggested that decision makers would take a staged approach to funding. Under this approach a certain amount of money would be set aside from the total funding pool to be equally distributed amongst regions. This ensures that each region receives at least some funding support. Another portion of the total funds could then be allocated by the MCA process, with panel members agreeing upon appropriate criteria weights. Lastly, a final portion of the funding could be allocated to fill special needs not adequately handled either through the MCA or equal distribution. The staged approach provides policy makers with more flexibility in decisions.

7 Discussion and conclusion

Fund allocation decisions will always be influenced by political factors given the often considerable losses and gains faced by communities affected. However, by introducing a structured framework for decision making trade-offs can be made explicit and scientific analysis be given better consideration. The MCA approach taken in this study helped decision makers understand trade-offs, and present clearly their reasons for supporting a particular fund allocation.

Whilst results of MCA models, such as that applied here, are rarely accepted outright the real benefit is the decision making process followed by decision makers. There was a clear relationship between the criteria, their weights and the fund allocation. Stakeholder groups not privy to panel meetings could easily appreciate the reasons behind a particular fund allocation, even though they may not agree with them.

Acknowledgements

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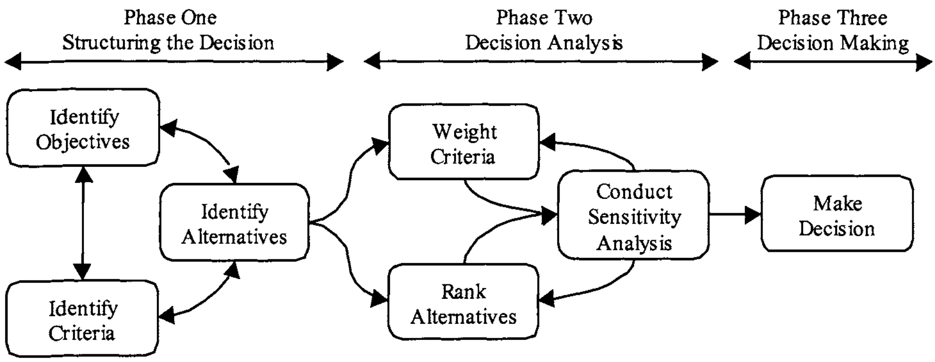

Figure 1: Multiple criteria analysis process

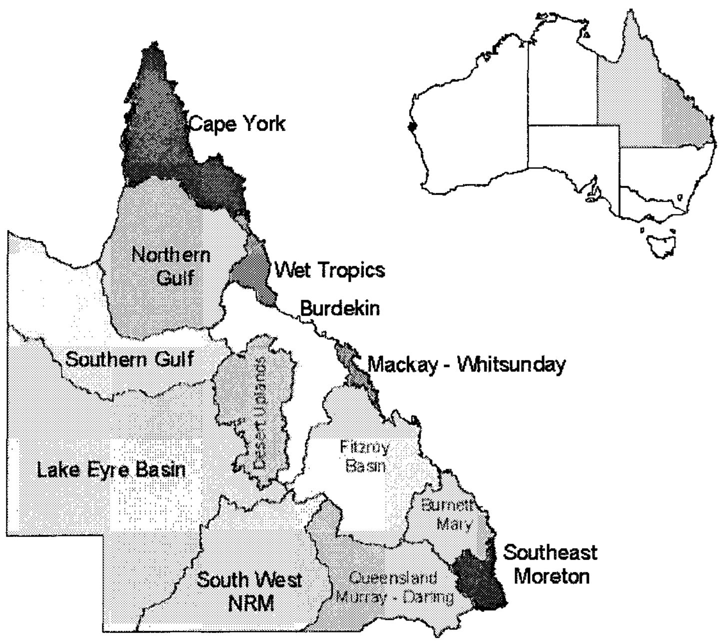

Figure 2. Queensland's natural resource funding regions and location within Australia

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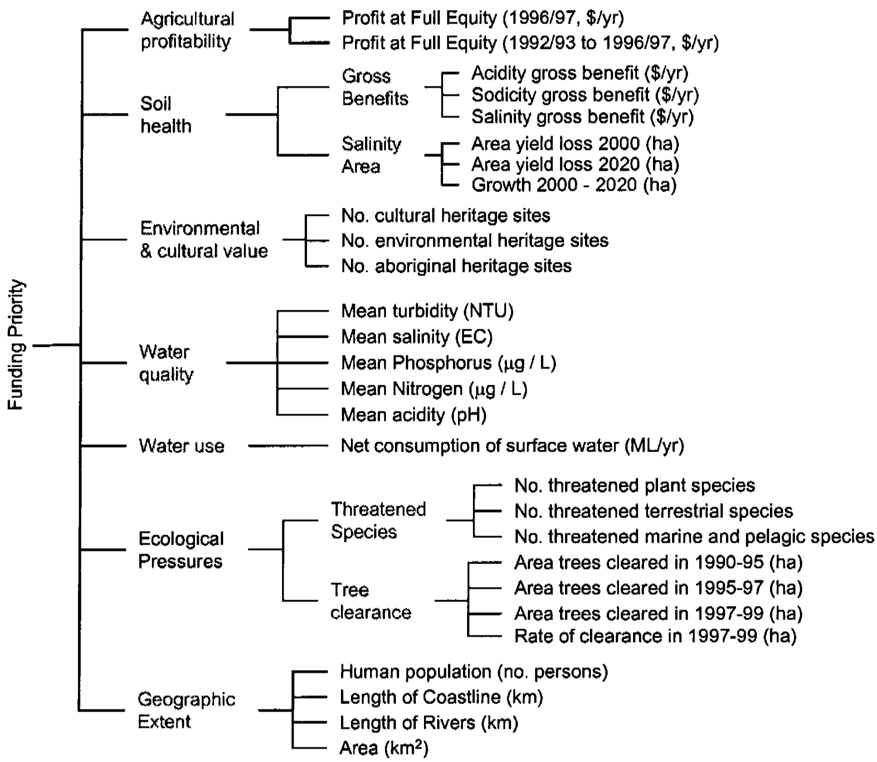

Figure 3: Full set of criteria used to evaluate investment priority

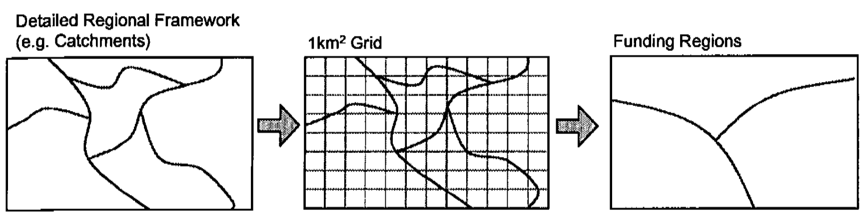

Figure 4: Process for transferring data between regions

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Criteria	Adjust	Weight
Agricultural profits		11%
Geographic extent		11%
Degradation Costs		11%
Landscape value		11%
Salinity area		11%
Threatened species		11%
Tree clearance		11%
Water quality		11%
Water use		11%
	1%	100%

Equal Wts | Hierarchy | Title Page

Region	Score
Burdekin	10%
Burnett - Mary	10%
Cape York	4%
Desert Uplands	5%
Fitzroy Basin	14%
Lake Eyre Basin	6%
Mackay - Whitsunday	4%
Northern Gulf	5%
Queensland Murray -	16%
South West Strategy	4%
Southeast Moreton	11%
Southern Gulf	5%
Wet Tropics	6%
Total	**100%**

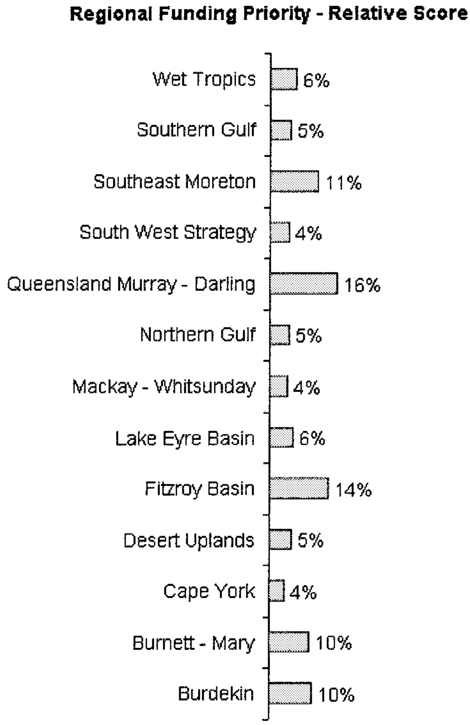

Figure 5: Interactive spreadsheet model