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Does MODSS offer an alternative to traditional approaches to natural resource management decision making?*

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There is an increasing awareness, on the part of decision-makers, of the need to develop new or to extend traditional evaluation techniques to facilitate a multidisciplinary and participatory approach to decision-making. Such an approach would be particularly appropriate for decision-making with respect to the management of natural resources. Not only are there multiple objectives involved in making a decision about natural resource management but many of the identified objectives are competing and conflicting. This paper presents a multiple objective decision support system (MODSS) which was developed to assist decision-making for a catchment in Far North Queensland. The MODSS approach is shown to be a process, capable of incorporating information from a number of disciplines as well as the preferences of identified groups of stakeholders, to support the prioritisation of options to manage land and water resources in the catchment. The final ranking of options is argued to be credible and defensible.

1.0 INTRODUCTION

The economic evaluation or appraisal of proposed public sector investment in infrastructure projects or programs is an important determinant of the efficient allocation of resources. Cost-benefit analysis (CBA) has been adopted as the standard evaluation technique because it provides a theoretically sound and consistent approach to prioritising investment in competing projects or programs. In essence, the technique provides a way of systematically organising information to determine whether or not public sector investment should proceed. It requires that all of the costs and benefits associated with a project be identified and valued in money terms. Projects are undertaken if, after reducing the future stream of costs and benefits to a present value (termed discounting), there is a net benefit to society as a whole. In short, the sole criterion for resource allocation using this technique is economic efficiency.

Although CBA is a standard tool used by economists to establish the efficiency of investment, there is an increasing body of literature about the limitations of the technique, particularly in its application where environmental issues are involved. These limitations primarily arise because of the complexity of ecosystems and uncertainty about the possibility of irreversible damage resulting from development. Valuation of non-marketed goods and services such as native flora and fauna and the landscape poses a problem for CBA, especially in relation to the methods of valuation and the reliance that can be placed on money estimates. As well, the discounting of

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future costs and benefits raises a number of questions when there is the possibility of environmental degradation in the distant future. Finally, CBA does not necessarily provide explicit information to decision-makers about the possible trade-offs that may underlie a decision to undertake a project, especially when there are multiple objectives or criteria to be considered and where the objectives or criteria may be conflicting or competing. There is increasing recognition that an evaluation technique is required that is theoretically sound, has the ability to incorporate information to address conflicting and/or competing objectives and facilitates consideration to impacts which may be difficult to value in money terms.

This paper first reviews some of the problems and methods proposed to address problems with standard approaches to project evaluation when there are multiple objectives and environmental impacts to be considered. Second, an overview of decision support systems is provided with a view to identifying the potential contribution of this technique for evaluation of resource management projects, where there are conflicting objectives or criteria to measure outcomes, and where some of these criteria could be non-quantifiable. Finally, a description of a multiple objective decision support system (MODSS) developed to assist natural resource management in a catchment area in Far North Queensland is provided, identifying areas where the approach has made a positive contribution to decision making.

2.0 APPROACHES TO ADDRESS PROBLEMS WITH CBA

2.1 Project appraisal with multiple and competing objectives

Recognition of the presence of multiple objectives, which are sometimes competing, is not new in economics and has been acknowledged and accommodated to some extent in economic or social CBA evaluation of projects since the 1960s. In this regard, a number of recommendations have been made in the literature to extend or enhance decision-making with CBA.

Some of the theoretical problems of subjecting public investment decisions to CBA have been explored by Marglin (1967). He argued that the goal of CBA, and of economic choice in general, was to maximise the utility function associated with resource allocation subject to the constraints that the economic and political environment imposed, which could be competing, including political or decision-maker preferences (p.15). Marglin (1967) suggested two methods to incorporate multiple and competing objectives within project appraisal. One method was to specify the relative importance of objectives by explicitly weighting the contribution of projects to each objective and to formulate project plans to maximise the weighted sum of benefits. Another method was for constraint levels on specific outcomes of projects to be established. This meant, for example, that choice of project would be determined by establishing that a specific level of aggregate consumption must be achieved for the nation and/or increased employment to a regional economy must be satisfied. Specification of constraint levels, which Marglin contended was superficially a different kind of decision from choice of weight, was expected to provide a method of blending conflicting objectives.

In its investigation into ways multiple objectives could be incorporated into CBA studies, the US Water Resources Council Special Task Force (1969) recommends the use of a systematic process to formulate alternative plans keyed to varying levels of achievement for each component of the multiple objectives relevant to the project. This is regarded as preferable to an explicit system of weights. An ordering of priorities among alternative projects is suggested in

terms of explicit trade-offs. The provision of information about trade-offs is expected to provide more than a single dollar value of a project's contribution to the national economy, as would be the case if a cost-benefit ratio was estimated (pp.6-7).

More recently, the *Resource Commission Act* 1989 required the Resource Assessment Commission to assess various alternative uses of resources indicating that an integrated approach to the conflict and trade-off between conservation and development aspects of natural resource use was required (*Resource Commission Act* 1989). This approach requires explicit consideration to the ecological sustainability of resource use.

2.2 Cost-benefit analysis and the environment

Project appraisal using CBA has proved to be problematic for project analysts when environmental impacts (particularly those of a negative nature) are associated with a proposed project. Two major problems have been identified. The first is the problem of valuation and the second is the choice of discount rate.

CBA requires a monetary value to be placed on all identified costs and benefits associated with a project. Where market prices are available on which to base monetary estimates of costs and benefits there is no problem. However, where there is no readily identifiable market, as is frequently the situation when environmental factors are involved, then the project analyst is required to use techniques which go beyond conventional markets to estimate or derive values. Research resources required to undertake these valuations can be substantial and questions have been raised about the validity of the results. Frequently, however, little or no attempt is made by analysts to value environmental impacts. Rather, analysts rely on making qualitative statements, leaving final decisions to the decision-maker.

The extent to which there is a trade-off between present benefits and future costs is largely determined by the choice of the discount rate. A frequent criticism of CBA is that those who receive the benefits accruing to a project are not necessarily the same people who pay the costs, or who would be expected to meet future costs. Discounting, or at least choice of an appropriate discount rate, is an important issue for environmental management. Particular concern is directed towards projects for which there could be environmental problems such as salinity, an externality which is currently a major problem in the Murray-Darling Irrigation Area, one of Australia's most productive agricultural areas. The costs resulting from the rising water table in the irrigation area were not considered in the initial conceptualisation of the development but they are presently being incurred by current landowners. In short, the beneficiaries of the irrigation development are not necessarily those who are currently paying the costs or who will be required to meet the costs in the future.

Costs caused by problems such as salinity, which could occur late in the life of an irrigation or water supply project where the effects could be long-lived, or indeed irreversible, are discounted if a positive discount rate is applied. This could reduce their impact when making a choice of project. In effect, the choice of discount rate has the effect of putting a weight on project outcomes and, in such cases, the costs to the environment in the future, which could result from the implementation of a water supply project, are minimised.

Recommendations to improve economic evaluation of projects include: improving techniques to value the environment; incorporating a sustainability constraint into the evaluation of projects with environmental implications; as well as, giving consideration to identifying and reporting possible trade-offs between economic development and sustainability criteria.

This paper contends that traditional methods for evaluating resource management programs or projects, in particular CBA and extensions of CBA, do not necessarily provide the opportunity for multiple objectives, which could be competing or conflicting, to be evaluated in a way that is transparent to all stakeholder groups. This paper proposes that a MODSS offers a participatory and transparent approach to decision-making which identifies and evaluates alternative courses of action in relation to their ability to meet the competing and sometimes conflicting needs of the stakeholders.

3.0 DECISION SUPPORT SYSTEMS

Definitions of decision support systems (DSS) range from those which are general, which include any system that contributes to decision-making, to those which are more process specific. Process specific definitions of DSSs emphasise information processing to support management decision-making, specifying a number of elements of a DSS including interactive computer-based systems that assist decision-makers to utilise available data bases and models to solve poorly structured problems. Cox (1996) regards process models as offering the potential for substantial payoffs because of the way [they broaden] the scope for shared experience and [capture] the synergy associated with combining perspectives. The construction, application and modification of models of various kinds may help bridge the gap between traditional systems of scientific thought and emerging systems of action (Cox, 1996: 28).

In this paper, a DSS implies a MODSS process model which:

- establishes the credibility of the resource problem to be addressed by putting together a comprehensive data base and or simulation model of the problem,
- incorporates the preferences of stakeholders who could have diverse and conflicting opinions and requirements from resource management,
- assists individual stakeholders or groups of individual stakeholders to identify a compromise decision, a decision which may not necessarily be the most economically efficient,
- supports, but does not replace, the judgement of individuals or groups of individuals; and,
- improves the effectiveness of the decision-making process.

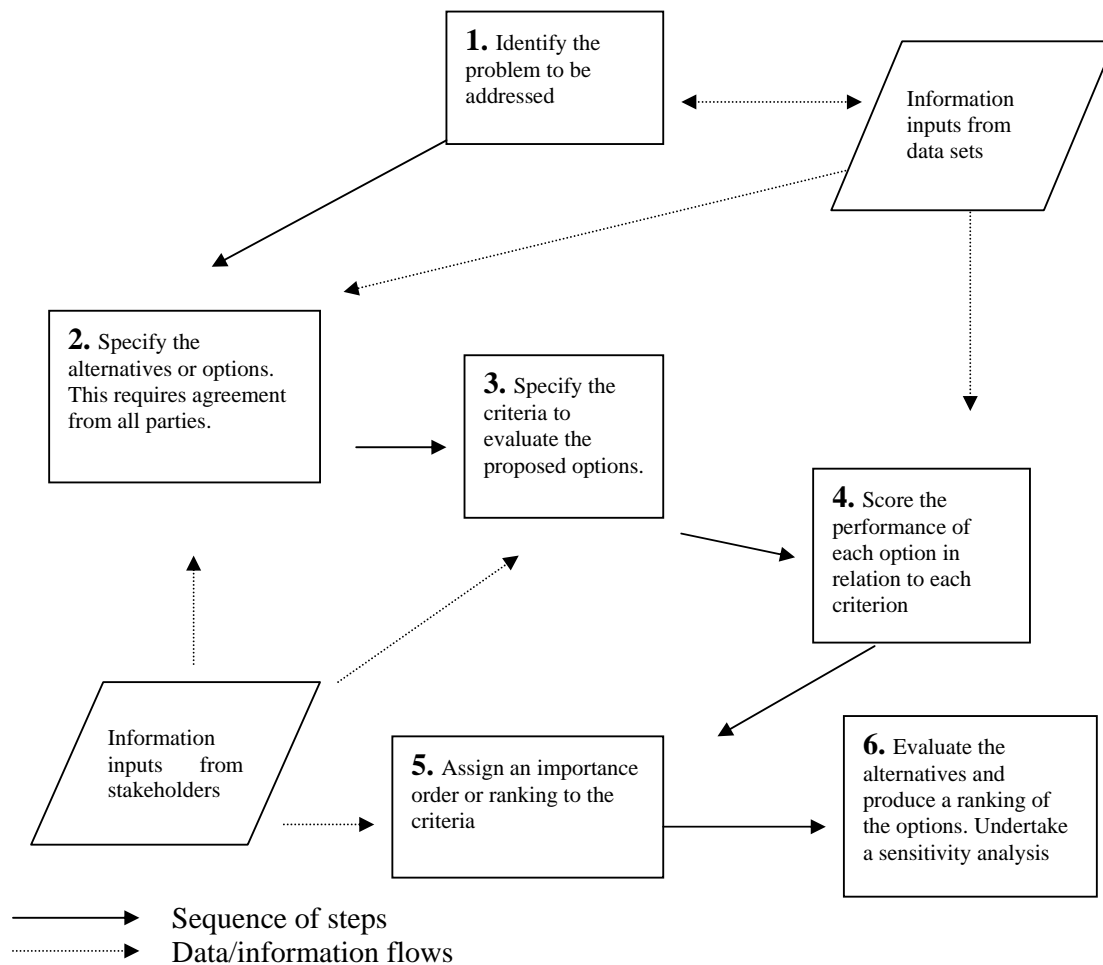
Recent trends in the application of multiple objective or multiple criteria techniques emphasise the importance of the *process* of decision-making rather than arriving at a "correct" decision. The Resource Assessment Commission (RAC) (1992) regards the objective of multiple criteria techniques to be the provision of a framework within which the effects of uncertainty and different objectives can be evaluated and explored (p.v). The Commission highlights the ability of multiple criteria techniques to deal with qualitative scores or a mixture of both qualitative and quantitative scores as well as providing flexibility to the decision-making process out of which a decision will be made.

Choices are made under conditions of uncertainty about future states and with limited information. The formulation of goals and subordinate goals on which to base a decision “will depend on the knowledge, experience, and organisational environment of the decision-maker” and can be influenced also by self-interest (Simon, 1979: 500). The MODSS process, by incorporating the available knowledge-base, including information from multiple disciplines as well as the preferences of the decision-maker or stakeholders, identifies a preferred course of action.

3.1 The MODSS process

The MODSS process is best described as a series of steps with data and stakeholder input incorporated throughout the process. These steps are summarised schematically in Figure 1. Although the steps in the analysis are presented in the order in which they would logically occur, the process is designed to be interactive with stakeholders and is likely to be cyclical with steps revisited as additional or more reliable information becomes available.

Figure 1 Schematic presentation of the steps in the MODSS process



More detailed discussion of these steps is provided in the description of the MODSS developed for the Cattle Creek Catchment.

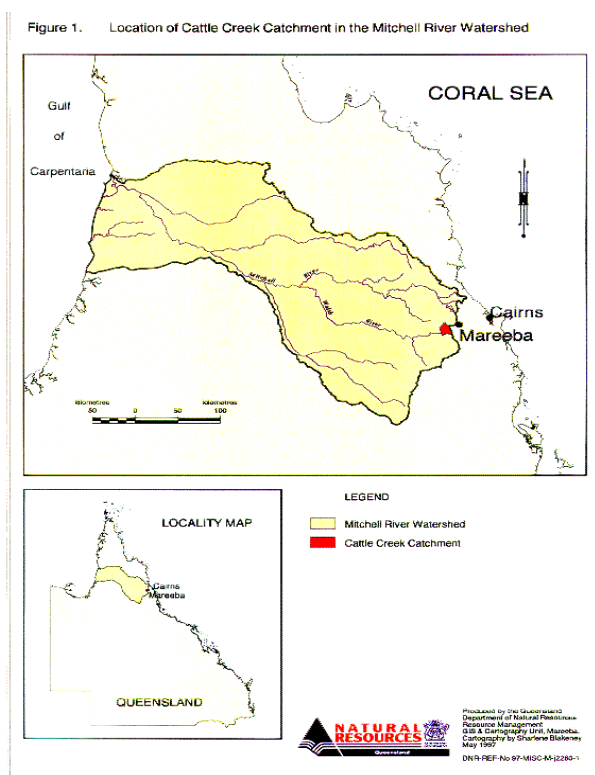
4.0 THE MODSS DEVELOPED FOR THE CATTLE CREEK CATCHMENT

4.1 *The problem to be addressed*

The Cattle Creek Catchment, which encompasses approximately 16,700ha of agricultural land within the Mitchell River Watershed in Far North Queensland, provides an appropriate case study for this paper (see Figure 2). Land and water resources in the catchment are under increasing pressure. The quality and depth to the groundwater in parts of the catchment is deteriorating whilst at the same time agriculture in the catchment is undergoing restructuring with farmers redeveloping as well as expanding production into crops which promise higher returns. Sustainable development is at risk unless current and future resource use can be managed to reduce, or at least stabilise, the groundwater problems.

Downstream of the Cattle Creek Catchment and within the Mareeba-Dimbulah Irrigation Area (MDIA) there are approximately 240 irrigators, many growing tobacco which requires irrigation water with less than 25ppm chloride. Some of these irrigators are drawing water from the Walsh River (approximately 31 per cent). These people would be affected directly by the quality of the water entering the Walsh River from Cattle Creek.

Figure 1 Location of the Cattle Creek Catchment



There are a number of characteristics about the natural resource problem in the Cattle Creek Catchment which make evaluation of the resource management options proposed for the catchment suited to a MODSS process. Firstly, the groundwater problem in the catchment is poorly defined and multiple, but not necessarily mutually exclusive, options to manage the problem have been identified. Secondly, there are multiple stakeholder groups involved with different sets of objectives or priorities for resource management. Some of the identified objectives or criteria are competing or conflicting making the ability to identify and measure any trade-offs associated with a final choice of option an essential element of the decision-making process. Finally, there is limited information and resources available to assign a monetary value to estimates of the performance of options to meet the individual objectives or criteria.

4.2 The MODSS process

The MODSS developed for the Cattle Creek Catchment was adapted from a prototype MODSS developed by the US Department of Agriculture, Tucson Arizona (Yakowitz *et al.*, 1992; Shaw *et al.*, 1998). The process closely follows the steps outlined in the schematic presentation (see Figure 1).

4.3 Data sets

Data sets about the current status of land and water resources and their management in the catchment was collected and collated by DNR (DNR, 1996). The extent of the problem, both the impact it is currently having on development and management of land and water resources in the catchment, as well as its possible future impact, was investigated and a simulation model developed (Bengtson and Doherty, 1997). The land and water data base and the groundwater simulation model increased stakeholder acceptance that a resource problem exists in the catchment and, in addition, increased the validity of the proposed options for management and their evaluation.

4.4 Incorporating information about the preferences of stakeholders

A survey of stakeholders, in particular those on whom resource management decisions are likely to impact directly, is a valuable part of the decision-making process. The survey provided an opportunity to inform people about the natural resource problem and the consequences of inaction and then to solicit their preferences about future management.

A number of management options were identified through community workshops. These included a number of soft options, such as planting trees and education; options of a regulatory nature, such as water pricing and restriction of water allocations; some requiring changes in farm management, such as efficient irrigation; and some which could best be described as engineering solutions, including an option to dewater areas at immediate risk. Criteria to evaluate, or measure the performance, of these options were identified also through community workshops. The criteria included cost considerations; the ability of an option to increase the depth to groundwater; as well as, consideration to reducing degradation downstream of the catchment. Stakeholder approval for the options and the level of support for the criteria were solicited through a survey (Robinson and Rose, 1997).

The results from the survey of stakeholders, categorised as Catchment Irrigator, Downstream Irrigator or Community Representative, suggested that all groups of stakeholders would prefer some form of resource management to be implemented, that is, they rejected the option to *do*

nothing. In addition, a ranking of the criteria by stakeholder groups demonstrated that cost and reduced degradation downstream were important considerations in the choice of management (Robinson and Rose, 1997).

4.5 Evaluating the options

MODSS presents the expected performance of management options in a score matrix, showing the score of each proposed option against individual evaluation criteria. This information can be presented to demonstrate the trade-offs underlying choice of an option as well as a ranking of options when stakeholder preferences are considered.

4.6 Scoring the expected performance of management options

The MODSS developed for the Cattle Creek Catchment provides an evaluation of options based on a scoring technique developed by Yakowitz *et al.* (1992). The scores, estimated by a number of Technical Experts, relate the numerical value of the estimated performance of an option against individual criterion to a measure of its utility, as compared to a do nothing option. The scores are standardised or converted into measures of the performance of options (such as dollars, meters per annum or qualitative measures such as high or low) within the range of 0.00 to 1.00 (Yakowitz *et al.*, 1992).

The scoring function developed for the Cattle Creek study recognised that Technical Experts would not necessarily be equally proficient at scoring the performance of options against all criteria. Specifically, the scoring function for a criterion X_i for each management option (MO_k) is defined as:

$$SC_i(X_i) = \sum E_{ij} * w_{ij} / \sum w_{ij} \quad (1)$$

Where E_{ij} is the score the j th expert placed on the i th criterion, w_{ij} is the level of competency of the j th expert in relation to the i th criterion, and SC_i is the weighted average of the Technical Experts' scores in the range of 0.0 to 1.0.

4.7 The trade-offs

The matrix of scores can be used to demonstrate the trade-offs that are implicit when an option is chosen. Table 1 provides a ranking of the estimated scores of four proposed management options against three of the criteria. It shows the trade-offs that would need to be considered when making a choice. This information is particularly valuable when stakeholders regard themselves to be in conflict with decision-making agencies.

Table 1 **Ranking the scores to show the trade-offs**

CRITERIA	MANAGEMENT OPTIONS			
	Plant trees	Efficient irrigation	Restrict water allocations	De-water
Cost to implement	1	2	3	4
Reduce degradation downstream	3	1	2	4
Increase depth to groundwater	4	2	3	1

Table 1 shows that *Plant Trees*, which was a preferred option for all groups of stakeholders, ranks well against the cost criterion, but its ranking to increase the depth to groundwater is not as impressive. The option which performed the best overall the criteria, *Efficient Irrigation*, involves a trade-off in relation to the cost and it is not the highest ranked option to increase the depth to groundwater. Interestingly, the option ranked as the most effective to increase the depth to groundwater, *De-water*, does not rank well against the other evaluation criteria.

4.8 Ranking options when the criteria are weighted

A logical progression from inspecting the trade-offs is to rank the options according to the aggregate score when the aggregate scores have been weighted according to the preferences of the stakeholders. Once an importance order or ranking of the criteria is established a ranking of options can be derived using the maximum and minimum total utility for each option. Aggregate and weighted scores are calculated for the maximum and the minimum likely performance for each option. The maximum or minimum aggregate score for each option, given the ranking of the criteria is given as:

Maximise (*minimise*):

$$\sum_{i=1}^m w(i) * Sc(i, j) \quad (2)$$

subject to

$$\sum_{i=1}^m w(i) = 1$$

and

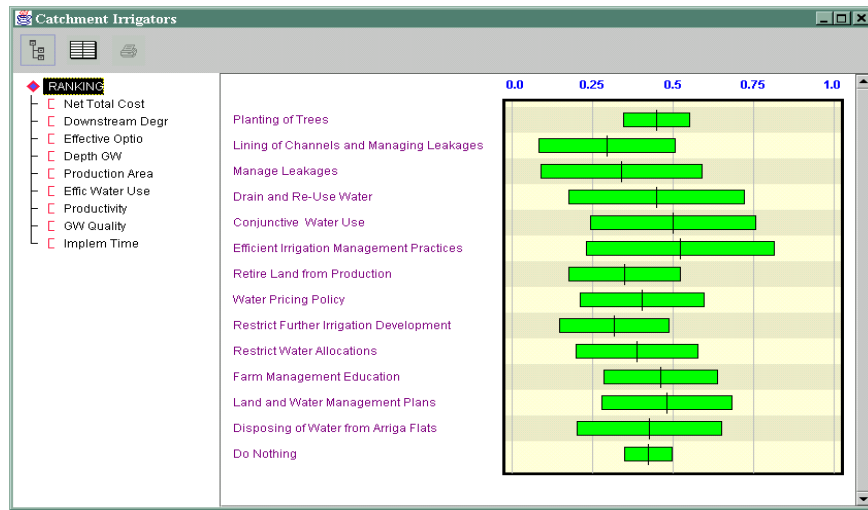
$$w_1 \geq w_2 \geq, \dots, \geq w_m \geq 0$$

where $w(i)$ = weight vector based on the ranking or importance order for criterion i ,
and $Sc(i, j)$ = score of option j evaluated or scored for decision criterion i .

These weighted, aggregate scores reflect the full range of outcomes consistent with the ranking of the criteria preferred by the stakeholders. In other words, given the ranking of the criteria, weights can be assigned to the scores for each criterion which results in a range of aggregate scores, from maximum to minimum. Calculation of the maximum and minimum aggregate scores for each option enables a ranking of options to be determined. The difference between the maximum and minimum aggregate scores for an option also provides information about the sensitivity of the scores to the weightings or importance order of the criteria.

This information is presented graphically for two groups of stakeholders, Catchment Irrigators and Downstream Irrigators, in Figures 3 and 4. The importance order of the criteria for each group of stakeholders is provided on the left of each figure. The length of the bars, determined by the ranking of the criteria, shows the difference between the maximum and minimum aggregate scores given the importance order or ranking of the criteria by groups of stakeholders.

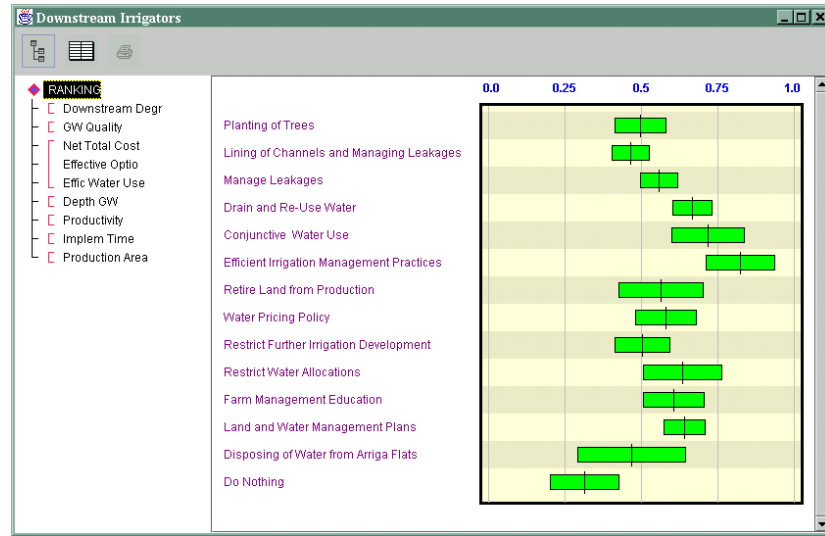
Figure 3 Performance of management options for Catchment Irrigators



Although an option may perform well in terms of its maximum aggregate score, its performance for the minimum score may be less impressive. The length of the bars is not the same for all options, for all stakeholder groups. For example, for *Efficient Irrigation* for Catchment Irrigators (Figure 3) and for Downstream Irrigators (Figure 4), shows that the ranking of the criteria by each group has a significant effect on the range of aggregate scores and that this range can impact on the ranking of the options.

Figure 3 shows the preferred ranking or importance order of the criteria for the Catchment Irrigators and the resulting performance of options. One end of the bar shows the maximum aggregate score for an option and the other end shows the minimum aggregate score. If the maximum aggregate score is adopted, then *Efficient Irrigation* is ranked first. On the other hand, if the maximum of the minimum scores is used, then the preferred option is *Plant Trees*. The performance of options for the Downstream Irrigators is shown in Figure 4 to be different.

Figure 4 Performance of management options for Downstream Irrigators



A final ranking of the options for each group of stakeholders, shown in Table 2, demonstrates that there is a compromise outcome available to stakeholders. In brief, *Efficient Irrigation* is shown to perform the best for all groups of stakeholders using the maximum aggregate score.

Table 2 Final ranking of management options, using the maximum aggregate score, for each stakeholder group, 1997

Stakeholder Group	Catchment Irrigators	Downstream Irrigators	Community Representatives
Efficient Irrigation	1*	1*	1*
Farm Management Education	4	5	5
Plant Trees	5	10	7
Land & Water Management Plans	3*	4	4
Conjunctive water use	2*	2*	2*
Lining Storage	14	12	10
Drain and reuse water	5	3*	4
Water Pricing	9	6	6
Retire Land	11	7	6
Restrict Water Allocations	10	4	3*
Manage Leakage	13	8	9
Restrict Irrigation Expansion	12	9	8
De-water	7	11	8
Do Nothing	8	13	11

* Ranked in first three.

The final ranking of options shows that although a soft option, such as *Plant Trees*, was a preferred option for stakeholders, it does not perform well against the evaluation criteria.

5.0 CONCLUSION

One of the advantages of adopting a MODSS approach to support decision-making, particularly when there are a number of options to be evaluated, and competing and conflicting criteria to be considered, is the opportunity it provides for incorporating information from a number of sources and the involvement of stakeholders. The involvement of stakeholders in the process of decision-making can diffuse a situation or prevent a situation from occurring where there are conflicting opinions and requirements from resource management. Soliciting of stakeholder preferences was used in the Cattle Creek study as a means of identifying and overcoming any conflict of interest between stakeholder groups over management of the groundwater resources in the catchment and to gain acceptance of the management options to be implemented .

The interactive and iterative approach to project evaluation goes some way towards addressing the problems highlighted earlier in the discussion about CBA where there are conflicting objectives and the weights or constraints on the project outcomes are ultimately determined by the decision-maker. The MODSS developed for the Cattle Creek Catchment demonstrates how stakeholder preferences can be incorporated into the decision-making framework to enable a compromise solution to be identified.

The management of natural resources is complex, requiring input and technical support from a number of social and scientific disciplines. The MODSS process identifies the data required to support a balanced approach to decision-making. The flexibility of the MODSS approach to accommodate both quantitative and qualitative information to score the estimated performance of options against the criteria enables trade-offs to be identified explicitly and to be given consideration within the decision-making process.

MODSS offers a formal process for decision-making as well as providing a means to measure the extent to which the options meet the project or program criteria. This paper contends that the interactive element of MODSS plays a valuable role in the decision-making process for resource management.

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