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Application of the Analytic Hierarchy Process to Riparian Revegetation Policy Options

M.E. Qureshi[1]
CRC Sustainable Sugar Production
James Cook University, Townsville, Qld 4810, Australia

S.R. Harrison
School of Economics, and Rainforest CRC
The University of Queensland, Qld 4072, Australia

While riparian vegetation can play a major role in protecting land, water and natural habitat in catchments, there are high costs associated with tree planting and establishment and in diverting land from cropping. The distribution of costs and benefits of riparian revegetation creates conflicts in the objectives of various stakeholder groups, and elicitation of importance weights of objectives and determination of rankings of a number of policy options by these stakeholder groups becomes critical in decision-making. The analytic hierarchy process (AHP) is a multicriteria analysis technique that provides an appropriate tool to accommodate the conflicting views of various stakeholder groups. The AHP allows the users to assess the relative importance of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner. This paper presents an application of AHP to obtain preference weights of environmental, social and economic objectives which have been used in ranking riparian revegetation policy options in a small catchment (watershed) in north Queensland, Australia. The preference weights towards environmental, economic and social objectives have been obtained for the various stakeholder groups (landholders, representatives of local sugar mill staff, environmentalists, recreational fishers and the local community). The AHP technique has proved useful in eliciting objectives and ranking policy options as well as in checking for consistency of the statements of stakeholder groups. Implementation of this approach requires a complex data elicitation process.

Keywords: multicriteria analysis, AHP, stakeholders, priorities, riparian vegetation, revegetation

[1] The author is currently working in the Australian Bureau of Agricultural and Resource Economics (ABARE) and the corresponding address is: Principal Research Economist, ABARE, GPO Box 1563 Canberra ACT Australia 2601, or mqureshi@abare.gov.au.

INTRODUCTION

The terms *small-scale forestry* and *farm forestry* are commonly used in Australia. These terms are applied to forestry undertaken on farms, including farm woodlots, windbreaks and shelterbelts, agroforestry and land-protection plantings, as well as harvesting of native forests (Harrison *et al*. 2002). Small-scale forests have multiple benefits and sometimes the primary benefits are not associated with timber. In the application discussed here, reforestation is carried out for streambank stabilisation, protection of instream habitat, providing a habitat for predators of agricultural pests, and other non-timber benefits.

In many agricultural areas, land has been cleared of trees close to watercourses, making riparian areas prone to erosion, bank slumping and weed and pest invasion, adversely affecting water quality and riparian biota and leading to increased downstream flooding and sedimentation. Planting trees and shrubs along riverbanks, lakes and streams is one of the elements of integrated catchment management (ICM) strategies in Queensland. The different catchment stakeholders view the desirability of riparian revegetation differently; planting and maintenance of trees and shrubs imposes costs on landholders, for the benefits of the wider community.

The desirability of revegetation of areas alongside watercourses and lakes which have been inappropriately cleared is widely recognised. According to Narumalani *et al*. (1997, p. 394), riparian buffer zones (or vegetated filter strips) are 'permanently vegetated areas located between pollutant sources and water bodies … which allow runoff and associated pollutants to be attenuated before reaching surface and underground water sources via infiltration, absorption, uptake, filtering, and deposition'. In some cases, the establishment and maintenance of vegetated riparian buffers along lake shores and creek banks has been mandated by local government (e.g. see Xiang 1996).

To determine appropriate riparian revegetation policy options, it is necessary to identify the issues to be resolved and the major parties or stakeholder groups involved. Estimates are required about what costs and benefits will arise from the alternative policies, both for individual landholders (private costs and benefits) and for the community in general (social costs and benefits). It is also important to know the perceptions and attitudes of various stakeholder groups and the preference weights they place on various objectives.

The management of natural resources, in particular riparian vegetation, in a watershed or region gives rise to frequent differences in objectives and priorities of affected parties. In these situations, the analytic hierarchy process is useful in structuring the decision problem and identifying criteria and alternatives in a logical manner. Through AHP, the judgements, personal values and preferences of each of the relevant stakeholder groups can be taken into account through explicit 'weights'. This allows users to assess the relative importance of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner. Riparian revegetation decisions are well suited to this kind of analysis, because of the multifunctional nature of riparian vegetation and its various environmental, social and economic impacts.

This paper briefly reviews the application of AHP in natural resource and environmental management. A case study is presented using AHP to obtain the preference weights of various stakeholder groups for environmental, social and economic objectives of riparian revegetation options along Scheu Creek in the Johnstone River catchment in North Queensland, Australia. Comments are made about the usefulness and role of AHP on the basis of the case study and other information.

REVIEW OF LITERATURE

The analytic hierarchy process (AHP) is a mathematical method for analysing complex decision problems under multiple criteria (Saaty 1995). The management options for a particular decision problem are characterised by their attributes with respect to a set of detailed criteria. An example of such a hierarchy is presented in Figure 1. At the top level, a goal is specified, in this case sustainable catchment use. At the second level, all the objectives or criteria are listed, which in this example are environmental, economic and social objectives. At the bottom level, all the decision options are presented.

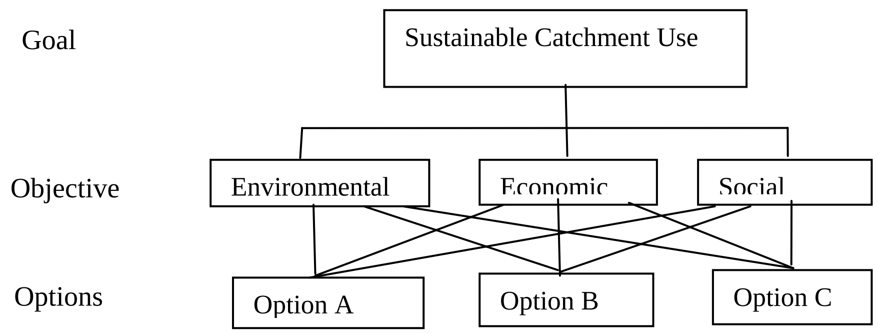

Figure 1. Example of an AHP structure

Criteria or objectives can be divided into sub- or sub-sub-criteria (objectives) for additional information and for clarification and refinement. Criteria can be subjective (such as impact of trees on recreational values) or objective (such as tree planting cost), depending on the means used in evaluating the contribution of those criteria below them in the hierarchy. Criteria are regarded as mutually exclusive and do not depend on the elements below them in the hierarchy.

AHP has been applied in many and diverse areas of decision-support, with respect to natural resource and environmental management in Australia and overseas, a selection of applications being indicated in Table 1.

Saaty and Gholamnezhad (1982) used AHP in comparing options for management of high-level nuclear waste, a complex decision problem involving many factors of a technological, environmental, social and political nature. They argued that there are many alternatives being proposed for the disposal of waste but, because of the lack of data, it is not an easy task to find the best alternative. In large part, the decision depends on the judgements of experts.

Table 1. Application of AHP in natural resource and environmental management

Author/s and country	Application area
Saaty and Gholamnezhad (1982), USA	Evaluation of strategies for the safe disposal of high-level nuclear waste
DiNardo *et al*. (1989), USA	Fisheries management in Maryland's river herring fishery
Kangas and Kuusipalo (1993), Finland	Integration of biodiversity into forest management planning and decision-making
Kangas (1994), Finland	Participative forest management planning of a nature conservation area
Reynolds and Holsten (1994), Canada	Determining relative importance of risk factors for spruce beetle outbreaks
Alho and Kangas (1997), Finland	Analysing uncertainties in experts' opinions of forest plan performance
Diaz-Balteiro and Romero (1997), Spain	Timber harvest scheduling problems with multiple criteria
Mainuddin *et al*. (1997), Thailand	Optimal crop planning for a groundwater irrigation project
Malczewski *et al*. (1997), Mexico	Multicriteria group decision-making for environmental conflict analysis
Itami and Cotter (1999), Australia	Ranking issues, projects and sites in integrated catchment management
Itami *et al.* (2000), Australia	Capturing expert knowledge for land capability assessment
Weiss and McLaren (2002), Australia	Pest plant prioritisation process in weed management

DiNardo and others (1989) noted that a major attraction of AHP is that it provides a framework for the decision-support process that is lacking in most fishery management agencies. They considered four groups of major factors or criteria for Maryland's river herring fishery, namely biological, political, economic and social. Three fishery management policy alternatives were compared with respect to each criterion. The authors concluded that AHP can provide a useful tool to assess policies regarding multi-species management and resource allocation among user groups.

Kangas and Kuusipalo (1993) used AHP to integrate biodiversity into forest management planning. They regarded biodiversity as comprising three species characteristics, namely richness, rarity and vulnerability. Importance weights of the components of biodiversity were assessed by pairwise comparisons, provided by an expert in conservation biology. In the planning problem of multiple-use forestry, maximising biodiversity was added as an objective to a decision hierarchy. The weighting of biodiversity, in relation to other objectives, was based on the preferences of the forest managers.

In a related paper, Kangas (1994) applied AHP for taking public preferences into account in choosing the management strategy for a forest area. Kangas argued that there is no limit on the levels in the planning hierarchy to which AHP can be applied in management planning. Kangas applied the approach at the national level for optimising the number, size and spatial distribution of protected natural areas with respect to various dimensions of biological diversity. This allowed the local, regional and national economic and social consequences of such protection to be compared. In a subsequent study, Alho and Kangas (1997) used AHP and a Bayesian extension of the regression technique to aid forest owners in the planning of future treatment schedules under uncertainty.

Reynolds and Holsten (1994) analysed relative importance of risk factors for spruce beetle outbreaks in Alaska, organising these risk factors into a hierarchical model. They argued that AHP is an effective method for eliciting expert knowledge and can be a useful tool for development of expert systems in natural resource management, where even expert knowledge is often incomplete.

Diaz-Balteiro and Romero (1997) derived preference weights from the application of AHP to a group of forestry experts. They incorporated these weights in a goal programming model, and tested several utility formulations including an additive and a Rawlsian function. This approach accommodated the multiplicity of criteria involved in the forest planning problem, and the solution generated by the model could be incorporated in utility terms without resort to complex multi-attribute utility formulations.

Mainuddin and others (1997) used AHP to select the optimal cropping plan in a multi-objective analysis, taking into account the preferences of the decision-makers, including farmers and irrigation project managers.

Malczewski and others (1997) developed a model to deal with a multicriteria group decision-making problem involving a set of feasible land-use options. The AHP was integrated with integer mathematical programming. They argued that the land suitability coefficients derived from AHP represent the contributions of particular attributes to the overall goal. When analysed by means of integer programming, the land suitability coefficients may be used to determine the land-use pattern that maximises consensus among interest groups.

Itami and Cotter (1999) applied AHP to three types of integrated catchment management problems (namely issues, projects and sites) in Victoria, Australia. They developed a software package called ‘Catchment Decision Assistant’ to link the AHP decision-making framework to geographic information systems. They used the package to: record the criteria and decision hierarchy; generate weights for each criteria; provide a framework for rating issues, projects and sites against the criteria; and report the results in tabular form (with mapping of sites). They reported the results of two pilot studies in the application of AHP to regional catchment issues including pest plants and biodiversity.

Itami *et al*. (2000) examined the utility of AHP as a tool for capturing knowledge on environmental systems where data are lacking. They argued that AHP has great potential for integrating judgements of experts with scientific information. They linked this technique to geographic information systems to overcome AHP limitations for ranking catchment issues that have a spatial dimension. This study demonstrated the use of AHP for capturing the knowledge of horticultural experts to rate factors for assessment of biophysical capability for horticultural crops, for the West Gippsland Catchment Management Authority in Victoria, Australia. The authors noted a caution in use of AHP; because the technique assumes linear relationships between variables, there are many cases where the pairwise comparison technique is not appropriate. However, the method of building a tree-structured hierarchy for criteria is seen as a productive framework for capturing expert judgement.

Weiss and McLaren (2002) develop an AHP-based risk assessment model that can be applied as a stand-alone procedure or integrated with a GIS-based system to determine resource conditions and then the risk or threat that weeds pose to these values. These authors argued that the AHP process allows for consultation with land managers to identify what land values are important to them and to place importance weights on these values. Weeds then can be assessed as threats against these values.

CASE STUDY ON APPLYING THE AHP TO ESTIMATE IMPORTANCE WEIGHTS ASSOCIATED WITH RIPARIAN REVEGETATION OPTIONS

Scheu Creek in the Johnstone River catchment in north Queensland runs for 13 km through predominately sugar cane land. Farmers along the creek have cleared trees off the banks and in some sections straightened the creek, increasing the water velocity and ultimately the risks of downstream flooding. Prolific growth of Para Grass (*Brachiaria mutica*) has reduced creek depth and flow capacity. Soil erosion is a common problem in the catchment and the creek is heavily degraded due to sedimentation. Sedimentation has reduced the depth and the attractiveness of local swimming holes. Water quality has deteriorated and fish numbers are low. To improve the quality of the degraded creek, a number of riparian revegetation policy options have been identified which differ in their environmental, social and economic impacts. The AHP has been applied to obtain preference weights for the objectives and sub-objectives by the various catchment stakeholder groups in multicriteria evaluation procedures for ranking alternative vegetation options.[2] Riparian plantings of trees and shrubs is carried out mainly for non-timber benefits, including streambank stabilisation, erosion control, instream habitat for aquatic biota, and habitat for sugarcane pest predators. While some valuable timber species are planted, and could subsequently be harvested, the future regulatory environment for timber harvesting is difficult to predict.

Identification of Objectives and Sub-Objectives

Major objectives and various sub-objectives of stakeholder groups with respect to riparian land management were investigated by Harrison and Qureshi (1999) in a survey of catchment management experts attended a riparian vegetation workshop at Innisfail. A list of potential impacts was presented, and respondents indicated those impacts they considered most important. These have been grouped under three objectives (environmental, social, and economic) with six environmental, three social and three economic sub-objectives, as in Table 2. Several potential issues

[2] Further details of this application can be found in Qureshi (1999) and Qureshi and Harrison (2001). The presentation here focuses particularly on application of the AHP approach and utility of the technique.

judged by the respondents to be of relatively low importance were excluded from this analysis, including greenhouse gas emissions, unemployment, affect on boating due to water odours, and impact on the Great Barrier Reef.

Table 2. Environmental, economic and social sub-objectives of stakeholder groups

Environmental sub-objectives	Social sub-objectives	Economic sub-objectives
Protection of groundwater quality Protection of surface water quality Protection of land stability Protection of watercourse stability Protection of ecological values of land habitat Protection of stream habitat	Protection of human health Protection of recreational fishing Protection of recreational values	Reduction in loss of crop land Reduction in water treatment cost

Source: Harrison and Qureshi (1999).

Identification of Appropriate Revegetation Policy Options and Stakeholder Groups

The appropriate design and width of riparian vegetation buffers is a matter of considerable debate, in part due to the multi-purpose nature of these strips, e.g. dense grass can control runoff problems but only large trees will bind banks and reduce summer water temperatures. Conservation agencies would like the buffers to be wide and well wooded. Farmers are loath to divert cropping land from growing sugarcane.

The Harrison and Qureshi (1999) survey revealed that riparian vegetation in the form of trees is the most favoured repair practice. Depending on the location on the bank profile, various species have been suggested as appropriate in previous studies, e.g. Goosam and Tucker (1995) and Bell (1996). Width of tree planting could be varied depending on the location along the creek and position in terms of straight reaches and meanders. After discussions with the scientists (involved in a riparian revegetation project) of the Queensland Department of Natural Resources and Mines and the Johnstone River Catchment Management Association Inc., four riparian revegetation options were identified for Scheu Creek, namely:

Option A: 3 m vegetated buffer inside meanders, 6 m buffer outside meander, 3 m buffer along straight reaches.

Option B: 5 m vegetated buffer inside meanders, 10 m buffer outside meander, 5 m buffer along straight reaches.

Option C: 5 m vegetated buffer inside meanders, 5 m buffer outside meander, 5 m buffer along straight reaches.

Option D: 10 m vegetated buffer inside meanders, 10 m buffer outside meander, 10 m buffer along straight reaches.

While much has been written on the importance of taking account of the interests of the various stakeholder groups, there is far less guidance in the literature as to how to identify appropriate stakeholder groups and their representatives, in a natural resource management context. Harrison and Qureshi (2000) addressed two questions: (a) how should relevant stakeholder groups for management of a particular resource bundle be identified; and (b) how should individuals be selected to represent the interests and objectives of the selected stakeholder groups. The first of these questions involves selecting the most appropriate groups or individuals for which objectives and preference weights are to be derived. The second involves issues of sample size and sample selection methods.

After identifying issues in the catchment and discussions with regulatory agencies, five major stakeholder groups were identified, namely farmers, sugar mill workers, environmentalists, recreational fishers and the local community. The decision was made not to include government departments involved in catchment management or tourists to the Great Barrier Reef.

The Stakeholder Survey

To elicit the preferences and weights of the stakeholder groups with respect to the major goal, the objectives, the sub-objectives, and the revegetation policy options, a hierarchy was formed and then a questionnaire was developed using the hierarchy framework. The hierarchy consisted of four levels, with 19 nodes[3], calling for a total of 93 pairwise comparisons. *Level 1* defines the central aim or major goal of the decision problem, i.e. sustainable catchment use. At *level 2*, the major goal is decomposed into three major objectives for sustainable catchment use, namely environmental, social and economic objectives. At *level 3***,** each objective is divided into sub-objectives which are meaningful to various stakeholder groups. The objectives are partitioned logically in a top-down fashion into another level representing their sub-objectives. *Level 4* or the lowest level of the hierarchy represents the four revegetation policy options.

The questionnaire comprised 96 questions in five sections. Section A included questions regarding preferences of the five stakeholder groups towards environmental, social and economic objectives. In each question, the respondents were asked to compare each objective with other objectives with respect to the goal. Section B consisted of questions designed to elicit preferences towards various environmental sub-objectives and respondents were asked to compare each environmental sub-objective with other environmental sub-objectives. In Sections C and D, questions were designed to identify the most important social and economic sub-objectives respectively. Section E contained questions to elicit preferences of the stakeholder groups for revegetation policy options with respect to each sub-objective of the three major objectives.

[3] Nodes represent the elements of decision including objectives, sub-objectives and policy options.

Respondents were asked to choose between various pairs of statements. For example, to elicit preferences for environmental versus social objectives, the following set of statements was presented to each respondent:

For sustainable catchment use, environmental issues are:

☐	*equally as important as*		
☐	*moderately more important/moderately less important*	☐	*than*
☐	*strongly more important/strongly less important*	☐	*than*
☐	*very strongly more important/very strongly less important*	☐	*than*
☐	*extremely more important/extremely less important*	☐	*than*
	social issues.		

When completing this question, a tick on the left side meant preference for the first objective over the second, while a tick on the right side meant preference for the second objective over the first. The five statements correspond to importance weights of 1, 3, 5, 7 and 9 in the Saaty (1995) scale. Prompt cards were used during interviews to explain the structure of the questionnaire and to present the questions. Farmers are potentially the group most affected by riparian revegetation; 13 of the 15 farmers agreed to be interviewed. Only one person – generally a recognised spokesperson – was interviewed from each of the other stakeholder groups. Interviews took about two to three hours, and were demanding on the concentration of stakeholders.

Estimation of Relative Priorities of the Major Objectives and Sub-Objectives

A Microsoft Excel spreadsheet has been used to calculate average scores of the objectives and the sub-objectives. Mean scores were calculated from the individual scores on the scale of 1 to 9 provided by the 13 farmers. The Expert Choice software package (E.C. Inc. 1995) based on the analytic hierarchy process (AHP) has been used to estimate weights of the importance of the three major objectives (environmental, economic and social) and their sub-objectives, and to test for inconsistency between preferences within individual stakeholder groups.[4] This package has also been used to estimate rankings of the four revegetation policy options for the stakeholder groups.

Graphs of the weights of the objectives and sub-objectives may be used to represent the relative priorities of stakeholders (Figure 2). Each circle in the figure indicates the importance of an element. For example, in Figure 2 the economic objective is 3.3 times as important as the environmental objective and 3.6 times as important as the social objective. The environmental and social objectives are considered equally important.

[4] The AHP was developed by Saaty (1990) and involves processes of normalisation, synthesisation and ranking of alternative options. The AHP deals explicitly with inconsistencies among the pairwise comparative judgements. The mathematical description and detailed procedure for testing for inconsistency are discussed by Saaty (1990, 1995).

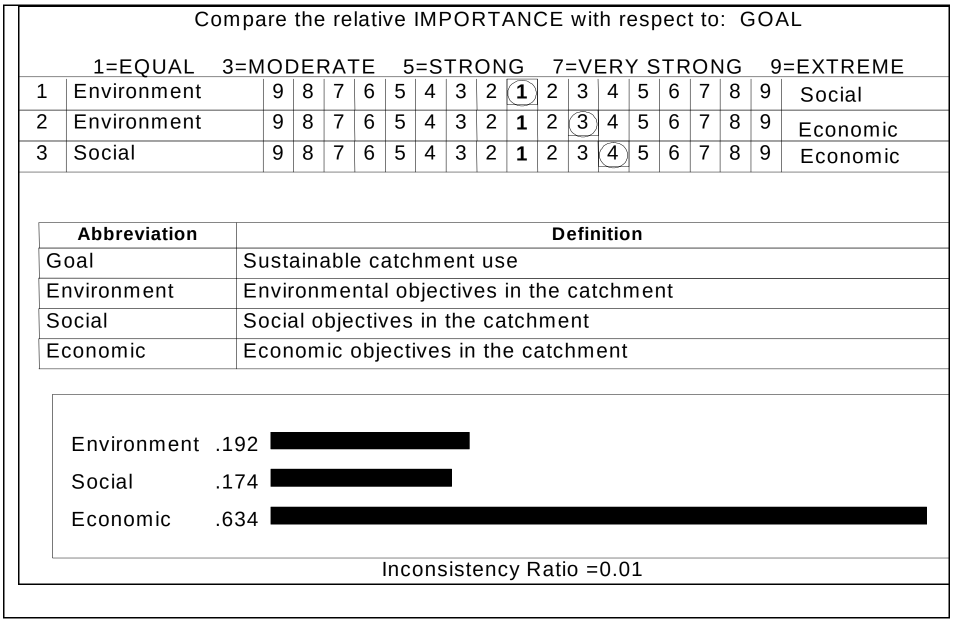

Figure 2. Graphical presentation of farmer preferences of the three objectives

Priorities for each objective and sub-objective of the five stakeholder groups, and inconsistency ratios for these, are presented in Table 3. The first column corresponds to the information in Figure 2. The pairwise comparisons by the sugar mill representative similarly accorded the highest priority to the economic objective, with equal priority for the social and environmental objectives. Representatives of fishers, local community and environmentalists placed highest priority on the environmental objective, followed by the economic and then the social objective. All groups placed a low weight on social objectives.

Table 3. Priorities assigned by the five stakeholder groups

Objective	Priority				
	Farmers	Sugar mill staff	Fishers	Local community	Environmentalists
Environmental	0.192	0.143	0.659	0.762	0.701
Social	0.174	0.143	0.156	0.076	0.097
Economic	0.634	0.714	0.185	0.198	0.202
Inconsistency ratio	0.010	0.000	0.030	0.420	0.130

Table 3 reports a relatively high inconsistency ratio for the representative of the local community.[5] Had time permitted, it would have been preferable to re-interview these informants. It is to be noted however that people's preference systems are sometimes inconsistent, so that re-interview would not necessarily remove this problem, though it would provide the opportunity to probe particular tradeoffs contributing to inconsistency.

Weights Assigned to Sub-Objectives

For each lowest level sub-objective, pairwise comparisons for each alternative have yielded stakeholder preference weights as reported in Table 4. Some clear differences arise between stakeholder groups. For example, the environmental sub-objective of protecting surface water quality was given a high weight by fishers, and this sub-objective and protection of stream habitat were highly weighted by environmentalists. Farmers placed a high weighting on the economic sub-objective of reduction in loss of cropping land. The local community representative placed highest weights on the environmental sub-objectives of watercourse stability and land habitat respectively, while the sugar mill staff representative gave the highest weights for the economic sub-objectives of reduction in offsite damage costs and water treatment cost.

Table 4. Weight assigned to each sub-objective by the five stakeholder groups

Sub-objective	Stakeholder Group				
	Farmers	Sugar mill staff	Fishers	Local community	Environmental-ists
Groundwater quality	0.019	0.010	0.057	0.018	0.041
Surface water quality	0.023	0.011	0.160	0.019	0.067
Land stability	0.043	0.030	0.037	0.157	0.067
Watercourse stability	0.041	0.053	0.114	0.242	0.122
Land habitat	0.029	0.023	0.131	0.180	0.202
Stream habitat	0.035	0.015	0.160	0.108	0.202
Protection of human health	0.128	0.107	0.112	0.060	0.062
Protection of recreational fishing	0.023	0.017	0.022	0.013	0.010
Protection of recreational values	0.024	0.019	0.022	0.003	0.025
Loss of land	0.349	0.127	0.026	0.010	0.013
Water treatment cost	0.133	0.217	0.026	0.094	0.054
Off-site damage cost	0.152	0.371	0.132	0.094	0.136

[5] It has been suggested by Saaty (1990) that inconsistency levels of up to 0.10 are acceptable.

Ranking of Revegetation Policy Options

The final step in the analysis is to rank revegetation policy options. This consists of deciding which revegetation policy option is preferred by each stakeholder group. Ranking of options involves not only preference weights of each objective and sub-objective but also estimation of environmental, social and economic impacts of each policy option (in the MCA procedure). Environmental and social impacts of each revegetation option were estimated as pluses and minuses (Qureshi and Harrison, 2001a). Economic impacts were estimated as net present value, taking into account revegetation establishment and maintenance costs, foregone cane production, and unpriced benefits of crop protection and watercourse and downstream benefits, as reported in Qureshi and Harrison (2001a, 2001b). The various impacts or 'effects' and their scores are reported in Table 5.

Table 5. Effects, revegetation options and their scores

Objective	Effect	Unit	Option A	Option B	Option C	Option D
Environmental	Protection of groundwater quality	---/+++	+	+	+	+++
	Protection of surface water quality	---/+++	++	++	++	+++
	Protection of land stability	---/+++	+	++	++	+++
	Protection of watercourse stability	---/+++		++	++	+++
	Protection of land habitat	---/+++		++	++	+++
	Protection of stream habitat	---/+++	+	+++	++	+++
Social	Protection of human health	---/+++	+	+	+	+
	Protection of recreational fishing	---/+++	+	+	+	+
	Protection of recreational values	---/+++	+	+	+	+
Economic	Net present value	$1,000	-222	-417	-337	-736

Source: Qureshi and Harrison (2001a).

Environmental, social and economic impacts were aggregated using the MCA software package DEFINITE (Janssen and van Herwijnen, 1994). Revegetation options were ranked using three MCA evaluation methods available in DEFINITE, namely Weighted Summation, Expected Value and Evamix. These methods incorporate both quantitative and qualitative information and standardise the estimated values for each objective. Assignment of importance weights to objectives is a critical step in MCA evaluation because it allows rankings of the various revegetation options to be expressed explicitly. The weights assigned to each objective by the five stakeholder groups using AHP (presented in Table 4) were multiplied by the standardised values of the objectives. Once the preference weights to each objective were assigned, the three MCA evaluation methods determined the optimal riparian revegetation options for each stakeholder group.

For both farmers and sugar mill staff, Option A dominated all other options, followed by Option C, B then D. The representative for recreational fishers ranked Option D ahead all other options under all evaluation methods, followed by Option B, C and A. Rankings by the local community representative were similar except Options C and B are tied under the Weighted Summation method. For environmentalists, under the Weighted Summation and Evamix methods, Option D was most preferred, while under Expected Value method Option B is most preferred. In summary, narrow riparian buffers were most acceptable to farmers and sugar mill staff, while the other stakeholder groups preferred wider buffers.

Rankings of policy options differ between stakeholder groups because of differences in the weights they attach to objectives. The socially preferred option could be A (preferred by farmers and sugar mill staff) or D (preferred by other stakeholders), or it could be some compromise between them. According to the discounted cash flow (DCF) analysis, the do-nothing option is the best approach for farmers because they do not suffer new outlays or loss of cane land. This option is acceptable if its social costs are minor or negligible. But according to the findings of MCA, there are social and environmental costs of not growing trees along the creek (i.e. not accepting any of the options A to D), and there are considerable benefits from implementing any of these options.

The results indicate that MCA does not determine which option is best, but only how each option affects each stakeholder group. No unique optimal revegetation policy can be identified unless a relative importance weight is attached to each of the stakeholder groups. However, political decision-makers with advice of resource management advisers in government have responsibility to decide on a revegetation policy which is socially optimal or near optimal (even if it is the do-nothing policy). A knowledge of the number of members in each stakeholder group, the initial property rights allocation, and the political feasibility of implementing riparian revegetation, would be off assistance to decision makers in this task. The analyst has limited ability to make the inter-group comparison, which is perhaps best handled by the political process.

Once an option is chosen, it must be implemented. Choice of implementation method involves questions of property rights and responsibilities, e.g. should landholders be required to repair riparian areas cleared in earlier decades (a *polluter pays* perspective) or should government assistance be provided (a *beneficiaries compensate* perspective). Economic instruments and regulatory approaches can play a role in implementation of the chosen riparian revegetation option. The former could include grants and subsidies, charges or fines on polluters, development rights, rate rebates and tax incentives. Tax deductions in combination with subsidies might be a better approach than coercive power through legislation, being less divisive in the community and avoiding enforcement costs.

CRITICAL REVIEW OF THE USES AND LIMITATIONS OF AHP

The AHP is by nature a multi-stakeholder and multicriteria approach to decision-support, well suited to examining tradeoffs between landholders and other interested parties in land management planning. Within a multicriteria analysis framework, it can be a powerful decision-support tool. While the attractive features of this approach are evident, some comment about limitations is warranted, and indeed Multi-Criteria Analysis (MCA) and Multi-Objective Decision Support Systems (MODSS) methods in general have their share of detractors. Some of the pros and cons of this approach are listed in Table 6, based on experience in the research reported here.

Table 6. Favourable features and drawbacks of the analytic hierarchy process

Favourable features	Drawbacks
A systematic approach is provided to identification of stakeholder objectives and preferences.	Priority rankings are confined to within stakeholder groups, and little assistance is provided towards dispute resolution.
Economic and non-economic (including social and environmental) objectives and sub-objectives can be taken into account in the assessment of management options.	There is lack of agreement on how to identify stakeholder groups, and how to select samples or representatives from them.
Quantifiable and non-quantifiable factors can be included in the analysis.	Questionnaire development can be difficult and time consuming.
Scientific judgment can be combined with personal opinion in the evaluation of policy alternatives.	Stakeholder interviews can be long and demanding of the interviewer and interviewee.
Relatively simple pairwise comparison allows elicitation of preferences for objectives by stakeholder groups.	The highly subjective nature of preference weights and rapid elicitation can lead to questions of validity.
The desirability of alternative management options can be ranked for individual stakeholder groups.	Problems with inconsistencies in preferences between objectives sometimes arise.
It can be a relatively rapid and low-cost approach.	AHP is sometimes thought of as a ‘soft’ decision-support approach, which does not tackle the difficult estimation problems.
	Results are not always widely accepted.
	Unrealistic expectations about policy decisions can be generated.

MODSS are sometimes branded ‘soft’ decision support approaches, in comparison with more detailed resource inventory and analysis methods. The AHP can be viewed by a community as a public consultation process that takes their views and aspirations into account, and generates expectations about management decisions. This can have a downside if tough decisions have to be made to arrest resource degradation. Anecdotal evidence suggests the decision-makers and other stakeholders are not automatically swayed by these kinds of methods; each stakeholder group may still insist on its preferred criteria and options. However, AHP does clarify the tradeoffs involved, and make the impacts of any particular course of action more transparent. In the case study, the AHP was linked with a generic multicriteria analysis model, and provided a means of structuring the decision problem and estimating importance weights for the objectives of the various stakeholder groups.

A drawback sometimes arises with AHP known as ‘rank reversal’, which is associated with the relative nature of the judgements involved. Here, changing the set of alternatives changes the ranking of all alternatives. If new alternatives are likely to be added to the model after initial analysis, and alternatives are amenable to a direct rating approach (i.e. not so qualitative as to require pairwise comparison), then an approach in which ratings of alternatives are assigned directly (such as the Simple Multi-Attribute Rating Technique or SMART) could be a better choice.

CONCLUDING COMMENTS

Clearing of trees and shrubs close to watercourses has made riparian areas prone to erosion, bank slumping and weed and pest invasion. It has adversely affected water quality and riparian biota and led to increased downstream flooding and sedimentation. Riparian buffer strips are a widely favoured method for protecting watercourses and water bodies from farmland activities. Re-establishment and maintenance of trees and shrubs imposes costs on landholders, for the benefits of the wider community. Typically, a variety of riparian revegetation options are possible, and differences arise in the objectives and priorities of affected parties. In these situations, AHP is useful in structuring the decision problem and identifying criteria and alternatives in a logical manner. The judgements, personal values and preferences of each of the relevant stakeholder groups are taken into account through explicit ‘weights’. Riparian revegetation decisions are well suited to this kind of analysis, because of the multifunctional nature of riparian vegetation and its various environmental, social and economic impacts.

The case study found that environmental, social and economic impacts could be identified for riparian revegetation options for the catchment stakeholder groups in Scheu Creek, a highly degraded small catchment in north Queensland. Clear differences in rankings of the revegetation options arose from the differing objectives of the various stakeholder groups, and no single optimal policy could be identified by MCA.

The information generated by this type of analysis is useful for resource managers when examining the appropriateness of alternative riparian revegetation options. The implementation of any revegetation policy would lead to some loss of land from farming. While there would be considerable social benefits, farmers would be loath to give up crop land. Typically, legislative acts available to protect natural resources do not have the capacity to force farmers to implement revegetation option (Qureshi and Harrison 2002). The findings of the current study can be used to demonstrate to the farmers and government agencies about need of riparian revegetation in the catchment and the benefits for society. If costs are made clear, landholders may be convinced to change their riparian land management by moral suasion and financial subsidy, avoiding the long lead-time, enforcement cost and social disharmony of compulsion by legislation or regulation.

A critical evaluation of AHP calls into question the role of multicriteria analysis methods in general. While an MCA can be conducted without resort to AHP, the converse in general is not true, that is, it is not really possible to evaluate AHP except in the wider context of multicriteria analysis. AHP has been used in many studies and stands on its own; however, it can complement other multicriteria methods by providing a sound basis of eliciting weights essential for these techniques. MCA approaches have been developed because of the clear need in natural resource management, especially when working at a scale beyond the individual property, to develop approaches which take account of the views of many parties with vested interests.

AHP is not so much a non-market valuation method as a means of integrating market and non-market values in the one analysis, where the latter are expressed in non-monetary terms. This can avoid the need for difficult non-market valuation efforts, and can be a major advance over simply treating non-economic factors as constraints. Alternatively, economic assessment can become a second tier of the AHP prioritisation process that allows for scenario building of different management options and their assessment.

AHP, and MCA methods in general, are highly effective for identifying conflicts between stakeholder groups, but not particularly useful for dispute resolution. There are many cases where the pairwise comparison technique is not appropriate and caution should be taken in using AHP for natural resource problems because the technique assumes linear relationships between variables. However, the method of building a tree-structured hierarchy for criteria is seen as a useful and transparent framework for capturing expert judgement. These methods have their advocates and detractors, and more experience probably is required before clear guidelines can be laid down as to when they are most appropriate.

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