Reconciling Value Conflicts in Regional Forest Planning in Australia: A Decision Theoretic Approach

J. ANANDA
G. HERATH

Poster paper prepared for presentation at the
International Association of Agricultural Economists Conference,
Gold Coast, Australia, August 12-18, 2006

Reconciling Value Conflicts in Regional Forest Planning in Australia: A Decision Theoretic Approach

Reconciling Value Conflicts in Regional Forest Planning in Australia: A Decision Theoretic Approach

1. Introduction

Policy making in forest management in Australia has always been divisive and controversial. Inadequate participation of stakeholders in policy decisions, lack of knowledge of their values and attitudes, conflicting multiple objectives and values pose a considerable challenge to forest policy planning and implementation. In 1992, the Commonwealth and State/Territory level governments entered into Regional Forest Agreements (RFAs) after several decades of conflict and debate over the management of Australia's forests (Dargavel 1995, 1998) RFAs involve agreements between the Commonwealth and State governments for the future management of specific forest areas taking into account economic, conservation and heritage and social impacts of various strategies (Coakes 1998).

After a decade of experimentation, it is argued that the RFAs have not reconciled the core values held by the stakeholders and disagreements prevail in several Victorian RFA regions (Bartlett 1999; Brunet 2000). Broad scale tree clearing still occurs in Queensland and New South Wales (NSW) despite the RFA process (Brunet 2000). Public participation (Kirkpatrick 1998; Mobbs 2002) in the RFAs did not effectively integrate stakeholder values in the final outcome (Dargavel *et al*. 2000). The key to successful forest management is gaining a thorough understanding of the stakeholders objectives and preferences in designing appropriate management strategies. Forest management is evolving into a multi-objective management approach.

Techniques of multi-criteria decision analysis (MCDA) can simplify and structure the forest management problem, facilitate explicit incorporation of multiple values, preferences and risk attitudes of stakeholders. These techniques can also accommodate conflicting values of the affected parties to arrive at a compromise (Martin *et al*. 2000; Russell *et al*. 2001). Three MCDA techniques namely Analytic Hierarchy Process (AHP), Multi-Attribute Value Theory (MAVT) and Multi-Attribute utility theory (MAUT) have been used in forest management in the past (Kangas 1994; Proctor 2000)

The aim of this paper is to :

(a) identify stakeholder objectives, preferences and risk attitudes for forest attributes in North East Victoria using AHP, MAVT and MAUT;
(b) develop optimal forest management strategies under AHP, MAVT and MAUT and compare them with each other ; and
(c) identify implications of the study in developing better forest management strategies .

The MCDA techniques used in this study are outlined in the next section. Section 3 describes the empirical application of MCDA methods in the North East Victoria forest region. Section 4 presents the comparative results of the three methods and some concluding remarks in section 5.

2. Research Methods

2.1 Analytic Hierarchy Process (AHP)

The AHP, developed by Saaty (1977, 1980), is a mathematical method based on a general theory of ratio scale measurement for analysing complex decisions with multiple criteria. In AHP the importance or preferences of the decision elements are compared in a pairwise manner. The decision maker has the option of expressing his or her intensity of preference on a nine-point scale. If two criteria are of equal importance, a value of 1 is given in the comparison, while a 9 indicates the absolute importance of one criterion over the other. Pairwise comparison data can be analysed using either regression methods or the eigenvalue technique. In the eigenvalue technique, reciprocal matrices of pairwise comparisons are constructed. Using the pairwise comparisons, the relative weights of attributes can be estimated. After generating a set of weights for each alternative under any criterion, the overall priority of the alternatives is computed by means of a linear, additive function. A Consistency Index (CI) measures the inconsistencies of pairwise comparisons is given in equation (1):

$$CI = (\gamma_{max} - n)/(n-1) \qquad (1)$$

Saaty (1977) has shown that the largest eigenvalue, γ_{max}, of a reciprocal matrix is always greater than or equal to n (number of rows or columns). The more consistent the comparisons, the closer the value of computed γ_{max} to n. The coherence of the pairwise comparisons can be measured by a Consistency Ratio (CR), given in equation (2),

$$CR = 100\ (CI/ACI) \tag{2}$$

where ACI is the Average Consistency Index. A CR value of 10 per cent or less is considered as acceptable (Kangas 1994).

2.2 Multi-Attribute Value Theory (MAVT)

The MAVT is a useful framework for decision analysis with multiple objectives (von Winterfeldt and Edwards 1986). The simplest and most commonly used value function is the additive representation, which is the summation of several single attribute value functions. Assuming mutual preferential independence, attributes x_1, x_2 and x_3 can be incorporated into a value function in the following additive form (Keeney and Raiffa 1976):

$$v(x_1, x_2, x_3) = \sum_{j=1}^{n} \lambda_j v_j(x_j) \tag{3}$$

where

(a) v_j (worst x_j) = 0, v_j (best x_j) = 1, j = 1, 2,...n;

(b) $0 < \lambda_j < 1$, j = 1, 2,…n;

(c) $\sum_{j=1}^{n} \lambda_j = 1.$

$v(x_1,x_2,x_3)$ represents the multi-attribute value function of x_1,x_2 and x_3 and $v_j(x_j)$ represents individual value functions and λ_j represents the weighting factors. The value functions are estimated using mid-value splitting or bisection method and regression analysis (Keeney and Raiffa 1976). The weights can be assessed using swing weights, rating, pairwise comparison and trade-off weights (Ananda, 2004).

2.3 Multi-attribute utility theory (MAUT)

MAUT is based upon expected utility theory. Keeney (1971). Using referential and utility independence assumptions, the multi-attribute utility function can be decomposed into a practical form for elicitation. Consider a multi-attribute utility function of the form of $U(Y_1, Y_2, Y_3)$. The attribute Y_i is utility independent of the other attributes, which might be designated as $Y_{\hat{i}}$, if preferences for lotteries over Y_i, with other attributes held at a fixed level, denoted by $Y_{\hat{i}}^*$, do not depend on what those levels are.

By definition, if Y_i is utility independent of $Y_{\hat{i}}$, then Y_i is preferentially independent of $Y_{\hat{i}}$, whereas the converse is not true. The theorem, which follows from utility independence is as follows. If each Y_i is utility independent of $Y_{\hat{i}}$, i = 1, …, n, then the utility function is either additive

$$U(Y_1,..., Y_n) = \sum_{i=1}^{n} k_i U_i(Y_i) \qquad (4)$$

or multiplicative

$$1 + KU(Y_1,..., Y_n) = \prod_{i=1}^{n} [1 + Kk_i U_i (Y_i)] \quad (5)$$

where U and U_i are utility functions scaled from zero to one, the k_i s are scaling constants with $0 < k_i < 1$, and $K > -1$ is a non- zero scaling constant. If U is multiplicative

$$\sum_{i=1}^{n} k_i \neq 1,$$

and if additive

$$\sum_{i=1}^{n} k_i = 1.$$

The additive form is the simplest form that can be assumed. If the k_i s are sum to one, the additive form is used. If the k_i s do not sum to one, the multiplicative scaling constant K must be determined (Keeney, 1972).

3 Empirical Application

3.1 Decision context

The aim is to use the three MCDA techniques to evaluate forest management alternatives. The empirical application was made for the North East Victoria Regional Forest Agreement (RFA) region. North East Victoria (NEV) forest region covers over 2.3 million hectares. One important aspect of the evaluation was to quantify key forestry trade-offs of the study area. This required identifying the key stakeholders, their objectives (attributes) and their values.

3.2 The objective hierarchy and attributes

Most forest stakeholders have multiple competing objectives that they try to maximize. However, because of difficulties in evaluating different management options with too many objectives, only three attributes, namely old-growth forest conservation, hardwood timber production and recreation intensity, representing ecological, economic and social objectives, respectively were chosen for this study. A simple objective hierarchy was constructed to reflect the decision process and to obtain stakeholder preferences and rank forest management options (see Figure 1).

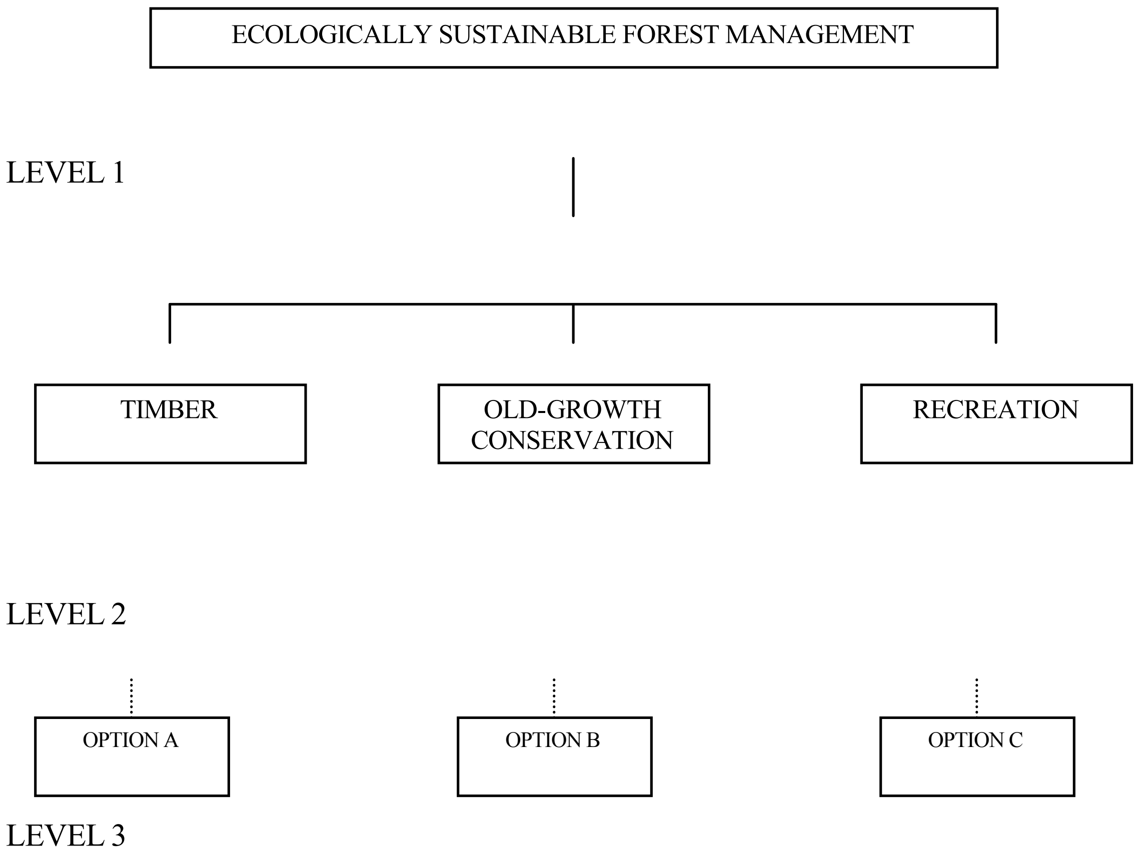

Figure 1: A decision model to evaluate forest land-use options

The ranges of the three attributes, their scales and unit of measurement are summarized in Table 1.

Table 1: Attributes ranges and measurements

Attribute	Description	Units	Range
a.Timber production	Production of hardwood sawlogs per year	Cubic meters	0-74000
b. Recreation	Recreational intensity per year	Recreation Visitor Days	0-1.6 million
c.Old-growth forests	Conservation of old-growth forest	%	0-100

3.3 Forest management options

The decision problem involves selecting from a set of forest management options. The government of Victoria makes decisions on the various levels of the attributes such as the level of the allowable cut, extent of old-growth conservation etc. which defines the management option or plan. The North East Victoria RFA accepted a plan to extract annually of 64,000 cubic meters of hardwood timber, recreational intensity of 1.2 million (recreation visitor days) RVDs and save 60 per cent of old-growth forest. These attribute levels were taken as the base case or plan to construct two additional options for evaluation in this study. The three options are given in Table 2. Table 2 shows that Option A consists of conserving 80 percent of old-growth forest, extracting 54 000 cubic meters of timber and 0.8 million RVDs. Option B is the government option. Option C consists of 40 percent of old-growth forest, 74 000 cubic meters of timber harvest and 1.6 million RVDs (for details see Ananda, 2004).

The decision problem is to choose the best forest management plan from these three options using MCDA.

Table 2: Attribute levels of forest management options for the NEV forest region

Option	Old-growth forest conservation (%)	Timber production Cubic meters/year	Recreation intensity RVDs/year (millions)
Option A	80	54,000	0.8
Option B	60	64,000	1.2
Option C	40	74,000	1.6

We selected stakeholders from the timber industry, the conservation movement, agricultural enterprises, tourism industry, and recreationists and the general community using 'Snowball' sampling (Harrison and Quershi 2000). A total of 106 respondents from the chosen stakeholder categories (Timber industry –24, Environmentalists –25, Recreationists –20, Farmers –26 and Tour Operators –11) were used for this research.

3.4 Value elicitation survey

The survey instrument comprised questions required to implement AHP, MAVT and MAUT which differ. A brief explanation of attributes and their current use levels in the study region, questions on personal information, illustrations to clarify value questions and land-use maps of NEV were also included in the survey instrument carried out using face-to-face elicitation sessions (Ananda, 2004).

Applying AHP

For AHP, the pairwise comparison questions between the three attributes were presented as follows.

TIMBER Production is 1 2 3 4 5 6 7 8 9 more important than OLD-GROWTH Conservation or

OLD-GROWTH Conservation is 1 2 3 4 5 6 7 8 9 more important than TIMBER production.

The respondent was first asked to choose the attribute that should be given more importance (or priority) and then circle the appropriate strength of preference (either on 1st or 2nd line), after referring to either the verbal or numerical preference scale. Then the attribute levels of the 3 hypothetical options were compared pairwise with respect to one attribute at a time. For example, the pairwise comparison of Option 1 (OPT 1) and Option 2 (OPT 2) with respect to timber production is as follows.

OPT 1 is 1 2 3 4 5 6 7 8 9 more important than OPT 2 or

OPT 2 is 1 2 3 4 5 6 7 8 9 more important than OPT 1.

Pairwise comparisons were also made among the five stakeholder groups in order to obtain weighting factors for stakeholder groups.

Applying MAVT

The Mid-value judgement elicitation in MAVT was carried out to determine the value functions (Ananda, 2004). The following exponential function

$$v_j(x_j) = a + be^{cx} \quad (6)$$

where $v_j(x_j)$ is the single-attribute value function for the attribute x and *a, b* and *c* are coefficients was used in this paper. The exponential functions fitted for the three attributes are given in Ananda (2004).

Applying MAUT

The single-attribute utility functions for the three forest attributes were elicited using the Equally Likely Certainty Equivalent (ELCE) method (Anderson *et al* 1977). In this method, a series of simple hypothetical gambles involving only 0.5 probabilities were presented to the respondent. The boundaries of the utility function were set as worst and best possible attribute levels. When the CE is less than the expected value, the decision maker is said to exhibit an aversion to risk. A detailed analysis of the risk attitudes and their distribution is given in Ananda (2004).

Probabilistic scaling was used to elicit the scaling constants. They were asked to compare a certain scenario and a lottery (uncertain scenario). The certain scenario comprised of one attribute at its best level and the other two at their worst levels. The lottery was comprised of all attributes are at their best levels with probability p and with all other attributes at their worst level with probability 1-p. The respondent was asked to indicate his or her preference between these two scenarios.

4. Comparison of the results from the there approaches

4.1 comparison of weights

This section compares the weight sets obtained by th e three MCDA methods. Table 3 shows that the old-growth conservation attribute received the highest mean weight followed by native timber production and forest recreation. There is no other clear similarity among the weights obtained from th e three methods.

Table 3: Weights differences among methods

MCDA Model	Sample size	Native timber pro.		Forest recreation		Old-growth conserv.	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
1. AHP	106	30.27	12.45	20.34	12.45	48.76	23.78
2. MAVT	72	36.48	13.32	25.17	10.41	38.36	12.53
3. MAUT	43	35.43	22.30	19.29	16.70	45.82	24.10

S.D.- Standard deviation

4.1 Convergent validity of weights

Paired correlation coefficients were estimated for nine pairs of attribute combinations (3 MCDA methods x 3 attributes). The paired correlations results are given in Table 4. All nine combinations showed statistically significant (at <0.01 level) and moderately strong positive correlations. In the case of the timber attribute, the highest correlation (0.592) was noted between AHP and MAVT weights. In the case of the forest recreation attribute, the highest correlation was observed between the MAVT and MAUT weights. AHP weights and MAUT weights showed the highest correlation for the old-growth conservation attribute (0.628).

Table 4: Paired sample correlation for various MCDA weights

Comparison	N	Spearman's rho	Sig.(1-tailed)
a. *Native timber production*			
(1) $Weight_{AHP} - Weight_{MAVT}$	72	.592**	.000
(2) $Weight_{AHP} - Weight_{MAUT}$	43	.524**	.000
(3) $Weight_{MAVT} - Weight_{MAUT}$	43	.484**	.001
b. *Recreation*			
(4) $Weight_{AHP} - Weight_{MAVT}$	72	.436**	.000
(5) $Weight_{AHP} - Weight_{MAUT}$	42	.416**	.006
(6) $Weight_{MAVT} - Weight_{MAUT}$	42	.526**	.000
c. *Old-growth conservation*			
(7) $Weight_{AHP} - Weight_{MAVT}$	72	.619**	.000
(8) $Weight_{AHP} - Weight_{MAUT}$	43	.628**	.000

(9) $Weight_{MAVT} - Weight_{MAUT}$	43	.512**	.000

** Significant at 0.01 level.

The paired sample t-tests are given in table 5. It shows that AHP and MAVT weights are significant for all three attributes at the 0.05 level, implying that mean weights are statistically different from each other. The mean weights between AHP and MAUT were not significantly different for any attribute at 0.05 level, implying that the weights obtained by those two methods are not different. The comparison between MAVT and MAUT weights revealed that except for the timber production attribute, the other two are statistically significant. This means that there are significant differences in mean weights obtained from MAVT and MAUT for recreation and old-growth conservation.

Table 5 Paired sample t-test results

Attribute/method	Paired differences		t	df	Sig.(2-tailed)
	Mean	Std. Deviation			
a. Native timber production					
(1) $Weight_{AHP} - Weight_{MAVT}$	-5.04722E-02	.19760	2.167*	71	.034
(2) $Weight_{AHP} - Weight_{MAUT}$	-5.281628E-02	.226086	-1.532	42	.133
(3) $Weight_{MAVT} - Weight_{MAUT}$	2.17651E-02	.196392	.727	42	.471

b. Recreation					
(4) $Weight_{AHP} – Weight_{MAVT}$	-5.48889E-02	.11073	4.206*	71	.000
(5) $Weight_{AHP} – Weight_{MAUT}$	1.11452E-02	.158162	*	41	.650
(6) $Weight_{MAVT} – Weight_{MAUT}$	4.68357E-02	.145837	.457	41	.044
			2.081*		
c. Old-growth conservation					
(7) $Weight_{AHP} – Weight_{MAVT}$	9.5986E-02	.18201	4.475*	71	.000
(8) $Weight_{AHP} – Weight_{MAUT}$	2.27023E-02	.207338	*	42	.477
(9) $Weight_{MAVT} – Weight_{MAUT}$	-7.004186E-	.207287	.718	42	.032
	02		-2.216*		

* Significant at 0.05 level, ** significant at 0.01 level.

4.3 Attribute rank comparison

The correlations between attribute ranking were studied using a score variable. This is constructed by assigning a score for each attribute rank combination: timber > recreation > old-growth = 1, timber > old-growth > recreation = 2, recreation > timber > old-growth = 3, recreation > old-growth > timber = 4, old-growth > timber > recreation = 5 and old-growth > recreation > timber = 6. The average ranking across the respondents for AHP, MAVT and MAUT were 3.93, 3.88 and 3.63, respectively. Spearman's rank correlations between the three methods were calculated and are reported in Table 6. The correlation coefficients for AHP-MAVT, AHP-MAUT and MAVT-MAUT were 0.470, 0.494 and 0.371 respectively and all were significant at 1 per cent or 5 per cent levels.

Table 6: Spearman's correlation coefficients for attribute ranks

Combination of methods	Sample size	Correlation coefficient	Sig. (2-tailed)
AHP – MAVT	72	0.470**	.000
AHP – MAUT	43	0.494**	.000
MAVT – MAUT	43	0.371*	.014

** Significant at 0.01 level, * Significant at 0.05 level.

4.4 Comparison of ranking of forest management options by the three MCDA methods

The ranking of options may remain the same even when there are differences in attribute weights of alternative MCDA methods. Two comparisons were made in this section: (a) comparing ranking of forest land-use options produced by the AHP,

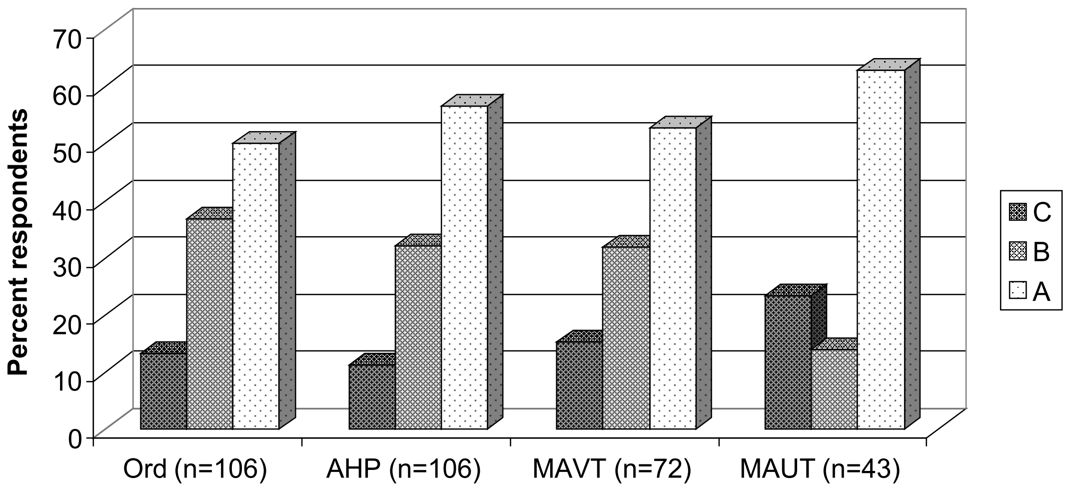

Figure 2: Ranking of forest land-use options by method of assessment

MAVT and MAUT and (b) comparing ranking obtained from these methods with ordinal ranking. These ranking comparisons are shown in Figure 2. All methods predict respondents' ordinal preferences well. The option with the highest overall score is the same (option A) with all three methods. There is a clear similarity of the order of option choice produced by the three methods and ordinal ranking the exception being MAUT under-predicting the preference for option B.

The complete ordering of options by the three methods is compared to assess the closeness of ranking. Non-parametric correlation coefficients were calculated for this comparison. Spearman's rho correlation coefficients and Wilcoxon Signed-rank test results reported in Table 7 show significant positive correlations among the three methods. The highest correlation coefficient was observed between MAVT and MAUT ranking. The Wilcoxon Signed-rank sum test results indicate that there are no statistically significant differences among the ranking produced by the three MCDA methods. These results confirm Shoemaker and Waid's (1982) conclusion that different MCDA methods can produce similar rankings despite having different weight sets.

Table 7: Test statistics for Spearman's rho and Wilcoxon Signed-rank tests

Comparison	Spearman's rho	Wilcoxon Signed-rank test	
		z-score	Asymp. Sig. (2-tailed)
(a) AHP-MAVT rank order	0.553**	-1.154	.249
(b) AHP-MAUT rank order	0.643**	-0.155	.877

(c) MAVT-MAUT	rank order	0.705**	-0.716	.474

** Significant at 0.01 level (1-tailed).

5. Conclusions

The analysis indicates that the old-growth forest is the most valued attribute. The timber production attribute appeared important but differed amongst the different stakeholders. The most preferred forest land management option was option A with a high level of conservation and low level of native timber extraction. Option A differed from the option chosen by the government for North East Victoria. Despite the different theoretical bases, the three MCDA techniques yielded similar findings in terms of ranking options. The major implication of this research is that MCDA can be used to choose forest management options and that policy makers will be able to strike a balance between competing uses and stakeholders thereby minimising conflicts. The three methods provide similar ranking of the management options and what method should one use depends on time, money and the type of stakeholders and the depth of analysis desired.

References

Ananda, J. 2004. Multiple Criteria Decision Making in Forest Management: An Application to the North East Victoria Forest Region in Australia, Ph.D thesis, La Trobe University, Victoria, Australia.

Bartlett, T. 1999., Regional Forest Agreements- a policy, legislative planning framework to achieve sustainable forest management in Australia, *Env. Planning and Law J.* 16 , 328-338.

Brunet, S. 2000., Reinvesting the bush, *Wildlife Australia*, 37, 14-16.

Coakes, S. 1998.,, Valuing the social dimension. Social assessment in the regional forest agreement process', *Aus. J. Env. Eco.*, 5, 47-53.

Commonwealth of Australia, 1999*, Directions Report- North East Victoria Regional Forest Agreement*, Joint Commonwealth and Victorian Regional Forest Agreement Steering Committee: Canberra.

Dargavel, J. 1995. *Fashioning Australia's forests*, Oxford University Press: Melbourne.

Dargavel, J. 1998.,, Politics, policy and processes in the forests, *Aus. J. of Env. Man.* 1, 25-30.

Dargavel, J., Proctor, W. and Kanowski, P. 2000, 'Conflict and Agreement in Australian Forests. In: Luca T. (ed.), Biodiversity and Ecological Economics: Participation, Values and Resource Management, Earthscan Publications Ltd, London, pp. 101-115.

Kangas, J. 1994., An approach to public participation in strategic forest management planning, *For. Ecol. and Man.* . 70, 75-88.

Keeney, R.L. 1992. *Value-focused thinking: a path to creative decision analysis*, Harvard University Press, Cambridge.

Keeney, R.L. and Raiffa, H. 1976. Decisions with multiple objectives, Wiley, New York.

Kirkpatrick, J.B. 1998., Nature conservation and the regional forest agreement process, *Aus. J. of Env. Man.* 5, 31-37.

Martin, W.E., Bender, H.W. and Shields, D.J. 2000., Stakeholder objectives for public lands: ranking of forest management alternatives, *J. of Env. Man.* 58, 21-32.

Proctor, W. 2000, 'Towards sustainable forest management: An application of multi-criteria analysis to Australian forest policy', Third International Conference of the European Society for Ecological Economics, Vienna, Austria, May 3-6, 2000.

Saaty, T. L. 1980, The analytic hierarchy process, McGraw-Hill, New York.