PREFERENCES FOR LAND-USE OPTIONS INVOLVING FORESTRY IN THE MACKENZIE/WAITAKI BASIN

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ABSTRACT

The Resource Management Act 1991 emphasises the importance of assessing the potential environmental effects of land-use change. Forestry is a potential land-use in the Mackenzie/Waitaki Basin but its effects are not acceptable to everyone. The preferences of stakeholders were investigated for different land-use options involving forestry. Using a "Q sort" technique, stakeholders expressed preferences for cards that presented environmental effects of a range of technically feasible land-use options, including forestry, agriculture, and conservation. Several indicators of the environmental effects for each land-use option were modelled, such as the visual effects of land-use regimes and consequential impacts such as wilding spread, and the non-visual environmental effects such as local income and employment and soil status. Seventy-seven respondents rated a total of 36 cards covering four landforms. Analysis of the results identified several clear "themes", or sets of preferences, characterised by a distinctive set of preferred land-use options, and a distinctive combination of effects. Each theme has specific criteria for judging acceptability. These preferences have possible implications for planning involving forestry under the Resource Management Act 1991.

Keywords: land-use; forestry; planning; environmental effects; Mackenzie country; Waitaki Basin.

INTRODUCTION

Traditional approaches to pastoral land-use are now generally recognised as being unsustainable over large parts of the New Zealand high country (Martin 1994). Extensive areas are experiencing land management problems and these problems are particularly acute in the Mackenzie/Waitaki Basin. The major problem is not simply the highly visible effects of infestation by rabbits or *Hieracium*, but the overall ability of the land to sustain families and local communities at current levels (Parliamentary Commissioner for the Environment 1991).

A number of alternative land-use options are being implemented or investigated (O'Connor 1994) ranging from intensification of pastoral use on improved and irrigated grasslands, to retirement of land from economic use. Several of these options include extensive planting of trees, and the potential role of forestry in the high country is receiving increasing attention (e.g., Ledgard & Belton 1985; O'Connor 1986a, b). The desirability of commercial forests on a considerable part of the Mackenzie/Waitaki Basin has been expressed by the Ministry of Forestry (Belton 1991a), the Mackenzie and Waitaki District Councils, the Canterbury Regional Council (Belton 1991b), and other interested parties (Parliamentary Commissioner for the Environment 1991). However, proposals to increase tree cover are opposed by a number of interest groups, who argue that the wide open landscapes of tussock grasslands, formerly characteristic of much of the high country, should be protected (Lucas 1987; Delamore 1994).

The resolution of such conflict may be addressed within a number of different statutory and legal contexts, amongst which the Resource Management Act 1991 is of particular significance. This legislation has as its overall goal the sustainable management of natural and physical resources. It requires local authorities involved in land-use planning to shift from their former concerns for permitting or prescribing land use, to an emphasis upon management of the effects of land-use, including the effects on local communities. Studies of forestry potential in the high country to date have concentrated on considerations of economic returns and biophysical effects. Social and institutional monitoring and evaluation within the Rabbit and Land Management Programme (Taylor Baines and Associates 1990) provides some background to the implications of land-use change for communities, but options for integrating forestry into agricultural regimes have not been fully examined, whilst further investigation of the apparently conflicting views is also needed.

This article reports on research that investigated attitudes towards the effects of a range of land-use options, including combinations of forestry, agriculture, and conservation. The research used images of expected visual changes, along with estimations of socio-economic effects and changes in soil status, to investigate the preferences of a range of stakeholders who have different kinds of interest in future land-use change in the Mackenzie/Waitaki Basin. This approach to community involvement recognises that land-use decisions are not decided by consensus or numerical majority but are the outcome of contested viewpoints. A set of distinctive preferences has been identified that each express a different combination of values, beliefs, and opinions about the acceptability of different land-use effects. These patterns of preference suggest certain implications for planning policy in the study area, whilst the methods used may have broader applicability to resource management involving forestry.

METHOD

One distinctive feature of this research was the use of image capture technology to prepare visual images of expected land-use changes. Photographic images of landscapes and landscape features have been widely used in assessing preferences (Kaplan 1985). Although the validity of using photographs as surrogates for actual landscapes in perception studies has been debated (Bernaldez *et al.* 1988), one undoubted advantage of their use for planning and related work is that they present detailed information in a realistic, familiar, and authentic format. The use of image capture technology in tourism, landscape, and forestry research has developed rapidly (Orland 1993) and the forestry applications of the new technology have been diverse. They include research on viewer preferences for spatial arrangement of park trees (Schroeder & Orland 1994), on preferences for roadside scenes (Kent 1993), and on homeowners' preferences for different forest harvest techniques as modelled for the view from their own homes (Johnson & Brunson 1994).

Portraying Land-use Effects

The survey strategy adopted for this study combined text and edited photographs in semi-formal models (Lyle 1991) of alternative land-use options. Each land-use option that was to be presented to respondents was summarily expressed in three ways—visually, economically, and biophysically. The visual portrayal was based upon analysis of the effects of similar land-uses elsewhere, transposed to the case-study locations, whilst the economic and biophysical predictions utilised the results of a range of previous and ongoing studies.

Three sets of indicators of change were selected for inclusion: a two-dimensional visual image of the land-use change, a statement of predicted local income and employment change, and a statement of predicted change in soil status. This choice of indicators was influenced by the methodological need to restrict the number of indicators included, and by the overall aims of the study, which involved development of a more generalised procedure. Locally significant issues such as water yield and recreational use of streams were therefore not included. The need to restrict the number of indicators in this way is clearly a limitation of the method used. The visual images included representations of specific land-use effects and biophysical impacts such as wilding spread, as well as the overall visual character of the different land-uses. For each land-use option, respondents were thus presented with an integrated overview of possible effects, summarised on a single information card. One of the 33 information cards is illustrated in Fig. 1. The preparation of the estimates of effects is discussed in more detail below.

Landform and rainfall were selected as key biophysical variables for derivation of the different land-use options considered technically feasible for the area (Ledgard & Belton 1985). Four montane zone landform categories were identified: three in the higher rainfall area (more than 800 mm per annum) and one in the lower rainfall area. Higher rainfall options comprised: hill slopes between 16° and 35°, lower slopes between 8° and 16°, flats less than 8°. The lower rainfall option (less than 800 mm per annum) included flats less than 8°. For each landform, a range of technically and economically feasible land-use options was developed. These were based upon different combinations of grazing, tree planting, and destocking. Grazing was either extensive or, where considered to be feasible, improved or irrigated. Tree planting was considered as either larger productive plantations, agroforestry woodlots (i.e., smaller woodlots associated with improved pasture), shelterbelts, or non-commercial soil conservation plantations.

A number of more intensive and innovative land-uses were considered during the early phases of the study, as were the effects of different phases of land management (e.g., log harvesting). However, the resulting diversity of possible options and uncertainties in feasibility and prediction proved to be too complex for stakeholders during pre-testing, and the field work was thus limited to the main focus of the overall programme—that is, generalised effects of extensive land-uses involving forestry.

Given the long time scale of tree production, two time scenarios were initially modelled: 10 years and 50 years. In the final survey, only the 50-year option was included in order to simplify stakeholder choices to a manageable range of options. Land-use change was

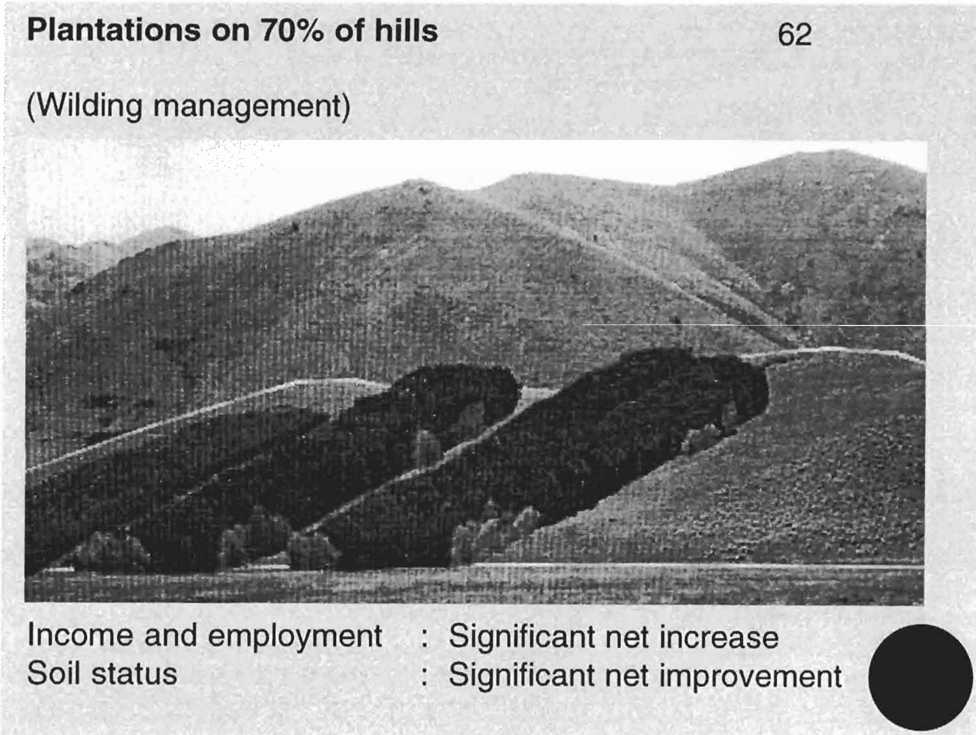

FIG. 1–Example of an information card

modelled on either 15% of the available land area, to represent a modest change option, or 70% of the available land, to represent a major change option. The plantation tree species modelled were Corsican pine (*Pinus nigra* Arn. subsp. *laricio* (Poiret) Maire) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), with poplar used for shelter planting on the flats. Wilding spread was included in some options, and wilding management, to limit or remove spread, in others.

Preparation of Visual Images

The primary purpose of the visual images was to communicate to respondents a consistent set of information about the likely character of different potential land-uses in the study area. The aim was therefore to produce a set of images that represented as authentically and consistently as possible the effects of a range of land-uses. Adobe "Photoshop", a 2D image-editing programme, was used to generate the diverse images on the four landforms.

Thirty-five-millimetre photographs were taken of typical examples of the four landforms to be modelled. The images for the study were selected to provide consistency of viewpoint at eye level from public roads and edited to ensure that land-uses being modelled commenced 1 km from the viewer. The scale of introduced objects such as trees was calibrated against known objects in the view to ensure that their relative size was accurate. Views were selected in which the target landform occupied the centre of the image, and this was demarcated with a white line. Within this line, land-use changes were modelled to cover an area visually proportional to the overall coverage of that landform in the study area, e.g., a 15% land-use was modelled to cover 15% of the apparent area of that landform in the image. Subsequent development of the visual modelling technique to incorporate 3D landform and improved scale and locational accuracy has been reported by Bennison & Swaffield (1994).

Shortly before the study was undertaken, landscape guidelines were produced in draft form as part of the Mackenzie District Scheme Review (Boffa Miskell Partners 1992a, b). These guidelines recommended that forestry follow the landform rather than conflict with it. Minimum setbacks from public roads were specified, and amenity plantings were suggested to soften the edges of plantations. These guidelines were incorporated in the visual modelling.

Economic and Biophysical Projections

The modelling was based on expert assessment of literature relevant to both economic and biophysical research in the study area. For the predicted income and employment effects members of the research panel drew on the work of Aldwell (in particular 1984a, b, 1987). That research examined the regional impacts of forestry growth in New Zealand, including social and economic effects, and was directly relevant to the estimations of income and employment required here. For the predicted soil status effect members of the research panel drew on the work of Davis & Lang (1991) and Belton *et al.* (in press), which examined nutrient availability under plantations in montane soils. For both income and employment and soil status effects, the predictions were presented in broad categories such as significant increase or decline, or net increase or decline. For other assessments of ecological effects (such as tussock spread) a range of studies was used, including those by the Parliamentary Commission for the Environment (1991), Treskonova (1991), Connor (1964, 1992), and O'Connor (1981, 1983, 1986b).

Q Method

The field investigation was based upon identification of stakeholders' expressions of relative preference for the combined effects represented on each information card. Respondents were asked to focus upon the overall effects of each land-use and therefore had to make trade-offs between the visual, economic, and ecological effects as part of their preference rating. The rationale for the composite approach was that forcing respondents to make choices between combined effects would reveal attitudes more closely corresponding to "real world" situations.

The survey approach chosen to present these composite information cards to stakeholders was the "Q method". This focuses upon the subjective views of respondents, and thus taps directly into their values, beliefs, and opinions (Brown 1980; Drysek & Berejikian 1993). Q method is a reconstructive technique that allows subjects to speak for themselves, and incorporates their subjectivity into the analysis. This is in contrast to many other methods that use measures pre-specified by the researcher. Further, it seeks patterns of response across individuals, rather than across variables, and measures socially assigned meaning directly. Brown, and Drysek & Berejikian, argued that this analytical approach provides more authentic understanding of socio-political attitudes than the findings of conventional opinion polls or surveys. Q method does not provide results concerning the proportions of types in the population as a whole.

Selected stakeholders performed a "Q sort" of the information cards for each of the four landforms, identifying those outcomes that were most acceptable and those that were least acceptable for that person. There were eight information cards each for the hills and lower rainfall flats, and 10 cards each for the lower slopes and higher rainfall flats. The total of 36 cards were finally sorted together to assess preferences for land-uses when considering the study area as a whole. Respondents were also questioned verbally and encouraged to comment upon their rationale for particular choices. Responses were recorded on Q sort data sheets for each respondent.

The Q sort data were analysed using centroid factor analysis to identify common patterns, or factors, among the respondents' preferences (Brown 1980: 208–24). Each factor comprises an array of image cards ranging from most acceptable to least acceptable, and is an array that best represents the constituent Q sorts upon which it is based. Each subject is associated to some degree with each factor, and the degree of association is assessed by the degree of similarity between the Q sort array and the factor array. A subject whose Q sort is highly correlated with a factor is said to have a high loading on that factor. The factors for the landform Q sorts were then described and interpreted by reference to the recorded comments of respondents who loaded highly on the factor and by direct examination of the factor array of information cards. For the overall Q sort the analysis was limited to the order of cards only because respondents made few verbal comments. Factor interpretation must provide a plausible explanation of the particular order of image cards and thereby make explicit the preferences of those respondents who load on that factor. Only factors with five or more significant respondent loadings were used in this analysis. Positive loadings identified respondents who selected the range of land-use effects in a certain order, with the first choice being most acceptable. Negative loadings identified respondents who defined acceptability in the reverse order.

After considerable pilot testing the information cards were refined and simplified before field researchers visited 77 stakeholders at their place of work or at home between May and June 1993. Stakeholders were selected non-randomly from the main interest groups in the study area, including runholders (22), service providers (10), local businesses (16), statutory advisors (11), other advisors (5), the Takata Whenua (2), politicians (4), and recreation/conservation interests (7). Previous work on attitudes towards trees in the high country (Swaffield 1994a) suggested that stakeholders from these groups would have a wide range of views but that these could be expressed in terms of a limited number of common patterns of preference. Such sampling is akin to a forest ecologist selecting the most likely places within Canterbury, for example, in order to find a new species association, rather than taking a random sample of locations that could represent the Canterbury area as a whole. The results comprise a categorisation of preferences prevalent in the community of stakeholders, rather than a representative profile of all community preferences. While analysis of preferences by type of stakeholder was not an objective of this research, we can report that there was no strong link between stakeholder type and the preference themes. Typically, each theme gained support from representatives of many stakeholder groups.

RESULTS

Landform Factor Preferences

The objective of Q method analysis is to identify and describe factors which derive from the Q sort data. For the hills Q sort there were four factors identified (hills Factor 1, 2, 3, and

4) and there were 52 respondents who had statistically significant loadings, either positive or negative, on to one of the four factors (Table 1). For a Q sort with eight items the factor loadings have to be high (at least 0.7 at the 0.05 probability level) before they are significant. Of the other 25 respondents, 23 had a non-significant loading between 0.5 and 0.7 and of these 23, eight loaded on only one factor and 15 loaded on two or more factors. These 23 "non-significant" respondents did, therefore, have some affinity with those who had significant loadings on the four factors. The final two respondents had loadings less than 0.5. They had little affinity with the factors and their Q sorts were unique and dissimilar.

TABLE 1–Numbers of stakeholders loading on factors for each landform

Landform	Factor				Subtotal
	1	2	3	4	
Hills	24	12	9	7	52
Lower slopes	23	23	11	7	63
Higher rainfall flats	35	22	4	3	64
Lower rainfall flats	33	15	6	–	54

For the lower slopes Q sort, 63 respondents loaded significantly on to one of four factors (factor loadings have to be at least 0.62 to be significant at the 0.05 level). For the higher rainfall flats Q sorts, there were 64 who loaded significantly on to one of three factors. Most respondents loaded on to Factor 1, and there were 12 positive and 10 negative loadings on Factor 2. The latter group form an alternative viewpoint which is equivalent to another factor. For the lower rainfall flats Q sorts, 54 respondents loaded significantly on to one of three factors. Most of the respondents loaded on to Factor 1.

The interpretation of all the main factors highlighted a number of criteria that were used to evaluate each set of preferences expressed by respondents. The eight main criteria are shown in Table 2 for each main factor for all four landforms. The crosses indicate which criteria characterised the factors. These features of each factor were manifest in both the preferred information cards and in the recorded comments about each card, and both were used to describe each factor in detail (*see* Fairweather *et al.* 1994). Further, similar themes of preference were expressed across the hills, lower slopes, and higher rainfall flats options, and we have called these composite themes (Table 2). The first composite theme (plantations) emphasised preference for the effects of larger productive plantations. This was illustrated by hills Factor 1, lower slopes Factor 2, and higher rainfall flats negative Factor 2. The second composite theme (grazing/trees) emphasised preference for the effects of grazing, wilding management, and some tree production. On the hills emphasis was given to larger plantations but on the lower slopes and higher rainfall flats it was on shelterbelts. This was hills Factor 2, lower slopes Factor 1, and higher rainfall flats Factor 1. The third composite theme (conservation) consistently emphasised preference for conservation outcomes and wilding management. On the hills emphasis was given to destocking and smaller plantations but on the lower slopes the effects of larger plantations were accepted. On the higher rainfall flats the major consideration was the retention of a sense of openness and of views to the mountains. This was hills Factor 3, lower slopes Factor 3, and higher rainfall flats Factor 2. The detailed landform factor data are shown in Tables 3, 4, and 5 for each of these three composite themes, and show the order of image cards numbered from most acceptable to least acceptable.

TABLE 2–Main criteria for each main factor for all landforms

Composite themes	Factor No.	No. of cases	Conser-vation	Shelter	Grazing	Plantations Small	Plantations Large	Wilding manage-ment	Visual aspects	Produc-tion
Hills										
Plantations	1	21					x			x
Grazing/trees	2	9			x		x	x		x
Conservation	3	6	x			x		x		
Lower slopes										
Grazing/trees	1	21		x	x			x		x
Plantations	2	20		x			x			x
Conservation	3	10	x				x	x		
Higher rainfall flats										
Grazing/trees	1	34		x	x			x		
Conservation	2	14	x					x	x	
Plantations	–2	8	x				x			
Lower rainfall flats										
Grazing/shelter	1	32		x	x		x			
Grazing	2	14		x	x		(Non-comm.)	x		

The factors derived from the Q sorts for the lower rainfall flats did not have the same distinguishing characteristics as those for the other landforms (Table 2). The two lower rainfall flats factors emphasised shelterbelts or grazing. It is plausible that preferences tended to converge on the lower rainfall flats because there is less potential for trees and fewer productive land-use options.

The three main preference themes described here (plantations, grazing/trees, and conservation) account for most respondents who had significant factor loadings. The number of cases shown in Table 2 includes only the positively loading cases (except for the higher rainfall flats Factor 2). The numbers of respondents loading on the factors do not match across landforms. For example, for the hills Q sort there are nine "grazing/trees" respondents, compared to 21 on the lower slopes and 34 on the higher rainfall flats. Further, preferences of individual respondents were not always consistent across landforms. Those who found plantations acceptable on the hills, for example, did not necessarily find plantations acceptable on the lower slopes. However, while individual respondents' definitions of acceptable land-use may have changed across landforms, there was enough similarity among the responses of the stakeholders as a whole to create similar factors for each landform.

Interpretation of Preference Themes

Analysis of the sequences of information cards, and their content, together with analysis of the recorded comments of respondents made during the Q sort process, allows qualitative interpretation of the preference themes identified in the factor analysis. In the plantations theme the important feature was the role of large plantations for production on the hills and lower slopes, and for soil conservation on the higher rainfall flats. Respondents subscribing to this theme saw trees as using and improving the land. They were not keen on grazing but saw a role for improved pasture on the lower slopes. In the grazing/trees theme the key element was the combination of trees and grazing for production, comprising plantations and grazing on the hills, and shelterbelts on the lower slopes and higher rainfall flats. Wilding management was an essential feature throughout the grazing/trees theme and was considered essential to allow for continued grazing on non-forestry land. The plantation and the grazing/trees themes appeared to place the greatest emphasis upon productive enhancement of the land resource, through either tree planting or improved pasture. In the conservation theme the essential features were small plantations and conservation on hills, larger plantations and conservation on lower slopes, and retention of views on the higher rainfall flats. For those subscribing to this theme conservation meant destocking. Wilding management was an essential feature throughout the conservation theme, to preserve existing vegetation cover. On the lower rainfall flats, these three themes were modified significantly to become characterised as either grazing/shelter, that emphasised the role of non-commercial plantations for shelter combined with grazing, or grazing only, maintained by wilding management.

Visual effects were significant for all themes, but each theme expressed a different landscape aesthetic. For the plantations theme, there was an apparent preference for "naturalistic" shaped plantations, expressed by the selection of images with either 70% plantations, or 15% plantations the borders of which were extended by wilding spread. Comments indicated that the attraction of wildings lay in the way that they helped blend plantations into the broader landscape. The grazing/trees theme, on the other hand, expressed a strong preference for clearly defined land-uses, with plantations, woodlots, and grazing marked by clear boundaries. On the flats, views of the mountains beyond were also important. For the conservation theme, the image of clean, open, tussock grazing land was critical, although it is important to note that small, clearly defined plantations were also acceptable on hills and slopes. On lower rainfall flats the main visual issue was retention of the sense of openness formerly associated with the tussock grasslands.

Conservation was a significant element in more than one of the themes, but its meaning was variable. In the conservation theme it meant a preference for land-use which more closely matched the pre-European land cover, with only some trees tolerated. Restoration of the tussock grasslands was emphasised. However, the plantations theme also had a conservation element, but here conservation was considered as using trees to improve the biophysical condition of the land.

The Overall Q Sort

In addition to the landform Q sort, all respondents were asked to Q sort the complete set of 36 information cards—that is, all cards for all landforms. This Q sort attempted to record preferences when respondents integrated all four landforms in a way that better represented the options for land-use change in the study area as a whole. This overall Q sort was observed to be quite demanding and caused a number of respondents significant problems in integrating all the visual and written information. Many respondents relied upon the images alone as the basis of their Q sort, and comments were made on only some of the 36 cards, unlike the landform Q sorts where most cards received a comment. We regard the landform data as the better basis for understanding preferences but include the following data to show that similar results were obtained from analysis of the overall Q sort data.

For 36 items in a Q sort the standard error of a loading was 0.33 at the 0.05 probability level, and with this criterion there were 64 respondents who loaded significantly, on a total of three factors. The order of information cards for Factor 1 of the overall Q sort is given in Table 3, with the most acceptable option at the top. Focusing on the land-uses shows that plantations over 70% were most acceptable, followed by shelterbelts and improved pasture on 70%. Least acceptable were continued grazing and destocking. The wilding management option for the various land-uses was distributed evenly across the array of cards, indicating that it was not an important issue. Factor 1 of the overall Q sort, therefore, appears to express the plantations theme that has been described earlier in the separate landform Q sorts.

The order of information cards for Factor 2 of the overall Q sort is given in Table 4. Focusing on the land-uses shows destocking was the most acceptable land-use, with some shelterbelts and some continued grazing also accepted. Least acceptable were continued grazing and plantations. Wilding management was very relevant to this factor: all options in the acceptable part of the array have wilding management, and all those in the bottom (least acceptable) part are without wilding management. In fact it is the wilding management option that differentiates the acceptable shelterbelts and continued grazing options from the unacceptable. Overall Factor 2, therefore, expresses the conservation theme. Thus, wilding management is a major issue for "conservation" orientated stakeholders.

The order of information cards for Factor 3 of the overall Q sort is given in Table 5. Focusing on the land-uses shows shelterbelts and improved pasture were most acceptable, with enthusiasm also for agroforestry (woodlots) and improved pasture. Some plantations options were acceptable and some were not. Least acceptable were destocking and continued grazing. Wilding management was also very relevant to this factor. All options in the acceptable half of the array have wilding management. The only wilding management options that were not acceptable were those associated with destocking, and it was the destocking that was objected to. Overall Factor 3, therefore, expresses the grazing/trees theme.

The basic landform Q sort data for each of the three main themes are included in Tables 3, 4, and 5. There is a good match between the order of landform factors and that of overall factors, but the match is not complete: the landform Q sort factors have some important differences because they were based on more careful discrimination between information cards.

DISCUSSION AND CONCLUSION

This research has reported attitudes towards the effects of a range of land-use options. The results compare well with some earlier studies and have important implications for planning policy in the study area specifically, and more broadly for resource management involving forestry. There are also some important implications concerning the methods used and we note three areas where improvement is needed.

There has been little scientific research into attitudes towards high country land-use, but much anecdotal commentary. Nonetheless, the underlying issues have been recognised for some time. O'Connor (1983) identified the potential polarisation of choice between forestry and grazing as a landscape planning issue over a decade ago, and the respective viewpoints have been well articulated in a number of surveys, seminars, and workshops (for example, Murray 1986; Gregory 1988). Two recent studies have undertaken systematic investigation of attitudes towards land-use change, and the results of this study agree with those findings.

TABLE 3–Plantations factor for the overall Q sort with the parallel landform Q sorts

No.	Statement	Hills	Lower slopes	Higher rainfall flats	Lower rainfall flats
62.	Plantations on 70% of hills (wilding management)	2			
33.	Shelterbelts & improved pasture on 70% of higher rainfall flats(wilding management)			4	
42.	Plantations on 70% of hills	1			
64.	Plantations on 70% of higher rainfall flats (wilding management)			6	
63.	Plantations on 70% of lower slopes (wilding management)		3		
34.	Shelterbelts & improved pasture on 70% of lower slopes (wilding management)		1		
38.	Plantations on 70% of lower slopes		2		
18.	Plantations on 15% of hills	3			
19.	Shelterbelts & improved pasture on 70% of lower rainfall flats (wilding management)				1
37.	Plantations on 15% of hills (wilding management)	4			
43.	Plantations on 15% of higher rainfall flats (wilding management)			7	
15.	Plantations on 70% of higher rainfall flats			1	
47.	A/f (woodlots) & improved pasture on 15% of lower slopes (wilding management)		5		
61.	A/f (woodlots) & improved pasture on 15% of higher rainfall flats (wilding management)			8	
40.	Non-commercial plantations on 70% of lower rainfall flats				2
66.	Plantations on 15% of hills (wilding management) (cadastral borders)	5			
70.	Plantations on 15% of lower slopes (wilding management)		7		
29.	Plantations on 15% of lower slopes		4		
39.	Plantations on 15% of higher rainfall slopes			3	
50.	Shelterbelts & improved pasture on 15% of lower slopes (wilding management)		6		
51.	Shelterbelts & improved pasture on 15% of higher rainfall flats(wilding management)			5	
52.	Shelterbelts & improved pasture on 15% of lower rainfall flats(wilding management)				3
53.	Non-commercial plantations on 15% of lower rainfall flats				5
67.	Shelterbelts & improved pasture on 15% of lower rainfall flats				4
59.	Continued grazing on higher rainfall flats			2	
7.	Destocking on lower slopes (wilding management)		9		
26.	Destocking on higher rainfall flats (wilding management)			10	
57.	Continued grazing on lower slopes		8		
55.	Continued grazing on hills	6			
13.	Destocking on hills (wilding management)	8			
74.	Continued grazing on lower rainfall flats				6
22.	Destocking on lower rainfall flats (wilding management)				7
58.	Continued grazing on higher rainfall flats (wilding management)			9	
56.	Continued grazing on lower slopes (wilding management)		10		
54.	Continued grazing on hills (wilding management)	7			
60.	Continued grazing on lower rainfall flats (wilding management)				8

TABLE 4–Conservation factor for the overall Q sort with the parallel landform Q sorts

No.	Statement	Hills	Lower slopes	Higher rainfall flats	Lower rainfall flats
26.	Destocking on higher rainfall flats (wilding management)			1	
13.	Destocking on hills (wilding management)	2			
22.	Destocking on lower rainfall flats (wilding management)				1
7.	Destocking on lower slopes (wilding management)		2		
33.	Shelterbelts & improved pasture on 70% of higher rainfall flats(wilding management)			7	
54.	Continued grazing on hills (wilding management)	8			
19.	Shelterbelts & improved pasture on 70% of lower rainfall flats (wilding management)				4
58.	Continued grazing on higher rainfall flats (wilding management)			2	
43.	Plantations on 15% of higher rainfall flats (wilding management)			4	
34.	Shelterbelts & improved pasture on 70% of lower slopes (wilding management)		5		
50.	Shelterbelts & improved pasture on 15% of lower slopes (wilding management)		6		
70.	Plantations on 15% of lower slopes (wilding management)		3		
51.	Shelterbelts & improved pasture on 15% of higher rainfall flats(wilding management)			5	
56.	Continued grazing on lower slopes (wilding management)		7		
62.	Plantations on 70% of hills (wilding management)	5			
37.	Plantations on 15% of hills (wilding management)	1			
61.	A/f (woodlots) & improved pasture on 15% of higher rainfall flats (wilding management)			3	
52.	Shelterbelts & improved pasture on 15% of lower rainfall flats(wilding management)				2
47.	A/f (woodlots) & improved pasture on 15% of lower slopes (wilding management)		4		
64.	Plantations on 70% of higher rainfall flats (wilding management)			6	
63.	Plantations on 70% of lower slopes (wilding management)		1		
60.	Continued grazing on lower rainfall flats (wilding management)				3
66.	Plantations on 15% of hills (wilding management) (cadastral borders)	3			
42.	Plantations on 70% of hills	6			
53.	Non-commercial plantations on 15% of lower rainfall flats				6
67.	Shelterbelts & improved pasture on 15% of lower rainfall flats				7
40.	Non-commercial plantations on 70% of lower rainfall flats				6
18.	Plantations on 15% of hills	4			
39.	Plantations on 15 % of higher rainfall flats			8	
15.	Plantations on 70% of higher rainfall flats			10	
29.	Plantations on 15% of lower slopes		9		
55.	Continued grazing on hills	7			
74.	Continued grazing on lower rainfall flats				8
57.	Continued grazing on lower slopes		10		
59.	Continued grazing on higher rainfall flats			9	
38.	Plantations on 70% of lower slopes		8		

TABLE 5–Grazing/trees factor for the overall Q sort with the parallel landform Q sorts

No.	Statement	Hills	Lower slopes	Higher rainfall flats	Lower rainfall flats
33.	Shelterbelts & improved pasture on 70% of higher rainfall flats (wilding management)			1	
34.	Shelterbelts & improved pasture on 70% of lower slopes (wilding management)		1		
19.	Shelterbelts & improved pasture on 70% of lower rainfall flats (wilding management)				1
50.	Shelterbelts & improved pasture on 15% of lower slopes (wilding management)		3		
47.	A/f (woodlots) & improved pasture on 15% of lower slopes (wilding management)		2		
52.	Shelterbelts & improved pasture on 15% of lower rainfall flats (wilding management)				3
51.	Shelterbelts & improved pasture on 15% of higher rainfall flats (wilding management)			2	
61.	A/f (woodlots) & improved pasture on 15% of higher rainfall flats (wilding management)			3	
58.	Continued grazing on higher rainfall flats (wilding management)			8	
43.	Plantations on 15% of higher rainfall flats (wilding management)			5	
64.	Plantations on 70% of higher rainfall flats (wilding management)			4	
54.	Continued grazing on hills (wilding management)	4			
70.	Plantations on 15% of lower slopes (wilding management)		4		
37.	Plantations on 15% of hills (wilding management)	3			
56.	Continued grazing on lower slopes (wilding management)		5		
62.	Plantations on 70% of hills (wilding management)	1			
66.	Plantations on 15% of hills (wilding management) (cadastral borders)	2			
60.	Continued grazing on lower rainfall flats (wilding management)				8
63.	Plantations on 70% of lower slopes (wilding management)		6		
67.	Shelterbelts and improved pasture on 15% of lower rainfall flats				4
42.	Plantations on 70% of hills	6			
53.	Non-commercial plantations on 15% of lower rainfall flats				5
38.	Plantations on 70% of lower slopes		7		
39.	Plantations on 15% of higher rainfall slopes			6	
18.	Plantations on 15% of hills	5			
15.	Plantations on 70% of higher rainfall flats			7	
29.	Plantations on 15% of lower slopes		8		
74.	Continued grazing on lower rainfall flats				6
55.	Continued grazing on hills	7			
40.	Non-commercial plantations on 70% of lower rainfall flats				2
59.	Continued grazing on higher rainfall flats			9	
57.	Continued grazing on lower slopes		9		
22.	Destocking on lower rainfall flats (wilding management)				7
13.	Destocking on hills (wilding management)	8			
7.	Destocking on lower slopes (wilding management)		10		
26.	Destocking on higher rainfall flats (wilding management)			10	

Swaffield (1991, 1994a) analysed attitudes amongst stakeholders in the Craigieburn Basin towards the role and management of trees and plantations. Seven common frames of reference were identified. Several were focused upon approaches to land-use planning, and are not of direct relevance to this study, but four of the common frames that emphasised land management outcomes correspond closely to the Q sort themes identified in this study. Swaffield identified a "multiple use management" position that favoured extensive plantings for production and soil conservation objectives, which corresponds closely to the "plantations" theme identified here. A second frame of reference was designated "conservation by control". This appears to correspond closely to the conservation theme in this study. The grazing/trees theme we have identified here appears to combine two further frames of reference: individual improvement (grazing with shelter) and conservative management (incremental change). In both approaches, respondents to Swaffield's survey accepted that tree planting had a modest potential role in high country land-use, either as part of a pastoral enterprise (shelter) or as a minor form of income diversification for high country properties (i.e., woodlots).

A second study provides further indicative support for the Q sort analysis. Wardle *et al.* (1993) undertook a pilot study that analysed policy preferences in the Rabbit and Land Management Area (part of this study area) and identified three distinctive social orientations: the "forest greens", who favoured forestry and conservation; "technocrats", who favoured a mixed use scenario; and "greens", who favoured conservation and recreation. These three categories match closely to the three main themes identified here, although it must be noted that the sample of respondents in the Wardle study was largely restricted to institutional stakeholders. The emergence of a similar three-way split in preferences in three studies using non-random samples, each structured significantly differently, provides significant support for the proposition that the themes identified reflect fundamental value splits within the community. The correspondence between the results of these previous studies and the results of the Q sort analysis, plus the strength of the revealed patterns, suggests that the overall results reported here are robust, despite minor variations and issues of interpretation.

These findings have a number of potential implications for resource planning and management in the Mackenzie/Waitaki Basin, and more generally in the high country. It is clear that despite the Parliamentary Commissioner for the Environment's (1991) expressed vision of an "aesthetic blend" of forestry, grazing, and conservation land-uses in the future, there remain diverse views as to the relative acceptability of the different components of such a vision, and thus of the preferred balance between them. Furthermore, the complex inter-relationship between different options will make development of coherent resource management policies based solely upon land-use effects challenging, and potentially problematic. This study shows that different stakeholders favour different trade offs between the potential environmental effects of different land-uses, and that these trade offs shift according to land type. Thus, not only are there three distinctive preference orientations (plantations, grazing/trees, conservation), but the preferred expression of these orientations varies across the landforms being considered. For example, a particular stakeholder may favour an overall grazing/trees orientation, but may accept within that the effects of significant plantations on hill slopes. Similarly, individuals may recognise beneficial outcomes of a particular land-use option (e.g., soil conservation benefits from tree planting) as valid and desirable, even though it may not match their predominant orientation.

One of the key elements of preference differentiating responses is the treatment of wildings. The three themes identified in the Q sorts clearly expressed different responses to this issue, with wildings largely accepted within the plantations theme, but rejected by the grazing/trees and conservation themes. Swaffield (1991, 1994b) suggested that this may reflect, in part, differing degrees of confidence in the ability of management regimes to control wilding spread, and differing perceptions of the implication of uncontrolled spread. For many of those with a plantations orientation, one of the advantages of wildings is that they help to visually integrate plantation boundaries within the broader landscape. However, for those with a conservation orientation, wildings represent a threat to the "natural" character and flora of the area (Swaffield 1994b). The issue of wilding management is clearly also vitally important for those with a grazing/trees orientation. Without exception, their preferred options all showed clearly defined boundaries between trees and other land-uses although, as Murray (1986) noted, the preference is related to the need to maintain open land for grazing, rather than because of fundamental concerns for conservation.

These differences in preference raise the question of whether it will be possible for planning authorities responsible for implementing the Resource Management Act 1991 (RMA) to identify a framework of policies acceptable to all stakeholders. One of the key mechanisms proposed for detailed planning under the RMA is the concept of performance standards—"biophysical bottom lines" (Upton 1991). The intent is that district councils will be expected to identify measurable thresholds beyond which environmental modification as a result of land-use change will be unacceptable.

The results of this study suggest two possible approaches to such standard setting: either to establish relatively "weak" standards that will enable a range of possible outcomes, that collectively reflect the diversity of preferences expressed by different stakeholders in the community, or to establish a "strong" set of standards which exclude changes deemed unacceptable by significant groups of stakeholders. The problem with the former (weak) approach is that it could result in significant effects that are widely opposed in the community, and in addition may not meet the underlying purpose of the RMA—that of sustainable management of resources. On the other hand, the latter (strong) approach could significantly limit potential land-use options, to the extent that on some land types there are no "permitted" options that are at the same time technically and economically feasible, acceptable to all key interest groups, and also within the overall spirit of the Act.

One possible resolution of the difficulties with standard setting is to adopt a compromise viewpoint. Further analysis of the Q sort results has identified two possible compromise scenarios (Fairweather *et al.* 1994). These both involved modest tree planting (15%), balanced by grazing and/or conservation. The primary distinction between the two was the inclusion or otherwise of wilding management. However, the disadvantage of both compromises is that none of the expressed preference themes are optimised. Furthermore, the composite land-uses envisaged under the compromise scenarios are largely uniform across all landforms, with little response to variations in land-use potential, and are arguably inadequate responses to the overall statutory goals of sustainable management.

Given the importance of landform in community preferences for particular environmental outcomes, it could be suggested that irrespective of whether "weak" or "strong" performance standards are imposed, the geographic zoning of standards should be an important consideration. The findings of this study suggest that landform-based performance standards could be a feasible option. However, preferences for effects on adjacent landforms are not entirely independent of each other, both because effects are visible from adjacent landforms, and because impacts such as wilding spread, for example, can move from one landform to another. Furthermore, the practical feasibility of particular options in terms of stock management, for example, will depend upon adjoining land-use. This suggests a need for a mechanism for ensuring integrated management across landforms. One possible approach may be to require comprehensive development plans on a property by property basis, similar to the property-based plans published under the former water and soil legislation and currently promoted under the Land Care schemes. This option has been suggested in a recent planning review of the Mackenzie District Scheme proposed for forestry provisions (A.Hearn unpubl.). A complementary part of such a strategy would be to identify the wider geographical framework for the development of particular performance standards (as proposed by Wardle *et al.* 1993), within which individual property plans are prepared. As a result, there may be significant geographical variation in the optimum balance sought between the different themes identified above.

One criticism of such planning strategies is likely to be that they appear at first sight to be more reminiscent of earlier phases of comprehensive land-use planning, than of the simplified and focused system envisaged by the architects of the RMA. It is somewhat of an irony that, in locations such as the Mackenzie/Waitaki Basin (where land-use options are severely restricted by natural constraints, and population densities are so low), planning for effects, rather than for land-use, may require more comprehensive planning intervention rather than less. One of the implications of this study has been to show that the requirements of the RMA to predict likely effects of land-use activity, and to provide for inclusive community participation in the evaluation of the acceptability of such effects, in combination reveal the complexity of effective community-based resource management. The requirements of the Act also highlight the central but frequently overlooked importance of scale in translating the actual goals of sustainable resource management to specific policy implementation (Fox 1992).

Our results indicate that the presentation of predicted effects of land-use change on information cards is a practical way to identify community preferences for management of environmental change including forestry. We were able to present a wide variety of land-use changes and effects, and the results yielded coherent patterns of preference among diverse stakeholders. However, the method needs improvement in three related areas. First, the initial prediction of effects was problematic. The need to present stakeholders with credible information encountered the problem identified by Amy (1990) of uncertainty in environmental assessment. All three predicted indicators relied heavily upon expert judgement, and this inevitably leads to the possibility of stakeholders disagreeing with the projections. However, baseline information upon which to improve predictions is frequently not available, and requires considerable investment in advance of community involvement. This inevitably limits the applicability of a technically based method. The alternative, which was followed here, is to present "best estimates" to the community early in the process, and to undertake further refinements as the study progresses.

The second area of improvement relates to the different types of information presented on the cards: these were not given equal attention by the respondents. Only 39% of significantly loading respondents made specific reference in their comments to the text information that was included on the cards on income and employment effects, or to soil status (although some of the other respondents may also have been influenced by this information and incorporated it into the Q sorts). The implication is that visual information dominated written information. This could have led to a bias towards visual factors in the responses. This may have reflected, in some responses, disagreements with the details of the projections that were included. Further, for the overall Q sort of 36 options the decision criteria seem to rest almost exclusively on the visual cues, because of the complexity of the choices faced by respondents. Future research is needed into how complex and inherently uncertain non-visual information can be presented in a way that is accessible and meaningful to respondents, and research is needed to address the best way to integrate preferences for all landforms. The limited number of eight to ten cards in the landform Q sorts enabled respondents to make reasonably fine discriminations between options. However, when faced with the 36 cards, respondents appeared to make rapid and more superficial visual evaluations. Perhaps overall Q sorts could be used as the sole data source with verbal comments actively solicited for each image card.

The third area where improvement is needed is in relating stakeholder preferences more closely to the underlying goal of the Resource Management Act 1991—namely, the sustainable management of resources. It could be argued that some of the more conservative options presented to stakeholders were not "sustainable", in that they retained significant areas under management regimes similar to those currently practised (e.g., 15% plantations with 85% continued grazing). However, the Act only controls changes in land-use activity. All options presented included change from present management involving some improvement in resource sustainability, but this was not highlighted to stakeholders, and the issue should be addressed in any subsequent study. Future research could usefully examine stakeholders' preferences for composite scenarios (as already planned) and explore more fundamental processes in landscape perception itself.

In summary, this study has identified a range of distinctive preferences among Mackenzie/Waitaki Basin stakeholders for the effects of different potential land-uses. The themes identified here clearly show that different land-use effects will be judged in a variety of ways by different interest groups. Regardless of the numerical size of each group, effective policies should take cognisance of these responses. The results also indicate some grounds for consensus, albeit for land-uses that perhaps would not be strongly favoured by any group. Finally, the attempt to include a wide range of community representatives in the evaluation of potential effects, as a basis for establishment of performance standards under the RMA, has highlighted the complexity of such a process, even when dealing with extensive land-uses in a sparsely populated area. Wilding management, conservation issues, and visual issues in particular will require careful attention to control mechanisms in any proposal for extensive land-use change.

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REFERENCES

ALDWELL, P.H.B. 1984a: Direct and indirect effects of expanding forestry in three New Zealand counties: An input-output based approach. Pp.273–93 *in* Papers of the Australia and New Zealand Regional Science Association, Melbourne.

———1984b: Impacts of large scale forestry in Bruce County, Otago: A case study. *New Zealand Journal of Forestry 29(2)*: 269–95.

———1987: Social and economic effects of large scale forestry in New Zealand: A review of issues and research. Pp.51–68 *in* "Proceedings of Harvesting Machines and Systems Evaluation Workshop", Swedish University of Agricultural Sciences, Garpenberg.

AMY, D. 1990: Decision technique for environmental policy: A critique. *In* Packle, R.; Torgenson, D. (Ed.) "Managing Leviathan: Environmental Politics and the Administration State". Hill and Broadview Press, Peterborough, Ontario.

BELTON, M.C. 1991a: "Potential for Forestry in the Mackenzie Basin with Particular Reference to the Rabbit and Land Management Area". Ministry of Forestry, Christchurch.

———1991b: "Land-use Options with tTrees and Forests in the Mackenzie Rabbit and Land Management Area". Ministry of Forestry, Christchurch.

BELTON, M.C.; O'CONNOR, K.F.; ROBSON, A.B.: Phosphorus levels in topsoil under conifer plantations in Canterbury high country grasslands. *New Zealand Journal of Forestry Science* (in press)

BENNISON, T.; SWAFFIELD, S.R. 1994: Visualisation of land-use scenarios using digital terrain models and image rendering techniques. *In* Proceedings of "Image of Vision" Computing Conference, August, Massey University, Palmerston North.

BERNALDEZ, F.G.; RUIZ, J.P.; BENAYAS, J.; ABELLO, R.P. 1988: Real landscapes versus photographed landscapes. *Landscape Research 13(1)*: 10–11.

BOFFA MISKELL PARTNERS 1992a: "Landscape Change in the Mackenzie/Waitaki Basins". Boffa Miskell Partners Ltd, Christchurch.

———1992b: "Landscape Guidelines for Forestry in the Mackenzie/Waitaki Basins". (A supplement to the report "Landscape Change in the Mackenzie/Waitaki Basins"). Boffa Miskell Partners Ltd, Christchurch.

BROWN, S.R. 1980: "Political Subjectivity: Applications of Q Methodology in Political Science". Yale University Press, New Haven.

CONNOR, H. E. 1964: Tussock grassland communities in the Mackenzie Country, South Canterbury, New Zealand. *New Zealand Journal of Botany 2*: 325–51.

———1992: The botany of change in tussock grasslands in the Mackenzie Country, South Canterbury, New Zealand. *Review: Journal of the Tussock Grasslands and Mountainlands Institute 49*: 1–31.

DAVIS, M.R.; LANG, M.H. 1991: Increased nutrient availability in topsoils under conifers in the South Island High Country. *New Zealand Journal of Forestry Science 21*: 165–79.

DELAMORE, R. 1994: High country forestry: A conservation perspective. *New Zealand Forestry 38(4)*: 6–9.

DRYSEK, J.; BEREJIKIAN, J. 1993: Reconstitutive democratic theory. *American Political Science Review 87(1)*: 48–60.

FAIRWEATHER, J.R.; SWAFFIELD, S.R.; LANGER, L.; BOWRING, J.; LEDGARD, N. 1994: Preferences for land-use options in the Mackenzie/Waitaki Basin: A Q method analysis of stakeholders' preferences for visual images of six land-uses on four landforms. *Lincoln University, Canterbury, AERU Report No.224.*

FOX, J. 1992: The problem of scale in community resource management. *Environmental Management 16(3)*: 289–98.

GREGORY, D. 1988: "Forestry in the Canterbury High Country". Canterbury United Council, Christchurch.

JOHNSON, R.L.; BRUNSON, M.W. 1994: Using image capture technology to assess scenic value at the urban forest interface: A case study. *Journal of Environmental Management 40(2)*: 183–95.

KAPLAN, R. 1985: The analysis of perception via preference. A strategy for studying how the environment is experienced. *Landscape Planning 12.*

KENT, R.L. 1993: Determining scenic quality along highways—A cognitive approach. *Landscape and Urban Planning 27(1)*: 29–45.

LEDGARD, N.C.; BELTON, M.C. 1985: Exotic trees in the Canterbury high country. *New Zealand Journal of Forestry Science 15(3)*: 298–323.

LUCAS, D.J. 1987: High country landscapes: Too much change, too fast. *Forest and Bird 18(4)*: 6–8.

LYLE, J.T. 1991: The utility of semi-formal models in ecological planning. *Landscape and Urban Planning 21*: 47–60.

MARTIN, G. (Convenor) 1994: "Final Report of the Working Party on Sustainable Land Management". Ministries of Conservation, Agratho and Environment, Wellington.

MURRAY, P. H. 1986: Attitude and opinions of high country farmers concerning exotic forestry. M.Appl.Sci. Thesis, Lincoln College, Canterbury.

O'CONNOR, K.F. 1981: Changes in the tussock grasslands and mountain lands. *Review: Journal of the Tussock Grasslands and Mountain Lands Review Institute 40*: 47–63.

———1983: Land-use in the high country. *In* Bedford, R.; Sturman, A. (Ed.) "Canterbury at the Crossroads". New Zealand Geographic Society, Christchurch.

———1986a: Roles for forestry in high country land-use. *Review: Journal of Tussock Grassland and Mountain Lands Institute 43*: 83–94.

———1986b: The influence of science on the use of tussock grasslands. *Review: Journal of the Tussock Grasslands and Mountain Lands Institute 43*: 15–78.

———1994: High country land-use: What are the issues for 1994? What relevance has forestry? *New Zealand Forestry 39(4)*: 2–5.

ORLAND, B. 1993: Synthetic landscapes: A review of video-imaging applications in environmental perception research, planning and design. *In* Marans, R.; Stokols, D. (Ed.) "Environmental Simulation: Research and Policy Issues". Plenum Press, New York.

PARLIAMENTARY COMMISSIONER FOR THE ENVIRONMENT 1991: "Sustainable Land-use for the Dry Tussock Grasslands in the South Island". Wellington.

SCHROEDER, H.W.; ORLAND, B. 1994: Viewer preference for spatial arrangement of park trees: An application of video-imaging technology. *Environmental Management 18(1)*: 119–28.

SWAFFIELD, S.R. 1991: Roles and meanings of landscape. Ph.D. Thesis, Lincoln University, Canterbury.

———1994a: Attitudes towards trees—A case study in the New Zealand eastern high country. *New Zealand Forestry 38(4)*: 25–30.

———1994b: Landscape as policy myth. *In* Proceedings, Ecopolitics VIII, July, Lincoln University, Canterbury.

TAYLOR BAINES AND ASSOCIATES 1990: Social and institutional monitoring and evaluation in the rabbit and land management programme. Report on Phases I and II covering the period November 1989 to May 1990. Ministry of Agriculture and Fisheries, Lincoln.

TRESKONOVA, M. 1991: Hieracium—An ecological perspective, *Review, Journal of the New Zealand Mountain Lands Institute 48*: 32–40.

UPTON, S. 1991: Legislation promoted sustainable management. *Environment Update 23*: 2.

WARDLE, K.; FORAN, B.; GIBSON, R. 1993: Developing sustainable use scenarios for the dry tussock grasslands of New Zealand. Semi Arid Lands Research Groups, Landcare Research, New Zealand.

MAGNESIUM NUTRITION AND DRY MATTER ALLOCATION PATTERNS IN *PINUS RADIATA*

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ABSTRACT

Pinus radiata D. Don seedlings grown in a range of magnesium solution concentrations showed differences in root : shoot ratios, with those exhibiting magnesium deficiency symptoms allocating proportionately less resources to the roots than healthy seedlings. A foliar spray of 2% magnesium solution with 0.2% Pulse™ in water alleviated the deficiency symptoms and improved dry matter allocation to the roots. In a 7-year-old *P. radiata* fertiliser trial, magnesium fertiliser treatments caused no improvement in basal area or height after 6 years but foliar magnesium concentrations had been raised above the critical level. Trees with adequate foliar magnesium had nearly double the fine root biomass of those with inadequate concentrations. This suggested that below-ground dry matter allocation was decreased in deficient trees, and that the noted slow growth response of *P. radiata* to magnesium fertiliser may be due to the need to rebuild the root system before an above-ground response occurs. However, while fine root (<1 mm) biomass was increased in 3-year-old trees treated 18 months previously with magnesium fertiliser, no relationship between root:shoot ratio and magnesium application was found. It was suggested that the changes in root:shoot ratio may develop over a period longer than 3 years.

Keywords: magnesium; root:shoot ratio; tree nutrition; *Pinus radiata.*

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