Using data visualization to evaluate economic/aesthetic trade-offs in forest plantation management

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Abstract

Commercial forest plantations have long been an important component of the New Zealand economy. Increasingly, international tourism also provides significant economic benefits. In some locations the effects of forest management have come in conflict with the landscape visual quality expectations of tourists, as well as arousing considerable negative response from local residents and from New Zealanders who visit forest areas for recreational pursuits. Responsible plantation management and specific provisions of New Zealand's Resource Management Act require careful balance among economic, environmental and aesthetic effects. Computer models for projecting plantation growth and economic models that schedule harvests to optimize net monetary benefits were combined to estimate the economic benefits associated with four possible management scenarios for a multiple-stand forest site. Using a combination of GIS, analytic data visualization (SmartForest) and digital video (photographic) imaging tools, visualizations were created for each of the four management scenarios. Visualizations were incorporated into a perceptual survey experiment to be presented over the WWW. Participants in the experimental survey are presented with visualizations in pairs, and record preferences on the basis of "perceived scenic quality." Subsequently the same respondents see composite visualizations along with printed information about the economic effects of each alternative and indicate which alternatives provide the best "overall outcome," considering both economic and visual aesthetic factors. Results

to date confirm the potential for integrating forest growth and economic models with data visualization techniques to obtain valid measures of public preferences for alternative management alternatives. The perceptual survey experiment is continuing on the WWW, with several content and procedural parameters being systematically varied and evaluated.

1 Background

A successful forest industry based on intensively managed *Pinus radiata* plantations has been part of the New Zealand agricultural economy for over 30 years. Currently the 1.5 million hectares of plantation forest is the third ranking contributor to the New Zealand economy. Forest products have a market value in excess of $2.6 billion (NZ) annually and provide employment for twenty eight thousand people. Typically, management options involve mechanical and/or chemical site preparation and planting of genetically improved seedlings, followed progressively by thinning and pruning, and then clearfell harvesting within rotation intervals of approximately 20 to 30 years (McLaren 1993).

Forest plantations are also important to the scenic beauty of the New Zealand landscape, a key contributor to the quality of outdoor recreation experiences and to a growing tourism industry. Commercial forestry practices, especially large scale clear cutting and site preparation practices, are encountering increasing objections from tourists, recreation visitors and from more sensitive local residents, particularly in areas with high visibility and use.

The responsibilities of the commercial forest industry for visual/aesthetic value protection have been unclear in New Zealand's past. Nevertheless, forest managers have historically forgone scheduled harvests in some visually sensitive areas or have used techniques such as landscape screening and amenity planting in an effort to mitigate visual effects and maintain desirable public relations (Lucas 1987, Moore et al. 1991, Sissons and Conway 1991, Tasman District Council 1997). The more recent dedication of the forest industry in New Zealand to the improvement of visual environmental quality can be largely attributed to the Resource Management Act (RMA, Parliament of New Zealand 1991), where aesthetic protection is specifically required. Thus, the provision of tools capable of effectively projecting and assessing the visual aesthetic consequences of alternative forestry practices is essential for the modern forest manager to aid the development of appropriate policies and practices, and presents a challenge for researchers.

The RMA controls activities such as use, development or protection of the natural and physical resources of New Zealand. The Act strongly emphasizes the investigation of the *effects* of proposed activities, rather than prescribing which activities shall or shall not be allowed. It includes the ethnic philosophy of *Kaitiakitanga* – the exercise of guardianship of the land and, in relation to a resource, includes the ethic of stewardship based on the nature of the resource itself. In addition to consideration of effects, any mitigation efforts must be communicated clearly among the forest operator, regulatory authorities and other interested parties.

The reasons for public objections to commercial forestry practices are diverse and complex, but visual impacts are a substantial contributor (Kilvert and Hartsough 1993). Abrupt alterations of scenic environmental settings (Thompson and Weston 1994) may pose direct threats to tourist and recreation industries, as well as residents' environmental quality expectations. In addition, visual effects often precipitate public concern for other potential environmental and cultural impacts.

Generally the public are able to readily identify visual change in the landscape (Benson and Ullrich 1981, Swaffield 1994, Kilvert 1995a, 1995b) and visual images are considered an excellent and valid medium for communicating the effects of forestry operations to the public (Daniel and Boster 1976, Daniel et al. 1990, Orland 1988, 1992). The idea of using computer-generated images calibrated to known resource attributes to derive human values is not a new one. Malm et al. (1981) used image-processing techniques to develop images of air pollution plumes in the Grand Canyon (USA). Plume parameters were based on the output of numerical models of atmospheric dispersion of visible pollutants from regional sources. The images were used in surveys to determine human perceptions and evaluations of the scenic impacts predicted for an array of air pollution scenarios potentially affecting views in the Canyon. This study established the effectiveness of computer imaging techniques, but used computing resources beyond the means of typical natural resource agencies. Subsequent studies have developed and used techniques available on more widely available personal computer platforms. Examples in the forestry context include Baker and Rabin's (1988) study of the visual effects of limb rust damage, the Orland et al. (1993) study of the impacts of bark beetle damage and silvicultural prescriptions in high-elevation spruce forests, Orland, Daniel and Haider's (1994) application to the visualisation of forest harvesting alternatives in Northern Ontario (Canada), and visualizations of alternative commercial forest management practices in New Zealand (Thorn et al. 1997).

The above and additional studies have shown the effectiveness of computer visualizations for representing the visual implications of natural and management-induced changes in forest landscapes. When these visualizations are incorporated into carefully designed perceptual survey procedures, quantitative measures of public preferences for alternative future forest conditions can be obtained. Critical to the reliability and validity of these measures of public perception and preference are 1) accurate projection of the visually relevant bio-physical changes in forest conditions associated with each studied management alternative; 2) accurate translation of projected bio-physical changes into realistic visual representations; and 3) a survey design that employs appropriate psychometric procedures and analyses, respondent population sampling, and a relevant judgement context (e.g. Brown & Daniel 1987). Even when these criteria are met, however, the public preference indices that result only address the visual/scenic features of the alternatives considered. That is, when respondents are limited to a visual representation of the alternatives, their expressed preferences should not be taken to represent evaluations of non-visual aspects of the alternatives represented (such as environmental or economic consequences).

Forest management decisions (as all significant environmental management actions) have multiple consequences. While visual/aesthetic effects are universally recognized as important, and visualization-perceptual survey techniques have successfully addressed this environmental value dimension, a larger question is how visual effects should be "traded-off" with other important effects in the selection of environmental management alternatives. The study described here presents an initial investigation of methods to combine visualization and perceptual survey methods with more conventional verbal survey techniques to determine how public audiences combine visual-aesthetic concerns with economic objectives in deciding the "overall" preferability of forest management alternatives. In particular, the long term value of the forest estate (expressed as present net worth) and employment related statistics (number of full-time equivalent jobs) were modeled for a set of New Zealand forest plantation management alternatives. These economic indicators are presented in conjunction with visualizations of the same alternatives to both New Zealand and international survey participants over the WWW. Participants express preferences among alternatives, based on scenic values alone and (separately) on the combination of scenic and economic effects.

2 Method

A panoramic landscape scene was chosen to represent typical forest conditions in New Zealand (Thorne et al. 1997, see Figure 1).

The selected scene was located in the Golden Downs Forest near Nelson, NZ. The terrain within the study

Figure 1. Panoramic view of study site prior to simulation/harvest.

viewshed was moderately complex, with the view extending across a rolling valley bottom then rising in the background to a steep valley side. Multiple stands of radiata and contorta pine, with a range of age classes formed the production forest cover. Forest harvesting plans for the landscape scene were developed in consultation with forest managers.

2.1 Alternative harvest scenarios

Individual scenarios for forest harvest and re-establishment were developed within constraints imposed by conventional forestry practices, including species selection, silvicultural optimisations, roading and hauler locations and ecological, riparian margin and landscape design considerations. Four different landscape management scenarios were created by varying combinations of harvest timing, cutting block shapes and sizes and site preparation and planting practices. Each scenario was developed in detail and represented by a series of maps designating which components of the scenario were to be implemented at each of 5 temporal stages. The four management scenarios were: 1) a "standard practice" (coded STD harvest sequence and pattern; 2) the standard scenario modified slightly to accommodate ecological and environmental considerations (STD-ENV), principally by leaving uncut strips along streams; 3) a variation from the standard practice (VAR) that breaks the scene up into smaller cutting blocks with less regular boundaries; and 4) a modification of the VAR scenario to include the buffer strips along the streams for ecological and environmental considerations (coded VAR-ENV).

2.2 Modeling Future Forest Growth

The New Zealand forest industry uses sophisticated forest management decision support systems (DSS) for growth and yield predictions, valuation and estate modelling. For our study, future forest stand conditions under each of the four management scenarios were predicted using STANDPAK (Whiteside 1990), a DSS designed to model individual stand growth and yield while optimising silvicultural management alternatives. A specific silvicultural regime was determined for radiata pine (Pinus radiata D. Don) and for Douglas fir (Pseudosuga menzesii) and held constant over the modelling exercise.

Silvicultural regimes consistent with expected future management schemes and log product classes were developed in consultation with silvicultural foresters. The radiata pine regime was specified as: plant 600–700 stems per hectare of GF25-28 tissue cultured seedlings with two pruning lifts at an age of 6–7 years to a height of 2–3 m for 350–400 selected stems and a further lift at age 8–9 to 6 m for 250 selected stems, followed by thinning to 300–350 stems/ha at 8–9 years. The Douglas fir regime was defined as planting 1 200 stems per hectare, followed by a sequence of pruning at age 11, 12 and 13 and a thinning at 17 years on mean top height basis to 500 stems per hectare.

2.3 Determining forest estate value

To establish the changing forest value as the individual scenarios were sequentially harvested and re-established and subjected to silvicultural operations, models were developed for each of the four scenarios within the FOLPI (Forestry-Oriented Linear Programming Interpreter) estate modelling system (Garcia, 1984). This modelling system has been used in a wide range of forestry applications and has evolved in response to experience gained while assessing long-term strategic and tactical planning over a time horizon of 60-90 years (Manley et al. 1991). FOLPI analysis enables yield regulation, management strategy evaluation, processing plant scenario evaluation, investment analysis and forest valuation leading to the determination of the optimum strategy for harvest sequence and rotation length. By constraining harvest ages to comply with each landscape management scenario harvest sequence, and allowing optimisation of the subsequent rotations until the year 2055 we were able to predict the NPV (based on a 60-year modeled life) for each of the scenarios. This extended model period was needed to portray the full economic implications of the different plans, at least through two full crop rotations. A discount rate of 8 percent was used to estimate NPV associated with the time steps/stages (1996, 1998, 1999, 2008, 2012, and 2016) associated with the visualizations. The NPV may be interpreted as the "price" one would expect to pay at the indicated time for the future economic benefits (revenues minus costs, discounted at a rate of 8 %) associated with the respective management options.

The FOLPI estate model system normally uses linear programming to find an optimal management strategy, by maximising the specified objective subject to user-defined constraints. Because of our requirement to mimic the pre-determined strategies we utilised the system as a simulator by constructing four models, corresponding to the four scenarios. A separate data file was required for each, incorporating the yield tables for the existing stands and those for the stands to be established under the relevant planting plan. In each case, constraints were entered to ensure that the existing stands would be harvested at the correct time, and the appropriate areas would be replanted.

FOLPI uses the concept of the *croptype* as the basis for modeling, where a croptype is an aggregation of forest stands which may differ in age and time of harvest, but are regarded as uniform with respect to future silviculture, yield production and the associated streams of inputs and outputs. In this case, aggregation was not required as the croptypes were defined by the management units assumed under each cutting and planting plan.

Data requirements for each croptype (Table 1) were assembled as follows:

Table 1. Number of croptypes identified for each scenario by operation.

Scenario	Number of croptypes		
	Cut Plan croptypes	Planting plan croptypes	Total croptypes
Ec	13	18	31
Ee	13	32	45
Vi	14	26	40
Ve	14	37	51

Area

An age class distribution is required for each croptype. For croptypes represented in the cutting plan, the current area was determined from the GIS analysis used to establish the stand boundaries. Stand age was determined for the forest managers' database. The area for croptypes which represented stands to be planted in the future was set to zero.

Yield table

A yield table was derived for each current and future stand using the stand prediction model, STANDPAK (Whiteside 1990). STANDPAK generates medium to long-term predictions by simulating growth, harvesting and processing on a stand basis. For this exercise, STANDPAK was used to generate yield tables, for radiata pine and Douglas fir. There was no differentiation in growth between stands of the same species. As all four scenarios assumed that the *Pinus contorta* stands would be felled and replanted to Douglas fir in the first year, a simple yield table was constructed for these stands which assumed a) a yield of half the radiata yield at the equivalent age, and b) only pulp logs produced.

Costs and labour

Labour requirements for and costs of silvicultural operations (Table 2) are generalised values for New Zealand

Table 2. Silvicultural regimes, costs and labour requirements.

Radiata pine

Age	Operation	Cost ($/ha)	Labour (days/ha)
0	Planting (including seedlings)	960	1.2
6	Prune	300	2.5
8	Prune	350	1.9
9	Thin	160	2.2

Douglas fir

Age	Operation	Cost ($/ha)	Labour (days/ha)
0	Planting (including seedlings)	1 100	2.0
11	Prune	400	3.4
12	Prune	360	2.4
13	Prune	300	3.1
17	Thin	180	1.6

Table 3. Expected stumpage prices by age, log grade and species.

Radiata pine prices

Age	Pruned	S1S2	S3L3	L1L2	Pulp
1 to 24	48	68	68	68	68
25 to 26	68				
27 to 28	88				
29 on	108				

Douglas fir prices

Age	Pruned	S1S2	S3L3	L1L2	Pulp
1 to 38	86	86	86	86	86
39 to 42	106				
43 on	126				

Pinus contorta prices

Age	Pruned	S1S2	S3L3	L1L2	Pulp
All	68	68	68	68	68

which in practice may vary on a regional basis in response to factors such as terrain and hindrance (Knowles et al. 1996, Hjortsø 1997, West, pers. comm.). The values used for Douglas fir regimes have been adapted from high stocking radiata pine regimes, while those used for radiata are from the low stocking regime.

Log prices

Expected stumpage prices for the five log grades (Table 3), predicted by the STANDPAK modelling runs, were determined in consultation with the forest managers.

2.4 Economic Projection

Forest value (NPV) was generally lowest for the two "standard" scenarios during the time steps that were visualised (Table 4). This is primarily the result of the early harvest at age 20 years of the foreground stand, in contrast to the optimum harvest age for the region of 28 years.

Table 4. NPV (8 % discount rate) by scenario and time step: 1996, 1998, 1999, 2008, 2012, 2016.

Scenario	STD	STD-ENV	VAR	VAR-ENV
Year				
1996	$5,781,647	$5,724,136	$5,824,358	$5,763,977
1998	$5,472,465	$5,401,107	$4,610,234	$4,531,024
1999	$1,775,413	$1,687,051	$3,595,241	$3,506,470
2008	$3,556,029	$3,378,028	$3,797,067	$3,611,672
2012	$1,635,826	$1,393,594	$5,171,178	$4,918,482
2016	$2,237,832	$1,906,921	$2,503,507	$2,158,657

The variation scenarios resulted in somewhat greater and more stable estate values over the simulation period, which is linked to the multiple harvest of smaller stand units and the optimisation of harvest to more mature stands.

2.5 Employment opportunity

The employment factor assumed was 0.0002 FTE/m^3, where FTE = Full Time Equivalent based on 235 days/year and 8 hours/day (Hjortsø 1997). Total FTE employment was computed for each of the four management scenarios.

Projected employment opportunity over the simulation period (Figure 2) is strongly linked to silvicultural operation and driven by the area of treatment within the year. Thus the employment opportunities for the STD-ENV and VAR-ENV scenarios are slightly less due to reductions in harvest area through retirement of riparian margin areas and the area above an altitude of 850 m which is considered unproductive.

The similarity of the pattern of employment requirements for the two standard scenarios and for the two variation scenarios, respectively, is due to both pairs of simulations utilising the same basic harvest strategy. Comparisons with the associated "environmental" scenario for each basic plan indicate the loss of jobs due to the small riparian areas excluded from the harvest. While the differences are not large for this

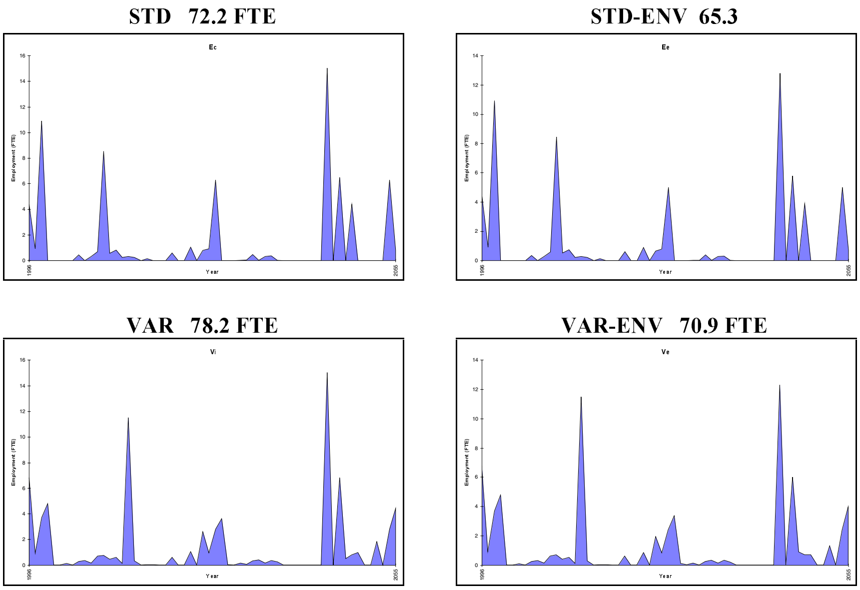

Figure 2. Projected employment opportunity 1996–2055 for alternative management scenarios.

small study area, each scenario projected an unique labour requirement for the simulation period, and the differences might be quite significant if projected for the much larger New Zealand forest estate.

2.6 Data visualisations

Each of the four harvesting plans and their respective projected future plantation conditions were mapped and entered as layers in a GIS data base. This database was used to direct the visualization process. Standard perspective view routines in GIS do not adequately display the height of "layers" of trees on the landscape so that visibility can be verified, and the thickness of linear graphical elements is such that boundaries seen at oblique angles cannot be differentiated. In our study a great number of attributes needed to be accurately represented visually, but equally significant was the interaction of those attributes in the visual display. For example, the size of a forest cutting operation cannot be separated from the forest type where it occurs, the shape and location of the cut, what is left as residual, or the amount of regrowth after the cut. Thus, a special software system was used to create schematic analytic 3-D representations to match specifications from the scenario prescriptions and to verify the appropriate spatial relationships among the attributes to be visualized at each stage of each of the four management scenarios modeled.

SmartForest II (Orland 1994) is a landscape visualisation software package capable of displaying a schematic representation of tree density, size and homogeneity of stand composition in correct visual perspective (Figure 3). The system was designed for application to planning forest landscapes at large scale, while at the same time being able to develop specific management strategies at a small, tree-by-tree scale. Rapid display of viewsheds and the capability to move viewpoints within the "scene" data space makes the tool eminently suitable for landscape planning applications. The software requires a workstation platform and is available via the World Wide Web at http://imlab9.landarch.uiuc.edu/SF/SF.html.

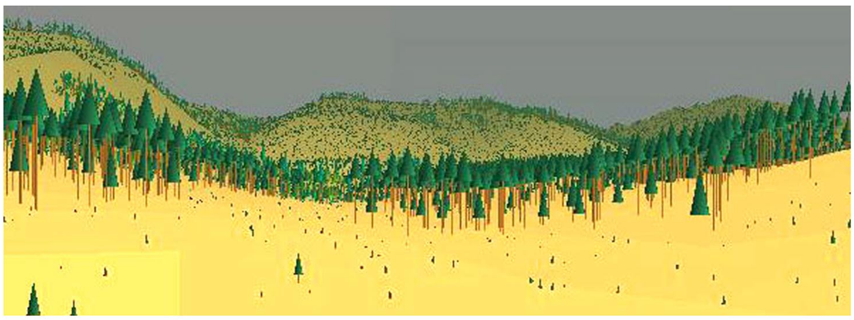

Figure 3. SmartForest II data-driven analytical visualisation for STD 1999 projection.

Source data for the SmartForest II modeling was compiled from several sources (Thorn et al. 1997). A digital elevation model (DEM) was generated from elevation data stored as contour coverages in a GIS, ARC/INFO® (ESRI, 1991) to provide topographical data for creating the landform features. Location and shape of stand boundaries for each of the landscape management scenarios were developed using TerraSoft® GIS (PCI, 1996) before being translated to ARC/INFO® stand boundary coverages. Records of the vegetation to place in each stand cell location were generated for each age class to be represented in the visualisations (0, 2, 3, 8, 10, 20 years). Growth at each stage was modeled with STANDPAK software for each management alternative.

SmartForest II is effective at showing significant structural changes in canopy configuration, such as edge conditions created in harvesting and the effects of near-view tree growth on visibility (or screening) of more distant stands. Through use of false colour, non-visible characteristics such as size class, age, species distribution and silvicultural history of trees/stands can also be shown. SmartForest II visualisations were stepped through the modeled time sequences to generate analytical simulations for each stage of all four management scenarios. The analytical simulations (Orland et al. 1997) provided geographically rectified templates to guide photo-realistic image editing. This approach provided a data driven and defensible linkage between landform, forest cover, and forest management effects displayed in the final visualization products.

2.7 Source image library

An important step toward creation of the final visualizations was to develop a library of imagery representing forest conditions (harvest, site preparation, planting, thinning, pruning and regrowth) that would be components in the visualizations. Care was taken to collect images for the library that were photographed from a similar viewpoint, aspect and distance as the selected simulation scene. During the spring of 1994 more than three thousand photos of forest conditions were collected around Golden Downs and Rai Forests near Nelson, and Whakarewarewa Forest near Rotorua.

Images were collected in the field as 35 mm color slides using a hand-held Nikon 8008 with autofocus and auto exposure. The majority of photos were taken at a 50-mm focal length setting. A moderate telephoto lens of 85-mm focal length was used at times for finer detail. The film was Kodak Ektachrome Elite, a 100 ASA semi-professional colour film with good colour rendition. A polarising filter was used at all times and camera direction of view was, to the extent possible, held between 15 and 60 degrees of a line directly opposing sun bearing. These latter two measures were to maximise colour saturation. Three hundred images were selected from the entire set based on an appraisal of image quality as well as suitability for filling the experimental design requirements. These source images were transferred to Photo-CD format using commercial processing by Kodak. Source images were stored at a resolution of 768 x 512 pixels with 24-bit colour depth, a compromise between quality needed and the size and concomitant complexity of the large image database. All images underwent histogram equalisation to achieve the best consistent contrast and colouration throughout the image set as it was clear at the outset that the study design would necessitate considerable image editing and the use of an extensive source image library. Adobe Photoshop™ software on Apple Macintosh computers was used for image manipulation. Orland (1988, 1993) has described the evolution of typical uses of these tools, the basic techniques, and issues of image validity and utility.

2.8 Creating calibrated images

The assembly of the final visualizations was a guided artistic process of taking appropriate image components from the source imagery files and combining them in the initial panoramic scene to fit the SmartForest II 3-D analytic templates. The templates assure geographic accuracy in the represented features, but the choice of specific image elements (instances of harvest, site preparation, etc) is largely up to the expert judgment of the visualization creators. A team of experienced Forest Research Institute and industry scientists and managers evaluated and critiqued each generation of the visualizations. Indicated modifications were then made and the revised visualizations were re-evaluated. This process was repeated until acceptable representations of the four management scenarios were achieved (Figure 4).

2.9 Validating visualizations

An important component of the New Zealand studies was to validate the visualization process by monitoring the progress of harvest and other management actions actually implemented. The planned approach was to implement one of the simulated management alternatives and then compare actual photographs taken at

VAR 1999

Figure 4. Example of photo-realistic visualization.

the end of each stage of operations to the projected visualizations of those same stages. In the end, because of business and other practical considerations the management procedures implemented and the temporal staging did not exactly match any of the simulated plans. However, as Figure 5 shows, the visualizations of projected conditions are clearly comparable to the actual conditions. Comparisons will continue in future years, but the indication is that the visualizations created to represent the four management alternatives are valid representations of actual conditions that would occur if those plans were implemented on the study site.

In the final visualizations, each management scenario was represented by a set of six panoramic images. The first image showed the projected effects immediately after the initial operations on the study site (modeled as 1996) followed by representations of forest conditions projected for subsequent stages at years 1998, 1999, 2008, and 2012. The final stage (2016) showed full canopy closure over the scene, with distinctions among the regrown stands visible only as subtle texture differences.

2.10 Perceptual survey experiment design

The visualizations and the economic data for each of the four scenarios will be combined into a three-part perceptual survey. In the first part participants are presented with pairs of individual panorama scenes and are instructed to choose the scene that they judge to provide the "best scenic quality." Pairs always contrast two management scenarios, each at the same stage of their respective management plans. In the second part of the experimental survey each management alternative is represented by a five-scene set, as illustrated in Figure 6.

In this second part of the survey experiment participants choose the member of each pair that provides the "best overall scenic quality," considering all represented stages of management. In the final part of the survey, the same four scene sets are presented again, but with the appro-

Actual Photograph of New Zealand Study Site 1998

Figure 5. Actual conditions for the study scene in 1998 (digitized).

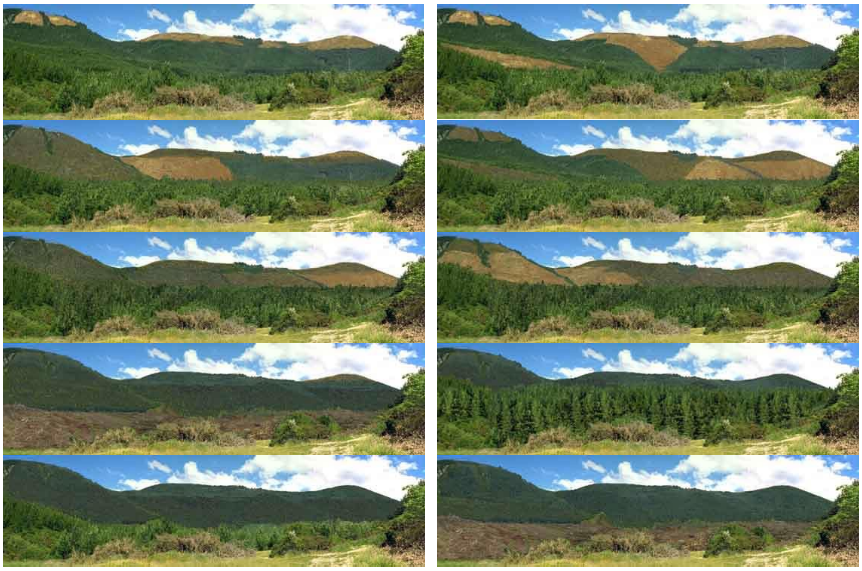

Figure 6. Example of paired five-scene sets.

priate economic data (present net worth calculated for 1998 and/or total FTE jobs over the model period) printed under each alternative. Participants are instructed to choose the member of each pair that provides the "best overall results, taking both scenic quality and economic benefits into consideration."

The introduction to the experimental survey briefly reviews key aspects of New Zealand forestry, emphasizing that coniferous trees ("pines") are "exotic" species that are typically grown in commercial plantations for the purpose of producing material for wood and paper products. The importance of forest plantations to the New Zealand economy is noted, as well as the role of the plantation forests as a significant scenic component of the landscape. It is explained that New Zealand law requires the management and harvest of forest plantations to take a number of environmental and social effects into consideration. In particular effects on visual aesthetics, an important contributor to quality of experience for tourists and for New Zealand residents who live or recreate in the vicinity of these plantations, must be considered.

The background instructions also point out that economic and environmental effects of forest management are typically measured and controlled by appropriate scientific and technical analyses, but that the scenic quality component requires the participation of people like themselves. Respondents are told that the judgments that they make in the survey will be very helpful in identifying what visual effects of plantation forest management are the most (and least) preferred by people who view these landscapes. It is emphasized in these components of the survey that respondents should only consider the scenic quality differences among the alternatives presented, as the other factors were being assessed by other methods.

Immediately before the third and final part of the experimental survey participants are told that we needed their help in determining the best "combination of visual and economic effects." They are instructed that, unlike the earlier parts of the questionnaire, they should consider both scenic and economic effects of each alternative and choose that alternative that achieves the "best balance" of effects.

2.11 Status of perceptual survey

The perceptual survey is being implemented as a continuous experiment on the WWW at http://ag.arizona.edu/EPLab/. The goal is to sample participants from throughout New Zealand, as well as interested individuals elsewhere in the world – with the latter assumed to represent potential international tourists who might visit the country and see the results of the forest plantation management practices similar to those represented in this study. Readers are invited to review the survey, and the full set of visualizations at the address shown above.

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