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Landscape visualisation tools and methods: Decision making with scenarios

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Abstract: Landscapes reflect the multifunctional nature of land and the complex relationships that exist between society and the environment. Land management systems have evolved to provide resources to meet societal demand but within a human lifetime these practices can significantly change both the landscape and the relationship that people have with the affected land. Land uses have differing, often conflicting objectives and making decisions on landscape futures is challenging to decision makers and compromises must be made between competing economic, ecological and social values. When dealing with competing criteria, land use decision-making is complex, made more so when we consider the spatial and temporal dimensions of the decisions. Scenario development is an effective way to present complex spatial and temporal information and geographical information systems provide a basis with which to assess the relative success of alternative landscape scenarios quantitatively.

This paper describes a software system – ScenarioBuilder - which allows stakeholders and expert groups to build landscape scenarios depicting different forest management strategies in a 68000 Ha study area in Southern Tasmania comprising private property, state forest and national park land. The ScenarioBuilder software built around ESRI ArcObjects is operator controlled and allows manipulation, selection and display of the underlying 2D polygon based forestry data. The software includes procedures to apply combinations of forest management systems to areas defined spatially or by combinations of attributes and to display this information via a range of thematic maps. Scenarios are quantified in terms of three primary outputs; Wood Supply, Environment and Amenity, each being a composite of other landscape sub-outputs. Conversion tables were developed to represent the relative sub-outputs of each of the forest management strategies and the primary landscape outputs were computed as the scenario developed. Constraints and prescriptions were developed to meet with current forest policy and operational practice and two types of scenario were developed; constrained and unconstrained. The constrained scenarios had all constraints and prescriptions automatically applied leading to a reduction in the harvestable area in addition to having a minimum timber production quota set. The unconstrained scenarios had no set minimum timber quota and optionally applied constraints and prescriptions to suit the scenarios objectives.

Fifteen expert groups produced twenty five scenarios each one represented as a map describing the groups' preference as to forest management strategy. Distribution analysis of the applied management systems indicated that within the study area, three geographic areas contained the most variation in preferred forest management system. This variation is an indication that the geographic areas are deemed by the expert groups to be more sensitive to the applied management system. As such, these areas of contention will form the basis for the second development phase of this study. This phase will build 3D visual models of selected scenarios and aim to determine levels of preference for the different scenarios in the general public.

Keywords: *Landscape Planning, Geographical Information Systems (GIS), Forest Harvesting Methods*

1. INTRODUCTION

Land and the way it is managed reflects the complex relationship that exists between people, their society and the environment. Landscape may be regarded as a geographical construct that includes not only biophysical components but also social, psychological and other components (Farina, 1998) and defines the relationship between people and place (Tress, 2001). Landscapes are multifunctional through their ability to simultaneously support habitat, productivity, social and economic functions and the degree of integration between social-economic functions and environmental functions including natural resource protection depends on the patterns and intensities of land use (Mander et al., 2007). The countryside supports urban growth, industrial expansion and the publics demand for recreational activities. It also provides natural resources, protected areas for species conservation and nature reserves. Land uses have differing objectives which may conflict (De Groot, 1987) or be constrained by legislative policy or accepted practice, adding additional complexity to land use planning.

Making decisions on landscape futures is challenging to both the decision makers and the researchers looking to represent options in the landscape. In considering land use decision-making, in the face of competing criteria, it must be recognized that (a) environmental decision-making is complex, multiple outcomes must be considered and realistic options are unlikely to satisfy all desired outcomes and (b) complexity of these decisions is even greater when we consider the spatial and temporal dimensions of these decisions. People are likely to weigh up outcomes differently if they are able to envisage these outcomes in a way that incorporates both temporal and spatial variation (Bishop, 2008).

Representing alternative future landscapes as specific scenarios is an effective way to present complex spatial and temporal information to both expert and non-expert groups. Geographic information system (GIS) databases provide a mechanism for manipulating existing conditions into future options while observing user imposed constraints. A key contributor to using GIS in landscape scale research is the growing recognition of the importance of having a landscape-scale perspective in tackling environmental management and for planners to have a “whole landscape” approach to planning problems (Lovett, 2009). The scenario development process generates a range of solutions which may be compared through derived landscape indicators and supports surrogates for ‘intangibles’ (e.g., scenic value) associated with landscape futures (Wollenberg, 2000). Appropriate landscape planning is especially important in areas dominated by production forests, where the planning and allocation of land and the harvest method employed is critical to ensure an adequate and sustainable timber supply, an ecologically sound environment and a visually acceptable landscape for the public. In this environment, the type and intensity of harvest system applied, directly affects the quantity of timber product extracted, the underlying ecosystems and the visual appearance of the landscape.

GIS centric visualization systems such as the CALP Visualization System (Meitner, 2005) are very sophisticated and aim to generate 3D landscape representations by integrating various environmental models with a rendering engine, whereas landscape planning toolsets such as CommunityViz (Kwartler, 2001) and Smartplaces (Croteau, 1997) also produce 3D landscape models but mainly focus on urban planning where placement of forested areas are an adjunct to landscape development.

Before visualizing future landscapes, the scenarios have to be developed and this paper presents a scenario development tool using a GIS based approach to landscape planning. The development tool, termed ScenarioBuilder, is the first part of the scenario development/visualization process. ScenarioBuilder is used in the context of representing a range of forested landscape scenarios depicting a number of different forest management techniques. ScenarioBuilder, based on ESRI ArcGIS ArcObjects technology, is designed to be used by an operator to display and manipulate a 2D map representing a 68000 Ha study area in Southern Tasmania. The scenarios are built by different groups of between one and four like-minded people recruited from publically available listings of stakeholder organizations and forest management experts. The groups included a range of stakeholder perspectives: timber industry, conservation and other forest resources; and a range of areas of expertise: native forest planning; private forest management; forest ecology and biology; soil & water; visual resource management and tourism development This ensured that a wide range of scenarios were developed that were meaningful and realistic within the group’s domain of knowledge and experience. The groups are tasked with (a) defining the scenario objectives, (b) selecting areas where no logging should occur and (c) selecting forest management types to be applied to the remaining land. The groups are asked to build two scenarios, one constrained by current legislation and accepted practices, and one unconstrained. The developed scenarios should reflect the group’s objectives in terms of forest management type for a period of 90 years. ScenarioBuilder enables the operator to apply preferred management systems to selected land areas and to compute overall landscape output to quantify the built scenarios in three areas: Wood products, Environmental Values and Amenity. In addition, the groups are asked to complete a questionnaire evaluating both the ScenarioBuilder system and the process of developing future landscape scenarios. In total 15 expert groups developed 14 constrained and 11 unconstrained scenarios. Analysis of these scenarios showed that certain forested areas had the greatest variation of applied management systems, and these 'areas of contention' should be investigated further.

To evaluate forest planning, the implications of applying different forest management systems should be assessed at a landscape level and the ScenarioBuilder tool allows the effect of these systems to be effectively visualised and quantified in terms of timber output, natural environment and amenity. The following section describes the study area, together with the data sources and methods used to produce the landscape scenarios. This is followed by some example scenario maps; an evaluation of the outputs achieved and planned further research

2. DATA PREPARATION

The study area (Figures 1 & 2) approximates 35km x 19km in size, and is located towards the southern end of Tasmania encompassing towns of Geeveston and Port Huon. Land tenure covers National Park, State Forest and private land with a large proportion of the National Park defined as a World Heritage Area. The major man-made tourist attraction in the area is the Tahune Airwalk located at the confluence of the Picton and Huon rivers in the northern part of the study area. The topography of the study area comprises flat coastal regions in the East towards the Huon River estuary with mountainous regions in the South and West that have Mount Picton and Hartz Peak view points. Except the private property in the East, the landscape is predominantly mature eucalypt forest with the majority of the logging activities occurring within the State Forest. Forestry Tasmania coordinate, manage and plan all logging activities in the State Forest area.

Figure 1. Study Area location

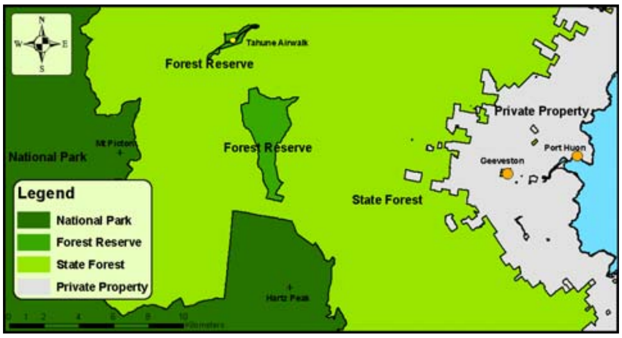


Figure 2. Study Area Land Tenure

Base Data– The data was supplied under license from Forestry Tasmania and consists of raster, vector and point data sets. The topography is a 25m resolution digital elevation model (DEM) raster, and the geographic distribution of photo interpreted vegetation types is provided as polygon shape files. Attribute data associated with each polygon describe specific features of the land encompassed by the polygon boundary i.e., type of forest cover, tenure or age of forest. The visual amenity data set was supplied by the Forest Practices Authority and shows landscape visual sensitivity ratings. The base data sets were pre-processed to provide data consistency in terms of spatial location of landscape elements and to eliminate redundancy in the description of the elements themselves. Additional data sets were derived from the base data sets (For example Polygon Mean Slope, Polygon Predominant Aspect). The Base Map formed the key data set used to control the selection and display of data in the system. It was a composite of 17 pre-processed layers (for example tenure, photo interpreted vegetation type, stream class) and derived layers (For example spatial buffers, establishment year, visual sensitivity rating).

Land Cover & Harvest Systems - The study area land cover was classified into seven basic types (Table 1) based on the photo interpreted vegetative cover data. There were 10 harvest management systems available

Table 1. Land Cover Type Classification

LAND COVER	DESCRIPTION
Agricultural, Urban & Exotic Vegetation	Predominantly agricultural land
Plantation	Blue gum plantations
Eucalypt – E1, E2, E3	Native Eucalypt forests with height potential decreasing from E1 to E3
Other Native Forest	Non Eucalypt native forest
Rain Forest	Rain forest species
Non Forest	Sedge and grasses
Unproductive /Unknown Forest	Unproductive forest or areas where the vegetation cover is unknown

Table 2. Applied Harvest Systems

BASE HARVEST METHOD	ROTATION (yrs)
Clearfell Burn Sow	65, 90, 200
Tasmanian Group Selection	90, 210
20% Aggregated Retention	90, 200
Plantation	15, 25
No Timber Harvest	-

(Table 2) comprising 4 basic harvesting methods with variation in harvest rotation period.

Landscape Outputs - Three primary outputs were developed to provide a relative measure of landscape function: Wood & Economic, Natural Environment and Amenity (Quiet Recreation). The outputs were presented as a 0-10 unit less scale and were based on averaging a set of sub-outputs (Table 3) whose value was dependant on the selected harvest system and where in the landscape the harvest system was deployed.

Table 3. Primary and Sub-Output Primary Parameter and Calculation Method

PRIMARY OUTPUT	SUB_OUTPUT	METHOD	PARAMETER
Wood Products	Saw logs	Area Weighted Average	Saw log Conversion
	Pulp Wood	Area Weighted Average	Pulp Wood Conversion
	Economic Efficiency	Area Weighted Average	Economic Efficiency Conversion
Natural Environment	Mature Forest	Area Weighted Average	Mature Forest Conversion
	Landscape Diversity	Simpson's Index	Forest Type & Area
	Species Habitat	Spatial Proportion	Proximity to sensitive areas
	Soil & Water	Area Weighted Average	Soil & Water Conversion
Amenity (Quiet Recreation)	Visual Amenity	Area Weighted Average	Visual Value Conversion
	Recreation	Spatial Proportion	Proximity to sensitive areas

Most of the sub-outputs were calculated using an area weighted average method in conjunction with conversion tables to represent the relative outputs from each of the harvest management systems. A spatial proportion technique was developed to represent harvesting close to recreational or ecologically sensitive areas, and Simpson's Index was used to calculate landscape diversity (Simpson, 1949).

Constraints, Prescriptions & Supporting Data – Constraints and prescriptions were developed to ensure that the scenarios met with legislative requirements and acceptable forest practice. Applying the constraints and prescriptions reduced both the land made available for harvest and the timber output due to operational and conservation requirements and additionally set a minimum timber production target. Constraints and prescriptions were automatically applied in the constrained scenarios and could be selectively applied in the unconstrained scenarios. Additional data layers were prepared and presented as visual overlay data (For example flora & fauna range boundaries, location of walking tracks, hazardous land etc.) to assist the scenario builder in decision making. To make the process of scenario development as transparent as possible, the expert groups have access to printed descriptions of all the data sets incorporated into the system, visual representations of the available forest management systems and a breakdown on how the landscape outputs are calculated.

3. METHODS

ScenarioBuilder was built in ESRI ArcGIS v9.2 using ESRI Arc Objects under the integrated Visual Basic for Applications development environment. ScenarioBuilder was designed for use by a GIS technical operator due to the high number of available operations. Direct use by the stakeholders or experts themselves would have required additional time for training and may have run the risk of unsatisfactory outcomes for both the scenario developer and the research team.

ScenarioBuilder was run on a laptop computer with the desktop display extended to a large external LCD display coupled to a video splitter with a second large external LCD display. The system operator viewed the laptop and primary display and was able to manipulate and control the information presented in the display panels. The participants viewed the scenario map and the computed landscape outcomes on the second external display. The arrangement of hardware was designed to be as compact and as portable as possible to accommodate the variety of venues selected for the scenario building sessions.

ScenarioBuilder presented four display panels; participants and the operator viewed the Main Map & Quantitative Outputs (Figures 3 & 4) and the operator viewed the Display, Selection & Reset (Figures 4 & 5).

Panel 1 – Main Map Display showed the study area in a number of prebuilt themes: Land Tenure, Forest Type, Harvest Management Type, Establishment Year and Aspect (Figure 3)

Panel 2 – Scenario Outputs panel showed the primary and sub-outputs, the applied constraints & prescriptions and net harvestable area (Figure 4).

Panel 3 – Display & Selection: This panel shows the operator controls for thematic map display & polygons selection by attribute (Figure 5).

Panel 4 - Outputs and Preset: This panel shows the proportion of applied harvest management system and provides the mechanism by which constraints & prescriptions can be applied and reset (Figure 6).

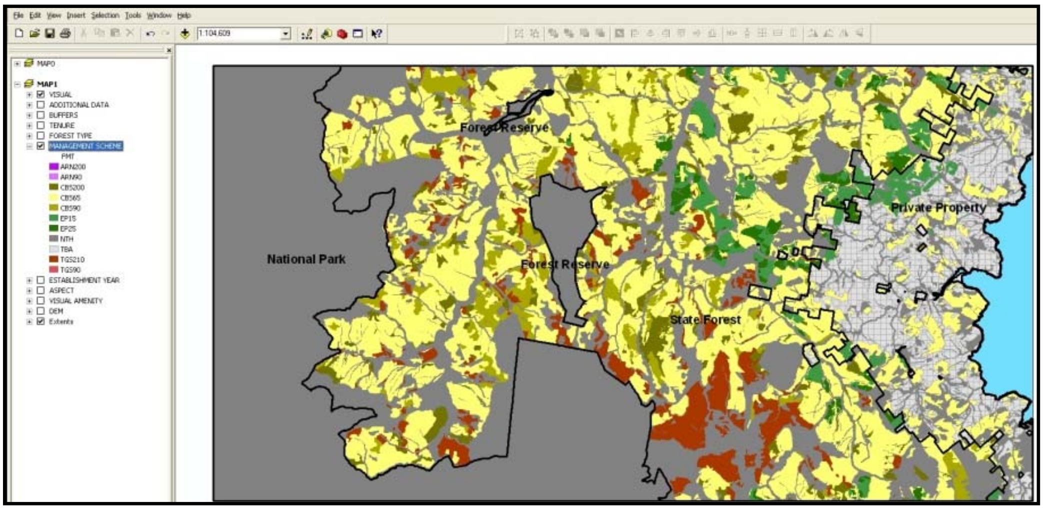


Figure 3. Panel 1 – Main Map Display showing a developed scenario in the Harvest Management Type theme.

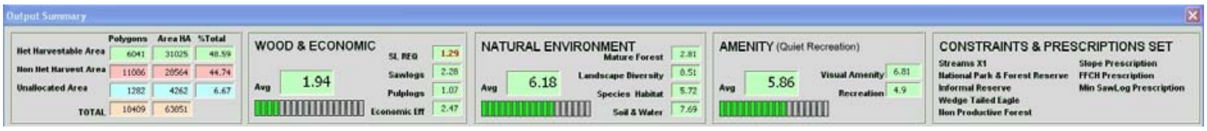
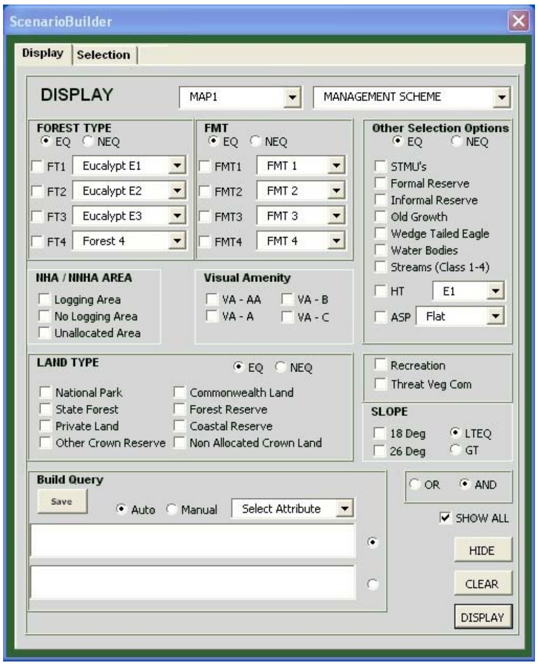


Figure 4. Panel 2 – Quantitative Output Display showing primary and sub-outputs, applied constraints & prescriptions and net harvestable area.



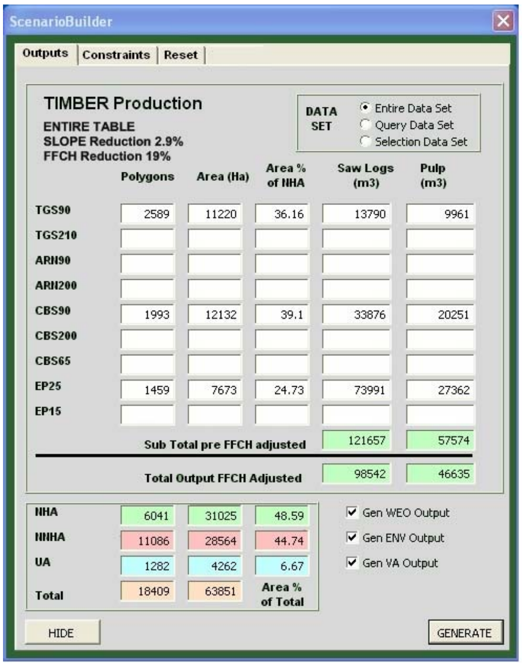


Figure 5. Panel 3 – Display & Selection Panel

Figure 6. Panel 4 – Output, Constraints & Reset

The ScenarioBuilder sessions were run in Hobart, Tasmania at both public and private venues to suit the availability of the participating groups. To ensure that scenarios were developed consistently and to minimize the time required to build each scenario, the groups were asked to follow a five step process (Figure 7). Steps 4 and 5 were iterative. For example, if the outcomes did not meet the timber production target set by the production constraint (when applied), then the forest management allocation had to be reconsidered.

At the start of the process, the entire landscape (excluding water bodies) was presented to the scenario builders with no harvest management system applied. The groups then chose to build a constrained or unconstrained scenario which defined the land made available for harvesting. In the constrained case, National Park, formal forest reserves, informal reserves, areas within predetermined distances of streams and areas defined as containing threatened fauna were marked by the system as having no logging applied. In addition, non productive land was also removed from available harvest area and a timber production output was set as the minimum quantity that the built scenario had to attain. In the unconstrained case, the scenario builders were free to apply any, all or none of the pre-defined constraints or prescriptions in the system. The groups then identified further land on which no logging should be applied which further reduced the land available for harvesting. The remaining land had harvest systems applied to meet the scenario objectives. Throughout the process, land selection was carried out by the operator through attribute, rule or spatial selection methods. Groups could request that the landscape outputs be computed at any point during scenario construction. This enabled the groups to evaluate the scenario incrementally as it developed.

On completion of the scenario building, the individual group members were asked to complete a questionnaire to evaluate the ScenarioBuilder toolset and the process of building landscape scale future forest scenarios.

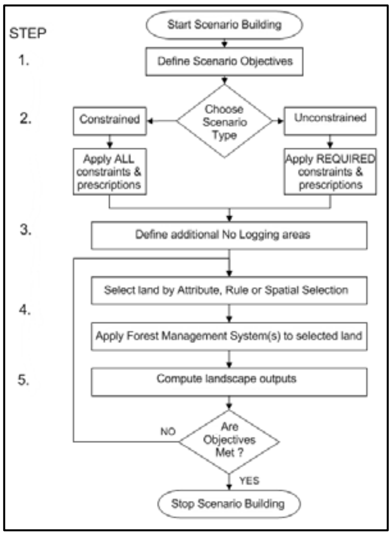


Figure 7. Five Step Scenario Development Process.

4. RESULTS

In the data collection phase, the aim was to have each group generate one constrained and one unconstrained scenario, however due to complexity in developing some scenarios, some groups chose to develop only a single scenario. In total 15 expert groups developed 14 constrained and 11 unconstrained scenarios. Within the 25 scenarios, all forest management systems were deployed at least once and distribution analysis (differential spatial overlay) of the applied forest management types showed areas of most contention i.e., areas that had the full range of forest management types applied (Figure 8). The areas of highest contention appear in distinct areas:

1. The Picton valley in the South-West of the study area
2. The area around Tahune Forest Reserve in the North.
3. Near the boundary between the state forest and private property.

In total, 25 questionnaires were completed and the responses showed that ScenarioBuilder was seen as a valuable tool for assessing the visual distribution and the associated landscape output of different forest management practices being applied to large areas of land with 96% of participants content with the system functionality. Due to the high number of manipulation options available, 88% of participants were content to have an operator at the controls. Although 2D representation was sufficient for the task one of the participants reported that selective 3D visualisation may have been beneficial to assess the anticipated view from publicly accessible viewpoints. There were requests for additional ecological data sets and to be able to link to dynamic hydrological and carbon sequestration models. The respondent groups found scenario building as a group activity beneficial as the process of defining a coherent landscape strategy requires clarification of priorities and that compromises have to be made.

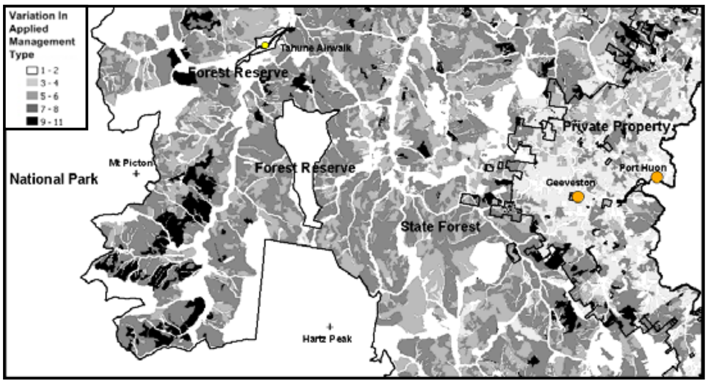


Figure 8. Constrained Scenario Contention Map with darker areas having the greatest range of applied forest management systems.

5. DISCUSSION AND CONCLUSIONS

Appropriate landscape planning is especially important in areas dominated by production forests, where the planning and allocation of land and the harvest method employed affects the environment ecologically, economically and visually.

The implications of applying different forest management systems should be assessed at a landscape level and this research shows that ScenarioBuilder is an effective tool for applying selected forest management systems and quantifying the effects that these systems have on the landscape.

Without the use of GIS based systems to manipulate and present information, this allocation process and the generation of landscape outcomes in near to real-time would be virtually impossible. The use of linear programming techniques for harvest allocation reflects the difficulty of working over large areas and large time frames. Those techniques are satisfactory when there is a clear objective i.e., maintenance of timber production, but are more problematic when multiple less tangible outcome are central to decision making. ScenarioBuilder is a system which provides all the necessary underlying data. Its mechanism for management system allocation is based on personal belief about the appropriateness in a variety of landscape conditions. The system also enables a quantitative check on the outputs which result from chosen allocations. As such ScenarioBuilder provides assurance on suitability, flexibility in approach and confidence that outcomes will be in accord with both known constraints and the personal objectives for regional forest management.

The variability in applied forest management type in the areas of contention is indicative of the range of opinions held by the expert groups. This research was conducted as the first of two phases into the tools and methodologies required at a landscape scale to present and assess the acceptability of a range of forest management options each having different social, visual, economic and ecological effects. The next phase of this research will investigate these contention areas further by selecting specific geographic areas, developing the spatial structures to represent the harvest systems and land structure at some future date, modeling the geographic areas as scenes in 3D and having these scenes compared and judged by members of the public.

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