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Landscape pattern, perception and visualisation in the visual management of forests

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Abstract

Forest planners, designers and managers have to incorporate visual landscape management into their plans as part of sustainable forest management (SFM). Over the last 20 years since the first ''Our Visual Landscape'' conference there have been numerous developments in visual management and design processes and techniques. Other developments, as part of SFM, such as ecosystem management and the need for more public participation in forestry planning, have also influenced the directions of forest management. The design of forest harvest units based on emulation of landscape patterns and processes means that landscape change can be driven by non-visual issues and principles and the earlier models developed for visual landscape management are no longer necessarily valid. However, the need for public participation means that landscape perception, in a broad sense, has become very important. Communication tools, such as computer visualisations of proposed landscape change have also been developed and present valuable possibilities. In order to help managers deal with both the changing forest landscape and the changing nature of perception, an approach is suggested that links landscape patterns and their manipulation with perceptions of them in order to help the development of positive design. In order for this to progress more effectively, several lines of research and development are suggested.

Keywords: Landscape; Ecosystem; Landscape ecology; Landscape visualisation; Perception research

1. Introduction

The visual landscape is one of the major realms where the work of forest planners, designers, and managers directly interacts with public perceptions and expectations. People tend to judge things on the basis of what they can see as much as or more than on what they know, and such judgements can have major implications for the public acceptability of foresters' plans. This is particularly the case when people may have preconceived ideas about the way forests ought to appear that may conflict with the most up to date understanding of dynamic landscapes.

This paper explores some of the issues that relate to the relevance of visual landscape management in forestry from the point of view of someone who has worked in the field for most of the time since the last conference in 1979. The paper will start by summarising some of the significant developments that have affected practice on the ground since 1979 and which are likely to be influential in the future. It will then go on to explore a potential means of linking the issues of changing landscape patterns and changing perception of landscapes for practical purposes of forest planning, management and design. It will conclude with some suggested areas where ongoing research

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and development might be further developed so as to help practitioners of forest landscape planning and design.

2. Changes in visual landscape management and design since 1979

In the last 20 years since the original ‘‘Our Visual Landscape Management’’ conference, there have been many developments in forestry policy and management practices that have, quite simply, changed the face of forestry. As a practitioner working in this area and developing programmes of visual landscape management and design, I have had to accommodate many of these changes. The main developments from a practitioner's point of view have been these:

2.1. Scenery management versus forest landscape design

There has been a move away from managing scenery towards designing forestry activities to fit into or at least to try not to cause negative impacts on the scenery. In this regard, there have been two distinct trends, which I will refer to as the ‘‘screening and hiding’’ and the ‘‘positive design’’ approaches. In 1979, the main players in the world were probably the US Forest Service and the British Forestry Commission. The US Forest Service had developed the first version of the visual management system in order to plan for and control the impacts of landscape change through logging, principally clearcut logging (USDA Forest Service, 1973).

One of the problems of the early visual resource management systems, notably that of the US Forest Service and its emulates, is the emphasis on the control of landscape change. This often related to the scale of alterations, such as logging, in a given vista. In other cases scenic management tended to concentrate on hiding activities, again, such as logging, from sight (as calculated from set viewpoints). Beneath these approaches is frequently an unstated objective of preserving the appearance of the landscape as it is. Visual quality objectives established under such systems, such as that implemented by the British Columbia Ministry of Forests, (Ministry of Forests, 1981) explicitly used ‘‘preservation’’ or ‘‘retention’’ as visual quality objectives (VQOs). These caused problems in practice because of the changing nature of landscape and the impact of insect infestations, fire, blowdown, and natural succession. Perhaps the main fault was the tendency in practice to look at visual management separately from the consideration of other resource objectives, in other words, there was no attempt at a multidisciplinary, integrated approach to forest management planning.

It is noteworthy that the US Forest Service has revised its visual management system at a time when clearcut logging and therefore drastic landscape changes on the national forests have virtually ceased (USDA Forest Service, 1995).

Although, there was some attempt to include design in the US Forest Service visual management system, in practice it mainly became a means of zoning activities to reduce visual impact. The British Forestry Commission chose to follow a different approach and to direct developments towards creative design of afforestation and forest harvest. This was due to the nature of forestry — primarily the afforestation of bare land and harvest of these plantations — in a small country with a large population which reduced the scope to hide activities virtually to zero (Forestry Commission, 1989; Lucas, 1991).

This movement towards design gained momentum in the 1980s and particularly in the 1990s, when some agencies became dissatisfied with the ‘‘hiding and screening’’ mode of visual resource management, such as the Ministry of Forests in British Columbia. The missing ingredient, design, was developed in the mid 1990s by adapting the ‘‘positive design’’ approach from the British system as part of the forest landscape management process (Ministry of Forests, 1994a).

The ‘‘positive design’’ approach has also been developed elsewhere, such as Eastern Canada (Bell, 1994), while in Tasmania in Australia a variant of the visual management system was developed during the late 1980s (Forestry Commission of Tasmania, 1990) and the Forest Practices Board there have recently been looking towards a greater input of design (Chetwynd, 1999, Pers. Comm.). New Zealand, before the privatisation of the plantation forests, had developed a design based approach that was ahead of its time (Anstey et al., 1982), although for political reasons, it is not currently applied to the now private forests.

2.2. Applied landscape ecology and ecosystem management

During the 1990s a parallel development has been that of ecologically based landscape planning for forestry. This sought to apply landscape ecological principles to forestry in a bid to present sustainable alternatives to the then current forestry practices dominated by clear cut logging. The seminal work of Diaz and Apostol ''Forest Landscape Analysis and Design'' (Diaz and Apostol, 1992) was based on this approach with the inclusion of some of the British design ideas. The application of this in Canada (Diaz and Bell, 1997; Murray and Singleton, 1995) attempted to achieve a synthesis of the landscape ecological model with the visual design approach. This has resulted in a process that could be called ''forest ecosystem design''.

This ecologically based approach has developed further through the work of numerous ecologists into the concept of ecosystem management, using landscape level analysis of natural patterns and processes in forests. Ideas of basing forest management practices, particularly timber harvest, on the emulation of natural patterns have gained currency. The role of forest ecosystem design is to help managers to define the character of those patterns in space and time for an entire forest landscape, usually of some tens of thousands of hectares in scale.

The development of forestry standards and certification, whether driven by political decisions of governments, pressures from non-government organisations or the market, has led to the development of forestry codes of practice, such as the British Columbia Forest Practices Code (Ministry of Forests, 1994a) or the UK Forestry Standard (Forestry Commission, 1998). These codes vary in their approaches from the tendency to set rules or standard practices that have to be applied everywhere (such as maximum sizes for clear cut harvest units) to those that allow more flexible solutions within a framework of guidelines. Many forest ecologists advocate the ecosystem based approach rather than one formed around a rule book and believe that the time has come to depart from ''administrative forestry'' to ''ecological forestry'' based on ''respect for nature'' (Kimmins, 2000).

2.3. Computer simulation

The use of computers and the development of computer simulation have proceeded at a pace undreamed of in 1979. Three interrelated fields are of note here. Firstly, the development of computer aided design (CAD) that enables landscape change to be designed and presented to various degrees of realism as an interactive process. This is widely used in architecture, urban and park/garden design but has been less available for forest design. A system called Tretop (TJP Envision, 1999) enables this interactive method of design to be applied to large scale forested landscapes, though the results cannot yet be presented in a photo-realistic way.

Secondly, the use of geographic information systems (GIS), some of which may also enable a degree of visualisation, have allowed managers to test the results of their proposed actions and to evaluate the results in terms of their visual impact. These started as rather crude representations but are now becoming more sophisticated and lifelike. The benefit of GIS is the ability to link data about the forest to visualisations and to use various forms of visualisation as a proxy for understanding other information, such as soils or wildlife values that are not obvious on the ground.

Thirdly, there has been the development of standalone visualisation systems which take data from CAD or GIS and present it in increasingly photo-realistic ways, including fly or drive through experiences using developments from virtual reality (Orland, 1994).

While some of these systems have been developed in response to practitioners' needs and demands, others remain in the research field and are not yet available to foresters in the field.

2.4. Public participation in forestry planning

In 1992, the World Convention on Sustainable Development was signed at Rio de Janeiro (Anon, 1992). Following this, several processes were adopted (Montreal and Helsinki for the northern temperate zones) to develop criteria and indicators for sustainable forest management (SFM). These include the requirement to involve the public more directly in decision making about forestry planning. Consultation about plans already prepared, is no longer adequate; local communities must be given the chance to become active participants in forestry planning. To do this, they need access to information presented in ways that they can understand, of which visualisation is a key element. These communities are also changing in their levels of knowledge, their economic and social conditions, and their acceptance of forestry activities from a moral or ethical stance. They are also subjected to various types of propaganda about the acceptability of various forest practices from a number of directions.

Forest planners, designers and managers are now therefore concerned in achieving a balancing act between the three interacting objectives of SFM: the economic, environmental, and social. Economic forces demand the continual flow of wood from forests; environmental forces require this to be done in such a way that the forest ecosystem is respected, while social demands include the protection of the visual resource among factors, such as jobs, community support and participation in planning. The questions raised for practitioners are as follows:

- Where does visual landscape management or design fit into a forest management system increasingly driven by ecologically based models?
- What is the best way of communicating with and involving the public in forestry planning?
- How do the developments of visualisation technology assist forest planners, designers and managers to achieve these goals?

To answer these questions it is useful to look at the problem in an integrated way. What foresters and ecologists are managing is a changing forest landscape. This landscape is both physical and perceptual, and presents itself in terms of spatial, structural and temporal patterns that arise through the effects of a number of climatically and ecologically influenced processes (such as colonisation, succession and disturbance). This landscape also changes through the influence of many agents, including humans, over varying time scales or cycles. What the public, who judge our actions, see are those same patterns.

Human perceptions of the landscape change due to the influence of economic, social, aesthetic and ethical factors. Often, public perceptions and understandings about landscapes are different from those of professionals, while the current state of any landscape tends to reflect priorities, understandings and functions of the past, albeit only the recent past. This is particularly true of forests and forest management. The visual effects of past practices linger on for many years, while the impact of current practices is unlikely to show up for some years into the future (Bell, 2000).

The process of perception of landscapes involves physical and psychological elements. An understanding of the relationship between patterns and perception could be one way in which to provide valuable tools that help planners, designers and managers to work, both with the ecosystem and with people in various communities, to develop sustainable forest plans. Visualisation is an extremely valuable tool to reproduce and present these patterns, and proposed changes to them, in ways that reflect the perception of the real landscape, thus enabling non-professional people involved in planning to evaluate change and decide for themselves whether it is acceptable.

It is not tenable in the long term to preserve or maintain landscapes, even though members of the public may want or insist on it. Perceptions of the static climax ecosystem and the unchanging natural scene should be challenged in order for truly sustainable solutions to be achieved. Improving the information available to the public and the ways it is communicated should enable better decisions about the future of forest landscapes to be reached.

3. Landscape patterns

The concept of landscape as a pattern goes back quite a long way, and several authors have presented ways of analysing landscape patterns (Stevens, 1974; Forman, 1995). We can use the concept of patterns as a very useful medium for discussing a wide range of aspects of the landscape and for synthesising the areas covered by a number of environmental disciplines. Landscape patterns can be understood in one way as the visual manifestation of the processes at work in the landscape. In fact patterns and processes are indivisible and feed back to one another. For example, climatic and geomorphological processes provide patterns of landform, microclimate and hydrology that direct the processes of ecological pattern creation and modification (Swanson et al., 1988). These in turn can affect geomorphology and climate in a progressive feedback loop. These patterns, at the scale of a landscape (a size of area between a site and a region), can be understood as mosaics of different elements which change over time at varying scales, spatial and temporal. Our perception of these changes can be negative if we happen to experience an infrequent, catastrophic event, while the continuous, small scale changes may well go unnoticed. This reaction to landscape change is a key one to be discussed further below.

As the landscape presents a pattern both arising from and influencing a range of processes, we can consider ways in which its management can proceed using such patterns as a guide. This is a fundamental aspect of one of the leading movements in forestry at the present time, ecosystem management, which bases harvest plans on natural disturbance patterns. An understanding of natural patterns and processes (their scale, dimension, intensity, frequency and character) can tell us how dynamic a landscape happens to be, the likely changes to the pattern over certain time scales, and the main agents likely to be influencing it. It is frequently the case that within a single scene some areas change catastrophically at relatively short intervals of time, while other parts remain relatively changeless, or continuously change at a very slow pace.

An example of this situation can be found in many forests in temperate regions, where the main natural agent of landscape change is fire (Pyne, 1982; Bell, 1999). Fire is caused by lightning strikes and if it takes hold, it can burn and kill large areas of forest. The spread of a fire across a landscape depends on several factors, such as the weather (wind blowing the flames, wet vegetation slowing the fire) or topography (fires often stop at the break of a slope, are unable to cross deep ravines or peter out at rocks). The character of the forest can also affect the spread of a fire. Resinous pines or firs burn faster and more readily than larches or broadleaved trees, for example. Forest types vary with aspect and elevation as do microclimatic conditions. Thus, across a landscape there is a greater likelihood of large, more frequent fires in some places (such as sunny, dry slopes) compared with others (deep damp valleys, shady slopes). The character of the pattern produced by such fires is partly dependent on the existing landscape structure and partly on the characterisation of the fire process. Generally there are irregular areas burnt within which individual thick barked trees and other clumps of trees (either of low flammability or in places less likely to burn) survive. While the resulting pattern cannot be accurately predicted, it is possible to describe its likely character. The forest then goes through the processes of ecological succession before being disturbed by fire once more.

To base patterns of forest harvest on such disturbance regimes may mean emulating the pattern of distribution of natural disturbances across a landscape in terms of their size, shape, resulting structure and occurrence over time. Such an approach does not, of course, replicate the complete range of ecological processes in the landscape since large amounts of wood are removed at harvest, and there may be site damage. In the absence of, for example, fire, the site may lack the right conditions for the commencement of forest succession (nutrient flush from ash, carbon from charred wood, stands of trees killed by the heat, release of seeds). However, there are ways to incorporate some of the site level structure, and the important elements of ecological functioning across the landscape can be retained. For example, if there are areas that a fire is unlikely to burn due to their damp conditions, these can be left at harvest, as can thick barked, fire resistant species.

If the management alternatives are either traditional clear cut or "ecological harvest" then the latter is the best option, although a controlled burn could be a better option if wood production was not an objective, as has been carried out at some national parks in Canada. This is the essence of the forest manager's balancing act. There are now many examples of this approach set out in the landscape, as much developed by ecologists as by loggers (Diaz and Bell, 1997; DeLong, 2000). It is also important that due allowance be made for natural fire to occur at some point in the landscape as well as for all the other ecological processes to continue.

Clearly there is a need to be sure that the process of ecological analysis is used to manage the ecosystem towards the creation of patterns even if the agent of disturbance is forest harvest rather than that of natural events. However, a question arises as to how "natural" appearing the design of such elements should be. It is not sufficient merely to make them look natural by giving them organic as opposed to geometric shapes or to leave unlogged patches only for visual effect. This becomes pastiche and is no guarantee of the continuation of ecological functioning or processes. It remains necessary to design harvest units to ensure that the characteristics of the natural disturbance patterns are retained where these are important for ecological functioning, such as their size, shape, edge structure, internal structure or the distribution of retained patches and trees. If ecological processes lead to the development of patterns, these patterns in turn also have an influence on ecological processes although, not necessarily the same processes.

Such practices are significantly different from the visual management method already discussed, based on control of landscape change in relation to visual quality objectives (VQO's), though the positive design approach can be applied very successfully. However, they are also likely to be more sustainable, as long as the plan based on natural disturbance is within the natural range of variability of the ecosystem and makes due allowance for unforeseen circumstances.

There are also practical problems of visual landscape management to a VQO by percent alteration, where only a net percentage of the scene can be in a logged state at any given time, and where the next logging is only permitted once 'visually effective greenup' is achieved (Ministry of Forests, 1994b). The rate of change allowed under this system often means that mature forest is retained in a landscape well beyond the time at which it could be expected to disintegrate. For example, lodgepole pine (*Pinus contorta*) is usually a 'fire climax' species that rarely lives beyond 100 years old or so. If a landscape of pine already 70 years old can only be altered by 15% every 20 years, it is inevitable that some of the forest must end up over 200 years old before it can finally be logged. This is highly unlikely, given the anticipated disturbance regime and fire return period to say nothing about the likely impact of bark beetles over that same period. The point of this example is to demonstrate that within a forest plan driven by ecosystem management, visual management without design is of no real help and can be a hindrance.

However, ecologically driven practices must be considered in relation to human perceptions before the idea of promoting natural patterns by emulating natural processes can be adopted widely. This is because of the conservative tendency in attitude towards sudden landscape change and the persistent belief still held by many people that forests grow to a climax type and naturally stay that way for ever. Botkin (1990) has pointed out that the problems with different mythologies of nature and the impact of fire suppression on reducing the public's experience of natural disturbance in the forest is significant in the USA through the impact of Smokey the Bear. Visual landscape management using the VQO approach recognises this social perception of landscape change but for the reasons stated above fails to deliver a practical solution.

The answer to the first question posed above is that when changing the landscape from what it is now towards some other, desired future condition, design is needed. It is important to try to design alterations to the landscape so that they meet the objectives of promoting ecological functioning and respecting the character of the landscape. This is not the same as reducing impact but does allow for the application of the positive design approach.

4. Landscape perception

When we talk about landscape perceptions, we refer to the physical aspects of the reception of visual stimuli, the intuitive recognition of an aesthetic quality and the ability of the mind to connect sensory information to other knowledge and so to develop opinions about what has been perceived. If we wish to communicate with people about the landscape, we need to understand how the patterns described above are perceived in all the meanings of the word, so as to use the most meaningful "visual language". The following section briefly reviews some of the main theories as a basis for later discussion.

Landscape perception can be said to start with the reception of stimuli — light energy, sound energy, chemicals, etc. by our brain. Visual perception is through our eyes and the light from all sources entering our eyes is known as the optic array (Bruce et al., 1995) and it is varied by intensity (darkness and lightness) and wavelengths (colour). The brain receives the image projected onto the retina and processes it to recreate the view that we experience. This is repeated as we shift our gaze. We see patterns defined by edges or light energy gradients. It is a matter of some speculation as to how our brain accomplishes this: which parts or belong where? Moving around helps to understand the spatial structure of the scene where one part is behind or partly hidden by another. Marr (1982) has proposed the 'primal sketch' idea to explain how we construct visual images in the brain. He uses ideas of signal processing (as used in electronics) to postulate similar processes occurring in the brain. He suggests that specialised cells have the job of detecting linear elements, 'blobs' or 'terminations' in the raw visual information. It is possible to demonstrate such 'primal sketches' using computer analysis of edges in a photograph, or ranges of intensity variation.

Another significant and well established body of theory is that of Gestalt psychology, where Kohler and his colleagues endeavoured to explain certain aspects of pattern recognition, such as 'figure and ground', 'closure', 'nearness' or 'similarity' (Kohler, 1947). These principles work in practice, although they are more descriptive than explanatory. A third aspect that contributes to our understanding of patterns is the theory of optic flow and affordance, advanced by Gibson (1966, 1979). This theory, sometimes referred to as the 'ecological theory of perception', is predicated on our moving through a landscape so that it 'flows' around and past us. In this way our spatial understanding of the landscape is greatly enhanced. Another facet of this theory is the idea that we do not perceive our environment neutrally, but view it in terms of what is affords us. This adds a utilitarian overlay to the purposes of perception, a very significant factor when we consider who is looking at our visual landscape and why (tourists, loggers, etc.).

It is a fairly straightforward connection from the notion that we are pattern-seeking organisms with a highly developed perceptual mechanism, to the idea that part of our natural response to what we perceive is aesthetic. If we are able, through our perception, to comprehend strong patterns in the landscape that are meaningful to us, then we may well find them more aesthetically attractive. For example, when trying to define the concept of beauty, the philosopher Schopenhauer considered that it occurs when a diversity of objects are found together, but at the same time 'exhibit themselves in a fitting association and succession', (Schopenhauer, 1969).

The aesthetic response starts with the initial sensory impression but as we add post-perceptual factors, such as knowledge, and undertake a kind of internal critical discussion on the scene presented to us, this changes. The intellectual tends to take over from the sensory. If the knowledge that we apply is faulty, incorrect or comprised of 'factoids' (when false statements are repeated often enough to be believed as hard fact), then it is possible that the intellectual aesthetic response may be inappropriate, based as it is on falsehoods. Thus, the perceptions held by individuals, social groups or whole societies towards certain aspects of landscape (such as, in forestry terms, clear cut logging) may be based on false, out of date or otherwise faulty information or understanding. This statement applies equally to certain groups in the forestry industry as it does to environmentalists or any other group or individual. This can also become an important ethical question (Bell, 1999).

In this predicament, research studies searching for what people like or dislike are as likely to pick up misconceptions about landscape as well informed perceptions. The best chance for better decision making is not therefore to try to replace one set of misconceptions with another but to try to engage people in a participatory process. Such a process can be time consuming but significantly better results (for all parties) can be obtained this way. In order for this to happen, participants must be able to judge the outcomes of various options they themselves generate or with which they are presented. Complicated models dealing with geographic information, presented as complex maps, statistics and so on may leave many members of the public out of their depth. In any case these do not enable aesthetic judgement to be made; this is best carried out using visualisation of various sorts. Sketches and manipulated photographs have been traditionally used and continue to be valued as quick, simple and cheap; they appear to work to some degree. Computer generated images, especially if linked to another aspect of landscape planning, such as geospatially based information through the use of GIS, look like being the future.

Practitioners are in need of better tools and many that are available are at face value highly attractive and exciting. However, in order to ensure that the best tools are developed, practitioners should be more widely consulted. Visualisation tools need to be fit for their purpose, but should also reflect something of the way perception works.

5. Questions for research and development

Forest planners develop plans for the exploitation of the forest to meet a range of social, environmental and, not least, economic goals. Any tools must help them balance competing objectives while meeting SFM. Forest designers endeavour to produce, through the application of the design process, patterns for the future landscape which meet the management objectives without negatively impacting other values, including the ecological and visual. Forest managers apply a range of forestry practices, such as silvicultural and harvesting operations, to the forest in order to implement forest plans and designs. It is these practitioners who should be considered as the main users of the tools developed for visual management.

As far as visual issues are concerned, any tools should improve the way forest planning meets the goals of maintaining and enhancing visual quality, help designers manipulate the landscape for positive visual results and enable managers to carry out operations cost effectively in the knowledge that they are not creating negative impacts.

Thus, research should be aimed at helping these practitioners by providing them with more and better tools, particularly for evaluating the potential effects of plans and designs and for communicating and participating with local communities. The following list is therefore compiled with this in mind, as well as referring to aspects of pattern and perception explored earlier in the paper. Questions of research into the applicability of ecosystem pattern based techniques and how they relate to ecological functioning are outside the scope of this paper. It is recognised that many people are working on these questions already and in some cases have reached conclusions or are developing tools that will soon find their way into practical application.

1. There is a need for more comprehensive testing of public perceptions of the visual results of forest management practices that attempt to emulate natural patterns and processes. Since cutblocks designed according to these theories are only now being laid out on the ground and harvested, it is only recently that examples have become available for such testing. It would be useful to find out how different groups of the public react depending on their background and ethical stance on forest management issues. This testing could also be extended using visualisations of different types of disturbance pattern. It is also not clear how the public react to the visual impact of natural disturbances, such as fires, wind throw or insect damage in the landscape. The application of the well established methods of assessing scenery using photographs, such as developed by Daniel and Boster (1976) and evaluated by Ribe (1989) should pose no problems, but it probably needs a wide range of examples representing a number of different forest ecosystem types to be comprehensive enough. This is because some disturbance regimes of high landscape impact are particularly applicable to some forest types rather than others.
2. More work is needed to compare the differences between cutblocks laid out according to ecosystem disturbance principles and those designed so as to be more sympathetic with the landscape, such as by incorporating the kind of visual design principles used in the "positive design" approach outlined earlier in the paper. There may be conflicts between the shapes, scale and relation to landform which mean that the best ecological designs are not the same as the best visual designs. The magnitude of any difference should also be evaluated.
3. Visual modelling of landscape changes needs to become more sophisticated. The cummulative impact of harvest that may be quite complicated on the ground, such as multiple entries in the same cutblock, as well as phasing between blocks and the continuing successional development of the rest of the forest, should be demonstrated so that visual developments and ecological functioning can both be evaluated. This would obviously be based on a GIS but would also need access to other models, such as stand growth models, ecological evaluation models and disturbance regime predictors as well as ecological site information in order to be able to model and visualise the changing forest in 'real time'. The application of values other than ecological in such a model would also be advantageous, such as the use of environmental accounting. Systems already in use or under development, such as 'Smartforest' (Orland, 1994) or that of Thuresson (Thuresson

et al., 1996) would be able to take such developments on board rather easily.

4. The use of visualisation as a tool for engaging the active participation of communities is another rich area for development. This democratisation of planning may also mean that access to information via the Internet may become the way forward. This has already received some attention for research purposes and so its potential has been evaluated (Wherrett, 1999) If it is to become a major tool, some technical aspects of access to models and interactivity with them will need more development. There are implications here for the way in which visualisations are used. Each visualisation will usually be prepared for a particular purpose, such as to present the effect of different forest management activities, but since different people may look for different things in the scene their responses may be difficult to disentangle for managers.
5. The understanding of pattern and process interaction in nature demonstrates that there is great uncertainty over the future of any forest landscape, yet foresters typically proceed as if they have complete control and they present plans that reflect this assumption to the public. This control was, in fact, one of the unstated goals of forest management at one time, demonstrated by vigorous fire suppression, insecticide application and yield regulation. Any ecosystem modelling and hence any visualisation, must be able to incorporate this uncertainty. When plans are being prepared that project forward several decades or even centuries, it is only possible to predict with, say, 60% certainty, what will happen over the next 5 years. It would be a mistake to involve communities in participatory processes that provoke a false sense of confidence conveyed by the persuasive images presented by visualisations.
6. The ability to answer the 'what if?' questions is needed, such as what if a hurricane/massive wildfire/outbreak of budworm affects the forest? Probablistic models can show what is the most likely scenario based on factors, such as the susceptibility of the forest to damage by various disturbance agencies. Visualisation of the results, both of the appearance of the landscape and the proxy indicators, such as the effects on water quality or biodiversity would be of use to community groups and managers alike. Real time simulations of potential landscape changes are becoming more accessible, started by workers, such as Molnar (1986).
7. There are also some questions that have arisen in terms of the technical content of visualisations. These might be details to those engaged in the development of visualisations but are important to the practitioner in the field.
   7.1. The amount of information contained in the visualisations remains a question not yet finally solved. Do they need to be photo-realistic or can simpler images suffice. Marr's concept of the primal sketch, discussed in the section on perception, suggests that certain key elements of a scene are crucial to how patterns are perceived, such as edges and contrasting areas (colour and intensity). Thus, visualisation that concentrate on the definitions of features in the scene that are more important for our perception than others, such as shapes, lines, edges and contrast may produce different results from other methods.
   7.2. It is generally accepted that in a research project the visual effect of the manipulation of one factor in a scene, such as the design of a cutblock, can be accurately measured when everything else in the scene stays the same. However, in the world of actual forest planning such controls are less likely to be available, the number of variable undergoing change is probably greater, and the people preparing visualisations may not be able to calculate statistical levels of confidence. Before any practitioners embark on the use of such visualisations, there needs to be a code of practice that ensures that rigorous procedures are adhered to whenever a project is carried out. This should include some level of analysis of the degree of confidence in the accuracy of the visualisation.
   7.3. In the section of the paper examining perception, Gibson's theory of optic flow and the ecological approach to landscape perception was discussed. This suggests that we should be less happy with visualisations

of static images compared with ones where we appear to be moving through the landscape. This technique also enables people to experience the landscape more fully and from whatever viewpoint they wish to choose for themselves, rather than one decided for them by the planner. If this is true, then this is a direction in which research and development should proceed with a view to making this type of visualisation easily available.

7.4. Modelling the effects of landscape change in terms of ecological, economic and social benefits can be difficult to present to members of communities unless some kind of visual rendering is available. Scientists already use visualisations to show, such aspects as pollution hotspots, energy flows and many other 'invisible' factors in the environment. To what extent these can be used with the public in participatory planning, perhaps to show changes to habitat value, water quality, forest productivity or pathogen intensity is a potentially exciting area well worth investigating.

6. Conclusions

As forest planners, designers, and managers, we are in the business of managing landscape change to satisfy the needs of, for example, timber production, ecosystem management, and ecological sustainability as well as the aesthetic demands of our stakeholders. We manipulate forest patterns in ways that hopefully produce positive results in all those areas. Perception of these patterns is the starting point for all subsequent aesthetic judgements and preferences, coloured by post perceptual information, some of which may be faulty. Perceptions change over time and can be affected by the kind of information available and the way it is presented to non-experts, for example within a framework of participatory planning.

In forestry landscape planning and design we have moved away from preservation of landscapes or of hiding activities to mitigate their effects into more challenging but more sustainable approaches using the deeper understanding of landscape patterns and processes. If we can link this to the perceptions of patterns and the aesthetic response in a very positive way we should be able to produce better overall results, rather than merely visual designs in isolation from other factors. Current practice assumes this is happening but more research would help to confirm it. In particular, the interaction between ecologically driven landscape change and aesthetic quality deserves more attention in terms of public perception and preferences. Visualisations help to convey the notion of the changing landscape for members of the public to evaluate, but more work is needed to ensure that these are as effective and meaningful as possible.

References

Anon, 1992. Earth Summit' 92, The Regency Press Corporation, London.

Anstey, C., Thompson, S., Nichols, K., 1982. Creative Forestry. New Zealand Forest Service, Wellington.

Bell, S., 1994. Forest Landscape Design: A Handbook for the Maritime Provinces of Canada. Maritime Forest Ranger School, Fredericton.

Bell, S., 1999. Landscape: Pattern, Perception and Process. E & FN Spon, London.

Bell, S., 2000. Ensuring the Social Acceptability of Ecosystem Management. In: D'Eon, R.G., Johnson, J.F., Ferguson, E.A. (Eds.), Ecosystem Management of Forested Landscapes: Directions and Implementation. UBC Press, Vancouver.

Botkin, D.B., 1990. Discordant Harmonies. Oxford University Press, Oxford.

Bruce, V., Green, P.R., Georgeson, M.A., 1995. Visual Perception Physiology, Psychology and Ecology (3rd Edition). Psychology Press, Hove, Sussex.

Daniel, T., Boster, 1976. Measuring landscape aesthetics: the scenic beauty estimation method. USDA Forest Service Research Paper RM-167, Rocky Mountain Forest and Range Experiment Station, Forest Service, Department of Agriculture.

DeLong, C., 2000. Approximating Natural Disturbance: Where Are We in Northern British Columbia? In: D'Eon, R.G., Johnson, J.F., Ferguson, E.A. (Eds.), Ecosystem Management of Forested Landscapes: Directions and Implementation. UBC Press, Vancouver.

Diaz, N., Bell, S., 1997. Landscape Analysis and Design. In: Kohm, K.A., Franklin, J.F. (Eds.), Creating a Forestry for the 21st Century. Island Press, Washington DC.

Diaz, N., Apostol, D., 1992. Forest Landscape Analysis and Design: A process for implementing land management objectives for landscape patterns. R6 ECO-TP-043-92, USDA Forest Service, NW Pacific Region, Portland, Oregon.

Forestry Commission, 1989. Forest Landscape Design Guidelines. Forestry Commission, Edinburgh.

Forestry Commission, 1998. The United Kingdom Forestry Standard. Forestry Commission, Edinburgh.

Forestry Commission of Tasmania, 1990. A Manual for Forest Landscape Management. Forestry Commission of Tasmania, Hobart.

Forman, R.T.T., 1995. Land Mosaics. Cambridge University Press, Cambridge.

Gibson, J.J., 1966. The Senses Considered as Perceptual Systems. Houghton Mifflin, New York.

Gibson, J.J., 1979. The Ecological Approach to Visual Perception. Houghton Mifflin, New York.

Kimmins, J.P., 2000. Respect for Nature: An Essential Foundation for Sustainable Forest Management. In: D'Eon, R., Johnson, J., Ferguson, E.A. (Eds.), Ecosystem Management of Forested Landscapes, Directions and Implementation. UBC Press, Vancouver.

Kohler, W., 1947. Gestalt Psychology, An Introduction to Modern Concepts in Psychology. Liveright Publishing Corporation, New York.

Lucas, O.W.R., 1991. The Design of Forest Landscapes. Oxford University Press, Oxford.

Marr, D., 1982. Vision: A Computational Investigation into the Human Representation and Processing of Visual Information. Freeman, San Francisco.

Ministry of Forests, 1981. Forest Landscape Handbook. British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Ministry of Forests, 1994. Visual Landscape Design Training Manual. British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Ministry of Forests, 1994. A First Look at Visually Effective Green-up in British Columbia; Recreation Branch Technical Report 1994:1. Ministry of Forests, Victoria, British Columbia, Canada.

Molnar, D.J., 1986. SCEEN: an interactive computer graphics design system for real-time environmental simulation. Landscape J., 128-134.

Murray, T., Singleton, J., 1995. The Malcolm Brook Forest Ecosystem Design. Unpublished Report from Canadian Forest Service, Fredericton, NB.

Orland, B., 1994. SmartForest: A 3-D Interactive Forest Visualization and Analysis System. In: Proceedings of Decision Support -2001. Combined events of the 17th annual Geograpic Information Seminar and the Resource Technology' 94 Symposium, Toronto: 181-190.

Pyne, S.J., 1982. Fire in America. Princeton University Press, Princeton.

Ribe, R.G., 1989. The aesthetics of forestry: what has empirical preference research taught us? Environ. Manage. 13 (1), 55–74.

Schopenhauer, A., 1969. The World as Will and Representation (translated by Payne, E.F.). Dover Publications.

Stevens, P., 1974. Patterns in Nature. Penguin Books, London.

Swanson, F.J., Katz, T.K., Caine, N., Woodmansee, R.G., 1988. Landform effects on ecosystem patterns and processes. Bioscience Vol. 39 (2), 92–98.

Thuresson, T., Näsholm, B., Holm, S., Hagner, O., 1996. Using digital image projections to visualize forest landscape changes due to management activities and forest growth. Environ. Manage. 20 (1), 35–40.

TJP Envision, 1999. TRETOP, Computer Aided Design Software for Forestry. TJP Envision Ltd, Edinburgh.

USDA Forest Service, 1995. Landscape Aesthetics; A Handbook for Scenery Management. USDA Forest Service Agriculture Handbook 701, Washington DC.

USDA Forest Service, 1973. National Forest Landscape Management. USDA Forest Service, Washington DC.

Wherrett, J.R., 1999. Issues in using the Internet as a medium for landscape preference research. Landscape and Urban Planning 45, 209–217.