PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

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Visualisations of New Zealand Forestry for Sustainability: A Literature Survey of Key Topics

Author:
Barbara Höck

Research Provider:
Scion

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EXECUTIVE SUMMARY

The literature on computer-based visualisations and their use and usefulness for visualising forestry issues is reviewed, with a focus on demonstrating sustainable forestry practices. The literature underpins the development of visualisations that form part of Objective 2.1 of the FRST project "Protecting and Enhancing the Environment through Forestry" through FFR.

The stakeholders of the forest sustainability dialogue, the intended viewers of such visualisations, are grouped according to their key accountability into three groups: "forestry practitioners" who are accountable in a business or economic sense; "researchers" who need to demonstrate scientific defensibility; and "secondary stakeholders" (see Table 1) whose value system can be a more important driver or justification than business imperative or scientific defensibility.

Visualisations have the potential to demonstrate concepts and issues in a compelling manner, and to be beneficial to developing knowledge. People can more readily identify with landscape visualisations that represent actual places and on-the-ground conditions. Visualisations of forests and forestry were initially developed for visual landscape management, with a trend from purely minimising negative impacts of landscape change, for example from harvesting, to a more active design approach to landscapes that include forestry. The more recent focus internationally on ecologically driven forest planning has seen less emphasis on landscape aesthetics. There are few visualisations of forest processes.

The visualisations required for international reporting on forest sustainability present the added difficulty of needing to visualise trends across all of the many indicators in a report such as for the Montreal Process.

Potential topics to consider for visualisations have been collated from the stakeholder groups but further investigation is required to refine, select and finalise the visualisations to be developed.

INTRODUCTION

The literature on computer-based visualisations and their use and usefulness for visualising forestry issues is reviewed, with a focus on demonstrating sustainable forestry practices. The literature underpins the development of visualisations that form part of Objective 2.1 of the FRST project "Protecting and Enhancing the Environment through Forestry" through FFR.

Forestry practices, including those in New Zealand, are being subjected to a need to demonstrate sustainability through a number of drivers, from local (e.g. forest certification) to international ones (e.g. Montreal Process reporting). This includes a need for more and better communication, which in turn includes in-person communication (e.g. stakeholder interactions) or other formats (reporting, web pages, etc). Visualisations are, or have the potential to be, a component of the communication of forestry issues including sustainability, whatever the direction of the exchange. While a discussion of the means, purposes and fora for such communication is not the focus of this paper, a brief description of the key stakeholder groups involved in this type of communication is included.

The topic of visualisations and its usefulness is covered next. The paper then reviews previous work on visualisations of forests and forest processes. With the increasing development of systems of reporting on forest sustainability such as the principles and criteria of the Montreal Process, visualisations for such systems are also discussed. Approaches for evaluating visualisations are introduced.

Finally a number of research issues for visualising forestry are introduced. These are intended to contribute to the discussions on the details of the visualisation developments for ongoing research on sustainable forestry practices.

STAKEHOLDERS OF NEW ZEALAND FORESTRY

Demonstrating Sustainable Forestry

Demonstrating the sustainability of NZ forestry includes the need for communication about sustainability. This communication raises a number of questions – for this paper the focus is more on who is involved in the communication and what is to be communicated, and for this subset the questions include:

- Who wants to be heard and who do they think should (be able to) hear them?
- How can the 'message' be made more understandable and accessible?

New Zealand's list of stakeholders in the sustainability of the planted forests is:

- central government (e.g. MAF and MfE) for national and international requirements, e.g. Montreal Process and CBD reporting, also reporting to FAO and contributing to the country's international commitments under the Kyoto protocol (UNFCCC, 2005);
- territorial regulatory authorities (regional and district councils) for policy at all levels; the implementation of the RMA and the resource consent process, and for district and regional plans;
- iwi as landowners and forest growers;
- communities as neighbours, users, and employees;
- NGOs representing special interests;
- consumer standards groups such as Green Building Council;
- national and international customers of the wood and fibre products, including retailers such as WalMart in the USA ;
- the owners of the land that the forests are being grown on, with particular mention of iwi regarding their increasing land ownership;
- shareholders in forestry companies, and forestry-reliant industry; and
- forestry practitioners; forest managers.

Stakeholder Groups

These stakeholders have been placed into three groups according to the basis of the accountability for their activities – the drivers of the justification rationales (Table 1).

The group named "forestry practitioners" focuses on those who, by their practice of forestry, affect both the sustainability of the trees on the land and the land that the trees are on. Core to their practice of forestry is that it is being practised as a business, i.e. for an economic return from forest productivity, predominantly wood and fibre based. Indirect participants in this group are others in the forestry business, such as shareholders and other businesses reliant on a sustainable forestry industry, or more indirectly national and regional supporters of economic development.

Another group of stakeholders in the sustainability of the planted forests is those tasked with providing defensible evidence of sustainability. The group has been named "researchers" as a broad term that includes all who are involved in developing scientifically defensible understanding of sustainability, regardless of the organisation they are part of. An example of this justification is publication in journals, books and other reviewed material.

The third group of stakeholders, the "secondary stakeholders" (see Table 1), encompasses those where values can be a more important driver or justification than business imperative or scientific defensibility. While values may also be important drivers of individuals in the other stakeholder groups, for this group their values need not be subject to business or scientific criteria. In addition, while being external to forestry as a business may be demonstrable, the boundary between scientifically defensibility versus value-based reasoning may be less clear, especially regarding environmental complexity (e.g. Graffy and Booth, 2008).

Table 1. Stakeholders in sustainable forestry practices in NZ

Stakeholder Group	Description	Who	Accountability / justification rationale (key driver only)
Forestry practitioners	Those who plan forestry actions and implement them	Forestry staff in forestry companies, some farmers	Economic / business
Researchers	Those who provide scientifically-based reasons and justifications for the effects of forestry actions	Scientists in CRIs, universities and other research organisation, in forest companies, and in local and national government	Scientific scrutiny / scientific review
Secondary stakeholders	Those who have some involvement or interest in or have the potential to be affected in some way by forestry practices	Includes land owners; communities (neighbours, users); NGOs (representing special interests); iwi (cultural); councils (resource consents, district plans); central government (MAF, MfE); consumer standards groups (e.g. Green Building Council)	Values / value-driven

The secondary stakeholders group is broad. The scale of the interested parties ranges from local (e.g. the “not in my back yard” or NIMBY attitude to local changes) to international (e.g. forest certification such as FSC), and the influence on forestry decision making ranges from low such as for the general public, to high such as for regional councils. The term “values” as used here reflects dynamic and explicit values (e.g. policy statement for a vote), to evolving ones (e.g. opinion survey; consumer standards), to those more implicit and entrenched in society (e.g. interpretations and enactments of law).

Communication between Stakeholder Groups

The foci of the communication between these stakeholder groups are introduced in Figure 1.

Demonstrating sustainable forestry practices between forestry practitioners and researchers constitutes, at its core, the ability to define what needs to be monitored over time and to monitor that. The ability to quantify information, even as surrogates, as estimates of qualitative measures such as numbers in survey responses, or as categorical values such as high/medium/low, allows change over time to be comprehended.

Communicating the sustainability of forestry practices between forestry practitioners and secondary stakeholders has more of a focus on what the practice is, how it is to be implemented and hence what effect is to be expected. Finally, for communication between researchers and secondary stakeholders, the focus for demonstrating sustainable forestry practices is on what constitutes or defines sustainability when this term is used for forestry as practices in New Zealand. There are country-internal and international aspects to such definitions of sustainability that are all a part of this communication

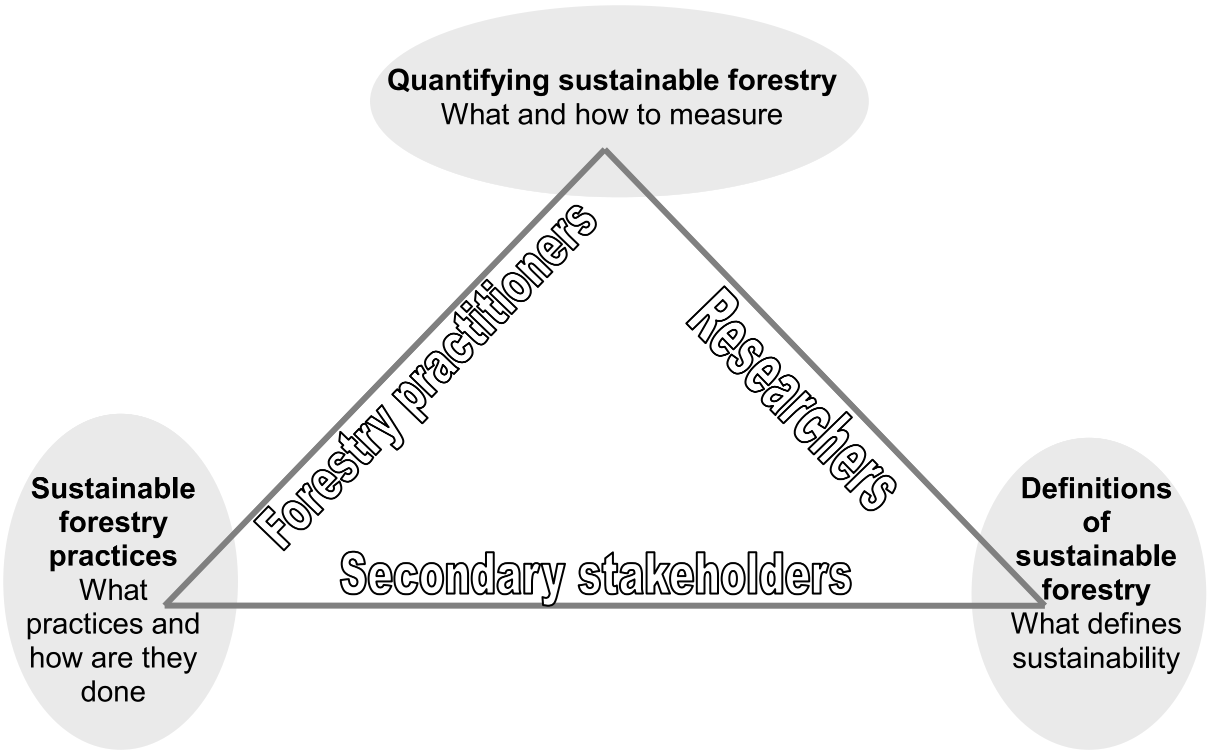


Figure 1. Key facets of the communication of sustainable forestry practices between the stakeholder groups

Communication between stakeholder groups needs to achieve sufficient understanding without necessarily being to the same depth of knowledge as can be the expectation for expertise within a group. For example, high level descriptive criteria for sustainable forest productivity may well be understandable to non-foresters while technical information is considered difficult to understand. Visual depictions of forestry practices, processes and effects may then provide an additional useful tool for communicating sustainability concepts across different knowledge levels.

The triangle in Figure 1 constitutes one approach to framing perspectives on sustainable forestry. The facets of the triangle reflect the stakeholder groups of Table 1.

The corners of the triangle in Figure 1, representing the main emphasis of the dialogue between the stakeholder groups, include a concept highly relevant to those types of discussions: that of boundary objects. A boundary object is the name given to a “concept (that) is able to maintain a certain integrity or core content while being flexible enough to be scientifically or politically meaningful for different actors” (Salmi and Toppinen, 2007). This partial elasticity of meaning allows for a certain level of ambiguity and even limited inconsistencies while retaining an internal coherence or robustness, making these useful terms for adoption and adaptation across diverse people when connecting across the diversity while still linking to and maintaining the integrity of their own concepts and knowledge fields (Fujimura, 1992). Essentially, dialogue is achieved without full knowledge of each others’ conceptual understanding of a term, only sufficient understanding, and without necessarily requiring everyone involved in the dialogue to have achieved full, in-depth specialised knowledge of a term.

It does need to be acknowledged and understood, nevertheless, that the meaning of a term or concept is embedded within the context of an individual or stakeholder group (Fonseca and Martin, 2005) and that developments of visualisations as part of the communication between groups need to respond to or incorporate this, or at the very least maintain an awareness of it.

VISUALISATION

Visual imagery is recognised as having the ability to convey a range of messages quickly and powerfully, with examples coming from commercial advertisements and the media, and others such as campaigns (Sheppard, 2005a). Research supports this with images shown to have the potential to improve cognition, influence decision-making and change behaviours (Sheppard, 2005a). The ability for visualisations to be highly persuasive (Duncan 2006), to be beneficial for developing knowledge (Eppler 2006; Rhyne, 2000; Zimmerman et al, 2006; Stappers and Flach, 2004), to facilitate collaboration (Rogers *et al.*, 2002) and for presenting information to the public in ways they can understand (Bell, 2001) have made them useful tools in environmental discussions. Zimmerman *et al*. (2006) demonstrated the importance of visualisations for public communications on model outputs. While such discussions themselves may not be problem-free and could also benefit form further research (Duncan 2006), this work focuses only on the role of visualisations within these discussions, specifically for forest-based environmental discussions.

While graphs, diagrams and maps are common tools for communicating technical environmental information, understanding is less guaranteed for those less accustomed to such representations. Reasonably realistic, close to real life representations have the potential to demonstrate concepts and issues in a compelling manner, including showing land- and landuse-based issues in reasonably realistic landscape visualisations (Sheppard, 2005a; Appleton and Lovett, 2002). Photorealism has been seen favourably compared to schematic representations (Daniel and Meitner, 2001; Sheppard, 2005b; Appleton *et al*., 2002). In addition, landscape visualisations that represent actual places and on-the-ground conditions that people can more readily identify with have a higher impact (Sheppard, 2005a).

GIS-based visualisations have developed along three themes (Appleton *et al*. 2002):

- Image draping, where satellite, aerial or land-based images are draped over GIS views, particularly in 3D
- Photorealistic renderings, where individual surfaces or items are drawn in a GIS view
- Virtual worlds allowing a much deeper level of interactions and explorations of the area

Each of these approaches has its strengths,weaknesses, and suitability, including such issues as costs and the ability to link to GIS data (Appleton *et al*. 2002). Immersive and interactive visualisations were found helpful in understanding impacts (Salter *et al*. 2009). Combining visualisations or visualisation types has the benefit of compounding the effect on the power of understanding of information (Arsenault *et al*. 2006).

Animation (movement) can be used to engage the viewers' attention (e.g. Meitner and Daniel 1997), while interactive visualisations facilitate exploration (e.g. Kalawsky, 2009). All approaches used should follow best practice guidelines for their development (e.g. Sheppard, 2001).

VISUALISATION OF FORESTS AND FOREST PROCESSES

Rodrigues *et al*. (2007) review a number of taxonomic approaches to organising visualisations. The sections below follow these approaches of identifying common characteristics, with adaptation to this research on forest-based visualisations.

Scales of Forest Visualisations

The scale of forest visualisations includes:

- a landscape or vista; and
- the trees themselves, i.e. without or with minimal surrounding context.

Meitner *et al*. (2005 based on Danahy, 1999) further differentiate a strategic landscape view where the viewing position is more representational of being in an aeroplane.

Examples of visualisations with a landscape emphasis include the introduction of forests into landscape by afforestation (e.g. Forestry Commission 2005; Dockerty *et al*., 2005; Hock *et al*., 2001; Auclair *et al*., 2001; Perrin *et al*. 2001) and the removal of forest from landscape by harvesting (e.g. Orland *et al*., 1997, Brunson and Reiter, 1996; Williams *et al*., 2007), whether with or without re-afforestation. Visualisations have explored issues such as the amount of forest in a landscape (Wissen *et al*. 2005; Hock *et al*., 1995; Fairweather & Swaffield 1999), the species or species mix within a landscape (e.g. Auclair *et al*., 2001; Perrin *et al*. 2001) including such features as edge screening trees (Thorn *et al*., 1997c), and different approaches to the layout of forests and forest patches within the landscape (e.g. Auclair *et al*., 2001). Locating forest patches within a landscape include investigating patterns created by, for example, the shape of the forest which may follow conceptual lines such as fence lines or follow landforms-based lay-outs (e.g. DeGraaf, 1999), and the presence of gaps in the forest (e.g. Meitner *et al*., 2005).

Focusing on the trees with minimal or no surrounding context has been used to draw the attention to details, such as when comparing different forest operations. These are described in the next section.

Purpose of Forest Visualisations

Visualisations of forests and the effects of forest activities, especially the effects of harvesting activities, were initially driven by the need for visual landscape management (Bell, 2001). This purpose has broadened to other aspects of forestry, and the intent of forest visualisations may be one or a combination of:

- aesthetics, with a trend in the past two decades from purely minimising negative impacts of landscape change from, for example, harvesting to a more active design approach to landscapes that include forestry (Bell, 2001);
- a specific forestry operation (e.g. establishment, thinning, harvesting);
- forest products and processes other than the traditional wood and fibre productivity model; and
- forestry issues that don't include forests or trees in the visualisations.

Managing the aesthetics of forest activities has been researched over a number of years, with nuances investigated such as differentiating between visual quality (pleasant to look at) and landscape aesthetics as they relate "to the informational and functional needs of humans" and addressing "conceptual properties such as coherence, legibility and mystery" (Brown *et al*., 1986). These concepts have grown to include stewardship, coherence, disturbance, historicity, visual scale, imageability, complexity, naturalness and ephemera (Tveit *et al*., 2006; Fry *et al*., 2009), with the capability of visualisation technology perhaps still in the aspirational stages of achieving all these concepts?

Forest visualisations that have been developed to manage visual aesthetics include most of the landscape visualisations of the previous section as well as Orland (1994) and Thorn *et al*. (1997b). Linked to this is the need to understanding people's perceptions of such visualisation (e.g. Daniel *et al*., 1997; Daniel and Meitner, 2001).

Visualisations of forestry operations, particularly those for planted trees, include:

- the effects of different establishment techniques such as contour planting versus down-up slope planting rows (Thorn *et al*., 1997a);
- different levels of initial stocking and thinning (e.g. Auclair *et al*., 2001);
- different harvesting approaches (e.g. Meitner *et al*. 2003; Thorn *et al*. 1997c; Orland, Daniel & Thorn 1997; Thorn *et al*. 1997a); and
- the long term effects of forestry practices (e.g. Chertov *et al*. 2002).

The ecologically and ecological functions of forests has grown in importance compared to forest aesthetics only, with ecological approaches to landscape management becoming increasingly important in forest management (e.g. Dakin 2003). An investigation of the influence ecological information has on aesthetic responses found variable effects (Brunson and Reiter, 1996). The trend toward ecological-driven planning has raised the concern that this approach may overlook the aesthetics impacts of such plans (Sheppard *et al*., 2004; also Swaffield *et al*., 2003).

The visualisations in the papers described above predominantly focus on managing the visual landscape under wood and fibre production regimes, but forests, including plantations (Hock *et al*., 2009) also provide a number of environmentally beneficial functions and ecosystem services. Visualisations of such non-wood products and processes for planted trees include:

- carbon sequestration (Chertov et al 2002);
- water movement (also soil movement/erosion) – at landscape level, i.e. more than schematic cross-section of for example Burt & Pinay (2005);
- biodiversity such as understorey (e.g. Suchan and Baritz, 2001); and
- recreation such as hunting, mountain biking, and walking (Yao *et al*. 2010).

Attempt at visualisations have been made of issues caused or affected by forestry but outside of or potentially even remote to the forest, such as infrastructure and employment options (Swaffield & Fairweather, 2000).

Use of Forest Visualisation

Visualisations have been used in surveys to determine values that people hold for forests; the survey approaches include interview-based surveys (Fairweather & Swaffield, 1999; Swaffield & Fairweather, 2000); internet survey (Beverley *et al.* 2008); and focus groups (Barnard *et al.* 2009a&b, Yao *et al*., 2010). Visualisations created by stakeholders themselves showed commonalities for all stakeholder groups except planners drew views of forests in the landscape from an oblique angle, rather than the traditional map view (Barnard *et al*., 2006; unpublished data, Tim Barnard, Scion).

Other Visualisation Applications

Visualisations are used to envisage future scenarios such as landscapes under different climate change policies (e.g. Dockerty *et al*., 2006 & 2005; Berry et *al*.., 2002; Sheppard 2006; Wissen *et al*., 2005). Future landscapes need to be derived from tentative scenario data rather than from previous monitoring or reasonably well understood predictions (Quine *et al*., 2004, in: Wissen *et al*., 2005).

Other visualisation include those not normally visible, such as trees at the cellular (e.g. Pont *et al*., 2007) or soil at the microscopic level (e.g. Payn and Clinton, 2005). Other techniques for visualisation include thematic overlays onto photorealistic images (e.g. Sheppard, 2005a; Meitner *et al*., 2003)

Visualisations of Forest Processes

Visualisations of forests have focused on the effects of processes rather than as means to explain the processes themselves, or if visualisations of forest processes have been developed, these are abstractions and are not shown as occurring in situ (e.g. Payn and Clinton 2005). Examples of effects-based visualisations include:

- achieving increased carbon sequestration has been shown as options of levels of tree plantings (Chertov *et al*. 2002); and
- insect damage or prevention has been shown as different amounts of dead trees (reviewed in Sheppard and Picard, 2006)

One area where forest processes have been visualised is for forest fire modelling, with visualisations of the fire behaviour and regeneration after a fire (Zimmerman *et al.,* 2006; Kaufman, 2006).

Visualisations matched to Montreal Process Criteria and Indicators

Published forest visualisations were matched to Montreal Process Criteria and Indicators (Table 2). Only those visualisations that clearly address an indicator have been included, rather than trying to force a fit for all the visualisations described previously.

Table 2. Published visualisations matched to Montreal Criteria and Indicators (see Appendix A for more detailed wording of the criteria and indicators)

Criteria	Indicator	Paper(s)
1 conservation of biological diversity	1.1c fragmentation of forests	Wissen *et al*. 2005; Auclair *et al*., 2001
2 maintenance of productive capacity	2.a area and % of forest land	Forestry Commission 2005; Dockerty *et al*., 2005; Hock *et al*., 2001; Auclair *et al*., 2001; Perrin *et al*. 2001; Wissen *et al*. 2005; Hock *et al*., 1995; Fairweather & Swaffield 1999
	2.9 annual harvest	Orland *et al*., 1997, Brunson and Reiter, 1996; Williams *et al*., 2007
3 maintenance of health and vitality	3.2 forest affected by biotic processes and agents	Sheppard and Picard, 2006
	3.b forest affected by abiotic agents, e.g. fire	Zimmerman *et al*., 2006; Kaufman, 2006
4 conservation and maintenance of soil and water resources	-	-
5 maintenance of contribution to carbon cycles	5.a total forest carbon pools and fluxes	Chertov *et al*. 2002
6 long-term socio-economic benefit	6.3a employment in forest sector	Swaffield & Fairweather, 2000

VISUALISATION OF SUSTAINABLE FORESTRY

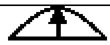
Sustainable Forestry Reporting

Reporting forest sustainability uses a range of concepts such as criteria and indicators of sustainability to provide measures which, when observed periodically, have the ability to demonstrate trends (e.g. Montreal Process). While reporting on an individual indicator is sufficiently complex and can in itself present difficulties in comprehension and inferences (Johnson and Chess, 2006), comprehensive reports covering a suite of indicators have the additional difficulty of presenting trends across all of the many indicators comprehensively.

Visualisations of Indicators of Sustainable Forestry

Attempts to create visualisations of the state, trend and potential error in measurement of the Montreal Indicator are summarised in Hendricks (2009). This includes symbols used for trends (Table 3) which may also be coloured according to the traffic light colour range with red for declining trends, yellow for unchanged, and green for improving trends. Other options include colour shaded maps, score cards, tables or as a matrix of values.

Table 3. Example symbology for trends in sustainability reporting

Improving	Unchanged	Declining
√	-	X
☺	😐	☹
▲	►	▼
		

Visualisations of the Relationship between Forestry Processes and Indicators of Sustainability

While there is ongoing research on visualisations for forestry and for indicators, the combination of the two, especially beyond the aesthetics of forestry, is a developing field.

Bell (2001) shows how landscape patterns are “visual manifestations of the processes at work in the landscape” such as climatic and geomorphological processes. For forests that require forestry practices to follow ecosystem-based patterns, disturbances and interventions, understanding the natural patterns produced by these processes becomes important. However, locating harvest units by ecological principle is not used for plantation forests in NZ, the focus instead being on other processes in the forest as described later.

Fry *et al*. (2009) describe the concepts that overlap both the field of ecological indicators and that of indicators of visual aspects of the landscape, specifically those that relate to landscape structure. Examples for landscape coherence are:

- The connectivity of forest patches may be ecologically important in a landscape
- Visually, connectivity and fragmentation can affect the harmony, unity, and balance and proportion of a landscape’s attributes
- Common to both visual and ecological themes for the concept of coherence are such concepts land use suitability and intactness

This conceptual framework may provide valuable insights for guiding further forestry visualisation work.

EVALUATING VISUALISATIONS

Visualisation to Facilitate Stakeholder Understanding

Visualisations need to be well designed to avoid overwhelming or confusing viewers, with techniques developed for the field of technical and medical illustration providing guidelines for developing effective illustrations (Gaither *et al.*, 2004). Research on the effectiveness of visualisations has looked at understanding the role aesthetics can have on helping to draw a viewer's attention (Healey and Enns 2002). Poor technique, on the other hand, provides what is essentially only an impressive graphic without the concomitant facilitation of understanding (Globus and Raible 1994).

Evaluating Cognition from Visualisation

Measuring the learning and understanding achieved by the use of visualisations or particular types of visualisation is a complex task, as the understanding is subjective. A common approach is to follow the use of visualisations with survey questions (for example, Johnson and Chess, 2006; Zimmerman *et al.*, 2006). Zimmerman *et al.* (2006) also present a brief review of the effectiveness of formal presentation approaches. If the theme presented in the images can be demonstrated by field visits, this can provide valuable information on the effectiveness of the visualisation (Williams *et al.*, 2007).

RESEARCH QUESTIONS

Research Issues for Forestry Visualisations

Selecting from Johnson's (2004) comprehensive list of research problems and issues for scientific visualisations provides some general topics relevant to the field of sustainable forestry. They are the need for:

- in-depth knowledge about the science of visualisation and of the application;
- quantifying effectiveness;
- representing error and uncertainty;
- developing effective human-computer interaction;
- including both global and local perspectives (ability to zoom in and out); and
- displaying time-dependent visualisations.

To this list can be added the need for (Appleton *et al*., 2002)

- visualisation techniques that work closely alongside traditional GIS

Developments of geovisualisation technologies, especially web-based ones, put pressure on ensuring ease of access and interaction with any new visualisations developed (Elwood 2009). Along with this, the ability for visualisations to be formed into basic narratives improves their emotional appeal and their potential impact (Burkhard *et al*., 2007; Perrin *et al*., 2009).

From a more conceptual basis comes the question of how each individual stakeholder group conceptualises the information to be visualised (e.g. Sawer and Huang, 2007); more on this in the section below.

Many aspects of ecological, economic and social effects can be difficult to demonstrate without some form of "visual rendering" (Bell, 2001); an example of demonstrating a potentially invisible environmental effect is that of pollution visualisation. For forestry, along with other topic areas, the question has become "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 … (and remains) a potentially exciting area well worth investigating" (Bell, 2001).

Potential Visualisations for New Zealand Forestry

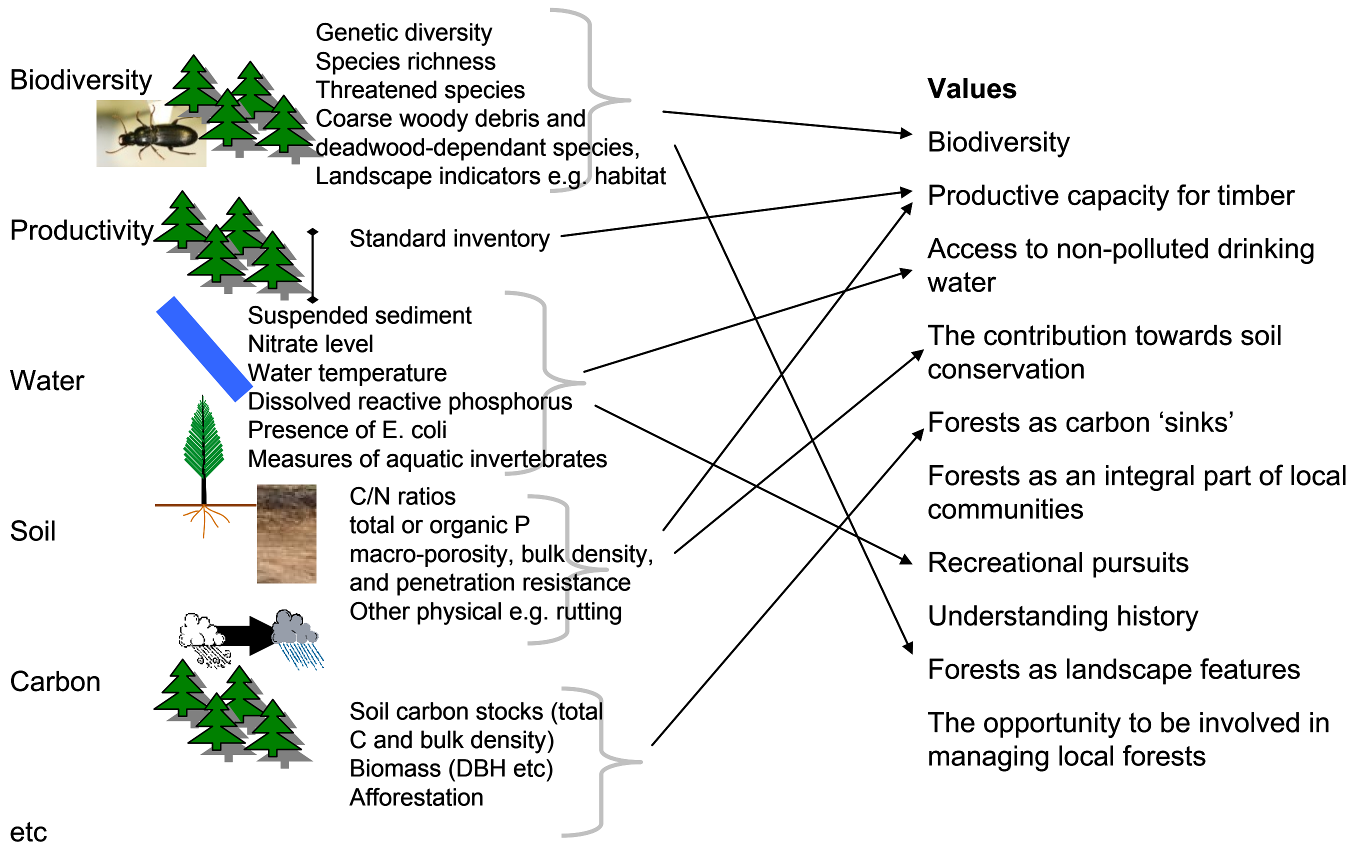
Sustainability is a concept that can be understood in multiple ways. For forestry, as for others, this includes economic, environmental and social sustainability.

For the secondary stakeholders in NZ, key issues are (Barnard *et al*., 2006, 2009a):

- Biodiversity
- Productive capacity for timber
- Access to non-polluted drinking water
- The contribution towards soil conservation
- Forests as carbon 'sinks'
- Forests as an integral part of local communities
- Recreational pursuits
- Understanding history
- Forests as landscape features
- The opportunity to be included in managing local forests

Figure 2 shows an example of matching typical field information (Jones *et al*., 2009) to the above issues; these values held by the secondary stakeholders are complex and will require deeper investigations to determine how visualisation can facilitate understanding of the current state of an environmental indicator and the trends.

Figure 2. Field measurements mapped to values of sustainability



Recent surveys evaluating this list and aimed at developing community generated indicators for sustainable forestry (Barnard *et al*., 2009b) added:

- Access

The forestry practitioners' stakeholder group are interested in visualisations that facilitate the practice of forestry. Their interest areas are influenced by current NZ issues, which include external drivers such as FSC. Table 4 represents a number of potential visualisation needs, which are in addition to such issues as sustainable soil productivity and carbon sequestration. Some of these issues may lack supporting data.

These points are detailed in Table 4.

Table 4. Potential visualisation topic areas for NZ forestry: topics from community values-based stakeholders

Visualisation	Description	Comment
Biodiversity	Maintenance of healthy forest ecology and indigenous biological diversity	Environmental sustainability
Productive capacity for timber	Forests continue to grow wood of economic value	Economic sustainability
Access to non-polluted drinking water	Evidence of waterway protection in forests; the nature of water within forests is protected and maintained	Environmental sustainability
The contribution towards soil conservation	Identification of the best use of land for forestry (e.g. for soil erosion and waterway protection) versus other land use	Environmental sustainability
Forests as carbon 'sinks'	Part of the carbon accounting policies	Environmental sustainability
Forests as an integral part of local communities	Opportunity to participate in forums and workshops about user-related issues; opportunity to develop agreements (e.g. MOUs) between user groups, local authorities and companies for managing certain sites and/or interests	Social sustainability
Recreational pursuits	Access to forests for recreation	Social sustainability
Understanding history	Long term age of forests is valued for its contribution to understanding local history and providing future opportunities	Social sustainability
Forests as landscape features	Wilding pines; felling	Social sustainability
The opportunity to be included in managing local forests	Interested in being involved on specific issues rather than overall forest management	Social sustainability

The forestry practitioner's stakeholder group are interested in visualisations that describe the practise of forestry. Their interest areas are influenced by current NZ issues which includes external drivers such as FSC. Table 5 represents a number of these potential visualisation needs, which are in addition to such issues as sustainable soil productivity and carbon sequestration. Some of these issues may lack supporting data.

Table 5. Potential visualisation topic areas for NZ forestry: topics from forest practitioners

Visualisation	Description	Comment
Sustainability of forest harvesting	Local clear-felling while maintaining age profile of whole forest	Economic sustainability
Flow of wood and wood products	Within and outside the forest – components of trees used for timber, paper, biofuel, etc. Includes location and number of people employed for each step	Social and economic sustainability
Forest recreation	For hunting, mountain biking etc	Social sustainability
Water quantity and quality	Forest as a component of a catchment/landscape; forest as a whole with temporary felled areas	Environmental sustainability
Non-timber products	Products such as honey, punga ferns; also recreation	Social and environmental sustainability
Sustainable forest management	Differences in the practise of forestry (care for equipment, adequately equipped people, investment in research & training, etc)	Economic and social sustainability
Health of forest	Health problems and treatments	Environmental and economic sustainability
Chemical spread	Extent of effects of e.g. spraying	Environmental sustainability
Biodiversity and harvesting	Mobile populations such as bats and falcons	Environmental sustainability
Wilding spread	Wilding spread from planted trees (South Island issue)	Environmental sustainability

For the researchers stakeholder group an important driver is to develop knowledge that meets scientific criteria. Existing knowledge provides a sound basis for the development of visualisations; while gaps in the knowledge base provide challenges. Table 6 provides a range of example topics; again without restricting the list to well studied subjects.

Table 6. Potential visualisation topic areas for NZ forestry: topics from researchers

Visualisation	Description	Comment
Nutrient flows	Added; within a site; removed or recycled after harvesting	Environmental sustainability
Logging roads	Construction impacts; also post-harvesting benefits e.g. for recreation	Environmental and economic sustainability
Water quality and quantity	Variations through rotation cycles; at stand and forest level	Environmental sustainability
Biodiversity	Trends; iconic species e.g. falcon; variations through rotation cycles	Environmental sustainability
Carbon sequestration	Models of rates of growth and carbon	Environmental and economic sustainability
Forest related employment	Through rotation cycles; flow-on employment, after harvest	Social and economic sustainability
Country comparisons	Comparison of international reporting	All aspects of sustainability
Plantations as neighbours	Impacts beyond forest – logging trucks, downstream effects, etc	Social sustainability

These topics arise from many perceptions and values for forests and forestry. They have different levels of relevance to the concept of sustainable forestry which need to be explored. The audience, the fora, the technology, and the intent of the visualisation – for example, visualisation for demonstration purposes or for dialog – remain to be finalised. Further input from stakeholder groups will be necessary to ensure a disconnect between developmental endeavours and stakeholders interests is not introduced (Andrienko et al 2006).

CONCLUSION

This report described the key stakeholder groups engaged in the communication of sustainable forestry, the foci of their needs and their communication wants. Past forest-based visualisation developments were reviewed, including examples from New Zealand, and a list of how they are associated to the Criteria and Indicators of the Montreal Process. Approaches for evaluating visualisations were discussed. Finally, a number of research issues for visualising forestry were introduced.

This review presents a range of literature and topics that underpin the proposed visualisation research, providing the background knowledge for the development of visualisations for demonstrating sustainable forestry. The next steps in the development of the visualisations themselves are described in Hock et al (2010).

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APPENDICES

Appendix: Montreal Process Criteria and Indicators

Note: These are the most recent indicators; New Zealand's 2009 report still uses the 2006 agreed Criteria and Indicators.

Montreal Process Criteria and Indicators (2009)

Criterion 1: Conservation of biological diversity

1.1. Ecosystem Diversity

1.1.a Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure

1.1.b Area and percent of forest in protected areas by forest ecosystem type, and by age class or successional stage

1.1.c Fragmentation of forests

1.2. Species Diversity

1.2.a Number of native forest-associated species

1.2.b Number and status of native forest-associated species at risk, as determined by legislation or scientific assessment

1.2.c Status of on site and off site efforts focused on conservation of species diversity

1.3. Genetic Diversity

1.3.a Number and geographic distribution of forest-associated species at risk of losing genetic variation and locally adapted genotypes

1.3.b Population levels of selected representative forest-associated species to describe genetic diversity

1.3.c Status of on site and off site efforts focused on conservation of genetic diversity

Criterion 2: Maintenance of productive capacity of forest ecosystems

2.a Area and percent of forest land and net area of forest land available for wood production

2.b Total growing stock and annual increment of both merchantable and non-merchantable tree species in forests available for wood production

2.c Area, percent, and growing stock of plantations of native and exotic species

2.d Annual harvest of wood products by volume and as a percentage of net growth or sustained yield

2.e Annual harvest of non-wood forest products

Criterion 3:Maintenance of forest ecosystem health and vitality

3.a Area and percent of forest affected by biotic processes and agents (e.g. disease, insects, invasive alien species) beyond reference conditions

3.b Area and percent of forest affected by abiotic agents (e.g. fire, storm, land clearance) beyond reference conditions

Criterion 4:Conservation and maintenance of soil and water resources

4.1 Protective function

4.1.a Area and percent of forest whose designation or land management focus is the protection of soil or water resources

4.2 Soil

4.2.a Proportion of forest management activities that meet best management practices or other relevant legislation to protect soil resources

4.2.b Area and percent of forest land with significant soil degradation

4.3 Water

4.3.a Proportion of forest management activities that meet best management practices, or other relevant legislation, to protect water related resources

4.3.b Area and percent of water bodies, or stream length, in forest areas with significant change in physical, chemical or biological properties from reference conditions

Criterion 5: Maintenance of forest contribution to global carbon cycles

5.a Total forest ecosystem carbon pools and fluxes

5.b Total forest product carbon pools and fluxes

5.c Avoided fossil fuel carbon emissions by using forest biomass for energy

Criterion 6: Maintenance and enhancement of long-term multiple socio-economic benefits

6.1 Production and consumption

6.1.a Value and volume of wood and wood products production, including primary and secondary processing

6.1.b Value of non-wood forest products produced or collected

6.1.c Revenue from forest based environmental services

6.1.d Total and *per capita* consumption of wood and wood products in round wood equivalents

6.1.e Total and *per capita* consumption of non-wood forest products

6.1.f Value and volume in round wood equivalents of exports and imports of wood products

6.1.g Value of exports and imports of non-wood forest products

6.1.h Exports as a share of wood and wood products production, and imports as a share of wood and wood products consumption

6.1.i Recovery or recycling of forest products as a percent of total forest products consumption

6.2 Investment in the forest sector

6.2.a Value of capital investment and annual expenditure in forest management, wood and non-wood forest product industries, forest-based environmental services, recreation and tourism

6.2.b Annual investment and expenditure in forest-related research, extension and development, and education

6.3 Employment and community needs

6.3.a Employment in the forest sector

6.3.b Average wage rates, annual average income and annual injury rates in major forest employment categories

6.3.c Resilience of forest-dependent communities

6.3.d Area and percent of forests used for subsistence purposes

6.3.e Distribution of revenues derived from forest management

6.4 Recreation and tourism

6.4.a Area and percent of forests available and/or managed for public recreation and tourism

6.4.b Number, type, and geographic distribution of visits attributed to recreation and tourism and related to facilities available

6.5 Cultural, social and spiritual needs and values

6.5.a Area and percent of forests managed primarily to protect the range of cultural, social and spiritual needs and values

6.5.bThe importance of forests to people

Criterion 7: Legal, institutional and economic frameworks for forest conservation and sustainable management

7.1.a Legislation and policies supporting the sustainable management of forests

7.1.b Cross sectoral policy and programme coordination

7.2.a Taxation and other economic strategies that affect sustainable management of forests

7.3.a Clarity and security of land and resource tenure and property rights

7.3.b Enforcement of laws related to forests

7.4.a Programmes, services and other resources supporting the sustainable management of forests

7.4.b Development and application of research and technologies for the sustainable management of forests

7.5.a Partnerships to promote the sustainable management of forests

7.5.b Public participation and conflict resolution in forest-related decision making

7.5.c Monitoring, assessment and reporting on progress towards sustainable management of forests