

# LASER-SCANNING FOR LANDSCAPE PLANNING: IMPLICATIONS FOR POLICY AND PRACTICE FROM AN END-USER'S PERSPECTIVE

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**KEYWORDS:** LiDAR; Landscape Assessment; Landscape Visualisation; Aesthetics; Urban-wildland interface; Visibility Mapping

## ABSTRACT:

Laser-scanning techniques can generate vast amounts of highly resolute 3D data on landscape characteristics. Do we need this much data in landscape assessment and planning, and what would we do with it if we got it? This paper reviews trends in landscape planning that may limit or benefit from the advances that laser scanning methods offer. Potential dilemmas and advantages associated with possible uses of laser-scanning data are reviewed in three contexts relevant to social aspects of landscape planning: general applications in transitional landscapes (with both buildings and trees), visual landscape assessment, and landscape visualisation.

## 1.0 INTRODUCTION

Aerial and ground-based LiDAR (Light Detection and Ranging) techniques, and allied remote sensing technologies, can now generate vast amounts of highly resolute 3D data on landscape characteristics. Do we need this much data in landscape assessment and planning, and what would we do with it if we got it? This paper reviews the context and trends in landscape planning in relation to the advances that laser scanning methods offer, and suggests some applications that appear to be consistent with these trends.

Clearly, systems that can generate much more accurate and detailed 3D data of the earth's surface features will have many applications to the biophysical sciences. This paper, however, focuses upon a definition of landscape assessment that explicitly incorporates social functions and values of landscapes; furthermore, it goes beyond assessment to consider the larger processes of landscape planning, in which landscape assessment represents one phase. In this

context, the question becomes: how do new sources of data such as LiDAR contribute to our understanding of social issues such as aesthetics, environmental learning, and cultural values, and what impact might it have on multi-objective decision-making where people have to make hard choices about actual landscapes?

## 2.0 TRENDS IN LANDSCAPE ASSESSMENT AND PLANNING

In the field of landscape assessment and planning, there are a number of trends that are likely to influence how laser scanning data is used. Some of these would appear, at least on first sight, to limit the usefulness of new highly detailed data.

One of these trends is the move over the last decade or so towards more environmental analysis and planning at the 'landscape scale' (Shindler, 2000), usually defined as relating to watersheds, to mosaics of ecosystems, and sometimes to viewsheds, somewhere between

the detailed site scale and the very broad regional scale. This is a scale which is meaningful to communities and planning agencies, where they can take into account contextual issues and spatial trade-offs or zoning between different resource values. In forestry terms, the landscape level applies between the stand level and the forest or sub-forest level, and fits well with new paradigms of ecosystem management. Landscape ecologists have become interested in large spatial patterns and various GIS-based landscape metrics (Foreman and Godron, 1986), rather than detailed site-specific data.

Another trend affecting many fields has been the reduction in trust in 'scientific experts' and the increasing value placed on other forms of knowledge (Williams, 2004), such as local or Traditional Ecological Knowledge which relies much less on quantitative measures and conventional data. Often, forest scientists for example have appeared pre-occupied with measuring and predicting timber volumes and timber-productivity related values; hence their conclusions, and to some extent their models and underlying data, have become suspect to a public concerned about the dominance of industrial priorities over other ecological and social values. This has been one factor contributing to a more interdisciplinary, socially focused, and qualitative approach to resource management.

A second factor driving this trend is the rise of certification in demonstrating the sustainability of resource management. Criteria and indicator-based systems such as the Montreal Process (Burley, 2001) and systems of certification such as the Forest Stewardship Council (FSC) scheme and the Pan-European Forest Certification (PEFC) system have been widely adopted. These require accounting for multiple ecological, economic, and social dimensions, and while there has been much debate over what social sustainability in particular really means (eg. Sheppard, 2003), in effect, forest managers must now broaden rather than deepen their knowledge and practice. Highly resolute data

would not at first sight appear to help here. However, we are likely to see the rise of more sub-disciplines and areas of specialized expertise within forestry, and certification of sustainable management will ultimately require much more rather than less environmental data, since it requires regular monitoring for adaptive management, with full and defensible documentation of this information for the auditors. Increasingly, social issues are being measured and incorporated in sustainable forest management (Sheppard, 2001; Sheppard, et al., 2004b), which will influence the type of data needing to be collected.

One of the consequences of certification has been to demand a much greater level of public appreciation in resource decision-making in many countries. This too has contributed toward the trend towards more social and qualitative analyses as part of planning processes, such as ethnographic studies of different cultures and ways to engage more lay-people in decision-making (Elmendorf and Luloff, 2001; Sheppard and Achiam, 2004). Increasingly, social issues, not highly technical data-driven ones, are holding sway.

However, a deeper look at these trends suggests some areas, even within the holistic and social aspects of landscape planning, where the highly quantified and detailed types of technical data produced by laser scanning could prove valuable. Advantages of this data over other forms of information used in landscape planning include:

- Its own **visual character**: the method of receiving light radiation in LiDAR technology is similar to that of human vision: broadly speaking, it sees (and collects) the same sort of data as the human eye, light reflected off physical surfaces in the landscape. The data is also presentable in a form (visual images in perspective) that the human perceptual system evolved to handle: the eye is brilliantly adapted to

making sense of clouds of data very quickly.

- **Level of detail:** especially with ground-based LiDAR systems, the minute detail and accuracy of 3D data capture allow the images to be related to personal and familiar landscapes, eg. ‘my driveway’, the local park); representing the familiar provides a new medium of engaging ordinary people in ways that more abstract, symbolic, or coarse-scaled data cannot.
- **Defensibility:** despite the public distrust of some scientists, there is still a high level of comfort in ‘scientific’ data which can be shown to be correct, unarguably quantifiable, and replicable. The scientific data capture methods for LiDAR, together with the essentially self-verifying nature of the perspective images (which can be compared with recollected mental images or actual photographs, for example), provides a high level of trust in the data.
- **A high-tech image:** at least for some time, the novelty and ‘wow-factor’ of the advanced state-of-the-art technology may prove a very attractive characteristic for agencies, consultants, and even communities involved in landscape planning. The ability to present the information visually and dynamically, eg. through animated ‘fly-bys’, should give it some of the same advantages as other forms of visualisation which have been shown to increase public attendance and engagement at planning sessions (Sheppard, 2004a).

These characteristics of detailed 3D data for use in accurate landscape modelling, and in particular realistic landscape visualisations, have possible ramifications for landscape planning in several areas, expanding our understanding of environmental perceptions, improving public involvement processes, contributing to more informed designs, and

managing various visual/spatial phenomena of importance to society in certain landscape types. At the same time, there are logistical and contextual factors which may limit the use of laser-scanning data in practice, as well as competition from cheaper and universally accepted forms of visual information such as photography. These issues are discussed in the context of three application areas within landscape planning: use in transitional landscapes such as the wildland-urban interface or rural countryside; use in visual landscape assessment; and use in generating landscape visualisations.

### 3.0 GENERAL APPLICATIONS OF LiDAR IN TRANSITIONAL LANDSCAPES

At the risk of oversimplifying, the use of LiDAR and pre-existing methods of remote sensing and surveying has been to date concentrated in two separate worlds, with their own systems of modelling and data needs: the natural, vegetation-dominated world, represented by forestry applications; and the urban, structure-dominated world represented by architecture and civil engineering applications. Typical applications in forestry have included forest inventory, biomass calculation, habitat evaluation, etc. With LiDAR techniques, improvements in crown mapping, tree structure analysis, underlying terrain mapping, understory structure, interpretations for biodiversity, etc., have become possible, as exemplified by the many other papers in these proceedings. These vegetated environments can be described as containing massive numbers of highly complex vegetative objects (plants), most of which are very similar to the eye. The data has been useful mainly to a few disciplines in the natural sciences, notably foresters and ecologists. Within these fields, the advantages of LiDAR are clear, given the crudity and/or expense of previous data sources (eg. low-accuracy digital terrain models, limited accuracy aerial photo

analysis, and site surveys to obtain cruise data). Such wildland, vegetated environments are often not easily accessible, nor are they easily visible below the forest canopy.

In urban environments, laser-scanning and other techniques have been applied to mapping the 3D forms of freeway structures, buildings, and even city neighborhoods (Figure 1), as well as to other engineering applications in various landscape types (such as dams, rock walls, etc). In general, these objects and environments are already quite well understood: the main structures are often relatively simple, with straight or clearly defined edges and rectilinear forms, although each building may be unique; they are usually easily accessible, quite visible, and readily photographed; and often, detailed plans or digital models already exist in CADD or as-built drawings and surveys. There may be multiple applications with this kind of data for engineers, architects, planners, safety officials, etc. For example, the accuracy of as-built plans can be checked, the design and condition of historic structures can be monitored, and 3D settings for new building design can be created. However, the logistical and accuracy advantages of LiDAR over existing data sources, such as photography and existing digital plans, may not be as clear as with forestry applications.



**Figure 1: Ground-based LiDAR image of city street (Tokyo).**

*Courtesy of Optech Inc.*

These two worlds come together in the urban/wildland interface (eg. second-homes in the forest or new developments adjoining forest land) or in other landscapes containing a balance of built structures and vegetation, as in suburbs or the pastoral and settled landscapes of Europe. Here we obviously need a wide mix of disciplines (foresters, civil engineers, planners, architects, landscape architects, safety experts, ecologists, etc.) and of data types, models, and joint applications. Often the systems used in the one world do not relate well to those in the other. These landscapes can be termed transitional in the sense that they may represent an actual transition from one landscape to another (eg. the urban fringe), or that they require a transition in thinking and methods to address the combination of multiple landscape features and values. Rural planners, urban foresters (Konijnendijk, 2000), and increasingly the cross-disciplinary field of fire management in the wildland/urban interface (Dwyer and McCaffrey, 2004) have established the precedent for more integrated assessment, planning, and management for whole landscapes. Transitional landscapes often have better access than the wildland forest, but may or may not be very visible or easily photographed from the ground due to vegetative screening and private land restrictions. Data here is often much poorer than in either the forest or urban situation, with inconsistent or imprecise mapping, often rapid change due to development or urban sprawl, and rapidly changing and diverse vegetation. There is often a complex mix of vegetation and hardscape at an intimate scale: individual buildings below tree canopy, narrow driveways, personalized gardens, etc.

In these transitional landscapes, detailed and continuous 3D data could be very useful in generating information for hybrid models of vegetation and built structures, eg. in computing fire risk from proximity and type of trees around and within housing areas on the urban-wildland interface. Social issues are inextricably entwined with the biophysical data, as with fuel hazard ratings, privacy

issues, proximity of mosquito habitat or predatory animal corridors to housing or schools, etc. LiDAR could be useful in calculating light paths or shadow footprints for buildings which might affect neighbours or sensitive habitats. The ability to map and classify street furniture and other local features such as lampposts, signs, gates, landmark trees, chimneys, decks, etc., would provide 3D data which links directly to form and character issues central to much local level planning and by-law enforcement. This constitutes an important data vacuum in many countries (including North America), a vacuum that LiDAR at various levels of resolution could help fill. The potential to purchase this kind of detailed 3D data, which we might call DLM (Digital Landscape Model) data, in standardized form on a routine basis from conventional sources such as the UK Ordnance Survey or United States Geological Survey, could revolutionize the basis for local-level planning and design in these transitional landscapes. However, the relative costs and benefits to users of on-the-ground photographic inventory, other ground-based survey methods, expert interpretation of LiDAR imagery, and automated classification of LiDAR data, would need to be investigated in order to assess the true potential of laser-scanning in these areas.

#### **4.0 APPLICATIONS OF LiDAR TO VISUAL LANDSCAPE ASSESSMENT**

Among the potential applications of LiDAR, are a number of visual assessment procedures relating to visibility and visual quality (Sheppard, 2004b). The potential to measure and generate models of complex 3D landscape structures and surface features in great detail may significantly improve our ability to quantify important experiential qualities of landscape. Much work has been done on methods of viewshed or visibility mapping (eg. Felleman, 1986) in relation to terrain models and, more recently, crown mapping (eg. Miller, 2001) and visual detection of small objects (Shang and Bishop,

2000). Here, where accuracy and precision count, ground-based LiDAR could contribute better inventory data, especially in subtle or lowland landscapes where the height of hedgerows or rooftops, or slight variations in topography or data quality, can make a big difference; for example, the visibility of publicly sensitive developments such as wind turbines on the skyline can be a crucial siting and project approval factor. New forms of viewshed mapping and visual vulnerability assessment (as currently being explored by researchers at the Collaborative for Advanced Landscape Planning (CALP) at UBC) would benefit from such improved accuracy in taking vegetation into account more accurately.

There may also be new contributions to quantifying visual and spatial relationships important to visual impact. Various methods have been proposed for measuring the visual scale of objects which affect visual quality, through analysis of ground imagery from fixed perspective views; for example, Hopkinson's (1971) Visual Intrusion Index and Iverson's (1985) Visual Magnitude approach. In applications such as view protection and housing impacts on sensitive areas such as Lake Tahoe's legally-contested shoreline, 3D data from ground-based LiDAR could be correlated with guidelines limiting the visual scale of features from any number of viewpoints. There are a number of such visual applications wherever view blockage, view corridor, and privacy issues arise.

Another important visual issue that relates to forestry stems from the recent move towards partial cutting as a more publicly acceptable form of timber harvesting in North America (Picard and Sheppard, 2002). Ribe (in press), among others, have investigated the thresholds at which screening of bare ground by dispersed leave trees shifts people's preferences for timber harvesting, with the more green tree retention the better: in essence, when does it start looking like clearcutting? Like photography, LiDAR offers a simple way to quantify these

relationships for a given stand after harvesting, but without the limitations of a fixed viewpoint at the time of photography.

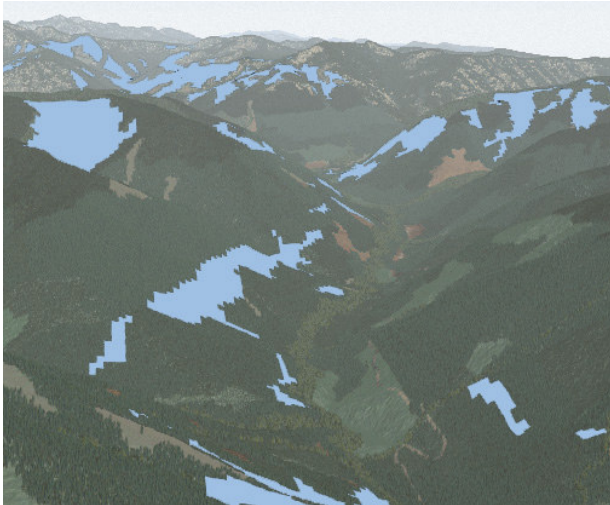
## 5.0 APPLICATIONS OF LiDAR TO LANDSCAPE VISUALISATION

Virtual reality systems and the new breed of landscape visualisations are already in use in forestry (Sheppard and Salter, 2004), urban design, and planning (Ervin and Hasbrouck, 2001). Visualisations play several roles in landscape planning, including general communication to the public, internal communication and feedback to designers, visual impact assessment, formal contributions to project approval and planning processes, and exploration/measurement of public perceptions and responses in practice and in research (Sheppard and Salter, 2004). It is widely recognized that visualisations can enhance learning and understanding relative to other forms of communication (Winn, 1997). Landscape visualisations attempt to represent actual places and on-the-ground conditions in three-dimensional (3D) perspective views, with sometimes very high levels of realism. They can help to map out the social dimensions of a landscape condition under proposed future management, in terms, for example, of recreation supply and experiential quality, tourism potential, other non-timber values, property values, etc).

Realistic landscape visualisations are capable of showing far more visual detail than is actually available currently in landscape data (Orland and Uusitalo, 2001). As mentioned above, laser scanning with automated object recognition could be very useful in developing accurate Digital Landscape Models (DLMs) to help fill this gap, with numerous potential applications in planning and design. While realistic visualisations have been in use for decades (Orland, 1986; Sheppard, 1989), the ability to generate 3D data-driven realistic visualisations has been more recent: programmes such as World

Construction Set and Community Viz allow great flexibility in modelling 3D and visual conditions, and can represent the landscape dynamically from any viewpoint and sometimes in real time.

However, do we need this much realism? People generally seem to want it, commonly equating realism with quality of the visualisation, perhaps fuelled by experience with movie special effects and video games. Nevertheless, many authors (eg. Orland and Uusitalo, 2001; Luymes, 2001; Sheppard, 2001) have raised concerns over realism as a cloak for inaccuracy or an inevitable (or deliberate) source of bias in multi-objective judgements of landscape issues. We remain unsure of the impact of realism, and therefore the need for highly resolute imagery in landscape planning; does it for example affect decisions or change opinions? The evidence so far suggests that realism is important for experiential issues such as aesthetics: Zube et al. (1987) and Bishop and Rohrmann (2003) believe that the greater the realism, the more similar the responses will be to real life. However, realism and detail may be counterproductive for cognition (Winn, 1997), where more abstract renditions can help simplify and explain complex relationships in complicated landscapes. At CALP, we are exploring forms of augmented reality in interfaces where realism can be combined with more abstract data on important non-visible information to capture the benefits of both (Figure 2). It does appear, however, that accurate data may be crucial to credibility of the visualisations, especially if the data-gathering process and processing in the visualisation can be simply and visually explained to sometimes sceptical observers (Figure 3). This is where the somewhat self-verifying visual nature of 3D LiDAR data and authenticity in relation to familiar landscapes can be an advantage.



**Figure 2: Computer-generated landscape visualisation of proposed forest management plan in the Arrow Forest District, augmented by overlays of old growth areas.**

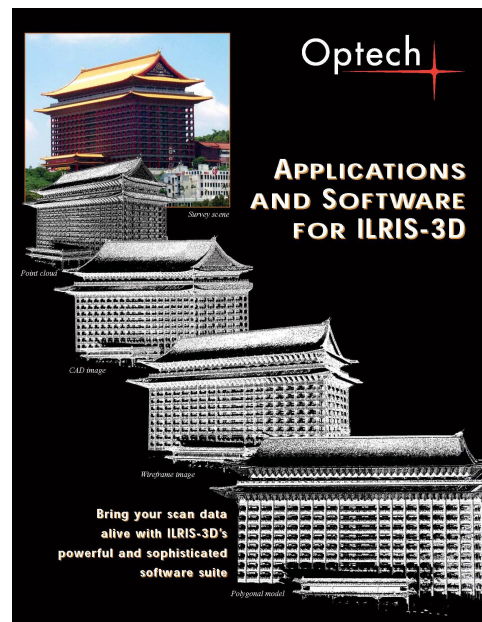
*Credit: Jon Salter and Duncan Cavens, CALP, UBC.*

Limitations on the application of LIDAR data to realistic landscape visualisation can be summarised as falling into the following circumstances:

- Where there is no need for realism, ie. visualisation has a primarily cognitive purpose which could be confused by detail, although LiDAR data can be useful in showing what is underneath the visible surface (eg. forest canopy or water surface).
- Where there are fears of having too much realism due to dominance of the aesthetic over cognitive information such as underlying ecological values.
- Where there is no need for specific realism or accuracy: Sheppard (1989) coined the phrase ‘generic simulations’ to describe realistic images that are not based on actual plans or objects but on generic objects, such as standard houses or typical trees; in our work with forested landscapes in BC, one coniferous tree tends to look much like another, even with different

species, and a small number of tree images repeated over large landscapes can work fairly well.

- Where you do need site-specific realism but where photographic visualisation (eg. with image processing software such as Photoshop) can deliver as well or better, inexpensively, and without the need for data classification or interpretation: photographic media can integrate effects not normally captured with LiDAR (<http://www.optech.on.ca/aboutlaser.htm>), such as colours, ambient light, atmospheric effects, and fine textures.
- Where future conditions need to be forecast: LiDAR captures only current conditions or accumulating historic conditions over time; much work needs to be done before LiDAR data can be seamlessly incorporated into the various predictive modelling systems needed to portray future conditions, eg. tree growth/modelling software (Muhar, 2001).



**Figure 3: Series of images showing progression from LiDAR imagery to CADD 3D model.**

*Courtesy of Optech Inc.*



Overall, despite these limitations, it would seem that there will be demand for LiDAR data in landscape visualisations, particularly if both the linkages to modelling and linkages to photographic data can be forged. Fusion of LiDAR data with photographic media to generate “intelligent photos” with automatically quantified variables important to landscape planning, could be valuable: for example, relating the visual phenomena in the photograph to specific measures of structure (eg. branch density, tree height, etc.). This would provide a richer basis for calibrating visualisation models to existing conditions than with current ‘xyz data-driven’, purely synthetic landscape modelling.

## 6.0 CONCLUSIONS

Clearly, there are both substantial opportunities and some important limitations on the use of LiDAR and allied technologies in landscape planning where social issues are engaged, particularly in transitional landscapes and in applications such as visual assessment and landscape visualisation. However, there are other logistical and contextual limitations that suggest caution would be advisable. Planning procedures and policies in most areas, even in developed countries, still lag far behind the technology in incorporating qualitative (people-centred) and experiential information, together with technical assessments and biophysical or engineering models, into planning and decision-making. As pointed out above, this is not necessarily all bad, since we understand very little about the effects of these new technologies and data sources on people’s understanding and decision-making behaviours (Sheppard, 2004a). It does mean that there may for some time be a missing link in the policies and procedures required to apply laser-scanning data appropriately. For example, the lack of broadly adopted guidance in planning circles on ethical use of highly realistic visualisations, which are capable of influencing people’s emotions and

attitudes on landscape issues, holds back the demand for such technologies in many jurisdictions, while failing to regulate how they are used in others. Commercial priorities, as in many previous situations, may for some time drive the usage of LiDAR data more than scientific factors or the public interest.

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#### ACKNOWLEDGEMENTS

Thanks go to Nicholas Coops at Integrated Remote Sensing Solutions (IRSS) at the University of British Columbia, Vancouver, and Mike Wulder at Pacific Forestry Center, Canadian Forest Service, Victoria, for help in obtaining information on LiDAR techniques. I also wish to thank Optech for permission to reproduce examples of their work on the ILRIS system; Michael Thies and his fellow NATSCAN conference organisers; and CALP members Adelle Airey, Jon Salter, Duncan Cavens, and Ken Fairhurst who contributed to this paper in various ways through their hard work and dedication.