23 Geographic Landscape Visualisation in Planning Adaptation to Climate Change in Victoria, Australia

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Abstract: Climate change is a global challenge for all scientists the 21st century with a certain amount of 'global warming' already inevitable. The magnitude and risks of climate change are now being more widely appreciated and the need for adaptation, including land use, is becoming a social imperative. Profound changes to ecosystems and biodiversity are predicted, and climate induced migration of biota is envisaged and is already being observed. Although the exact changes remain uncertain, landscapes and biota will be affected at all scales — from the local to sub-continental level. Space for biodiversity to 'self-adapt' is required. Maintaining and restoring ecological connectivity and resilience — biolinks — across landscapes are likely to be crucial aspects of adaptation to climate change. This is particularly so across human modified landscapes (e.g. agricultural landscapes) where the environmental legacy of habitat fragmentation and degradation is already a major global conservation issue. Past and current spatial patterns of human land use and management will also be affected by biophysical drivers and human adaptation.

What will be the function, patterns and processes of future landscapes that we bequeath to future generations under climate change? What they look like will be product of societal choices informed by the community's 'sense of place', that now includes biodiversity conservation. Visualisation tools, particularly when accurately linked to Geographic Information Systems, ecological perspectives and realistic photographic libraries, offer powerful facilities to assist the community, scientists, planners and all major stakeholders to plan for new landscapes that consider climate *change, including biolinks. These digitally created landscapes that display physical properties of the real world can provide a useful medium for visualising the results from experimenting with outcomes of different management approaches building in biodiversity conservation. 'Seeing' can augment meaning and 'sense of future place', particularly when linked to a realism derived from ecology. This chapter examines the use and potential of various visualisation tools as part of the emerging debate about biodiversity and adaptation to climate change in south-eastern Australia.*

23.1 Introduction

Global warming is the major environmental and economic threat of this century with mass extinctions projected due to a variety of factors including the changing spatial distribution and condition of populations and habitat at sub-continental scales (IPCC 2007; Stern 2006; Thomas et al. 2004). These phenomena will be exacerbated in areas of fragmented and degraded habitats and landscapes (Brereton et al. 1995; Thomas et al. 2004). Biophysical fingerprints of the warming over the 20th century are being documented globally and in Australia (Root et al. 2003; Umina et al. 2005). In Australia this is particularly relevant as it is the driest inhabited continent with the most variable climate and a global mega bio-diverse region. A certain degree of climate warming is now inevitable, thereby increasing the societal need for adaptation to these changes and potential risks (IPCC 2007). Land uses and management (e.g. agriculture, reserve and forestry systems), based on historic allocations and presumption of climate, will also need to adapt to climate change and related consequences. Reconnecting the ecological connectivity of landscapes (biolinks) to allow for species re-colonisation and migration has been called for in various parts of the globe (Brereton et al. 1995; Hilty et al. 2006; Opham and Wascher 2004; Soule et al. 2004). As ecological connectivity has a large visual impact on landscapes, visualisation tools offer an important component to inform the debate about future landscapes. South-eastern Australia now faces a warmer and drier future with irreversible climate changes already in train (Government of Victoria 2006) which means change in both 'natural' biophysical and human-induced landscapes. The capacity to realistically visualise these future landscapes at various scales will assist the emerging societal debate, and consequent planning for more resilient landscapes.

Landscape visualisation has substantial advantages as an investigative and communication medium in designing these new landscapes and enhancing the debate. It allows landscapes to be re-imagined. This is particularly so when combined with the scientific data from ecology. A visual synthesis of vast amounts of environmental historic data is an especially attractive feature as it can rapidly conceptualise the extent of the changes over time and in space. It provides a platform for realistic place-based future scenarios. It can also create meaning to present actions and assist in explaining the manifestations of ecological processes. In this chapter we show a variety of visualisation techniques that have been used and are being developed to provide a better understanding of the past to enhance our capacity to envisage biolink zones in future landscapes. These techniques are important to illuminate the inter-generational equity issues around landscape, biodiversity and natural resource management under changing climate. Visualisation can make a significant contribution to planning these new landscapes and, we argue, is best based within a 'sense of place' and on visual benchmarks of the past linked to ecological concepts and datasets and realistic photo libraries.

We explore these concepts through asking:

- What is the historic context of visualisation in redefining 'sense of place' and landscapes for the future?
- After examining the magnitude of the problem: how can techniques of geographic visualisation help knit a landscape policy narrative from the past to potential futures that include biodiversity conservation (bio-links)?
- How can ecological datasets be utilised and realistic images be incorporated into visualisation of future desired landscapes?

23.2 Context of Visualisation and 'Sense of Place'

Humans imbue landscape with meaning and create and conserve them as manifestations of these meanings which are connected to both the past and projected future (Schama 1998). Colonial societies transformed landscapes from the original into new 'future' productive vistas in their image.

The visual is a powerful, yet often neglected, medium in determining future landscapes. Landscape painting is an early version of visualisation and perceptive artists can reflect and *effect* a changing sense of place. Colonial depictions of 'Europeanised' Australian landscapes, where eucalyptus look like English oak trees, were challenged by the Victorian 'Heidelberg School' in the late 19th century (Clark and Whitelaw 1985).

These images changed the way landscape was perceived, and implicitly what future landscapes could be. Fred McCubbin's iconic *The Pioneers* (1904) hangs in the foyer of the Victorian Parliament depicting the change from pioneering in the Australian bush to the encroachment of civilisation. In the 1930s Arthur Streeton painted *The Vanishing Forests* (1934) — a statement on deforestation of the Dandenong Ranges and the environmental cost of settlement (Smith 1995). Through visualisation, a different landscape 'meaning' was added to colonisation. In the 1940s and 1950s, Sidney Nolan's iconic images of Australia in drought reinforced Australian's appreciation of living *within* the climate and landscapes. Michael Leunig, a nationally recognised Australian artist, articulated these changes in a painting of a mob of native sulphur-crested cockatoos, under which he annotated:

> 'In the tightening uniformity of global culture it is our unique indigenous natural heritage which reminds us of not only the of brilliance and beauty of difference, but also the value of protecting and cherishing what is true to this continent…' (The Age, 22 January 2005, p. 1)

Innovative uses of modern visualisation technology have an important part in re-imaging new biocultural landscapes. To be realised, the technologies must have a realism based on local species, a purposeful view of landscapes based on ecological insights and future climate change.

23.3 Climate Change Predictions and Impacts in South-eastern Australia

Future regional climates are difficult to predict with certainty, but some trends are evident. Increases in CO_2 and changes in the spatial and temporal distribution of climatic variables (temperature, precipitation, etc.) will induce changes to a range of biological assets and ecological processes already severely fragmented and degraded through past land use (NLWRA 2002). Under a high warming scenario, temperatures are projected to increase and by 2070, most of south-eastern Australia (particularly the State of Victoria) will receive 10% to 20% less rainfall than at present (Suppiah et al. 2007). The drought–fire–flood cycle, a persuasive determinant of Australian environments, will accelerate.

Such climate change will also have direct and visual effects on other important environmental drivers in the Australian landscape — stream flows and fire regimes (Hennesey 2005; Jones and Durack 2005; Mansergh and Cheal 2007). These changes will have major effects on the spatial distribution and extent of all life, including resource based industries, such as agriculture, which will have to adapt as the basic biological productivity changes spatially (e.g. water availability). Manifestations of these changes that can be visualised include patterns and processes of land use; structure and function of ecosystems, changing vegetative community structure, the spatial distribution of species and communities, and restoration of connectivity (Lau et al 2006; Mansergh and Cheal 2007).

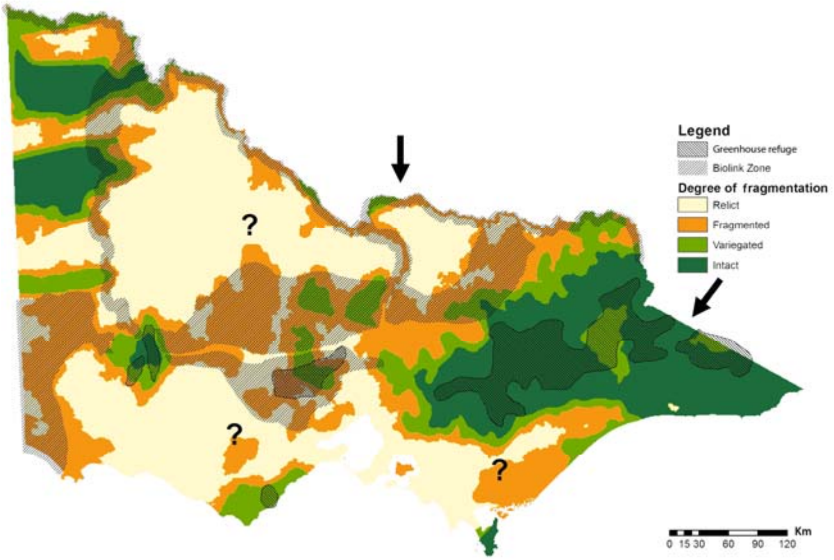


Fig. 23.1. Victorian biolinks and refugia overlaying the degree of fragmentation of native vegetation. Arrows indicate direction of climate-induced movement; question marks indicate potential biolink zones (Bennett et al. 1992; Brereton et al. 1995; fragmentation mapping DSE data, Mansergh and Cheal 2007)

23.3.1 Climate Change and the Need for Ecological Connectivity

Discussing climate change in a recent global review of ecological corridors, Hilty et al. (2006) found it ‘hard to imagine any realistic alternative [to large scale linkages] that would be conducive to species persistence’. Opdam and Wascher (2004), in analysing the synergenetic effects of habitat fragmentation and climate change on biodiversity, called for ‘bold connectivity zones’ and Stern (2006) alluded to them in a economic analysis of adaptation to climate change. Earlier modelled analyses of the impacts of climate change on south-eastern Australian species indicated broad-scale movement of biota, generally to higher latitudes (southwards) and higher altitudes with species vulnerability within the global range of 15% to 37% at risk of extinction. Climatic refugia were also identified. It was concluded that adaptive strategies must include large-scale restoration of ecological connectivity — biolinks (Fig. 23.1) — a new land use to allow space for biota to recolonise and migrate (Brereton et al. 1995; Damschen 2006; Newell et al. 2001; NRMMC 2004; Thomas et al. 2004).

23.3.2 Biolink Zones in South-eastern Australia

The overall objective of biolinks is to optimise the biota's capacity to self-adapt through restoration of habitat heterogeneity, permeability and connectivity across the landscape for multiple species. Traditional 'wildlife corridors' join A to B by a continuous band of more or less homogeneous vegetation generally for a single 'icon' species with harsh boundaries between adjoining land uses (Mansergh et al. 2005). Biolinks may contain such corridors but these zones would feature mosaics and patchworks of native vegetation over much larger areas (100s of kilometres long and 10,000 km^2 in area, Fig. 23.1) where people would live and work.

Within the zones (post-traditional agricultural), the overall density of native vegetation may be greater than 50% with regeneration of long-lived eucalyptus (>150 years) providing a variety of micro-climates and micro-habitats for other biota, for example, tree hollows (Vesk and Mac Nally 2006). The resultant vegetation communities and habitats will not be exact replicates of the past, rather, novel variants responding to the changed climatic conditions. In short, they represent new 'biocultural' landscapes, neither 'conserved' national park nor 'European-like' agriculture. Biolinks would be consciously created and many zones correlate with emerging compatible land-use trajectories (e.g. Amenity Landscapes of Barr 2005). Over time, these zones will look different at all scales. In the course of exploration of biolinks amongst a variety of interested parties (landholders, scientists, policy formulators) it became apparent that visualisation techniques could be used to explain the necessary context (landscape legacy), concepts (ecological connectivity), effects of climate change, and what future landscapes could 'look' like.

23.3.3 Visualisation Tools for Explaining the Context of Biolinks

The potential new land use, biolink zones, have had to be explained to a range of people — both the 'big' picture and implications at smaller visual scales. At a macro statewide level, temporally modelled *Landsat TM* satellite images, including a compilation at pre-settlement (early 19th century) images, allow the visualisation of land use changes since European arrival to present (Fig. 23.2).

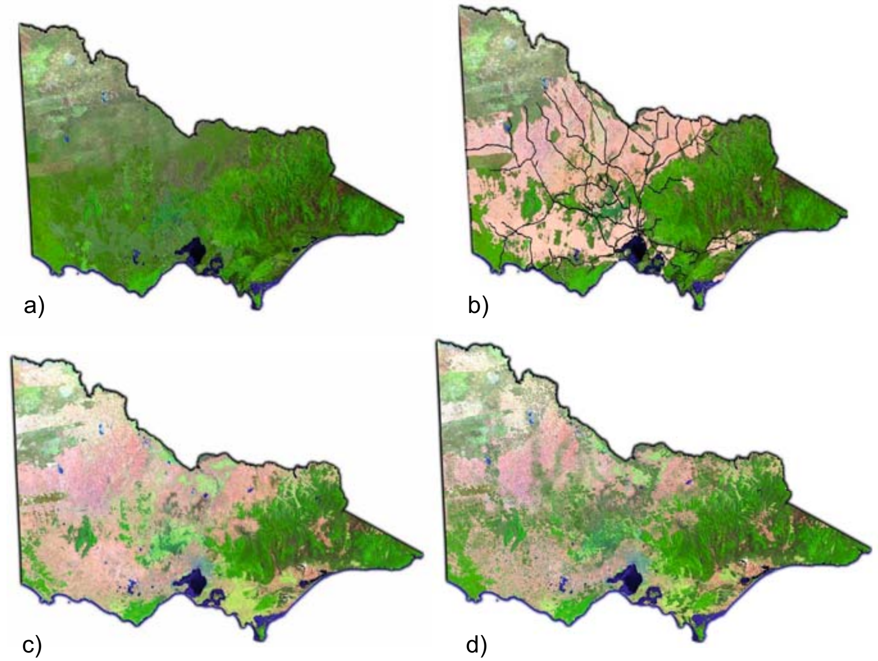


Fig. 23.2. Modelled satellite images of Victoria around (**a**) 1800, (**b**) 1900, (**c**) 2000 (actual) and (**d**) 2100 with revegetation concentrated within biolinks

23.3.4 Visualisation of Environmental Change at a Site over Time

Just as the modelled satellite images provide historical context at the broad scale, early aerial photographs provide a specific place-based visual benchmark in time. The first comprehensive aerial photograph series over the Australian State of Victoria occurred in the 1930s and 1940s, approximately midway between the first wave of large-scale clearing and the present (Mansergh et al. 2006). These images provide a strong basis for comparison to the present and can be overlaid with recent remotely sensed images and data (e.g. LiDAR – Light Detection and Ranging). This also allows the use of three-dimensional geographic landscape models that allow visualisation at the site level. The advantage of such graphic representation is not only its realism but also ability to illustrate the fourth dimension —

time (Fig. 23.3). Decades of past change and *potential futures* can be explored in a relatively short space of time.

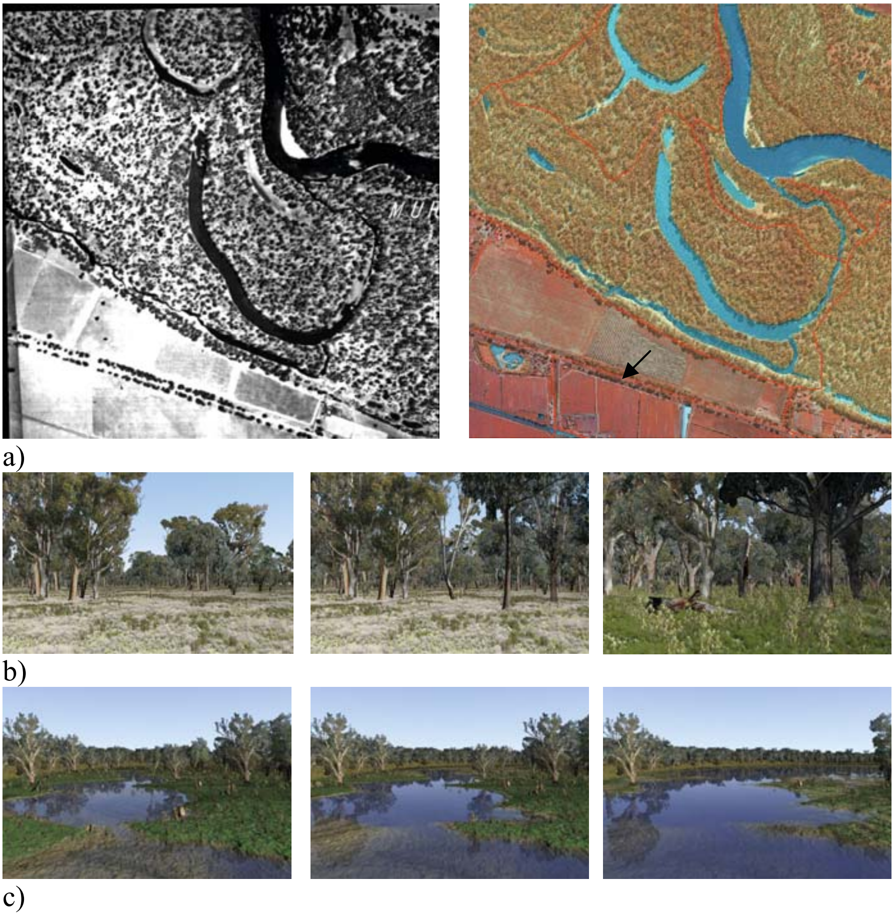


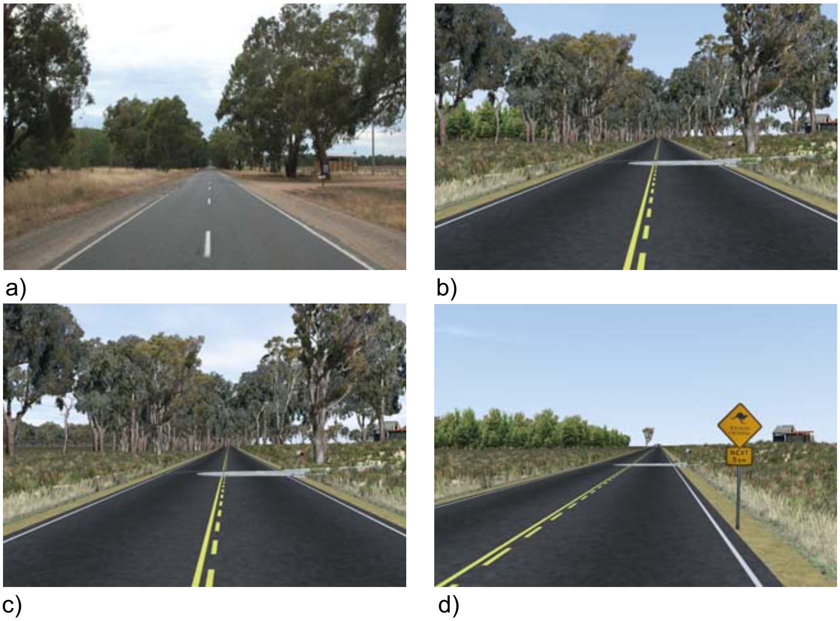
Fig. 23.3. (**a**) Modelling changes in river red gum forest data in 1941 (aerial photo) and 2005 (satellite and LiDAR), note regeneration on sand banks. Arrow indicates roadside site of Fig. 23.4 (**b**) Site in upper landscape showing 1941, present and 2100 views in a virtual landscape as forests mature. (**c**) The virtual landscape can accurately show water levels under any flow regime (see text)

The Murray River is the longest river in Australia, and the Murray–Darling Basin dominates the zone of intensive agricultural production in eastern Australia. The river and surrounding flood dependent red gum forest are a vital east–west biolink at the continental scale and a major ecological transition zone between arid and cool–wet climate zones of Australia (DCE 1992; VEAC 2006; Fig. 23.1). On the basis of spatial information (location and height of all trees), three-dimensional landscape models were built for red gum forest sites, going backwards to 1941 and forwards in time to what it could become if managed as a biolink (Fig. 23.3). Different growth stages of the forest look different and provide different ecological attributes.

Apart from illustrating change in the forest, such realistic three-dimensional models can be used to communicate the ecological effects of changes of climate:

- seasonal flooding on plant condition and distribution
- changes in composition and distribution of animal habitat (e.g. tree hollows, Fig. 23.3).

Realistic geographic visualisation also allows evaluation of the effects of potential policies critical to climate change adaptation and biolinks (e.g. C-sequestration in native vegetation or plantations, management of roadside vegetation). Linkages to ecological datasets allows attributes (e.g. habitat connectivity, species persistence, carbon sequestration) to be quantified. Policy consequences, including sense of place, can be accurately 'seen' and evaluated in virtual reality (Fig. 23.4).



a) b) c) d)

Fig. 23.4. Roadsides contain remnant trees that are critical to biolinks and 'sense of place'. Red gum and box trees on roadside site (indicated by arrow in Fig. 23.3a), showing 2005 photograph (**a**); in virtual geographic landscape (**b**); with native vegetation protected and poplar plantation removed (**c**); and, native vegetation removed (**d**)

Although highly degraded at present, riparian vegetation provides crucial habitat refuges and a network of arteries within and feeding into biolink landscapes (Mac Nally et al. 2000; SRWSC 1983). By taking a real Victorian landscape, presently denuded of native vegetation, the riparian zone can be progressively 'revegetated' in virtual reality and can be viewed from various perspectives, scales and time periods (Fig. 23.5). The three-dimensional view is recognisable to stakeholders, including landholders and neighbours who can evaluate which future alternative view conforms to their sense of place. The 'realism' of this view is dependent upon the visualisation using recognised species and vegetation — a realistic library of images. As these early examples demonstrate, visualisation offers an exciting medium for exploration of biodiversity and adaptation to climate change. To fully realise the potential of visualisation we now examine linking further developments through geographic databases and ecological research.

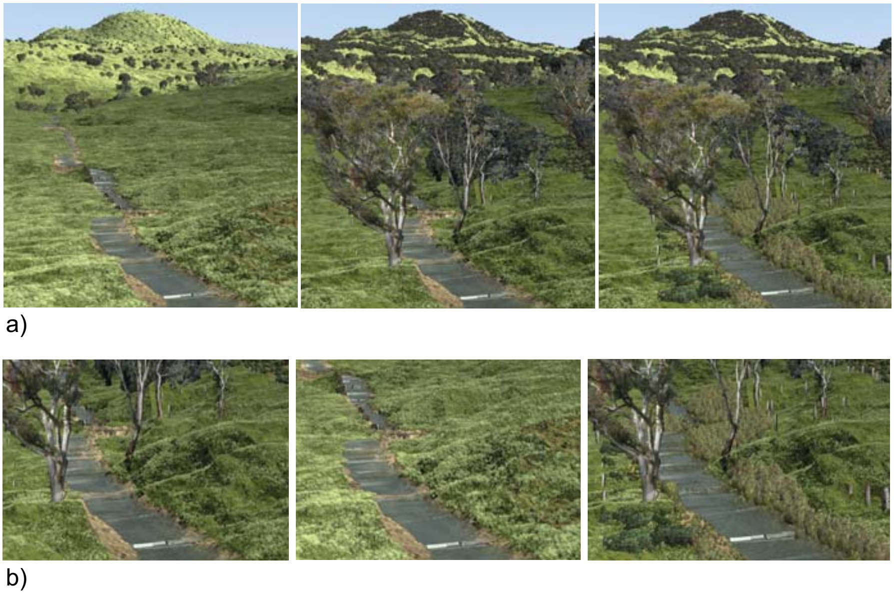


Fig. 23.5. Real Victorian landscape (DEM) in virtual reality, allowing visualisation of revegetated riparian corridor. (**a**) Landscape with a background of mosaic on topographically diverse hills. (**b**) A three-dimensional landscape model allows detailed scale

23.4 Realism behind Visualisation Technology

Landscape visualisation has been used in simply explaining complex ecological issues vital to the establishment of biolinks, for example, vegetation condition (Lau et al. 2006; Mansergh et al. 2006) and the legacy of habitat fragmentation (Fig. 23.2). There is a need to further develop the technology and link it to the evolving sciences of ecological connectivity and catchment management overall. The GIS-modelling environment is an important component of this research to which the visualisation may be linked. We see visualisation becoming an integral component of research into landscape change. New visualisation techniques potentially provide a method to 'see' landscape implications of scenarios (GIS-derived) and policy responses, and rapidly modified these scenarios with new information.

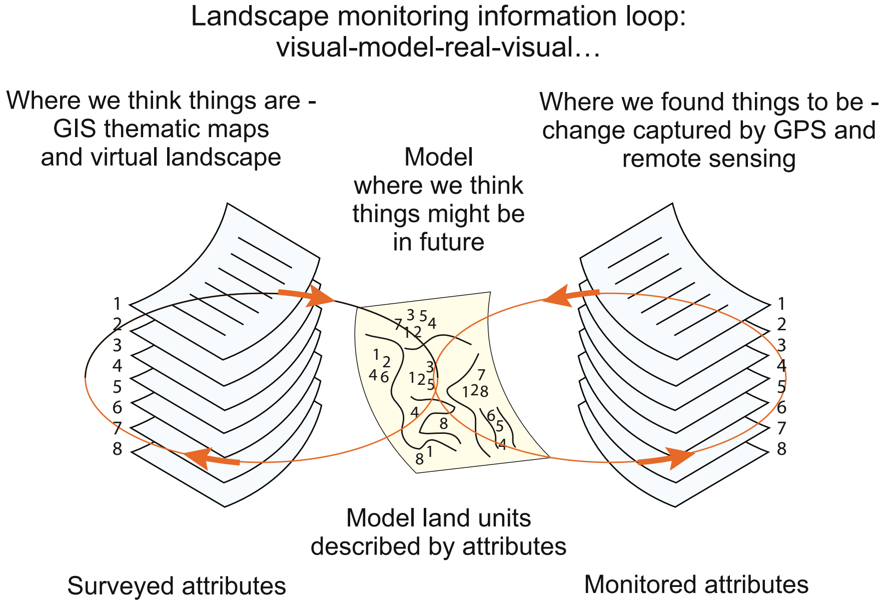


Fig. 23.6. Scheme represents the flow of information essential for planning and implementation of biolinks. The layers on the left represent spatially the current state of land attributes. The attributes become a subject of forward modelling allowing for exploration of different planning scenarios — the middle layer. Layers on the right represent spatially the state of same land attributes after a period of time. The feedback loop is shown by arrows. To be effective in planning and implementation of biolinks, geographic landscape visualisation needs to be a part of information loop with stake holders' feedback

There are two relevant elements to this realism:

- the realism of the underlying ecological analysis and future climatic change (which requires the visualisation medium to be connected to GIS modelling and analysis of real biophysical data)
- the realism embedded in the end product (which requires an extensive three-dimensional library of regional relevant images of species and communities).

As new specific knowledge of ecological connectivity becomes available, this provides a basis for modelling with GIS to provide alternative spatial configurations from the theoretically optimal to those with lesser functionality. To be effective in biolink planning and establishment, geographic landscape visualisation needs to be part of this information monitoring loop (Fig. 23.6). The loop links landscape surveys, predictive scenario modelling and monitoring surveys in a flow of information that is best represented, due to its complexity, by visual means (Asner et al. 2007). Emerging sophisticated catchment modelling (Eigenraam et al. 2005) allows quantification of many ecosystem services, including biodiversity, water and carbon sequestration. A cross-disciplinary approach to capture landscape complexity in digital models allows a multitude of scenarios each of which will look and perform differently under climate change. These developments are progressing, however, the realisation of portraying biolink landscapes, native vegetation and indeed a ‘local sense of place’ is severally inhibited by the lack of a three-dimensional electronic library of native Australian flora.

23.5 Realism at the Front End

Planning for ecological connectivity and habitat diversity (e.g. age classes) will manifest itself differently in different landscapes and have different visual impact over time. Most aspects are theoretically capable of rapid and realistic three-dimensional visualisation. However, the lack of a full range of visual objects and modelling structures necessary to drive the creation of images hinders the process of landscape visualisation, specifically for biolinks where local species are imperative.

Trees (long-term ecological assets) have different visual impacts at different stages in their life cycle — seedling, sapling and young tree to maturity — with the ecologically important tree hollows developing after 100 to 120 years (Manning et al. 2006; Fig. 23.3 and Fig. 23.8). Under climate change, the understorey and ground cover may evolve to take different forms, or the modelling may show that components of the canopy itself may change. Visualisation is potentially able to show the visual and ecological effects of fire and recovery of habitats, consequences of management regimes, risk factors (weed invasion) and stochastic events (flood and fire). If these are to be ‘seen’ at site-scale the images assist landholders’ and the community’s knowledge of the patterns and processes of future local environments.

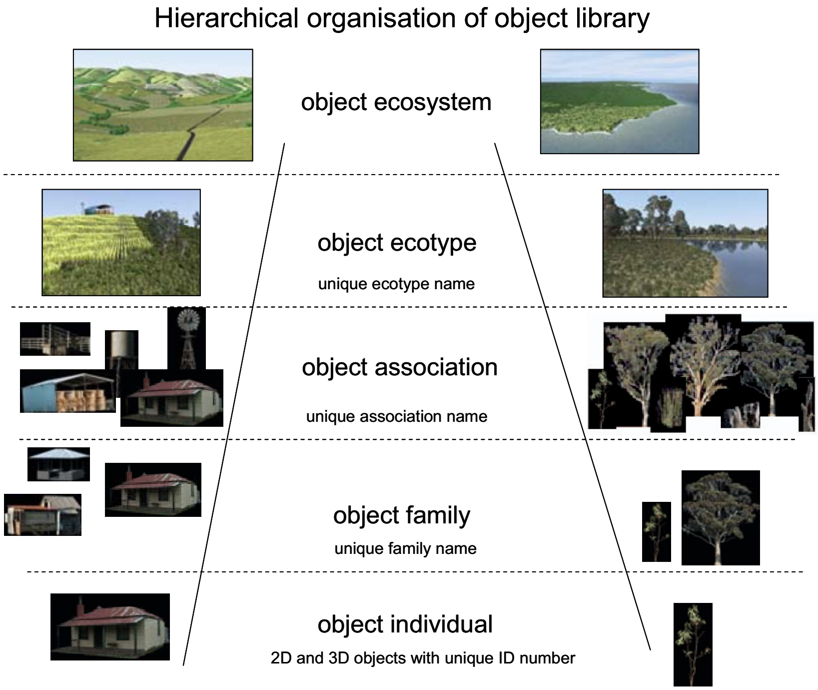


Fig. 23.7. An example of a hierarchical organisation of two- and three-dimensional objects. Well-designed storage of landscape objects facilitates an efficient retrieval and allocation of appropriate objects in a virtual space. Organising individual uniquely numbered objects into hierarchically structured groups that mimic natural patterns of the object’s occurrence in real landscapes ensures populating of virtual landscape becomes more reliable, allowing for better quality control. A well-designed database of objects is an essential part of geographic landscape visualisation

Currently most environmental planning and management projects consider the use of landscape visualisation as an extraneous addition. To fully benefit from seeing the past, present and possible future of a landscape under climatic changes, it is critical to develop the potential of visualisation so that it can be embedded in the framework and output of projects. This, in turn, can improve stakeholder involvement in planning and implementation feedback. Realistic visualisation of spatial habitat heterogeneity requires a complex range of objects and entities that change over time. Thus it is also essential to invest in incrementally building a hierarchical object library (Fig. 23.7), so that the construction of a realistic visual landscape model is possible. A hierarchical structure will ensure a much faster retrieval of groups of objects that represent complex entities such as vegetation communities (Ecological Vegetation Classes — EVC — can contain more than 100 species). Also it is practical to maintain two-dimensional and three-dimensional objects of the same landscape element in varying file types and sizes to aid in rendering time (Fig. 23.8).

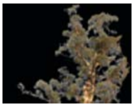


Fig. 23.8. Examples of two-dimensional *Eucalyptus* spp. objects (**a**) and three-dimensional volumetric objects needed for Australian plant library (**b**) showing trees in different serial stages. Both two- and three-dimensional types representing different ages of plants need to be prepared and stored (three-dimensional volumetric tree model produced by *Bionatics*)

In the development of biolinks, geographic visualisation has the potential to play a powerful augmenting role to spatial analysis. It will help to close communication gaps and promote debate between scientists, policy makers and land managers all of whom will need to be active participants in the planned biolinks.

23.6 Future Directions

Geographic visualisation, as evidenced in Al Gore's movie *An Inconvenient Truth,* is a powerful tool for explaining impacts of climate change. A crucial next step is to provide the capacity to fully use visualisations in the place-based adaptation debate. Although uncertainty is inherent in climate change modelling and related impacts, the broad trends on biodiversity and land use are potentially profound. Adaptation to some amount of inevitable global warming will become increasing more importance. As an adaptive response, biolinked landscapes represent a major new land use at the continental scale (Fig. 23.1). Building new biocultural landscapes will require social debate. What will our future landscapes look like under climate change, and what can we do to adapt and conserve the elements we value?

New forms of visualisation offer exciting possibilities to inform this debate. The scientific imperatives of restoring ecological connectivity with biolinks need to be within the domain of the social landscape or 'sense of future place'. A major gap in visualisation being able to fulfil this role is the lack of an accessible, effective three-dimensional image library of the diversity of Australian biota, particularly plant species. Realistic future visualisation of local–regional landscapes, using only foreign images creates, at best, false impressions and, at worst, cartoon-like landscapes.

The last twenty years has seen rapid evolution of the main geographic tool — GIS. A noticeable change in GIS developments is the rise of three-dimensional ability (Asner et al. 2007) from gimmicky addition to a more sophisticated volumetric tool, allowing viewing of maps and images to drape on digital terrain models. Additionally, the process of three-dimensional developments is aided by popular demand for more realistic representation of landscape features, largely thanks to the rapid development of *Google Earth* and the game industry. Using ecological research, geographic landscape visualisation is an excellent tool for illustrating patterns of changes in condition and composition of flora and restoration of vegetation over time (Parkes et al. 2002; Fig. 23.3). Looking to the future of landscape visualisation it is possible to imagine individual virtual landscape objects with programmed physical and behavioural properties. These would have an important ‘educative’ factor in adaptation to climate change. A virtual three-dimensional tree, herb or grass could have information about its size, seasonal appearance, occurrence in the floristic associations and sensitivity to climate parameters. The rules of allocation of such objects during the construction of a virtual landscape could have better quality checks in terms of correct location and association. More importantly, spatial allocation of objects could be a stochastic modelling exercise in a real-time display of a virtual landscape.

However, well chosen narrative remains the most vital component of landscape visualisation. This is often overlooked when technological pursuits dominate visualisation efforts. In the development of planned biolinks, geographic visualisation has the potential to play a powerful augmenting role to spatial analysis. It will help to close communication gaps and promote debate between scientists, policy makers and land managers all of whom will need to be active participants in the planned biolinks.

23.7 Conclusion

Inevitable climate change will initiate major land use change and have large effects on biodiversity. Re-evaluation of what we want future landscapes *to be* and *to provide* is an important societal question. Adaptation to climate change requires us to re-envisage landscapes. Early examples of visualisation have shown it to be effective in communicating the problem of biodiversity under climate change and potential solutions. Biolinks is a new land use — a risk management strategy for biodiversity that requires new forms of landscapes to be developed. Scientific research (e.g. spatial manifestation of ‘ecological connectivity‘) will continue to evolve (and be informed by climate science) with results increasingly derived from modelling within a GIS framework. Digital landscape visualisation is a powerful communication medium to synthesise and add meaning to these results. These qualities can be further enhanced through progress in the digital simulation of landscape objects. The digitally-created landscape — which displays physical properties of the real-world related to ecological meaning — has the potential to become a powerful medium for experimenting with different management approaches and land use policy development, as well as informing public debate. Such technologies will be increasingly needed for appreciating land use issues that are the result of the impacts of a changing climate.

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