Transactions in GIS, 2002, 6(1): 69–78

Research Article

Historic Landscape Reconstruction and Visualisation, West Oxfordshire, England

Joanne T. McLure
Department of Geography
University of Reading

Geoffrey H. Griffiths
Department of Geography
University of Reading

Abstract
As part of the Wychwood Project in West Oxfordshire, England, aerial photography and historic maps are being used to reconstruct landscape change in the former medieval Royal Hunting Forest of Wychwood. An important objective of the project is to stimulate local interest in Wychwood and promote understanding of its evolution, thereby encouraging the support of stakeholders in the design of future landscapes. The parish of Leafield was selected to develop and test a method for reconstructing and visualising past and present landscapes to present to the public for evaluation and comparison. Leafield contains fine examples of both early and late enclosure landscapes and underwent large-scale disafforestation following the Enclosure Act of 1856. Ordnance Survey (O.S.) 1:10000 Landform Panorama contour data were used to create a digital elevation model (DEM) of the parish using ArcView 3D Analyst, enabling the user to create perspective views of the landscape from any height and viewing angle. Contemporary aerial photography was scanned and geo-rectified to create an overlay for 'draping' onto the DEM. Historical maps provided the reference for modifying the aerial photography using the PaintShop Pro graphics package. This paper presents and reviews the results and compares the method with other techniques, including VRML.

1 Introduction

In 1086 the Royal Forest of Wychwood covered much of what is now West Oxfordshire, an area of approximately 500 km^2 (Figure 1). The early medieval forest was a mosaic of sheep-walk (downland), meadows, open arable fields, heathland and wood pasture, with woodland the dominant landscape feature. This medieval

Address for correspondence: J. T. McLure, Department of Geography, University of Reading, Whiteknights, Reading RG6 6AB, United Kingdom. E-mail: j.t.mclure@reading.ac.uk

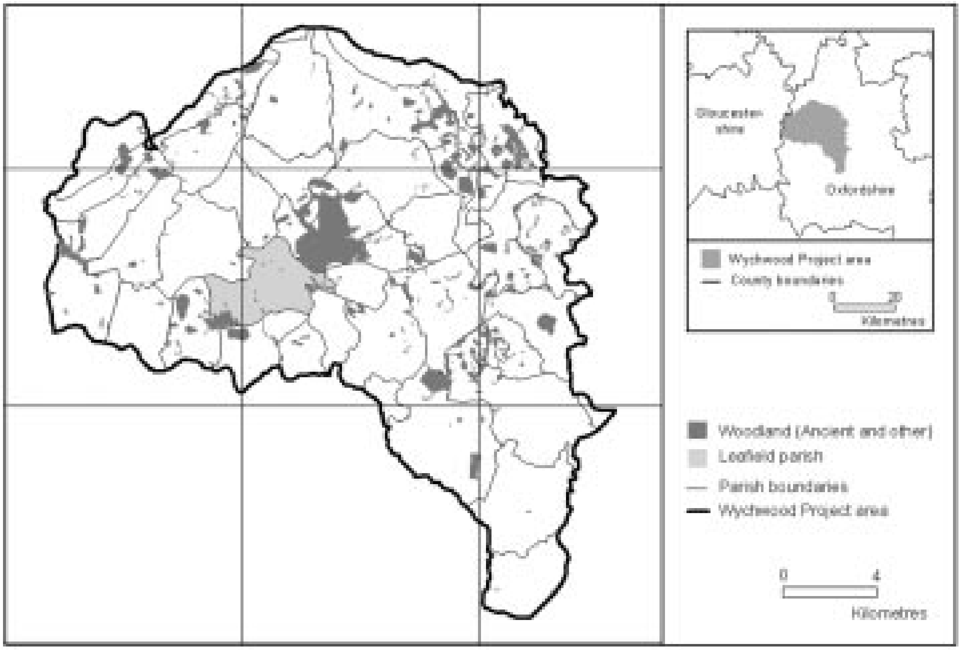

Figure 1 Location of the Wychwood Project and the parish of Leafield

landscape remained largely intact until the enclosures of the late eighteenth and nineteenth centuries led to extensive deforestation and the conversion of the open field system to enclosed fields (Schumer 1984). A second period of rapid and dramatic landscape change resulting from agricultural intensification has occurred in the 50 years since the Second World War (Adams 1997) and, in this part of the southern Cotswolds, the conversion of sheep-walk into large arable fields with the loss of many small habitats and linear features.

The Wychwood project was established in 1997 with funding from the Countryside Agency (formerly The Countryside Commission) and West Oxfordshire District Council to: raise awareness of the history and identity of Wychwood; enhance the visual landscape; restore and maintain the wildlife interest of the region (Corbett 1998). An important and innovative aspect of the project is the critical and integral role of public participation, involving different stakeholders with diverse perceptions of the value of landscape and differing interpretations of countryside management. Knowledge about public perceptions of the economic, aesthetic and ecological value of different features in the landscape is required to inform discussion about options for change and develop a vision for the future of the countryside (Harrison et al. 1998). Amongst stakeholders the support and co-operation of landowners, including the many large estates typical of the region, will be vital in achieving targets for landscape restoration and enhancement.

Thus, a major aim of the project is to increase public awareness of the historical and ecological importance of different landscape features and to engender a greater understanding of the historical processes that have shaped the present landscape. There is, for example, a popular misconception that a medieval forest was all woodland. Reconstructing and visualising a typical pre-enclosure Wychwood landscape should help people to appreciate the typically mosaic character of former Royal Hunting Forests and therefore to accept the need for the restoration of a range of habitat types as opposed to woodland planting alone.

2 Methods

It was recognised early in the history of the Wychwood Project that GIS would be an important tool, providing the means to capture, store and visualise information on the history, landscape and ecology of the region. However, it was also clear that the traditional two-dimensional mapping output from GIS was not sufficiently 'visual' to engage people's interest and that three-dimensional (3-D) modelling was needed to represent past, present and, in the longer-term future landscapes, in an interactive and realistic way. At its best the combination of a topographic context with the texture, colour and dimensionality of landscape features such as trees, hedgerows and building in a 3-D landscape representation, provides a degree of realism entirely absent from 2-D mapping (Dykes et al. 1999).

The development of computer tools for creating and representing virtual worlds has dramatically increased our ability to capture salient aspects of the landscape and to communicate them to audiences remote from the landscape under study (Sheppard 1999, Bishop et al. 2001). Techniques for the identification, evaluation and communication of landscape evolution include textual description, mapping, photography (terrestrial and aerial) and modelling (usually, but not exclusively, with computer techniques) (Miller 2001). An early example of modelling by O'Riordan et al. (1993) for example, used a non-computerised approach. Seven future landscapes for a typical scene in the Yorkshire Dales were painted by hand, based on different assumptions about the social and economic conditions driving change in the countryside in the 21st century. The purpose of the exercise was similar to the present project; a touring exhibition of future landscapes and ancillary interpretative material was used to 'discover how far people could grasp the processes leading to landscape change, become aware of why these forces were happening and become sufficiently concerned for the future to participate in the creation of landscape design of their choice' (O'Riordan et al. 1993). More recently, Lovett et al. (2002) has used Virtual Reality Modelling Language (VRML) to simulate future 'ecological' landscapes to assist with the design of a sustainable countryside, following consultation with agencies such as the Royal Society for the Protection of Birds, English Nature, the Farming and Wildlife Advisory Group and others. The creation of modelled landscapes in VRML by Lovett et al. (2002) contrasts strongly with the hand-painted landscapes of O'Riordan et al. (1993), although the objectives of both research projects were similar. The present project takes an intermediate approach; exploiting the advantages of photo-realism possible from aerial photography, but at the cost of losing some of the creativity and imagination possible in the painted world and the flexibility and dimensionality possible in the virtual world.

The Wychwood Project was also interested in a pilot study on landscape reconstruction and visualisation. Firstly, visualisation was considered to be an integral part of the GIS-based inventory of landscape features, providing a more complete picture of the cultural and natural features within the project area and relating more closely to the public perception of a landscape and its attributes. Secondly, it was recognised that decisions about the enhancement and restoration of landscape, both in aesthetic and ecological terms, are only likely to be successful if based on a sound understanding of the forces that have shaped the character of the landscape over time. Visualisation therefore, was seen to offer the potential for improving landscape character assessment. The idea that the countryside can be sub-divided into character areas on the basis of natural, cultural and ecological features culminated in the publication of the Countryside Commission's map of 'Countryside Character Areas' (Countryside Commission and English Nature 1996, Swanwick 1997). The potential role of the landscape character approach for rural land use policy, especially the targeting of agri-environmental schemes, for development planning and for the assessment of ecological function (Simmons et al. 1999), is increasingly being recognised, especially by local authorities. However, landscape character assessments have been reliant on purely visual indicators of character, thus missing the opportunity to include the palimpsest of cultural and historical layers that define the 'intrinsic character' of the landscape and that are important as a framework for informed debate about future options for countryside change (Warnock and Brown 1989). Increasingly, methods of landscape character assessment incorporate cultural information (enclosure, settlement pattern and land use) in addition to physiographic factors (topography, soils and geology) to provide greater 'time-depth' to landscape assessments. Visualisation could be a vital part of this process, providing a different perspective on the spatial patterns in the landscape that determine its historic origins and thus its character.

Thirdly, landscape visualisation is finding application in landscape ecology. There is an increasing body of evidence (e.g. van Dorp and Opdam 1987, Saunders et al. 1991) that demonstrates the importance of structure in the landscape for the maintenance of healthy and diverse populations of plant and animals. This knowledge is now sufficiently advanced for ecologists to consider the possibility of designing, and visualising, future ecological landscapes that are optimal for selected species or groups of species. However, the potential for conflict between stakeholders with widely differing goals about the future of the countryside, from those who promote the need for a sustainable countryside to those whose interests are primarily in an agriculturally productive countryside, is high. Visualisation could play a role in resolving such conflict by presenting future landscapes based on a range of social and economic scenarios as the basis for more informed consultation between interest groups.

There is currently considerable interest in the potential of VRML (Virtual Reality Modelling Language) for landscape visualisation and a wide range of software is now available. A good example being used specifically for landscape visualisation and a package that was initially investigated for the present project is PAVAN (http://www.pavan.co.uk; Smith 1997). Java software is being used to interact with a three-dimensional VRML terrain model as part of the creation of the Virtual Field Class (Dykes et al. 1999, Moore et al. 1999). Within geography where much spatial analysis is now based on the manipulation of geospatial data within a GIS, the 2-D GIS database is commonly used as the basis for converting landscape features into 3-D representations in VRML. VRML has a number of advantages in that its flexibility allows for the selection of colours, shapes and textures, for example in the simulation of vegetation. This flexibility also offers the possibility to create selected views from specific viewpoints enabling the viewer to 'walk-through' the landscape, based on the superimposition of modelled landscape features onto 3D topography. The true perspective nature of the virtual landscape also offers scope for viewing scenes at a range of spatial scales, from the distant view at a pre-defined viewing height and azimuth to a 'close-up' of a specific part of the scene. However, this flexibility comes at a price; a powerful graphics workstation is required and the simulated nature of the landscape frequently appears artificial, resulting in a mismatch between public perception of landscape reality and modelled representation. At the very least, users need to be able to recognise a specific location if they are to be convinced by the opportunities that VR offers and not immediately revert to the more traditional 2-D map. Whilst the potential for interaction is great, representation at the range of spatial scales and especially at the farm or land parcel often required for planning, may be insufficiently convincing to be useful in discussions about options for landscape enhancement and ecological restoration.

It was felt that the needs of the Wychwood Project would be better met by the adoption of a more 'photo-realistic' approach, based on the assumption that public identification and engagement with simulated landscapes would be encouraged with realistic as opposed to an 'artificial' VR landscape. Recent research in Switzerland (Lange 2001) has demonstrated that the critical factor contributing to degree of realism, based on a sample of 90 differently rendered images presented to 75 test persons, is the terrain model draped with ortho-photos. For this reason, aerial photography was selected as the primary data source for this project, providing a faithful representation of the tones and textures of the countryside that correspond to public perception of what the countryside 'should' look like.

3 The Study Area

The parish of Leafield, which is located at the southern boundary of the present Wychwood forest, was selected as the study area (Figure 1). The evidence for considerable change within the parish from the mid-nineteenth century and the availability of a large-scale map of the pre-enclosure landscape in 1812, made Leafield a suitable parish for the development and testing of the methodology. The parish is within the boundary of the Norman Forest defined by Domesday in 1086 (the limits of the current Wychwood Project) and is shown from the Perambulations of 1298 and 1300 to be surrounded by the late medieval forest, a situation that continued until the disafforestation resulting from the Enclosure Act of 1856. The late Enclosure Acts of the mid-nineteenth century in England were the culmination of a long process of enclosing the former open field system into a new pattern of land ownership based upon bounded, often regular, fields.

Until the disafforestation, the parish remained largely enclosed by woodland, reflecting the origins of its name (*feld*) referring to an open clearing mostly surrounded by woodland. The medieval system of open fields is clearly visible on the 1812 map (Plate 8, see plate section) and would still have been in use at this time. In addition, Leafield has an active local community group with a strong interest in the history and landscape development of the parish. The parish contains fine examples of both early and late enclosure landscapes the irregular pattern of small fields resulting from early enclosure contrasting with the later pattern of large, more regular fields. This contrast is apparent even in the contemporary landscape and is captured by the Ordnance Survey Land-Line data for the parish (Figure 2), which shows small irregular early enclosure fields in the centre of the parish to the south of the village and the larger and more regular enclosed fields to the north and west.

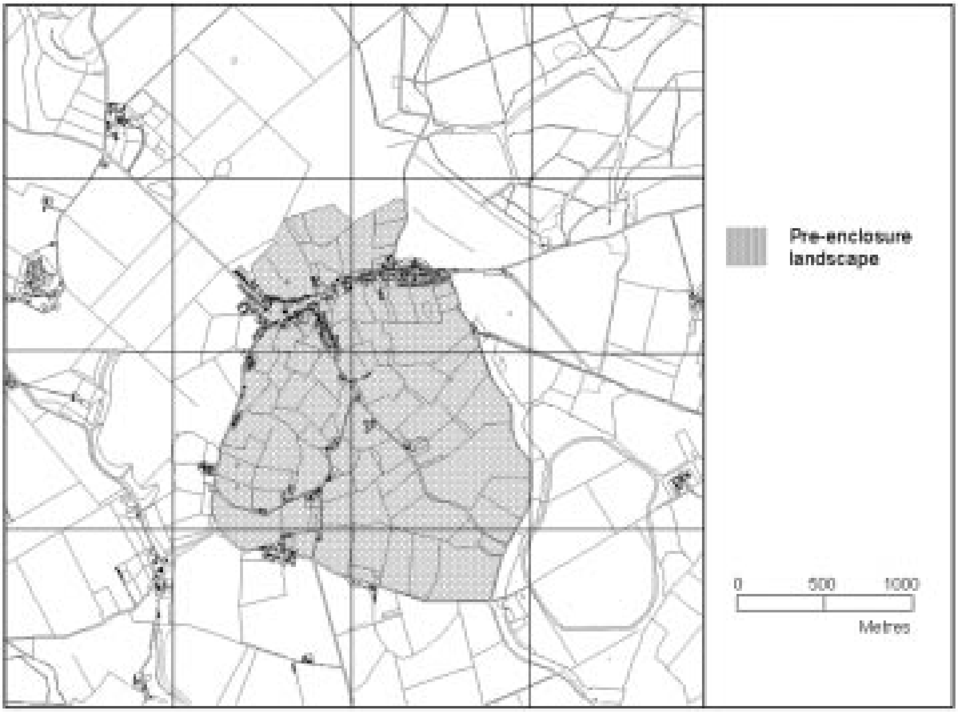

Figure 2 Land-Line O.S. digital data for Leafield (Crown Copyright Ordnance Survey, an EDINA Digimap/JISC supplied service)

4 Data Sources

4.1 Digital Elevation Model

A key requirement was the capability to drape the aerial photography over a digital elevation model (DEM) to create perspective views. O.S. Landform Profile terrain data derived from the 1:10000 scale mapping (5 m contour interval), was obtained for the whole of the parish. The 3D Analyst extension in ArcView GIS was used to convert the contour data into the DEM. The Landform Profile and Land-Line data were available in the Department of Geography at the University of Reading under the terms of access to O.S. digital data provided by Digimap in Edinburgh. Each tile of data is 5 km × 5 km and two tiles were required to cover the parish. The tiles were converted from O.S. NTF (National Transfer File) format and combined into a single file in ArcView.

4.2 Historical Maps and Aerial photography

Aerial photography was used as the data source for information on the appearance of the contemporary landscape. Six colour aerial photographs acquired in 1990 at a scale of 1:10000 were obtained from West Oxfordshire District Council and digitally scanned at 300 dpi. Geo-rectification was achieved in ArcInfo using approximately 60 ground control points (GCPs) identified on both the aerial photography and O.S. Land-Line data. The geo-rectified images were subsequently mosaiced using the PaintShop

Pro graphics package and a further set of GCPs selected to improve the goodness of fit between the air-photo montage and Land-Line map.

The basic source of data for the historical reconstruction is the 1812 map of the parish (unsourced), supplemented with information from the Old Series O.S. First Edition one inch to one mile maps (c. 1850) (Harley 1975).

5 Terrain Visualisation

The contemporary landscape was created by draping the 1990 geo-rectified aerial photography onto the DEM. The 3D Analyst extension in ArcView allows the user to view the landscape from different positions in elevation and azimuth. In this example the parish is viewed from the SW at an elevation of 45º. A vertical height exaggeration of three was used to give suitable relief enhancement for viewing. Initially image sharpness and contrast were poor, a potential failing of ArcView, and an Avenue script called '3D Raster Resolution' was used to improve the brightness and sharpness of the image.

Paint Shop Pro was used to modify the 1990 aerial photography to simulate the pre-enclosure landscape. This involved the removal of buildings, the addition of woodland and the creation of field patterns to reflect, for example, the transition from the medieval open-field system to the post-enclosure landscape. To reconstruct the pre-enclosure landscape evident from the old maps (1812 and 1850), the air-photo mosaic was edited interactively on-screen to remove some features of the landscape and add others. Thus, new field boundaries were created by extracting a length of typical hedgerow from one part of the aerial photograph mosaic and inserting it into its new position according to the available historical map information. Similarly, woodland was created by copying a woodland area and repositioning it within the reconstructed map.

The results are displayed in Plate 9, see plate section, which show a portion of the parish (4 km × 4 km) in 1990 (Plate 9a) and the same area *circa* 1850 (Plate 9b). The contraction of the forest area is obvious, the village being transformed from its formally almost enclosed situation to the present, open aspect on a high wold that the village enjoys today. Other more subtle changes are also apparent, including the loss of hedgerows, the conversion of open fields and the development of the village from its core centred on the ancient barrow site, to its more extensive and linear shape today. The time-consuming nature of the process means that the process is selective; a past, or future, landscape is visualised not precisely recreated.

The technique allows for the visual query of small portions of the landscape by consecutively overlaying the two draped images (past and present) whilst keeping the angle of view and zoom extent constant. In this way the user can select a range of perspective views for comparison and evaluation.

6 Discussion and Conclusions

The rendering of photo-realistic landscapes has both advantages and disadvantages compared with VRML techniques. The aerial photography captures and reproduces the colour and texture of point, linear and area features (e.g. woodland or a hedgerow). Each of these features can be enlarged, reduced or reshaped as necessary and located within the new scene to create the past (or future) landscape. The landscapes produced, which were 'field-tested' at a Wychwood Project exhibition as part of an interactive computer display, were considered by members of the public to produce realistic visualisations.

Once the landscape has been constructed views can be changed interactively, allowing the viewer to simulate different perspective views and select the one that best captures the essence of the landscape for a particular purpose. This is not currently possible with VRML, where the viewer is restricted to views that have been pre-simulated and are displayed to the screen from a file or from the Web with an Internet browser.

There are, however, a number of methodological limitations that need to be overcome. The first is the time involved in the landscape rendering. The parish map of 1812, although large scale requires careful interpretation of boundaries and features. The map is also essentially a record of property, woodland and agricultural land; areas of semi-natural land, for example heathland which was extensive in the neighbouring parish of Ramsden, are not mapped but may have been present. This raises the important question of whether the mapping should be constrained by the actual features shown on a particular map or whether other sources of documentary evidence and physical factors (soil type, topography) should be used to interpret the past and create a *representative* rather than an *actual* landscape. In fact, as we go back in time, precise mapped information becomes fragmentary and reconstruction has to rely more on documentary and, in the case of Domesday, place-name evidence.

Ideally the system should be sufficiently flexible and rapid to enable changes to be mapped and visualised to reflect policy change in the countryside across a much wider area than was achieved in the present project. The acquisition, scanning, mosaicing and geo-rectification of colour aerial photography remains a time-consuming task. It is anticipated that recent increases in the availability of ortho-rectified colour aerial photography will improve this situation.

By contrast, the possibility for landscape simulation over large areas using VRML is a potentially significant advantage. The 'walk-through' capability of VR also has a powerful allure and cannot be reproduced using the air-photo techniques employed in this project. A major limitation of rendering aerial photography is that the actual landscape *features* do not possess a third dimension; the realism is an illusion based on the texture and tones that are a strong feature of colour aerial photography. As a result, the viewer is restricted to an oblique view above the landscape, albeit at a range of viewing heights and angles. Attempts to create a three-dimensional 'feel' to landscape features, for example linear field boundaries, by extruding them above the landscape using a routine available in 3D Analyst, were not successful. This was because the aerial photograph does not drape over the extruded feature and appears to 'float' beneath it, reflecting the shape of the underlying topography.

The landscape reconstruction only proved to be successful at specific spatial scales. 'Zooming-in' too close to the landscape loses realism; features such as stone walls and other detail are absent and trees and hedgerows, which are represented as blocks, lack the structure that provides convincing realism at large scales in the near foreground. This is problematic given the need to visualise at the farm level where important decisions need to be made about, for example, planting schemes and options for ecological restoration of various kinds. In fact, at high levels of magnification (large scales), the TIN (Triangular Irregular Network) structure of the DEM becomes apparent, suggesting that a higher resolution DEM is also required for work at this scale. The more sophisticated simulation possible with VR, allowing for proper perspective views of actual landscape features, may be more successful at this larger scale. An alternative, and one that has been used in the present project, is to provide a 'hot-link' to a photographed landscape from a number of strategic viewpoints. The user is restricted to the views stored on file, but similar rendering techniques could be applied to each scanned photograph to illustrate former landscapes and their evolution into the future for a range of scenarios and in great detail. There is considerable potential, which can only grow with the advent of digital cameras, in the use of computer based graphics packages for creating and manipulating photo montages and panoramas (Simpson et al. 1997) that can be hyper-linked to specific viewpoints.

In addition to the need for more technical work that would ideally combine the advantages of aerial photography rendering at the 'middle' landscape scale with VRML at the 'field' scale, there is also a need to involve historical geographers and local historians in the reconstruction of former landscapes. This is scholarly and painstaking work, attracting only relatively few adherents in geography (see for example, Hooke 1989). Wychwood was a Royal Hunting Forest until 1857 and there are numerous forest records, including maps and documents, relating to land use, management and patterns of ownership from Domesday onwards. The 1300 Perambulation in particular is invaluable, as it describes the boundary between the areas that remained within the Forest and the woods that were being disafforested, so providing details of the location and extent of woods at that date.

There is the potential, therefore, to reconstruct a Domesday landscape from place-name evidence, a late Medieval landscape from the Perambulations of 1297 and 1300 and an early modern landscape from the survey of 1609 commissioned by James 1, a politically motivated survey designed to increase revenue to the Crown. The Perambulations were also surveys designed to lay claim to land by the Crown. As we move back in time however, precise reconstruction from actual maps becomes more difficult and is increasingly reliant on documentary evidence. For example, the Hundred Rolls of 1279 provide records of woods and assart land (forest cleared for agriculture) thus providing evidence for large-scale change between Domesday and 1279. The Domesday landscape of Wychwood has been reconstructed by Schumer (1984), largely from place-name evidence, but the mapping is indicative and visualisation would be of a *representative* rather than an actual landscape.

Reconstruction of past landscapes is of course, relatively easy compared with 'imagining' future landscapes; the past is recorded and can be reproduced, the future is unknown and must be simulated on the basis of assumptions about social and economic imperatives. However, as the Wychwood Project develops the visualisation of future landscapes will become increasingly important as the basis for planning habitat restoration and woodland planting schemes based on assumptions, for example, about the level of agricultural subsidy under the Common Agricultural Policy (CAP) and the take-up of agri-environmental schemes (Whitby 1994).

Acknowledgements

We would like to thank West Oxfordshire District Council for the loan of aerial photography and Erika Meller in the Department of Geography for undertaking the scanning. Land-Line and Landform Panorama data were supplied by permission of the O.S. under the terms of The Digimap Project. Advice on historical mapping and the evolution of the Wychwood landscape was willingly given by Richard Bidgood (Leafield), Alan Spicer (Charlbury) and Beryl Schumer (London). The authors would also like to extend their thanks to the Wychwood Project Officer (Belinda Flitter) and the members of the Wychwood Executive for their support and encouragement.

References

Adams W M 1997 *Future Nature*. London, Earthscan

Bishop I D, Wherrett J R, and Miller D R 2001 Assessment of path choices on a country walk using a virtual environment. *Landscape and Urban Planning* 52: 225–37

Corbett J E M 1998 Creating a new conservation vision: The stakeholders of Wychwood. *ECOS* 19: 20–30

Countryside Commission and English Nature 1996 *The Character of England: Landscape, Wildlife and Natural Features*. Cheltenham, The Countryside Commission

Dykes J, Moore K, and Wood J 1999 Virtual environments for student fieldwork using networked components. *International Journal of Geographical Information Science* 13: 397–416

Harley J B 1975 *Ordnance Survey Maps: A Descriptive Manual*. Southampton, Ordnance Survey

Harrison C M, Burgess J, and Clark J 1998 Discounted knowledges: Farmers' and residents' understandings of nature conservation goals and policies. *Journal of Environmental Management* 54: 305–20

Hooke D 1989 Preconquest woodland, its distribution and usage. *Agricultural History Review* 37: 113–29

Lange E 2001 The Limits of Realism: Perceptions of Virtual Landscapes. *Landscape and Urban Planning* 54: 163–82

Lovett A, Kennaway R, Sunnenberg G, Cobb R, Dolman P, O'Riordan T, and Arnold D 2002 Visualising sustainable agricultural landscapes. In Fisher P and Unwin D (eds) *Virtual Reality in Geography*. London, Taylor and Francis: in press

Miller D R 2001 A Method for Estimating Changes in the Visability of Land Cover. *Landscape and Urban Planning* 54: 93–106

Moore K, Dykes J, and Wood J 1999 Using Java to interact with geo-referenced VRML within a virtual field course. *Computers and Geosciences* 25: 1125–36

O'Riordan T, Wood C, and Shadrake A 1993 Landscapes for tomorrow. *Journal of Environmental Planning and Management* 36: 123–47

Saunders D, Hobbs R J, and Margules C R 1991 Biological consequences of ecosystem fragmentation: A review. *Conservation Biology* 5: 18–32

Schumer B 1984 *The Evolution of Wychwood to 1400: Pioneers, Frontiers and Forests*. Leicester, Leicester University Press, Department of English Local History, Occasional Papers, Third Series, No 6

Sheppard S R J 1999 Visualisation software brings GIS applications to life. *GeoWorld* 12: 36–7

Simmons E A, Griffiths G H, and Warnock S 1999 Landscapes for biodiversity: Landscape character and ecological integrity. In Marshall J and Maudsley M (eds) *Proceedings of the Eighth IALE UK Annual Conference on Heterogeneity in Landscape Ecology: Pattern and Scale*, Long Ashton, Bristol, September 1999: 219–23

Simpson I A, Parisson D, Hanley N, and Bullock C H 1997 Envisioning future landscapes in Environmentally Sensitive Areas of Scotland. *Transactions of the Institute of British Geographers* 22: 307–20

Smith S 1997 A dimension of sight and sound. *Mapping Awareness* 11(8): 18–21

Swanwick C 1997 Characterising the countryside. *ECOS* 18: 53–60

van Dorp D and Opdam P F M 1987 Effects of patch size, isolation and regional abundance on forest bird communities. *Landscape Ecology* 1: 59–73

Warnock S and Brown N 1998 A vision for the countryside. *Landscape Design* 269: 22–6

Whitby M 1994 *The Incentives for Countryside Conservation; The Case of ESAs*. Wallingford, CAB International