Using contemporary and historical maps to determine the spatial and temporal characteristics of woodland patches.

Adam Kimberley[1, 2] Simon Smart[1], Alan Blackburn[2], Duncan Whyatt[2]

1. Centre for Ecology and Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster, LA1 4AP. E-mail: adakim@ceh.ac.uk
2. Lancaster Environment Centre, Lancaster University, Bailrigg, Lancaster, LA1 4YQ.

Keywords

Habitat fragmentation, Land Cover Map 2007 , Countryside Survey, Spatial ecology, Patch geometry

Summary

Recent changes in land use have caused widespread alteration in the amount and configuration of woodland habitat in Britain. Detailed vegetation data collected during repeated field surveys of Great Britain exist but wider spatial and historical context is needed to fully investigate how the configuration of the remaining woodland has influenced species and trait composition. This study combines a number of data sources using GIS to determine the age and spatial characteristics of woodland patches. Ongoing analyses will quantify the effects of these factors on woodland plant species composition within habitat patches.

1. Introduction

1.1 Woodland Habitat Modification

Urbanisation and agricultural intensification have dramatically changed landscapes worldwide (Foley *et al.* 2005). One consequence of this has been the loss and fragmentation of woodland habitat across much of Britain. This study investigates how plant species occurrence is influenced by variation in the size, shape and history of woodland patches. In a fragmented landscape habitat patches become smaller and less connected, causing populations of species that rely on this habitat to become more vulnerable to localised extinction (Fischer & Lindenmayer 2007). It is therefore hypothesised that the richness of woodland specialists decreases as woodland patch size and connectivity decrease, since these species are more likely to have been lost from small, isolated patches.

GIS techniques were used to combine a number of contemporary and historical data sets, creating a database from which the spatial and temporal characteristics of woodland patches and hence levels of fragmentation, could be determined. This information will ultimately be used to analyse detailed data on the vegetation present within patches, collected as part of field surveys, to explore the influence of habitat fragmentation upon the composition of woodland communities.

Woodlands were chosen as the initial focus for a number of reasons. Firstly, accurate, well established map products delineating woodland extent already exist, allowing the area and shape of woodland patches to be determined. Obtaining equivalent information for other habitats in the future may be more problematic. Secondly, woodland plant species tend to be specialised, poor dispersers (Hermy *et al.* 1999); traits that are thought to infer a strong reaction to habitat fragmentation (Henle *et al.* 2004;

Schleicher et al, 2011). Signals of response to spatial variation in habitat patches are therefore likely to be picked up in these species.

Although woodland habitats are considered here, these methods will also be applied to data from other habitat areas, such as agricultural landscapes and grasslands where plant response to fragmentation may be very different. Our aim is ultimately to statistically model plant species responses to spatial and temporal variation in patch geometry conditional on the effect of other global change drivers (e.g. climate, pollution).

1.2 Using GIS to make the most of existing data

Countryside Survey (CS) provides a detailed field-based assessment of a randomly selected sample of 1 km squares of land (maximum 591 in 2007) throughout Britain, stratified by land class to fairly represent all habitat types. Five surveys have been conducted since 1978, most recently in 2007, mapping land uses present within each 1km square. Detailed vegetation data are also collected for selected plots within each square; sampling plant species composition (see Figure 1). The plant species composition data collected in these vegetation plots as part of CS are used to provide information on the species composition of broad leaved woodland patches across Britain.

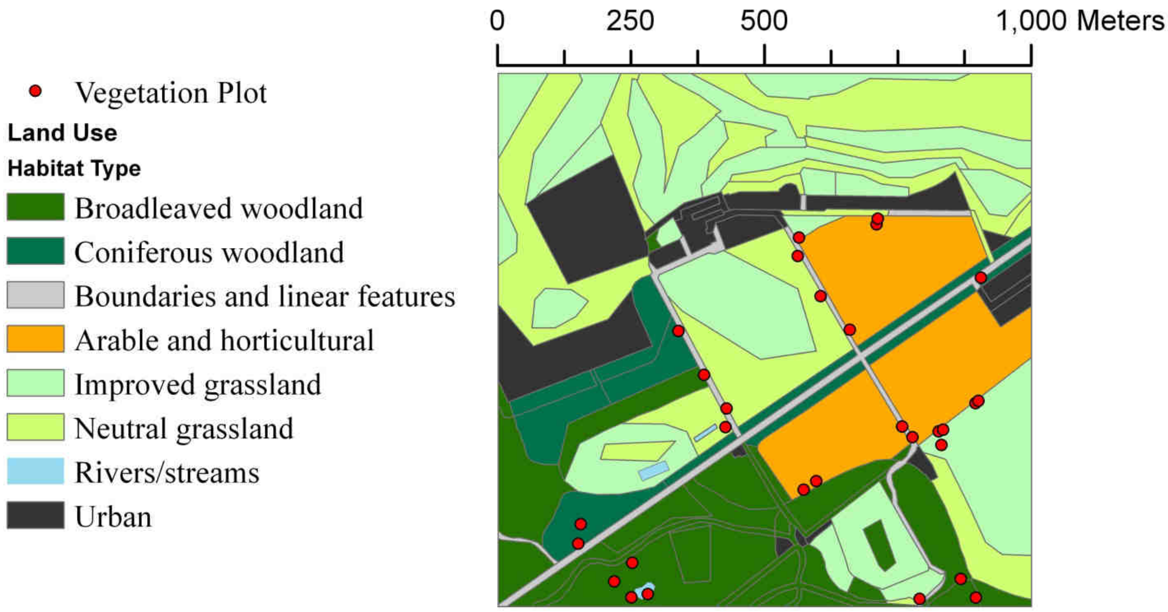

Figure 1. Example 1km Countryside Survey square with land use mapped, in this example showing broadleaved woodland habitat polygons at the bottom of the square. The location of the CS vegetation plots where plant composition was sampled are also shown.

In order to investigate how the configuration of habitat within a landscape influences plant species, information on spatial metrics (such as the area and perimeter of woodland patches) needed to be derived. As seen in Figure 1, the land use polygons mapped as part of CS provide measurable habitat patches around the vegetation plots but these are clipped to the edges of squares. In reality these squares form part of a wider landscape with habitat patches continuing beyond the artificial boundaries created by CS sampling. To overcome this problem and allow the true spatial characteristics of the woodland patches to be determined, GIS was used to combine the CS 1km square data with other information on woodland extent in the surrounding landscape.

Studies have shown the significance of patch age and past land use in determining species composition of woodland patches (Dupouey *et al.* 2002) and hence it is important that the history of patches is also considered when analysing their present species composition. First Series Ordnance Survey maps from the 1880's were overlaid onto the CS data, allowing the age and historic extent of contemporary woodland patches to be estimated and related to the vegetation data.

2. Methodology

2.1 Data Sources

The sources of information combined to analyse the vegetation data are listed in Table 1. Each provided important information but had limitations, hence could only be used in combination with other sources in order to assess spatial and historical patterns of woodland habitat. Data on the occurrence of plant species within habitat patches could then be compared to the spatial and historical information produced to assess the impacts of habitat fragmentation on woodland plants.

Table 1. Sources of woodland habitat data

Data	*Source*	*Scale/resolution*	*Use*	*Limitations*
Vegetation and land use data	Countryside Survey 2007 (CS)	Field data, 1:1	Obtaining detailed vegetation data at points. Identifying woodland habitats within CS squares.	Habitats clipped to 1km square boundaries
Current woodland habitat data	Land Cover Map 2007 (LCM)	25 metre resolution	Extending habitat patches beyond the 1km square.	Satellite-derived, hence coarser resolution than CS data
	2011 woodland layer from OS VectorMap District product (EDINA, 2011)	1:25,000	Validating the presence of LCM woodland.	No distinction between broad-leaved and coniferous woodland
Historic woodland habitat data.	Digitised OS County Series product (~1880) (EDINA, 2011)	1:10,000	Comparing historic woodland distribution to current.	Possible uncertainties over spatial and thematic accuracies

2.2 The “Beyond the Square” Problem

An accurate assessment of patch size and shape is necessary in order to properly analyse the influence of patch geometry on plant species composition. Habitat patches therefore have to be extended beyond their artificial CS square boundaries in order to determine their true spatial extent. An example of this problem and how it was solved can be seen in Figure 2. GIS software was used to combine CS data with Land Cover Map (LCM) woodland polygons in the wider landscape, dissolving internal boundaries to produce individual, measurable patches as polygons that extend beyond the original square.

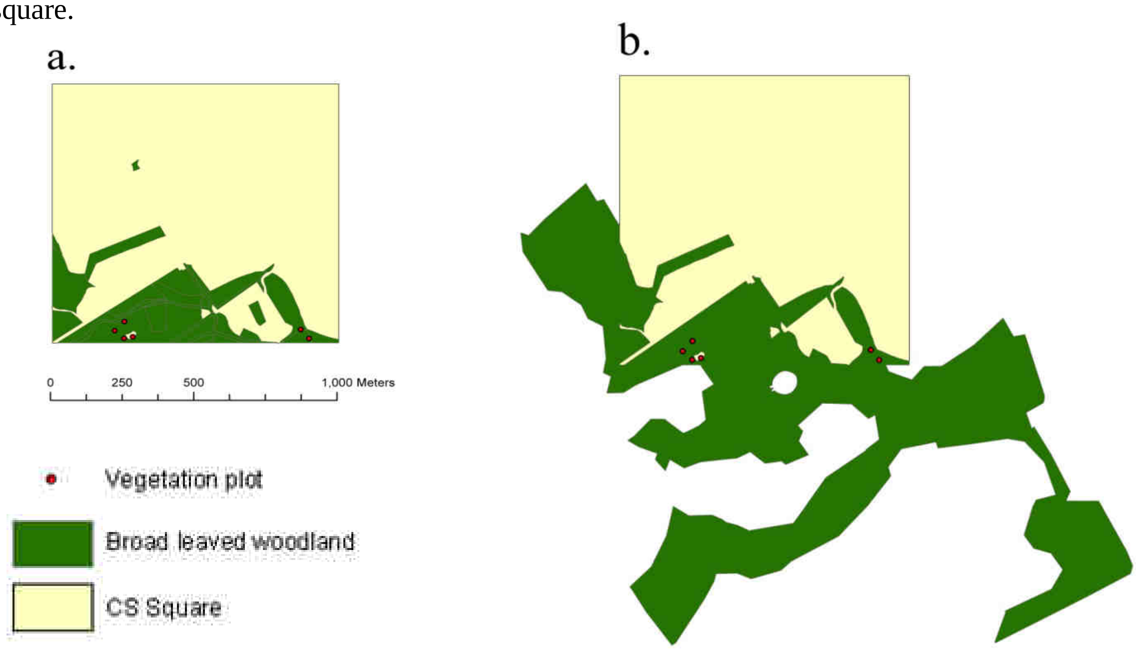

Figure 2. Example Countryside Survey square, this time with only broadleaved woodland habitats and plots that fall within this habitat type mapped. Figure 2a shows the original CS square, with the woodland habitats in the lower half of the square clearly interrupted at the boundaries. Figure 2b shows the same square, this time with CS woodland habitat patches combined with additional LCM data.

3. Example Analyses

3.1 Comparing Land Cover Map Woodland and Ordnance Survey Woodland

Although LCM provides a way of extending habitat patches beyond the CS squares, it is derived from remotely-sensed data which is much coarser resolution than the CS habitat data. In order to validate the presence of woodland therefore, Ordnance Survey (OS) woodland extent was compared to the LCM woodland extent to assess its usefulness in this study. Figure 3 compares LCM woodland with OS woodland for one example CS square, showing how the different sources provide different measures of woodland extent. GIS was used to calculate the differences in area and perimeter between these sources across all of the CS squares (Table 2). The categorisation of woodland is clearly different between the two sources, and the ecological importance of these differences is likely to be reflected in the analysis of the plot data.

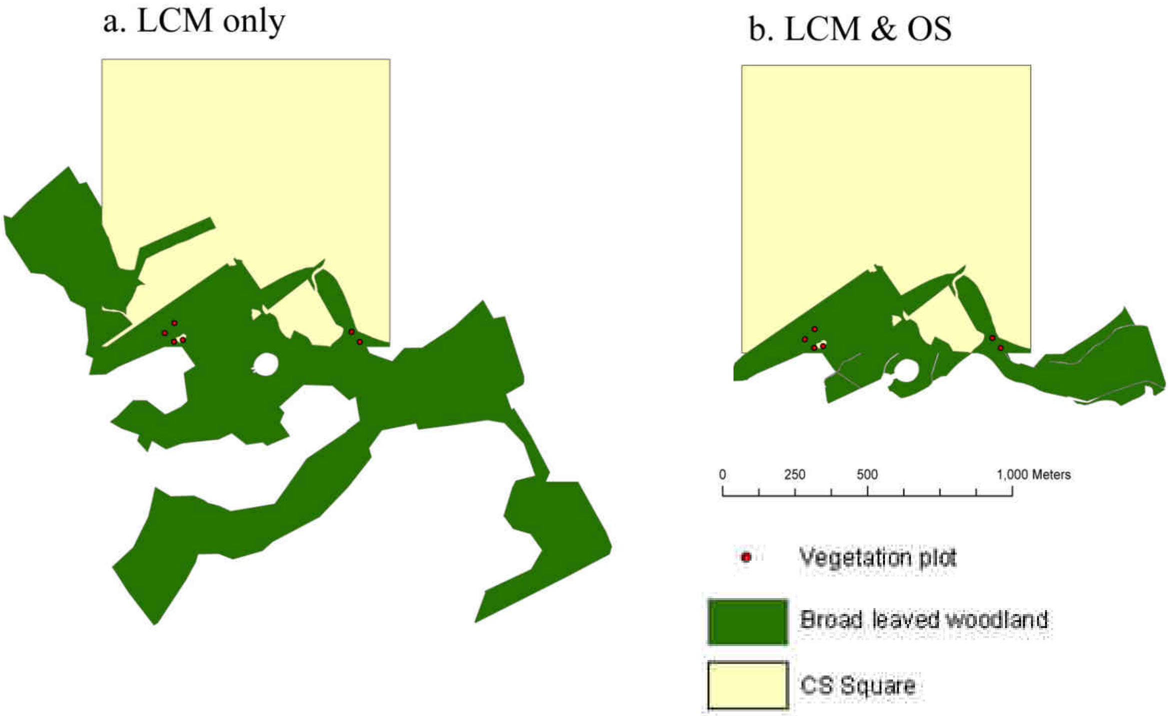

Figure 3. Example of the comparison of beyond the square patches created using; a. All LCM woodland, and b. Only LCM woodland that spatially corresponds with OS woodland.

Table 2. Comparison of LCM and OS-validated LCM woodland patches for all patches containing CS plots throughout Britain.

Source	*Number of Patches*	*Mean Patch Area (km^2)*	*Mean Patch Perimeter (km)*	*Total Woodland Area (km^2)*	*Total Woodland Perimeter (km)*
LCM woodland	560	0.094	1.83	52.78	1026.25
OS validated LCM woodland	576	0.038	1.22	21.70	704.95

3.2 Historic versus Current Woodland

Data digitised from First Series OS maps (~1880) were used to compare current woodland to historic woodland extent, discerning areas of ancient woodland from those that have been more recently established. An example of this comparison for one CS square is shown in Figure 3, where the change in woodland structure between the First Series OS map and 2007 can clearly be seen. This analysis was carried out across all vegetation plots, using GIS to identify whether each plot lies in continuous or secondary woodland, allowing the species composition of older woodland to be compared with more recent woodland. The effect of patch age on plant species composition and any interaction this has with the spatial variables will be investigated in ongoing analyses.

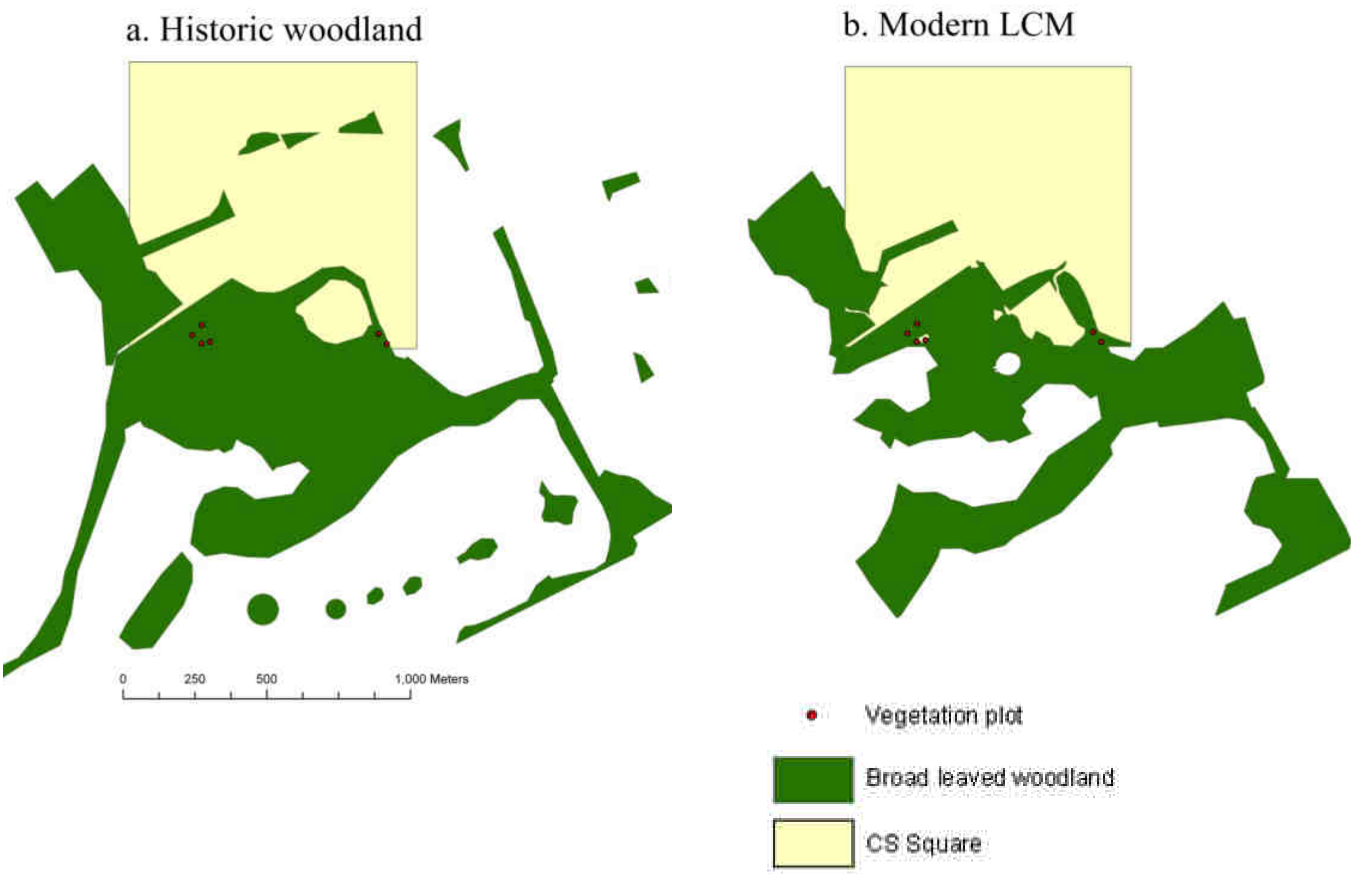

Figure 4. Historic and Current Woodland Distribution. Figure 4a shows the extent of woodland in the First series OS map as digitised around a Countryside Survey square. Figure 4b shows contemporary woodland extent around the same square in 2007 assessed using Land Cover Map.

4. Discussion

Modification of landscapes often causes a decrease in the area and connectivity of habitat patches within the landscape. This fragmentation is thought to result in lower species richness of organisms which rely on the modified habitat. A number of sources of habitat information exist for British woodlands, but these are often limited in the extent of the information that they supply. This study uses GIS to combine these sources into a single database containing information on the spatial characteristics of British woodland habitat patches, along with information on their historical land use. On-going work is now comparing this spatio-temporal information with vegetation present within the patches to measure the response of plant species to fragmentation.

GIS is also being used to measure the amount of both contemporary and historical woodland around each plot in order to estimate the connectivity of the landscape and investigate its influence on species composition. Since the wider pattern of habitat (or even the historic pattern) may affect plant species occurrence (Metzger *et al.* 2009), analysis will be performed on the landscape characteristics surrounding plots at various distances, investigating how the size of the landscape considered impacts upon results obtained (Smith et al, 2011).

Although woodlands are considered here, further work on other habitat types will allow differences in the levels of response to spatial change in different habitat types to be investigated. For example, plant species in agricultural landscapes may have very different characteristics to ancient woodland plants and therefore react in a different ways to habitat fragmentation. Measuring differences in the way species with different traits are influenced by variation in their habitat structure will help to identify and quantify this difference in response.

5. References

Dupouey, J.L., Dambrine, E., Laffite, J.D. & Moares, C. (2002). Irreversible impact of past land use on forest soils and biodiversity. *Ecology,* **83,** 2978-2984.

EDINA (2011). Digimap online mapping service (http://edina.ac.uk/digimap). © Crown Copyright and Landmark Information Group Limited 2011. An EDINA Digimap/JISC supplied service.

Fischer, J. & Lindenmayer, D.B. (2007). Landscape modification and habitat fragmentation: a synthesis. *Global Ecology and Biogeography,* **16,** 265-280.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Gordon, B., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. & Snyder, P.K. (2005). Global Consequences of Land Use. *Science,* **309,** 570-574.

Henle, K., Davies, K.F., Kleyer, M., Margules, C. & Settele, J. (2004). Predictors of species sensitivity to fragmentation. *Biodiversity and Conservation,* **13,** 207-251.

Hermy, M., Honnay, O., Firbank, L., Grashof-Bokdam, C. & Lawesson, J.E. (1999). An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation. *Biological Conservation,* **91,** 9-22.

Metzger, J.P., Martensen, A.C., Dixo, M., Bernacci, L.C., Ribeiro, M.C., Godoy Teixeira, A.M. & Pardini, R. (2009). Time-lag in biological responses to landscape changes in a highly dynamic Atlantic forest region. *Biological Conservation,* **142,** 1166-1177.

Schleicher, A., Biedermann, R. & Kleyer, M. (2011). Dispersal traits determine plant response to habitat connectivity in an urban landscape. *Landscape Ecology,* **26,** 529-540.

Smith, A.C., Fahrig, L. & Francis, C.M. (2011). Landscape size affects the relative importance of habitat amount, habitat fragmentation, and matrix quality on forest birds. *Ecography,* **34,** 103-113.

6. Acknowledgements

The authors wish to acknowledge the Centre of Ecology for Hydrology and EDINA for supplying map data. Funding for Adam Kimberley was provided by the Natural Environment Research Council (NERC). Project number: NEC03454.

7. Author Biographies

Adam Kimberley is a first year PhD student with the University of Lancaster and the Centre of Ecology and Hydrology, studying spatial aspects of landscape and vegetation change in Britain.

Simon Smart is a plant ecologist at the Centre of Ecology and Hydrology, Lancaster.

Alan Blackburn and Duncan Whyatt are senior lecturers in remote sensing and GIS at the University of Lancaster.