Landscape ecology: emerging approaches for planning and management of forests and woodlands within Britain

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BACKGROUND

The need to develop a 'landscape' approach has been a common demand in many recent statements of British forest policy and identified as a major challenge facing forest managers. Such statements reflect a trend towards broader scale spatial and temporal planning – and the need for, and difficulties of, integrating multiple uses. Arguably, some of these themes can be traced back to the developments in landscape design and land use allocation of the late 20th century. Before these developments, much forest management had been characterised (or caricatured) as assembling a set of decisions taken at the stand scale, i.e. the basic unit of management. That the simple accumulation of such decisions was inadequate to deliver requirements at broader scales was first identified in the aesthetics of landscapes – and triggered the pioneering work of Sylvia Crowe and the introduction of 'landscape design'. Subsequent responses to these landscape-scale demands included development of forest design principles, indicative forest strategies and *Forest & water guidelines*. With further broadening of management objectives, the demand to develop new approaches has accelerated. In particular, there is a growing realisation that conservation and enhancement of biodiversity cannot be achieved by a stand level approach or a rare site protection policy, nor can it be guaranteed by concentrating on landscape aesthetics and assuming that ecological benefits are linked. Organisms and ecological processes are not constrained by management or ownership boundaries, and hence there has been the need to develop an approach to landscape ecology.

Introduction

This article describes recent developments of an ecological approach for landscapes, and suggests likely applications and future refinements. Land use plans and indicative strategies based on such principles are finding increasing application throughout the USA and Europe including, recently, the UK. Before describing the work, it is worth observing that though fashionable, the use of the term 'landscape' is often applied rather loosely, and can include landscapes as:

- A focus of attention, and a perceived quality – 'landscape planning', landscape character areas, landscape view.
- A spatial scale and extent – expressed in geographic terms as the 'landscape scale', often of several square kilometres.
- An arena within which to target action, for example the Forest Landscape Restoration initiative.
- An entity with structural elements of patch, mosaic and corridor, reflecting a mix of ecosystems and habitats (for example, Figure 1).

Such diversity of definition is also prevalent in the discipline of landscape ecology. Some consider it to be very broadly based, integrating a wide range of interests in the landscape including cultural values. Thus landscapes are often characterised as having three particular facets of interest – structure, function and change. *Structure* describes the composition and configuration of distinct elements in the landscape; *function* describes the interaction between the structures through ecological processes (for example, biodiversity function is often related to the movement and viability of particular species within these structures); and *change* (whether driven internally or externally) as driving the interaction between them. Other landscape ecologists espouse a much narrower focus on the interaction between landscape pattern, landscape process and the distribution and abundance of organisms (Figure 2).

Our subsequent discussion will consider landscape ecology as a basis for understanding the spatial and temporal dynamics of the landscape by considering the inherent ecological structures (often based on elements such as patch, corridor, matrix) which promote different ecological functions. We will consider landscapes primarily as an entity with the most appropriate landscape scale being determined by the particular research issue being addressed, and a focus on landscapes with trees – existing or planned. It is interesting to note that as recently as 1998, the focus of landscape ecology research in British woodlands was in the area within the forest boundary but is now more likely be considered within catchments or other topographic, or administrative, units. The appropriate scale may therefore vary from the forest (several square kilometres), through to the catchment or region (tens to hundreds of square kilometres) or to whole country (hundreds to thousands of square kilometres).

Figure 1

Woodlands within a mosaic of other open habitats on the Isle of Wight.

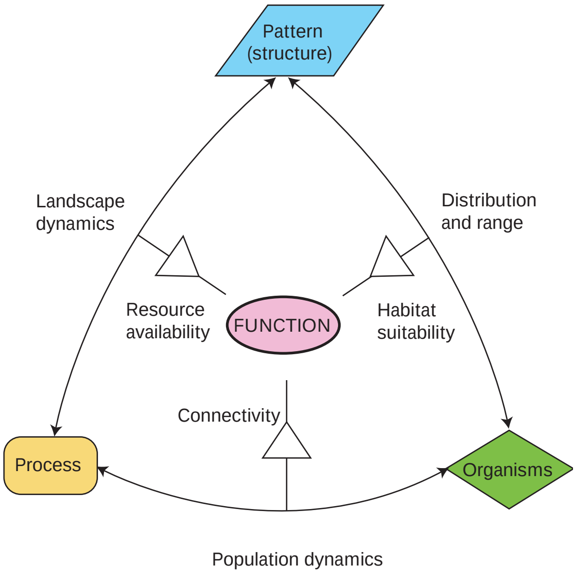

Figure 2

Flowchart describing the interaction of pattern, process and abundance/distribution of organisms within landscapes.

The drive towards a landscape approach

Policy drivers

There are a number of policy drivers demanding a landscape approach:

- The Convention of Biological Diversity, and subsequent commitments to conservation of biodiversity at the landscape scale.
- The application of EU Habitat and Species Directives, and the commitment to UK Biodiversity Action Plan targets (especially habitat action plans).
- The pursuit of forest landscape restoration, e.g. FC/WWF initiatives, and creation of Forest Habitat Networks.
- The evolution of Land Use policies, e.g. the Common Agricultural Policy and Water Framework Directive, demanding approaches at landscape scale – and integration across land uses.
- The proposal to develop adaptation strategies for climate change.
- The desire for targets and indicators to measure and monitor policy delivery for most of the above.

Practice drivers

Changes in forest and woodland management are also demanding landscape approaches:

- Developments of ecosystem approaches, adopted from North America and Scandinavia.
- Development in operational forest design and strategic planning.
- Demands for targeting of grant aid to deliver public good, and the associated involvement of multiple stakeholders in these decisions.
- Demands of single species conservation, e.g. wide-ranging species such as red squirrel, black grouse, capercaillie, golden eagle.
- Increased availability of Geographic Information Systems and associated tools, including Ecological Site Classification.
- Changes in management practice, e.g. restructuring, and attempts to prioritise habitat restoration.

Research drivers

Scientific progress has also contributed to the need to scale up:

- Conceptual developments in the application of island biogeography, and species–area relationships.
- Empirical findings of responses of plants and animals to landscape-scale structures and processes (including metapopulation dynamics).
- A greater understanding of abiotic processes within landscapes, and the extent to which they vary enormously with short distances.

Overall, these drivers are creating pressure for guidance and support in three areas:

Landscape change: methods to identify past and future landscape development.

Landscape analysis: methods to characterise current/future (and sometimes past) landscapes.

Landscape planning and evaluation tools: integrated techniques for use by practitioners to guide policy and practice.

Recent approaches to landscape ecology in British forests

This section provides a brief overview that illustrates the development of landscape ecology approaches, which we have also summarised in Table 1.

Landscape change – dynamic modelling

Many demands for a landscape approach relate to considerations of future options – and not just description of the present or change between past and present. Deciding what landscape change may occur is sometimes simple; for example, in the case of planned landscape change resulting in transformation of agriculture into woodland. However, many of the landscapes of interest are semi-natural, and ecological dynamics also govern the evolution of habitats (extent and quality) over time – and space!

The development of sophisticated computer models of landscape dynamics has been possible in areas where land use allocation is relatively fixed, and habitat dynamics have a greater influence on character and composition of a landscape. A study conducted in Glen Affric has developed a simulation model (Hope, 2003), the result of which can be subject to analysis by a variety of means. Lessons learnt include the lack of knowledge and understanding on some key landscape processes, such as herbivore impacts, and lack of data on habitat character, and importance of initial conditions.

Landscape analysis – landscape metrics

Landscape structure, e.g. formed by a mosaic of habitats, is a very visible attribute and with the availability of digital maps is increasingly susceptible to pattern analysis (Figure 3). A suite of metrics has been developed by a number of authors for summarising and analysing the structure of landscapes. They are conceptually attractive – and often seen as an appealing solution to the demands for targets and indicators.

Table 1

Recent approaches to landscape ecology in British forests.

Aspect of landscape ecology	Technique	Implementation and interpretation	Reference
Establishing landscape change (in terms of extent of habitats/elements)	Land use analysis	Simple re-classification of landscape elements – e.g. conversion of agriculture to woodland. Subjective and may be simplistic.	Ferris and Purdy, 2003a
	Landscape dynamic modelling	Complex spatio-temporal modelling requiring considerable source data and effort. Difficult to validate.	Hope, 2003
Analysing landscape structure	Landscape metrics	Produces sets of measures summarising pattern of landscape structure. Simple to calculate but may be difficult to interpret ecologically.	Ferris and Purdy, 2003b
Analysing landscape function	Habitat suitability analysis	Analyses landscapes for extent of suitable habitat for target species. Habitat quality information may be missing, and knowledge of relationships may be questionable.	Poulsom *et al.*, 2005
Analysing both structure and function	Landscape evaluation: Diaz approach	Subjective approach that contrasts situation with natural landscapes. Difficult to apply to heavily modified landscapes.	Bell, 2003
	BEETLE modelling	Quantitative, analytical approach. Requires dialogue over assumptions and objectives.	Watts *et al.*, 2005

However, there are a number of difficulties that have emerged during test applications in Britain and elsewhere. In particular, their interpretation depends upon assumption of strong linkage between pattern and process, and there is relatively little evidence to support this. The proliferation of potential measures leads to confusion, and there is substantial redundancy between measures (e.g. studies have shown that a potential field of 60 might be whittled down to less than 10). The technical ease of application via GIS may mean that they are uncritically deployed. Finally, there are problems with some where the assumptions may not be supported by the most recent evidence from ecological studies.

Some of these shortcomings can be overcome and in particular by a clear consideration of the purpose of applying the metric (or indicator), and an acceptance of the assumptions. An example of this can be seen in Table 2. It would seem best to treat these metrics as relative measures rather than absolutes and embed them in a process involving active discussion of underpinning assumptions.

An alternative form of analysis is to consider the suitability of the landscape for particular target or valued species. This can be an appropriate form of assessment for conservation measures for the particular species, but is sometimes used in the assumption that such action will create greater benefits. As a result many such models are single species models – and their use therefore depends upon the degree to which that species represents the wider target (biodiversity!). Unfortunately, there is a growing body of evidence to suggest that such an assumption is rarely met.

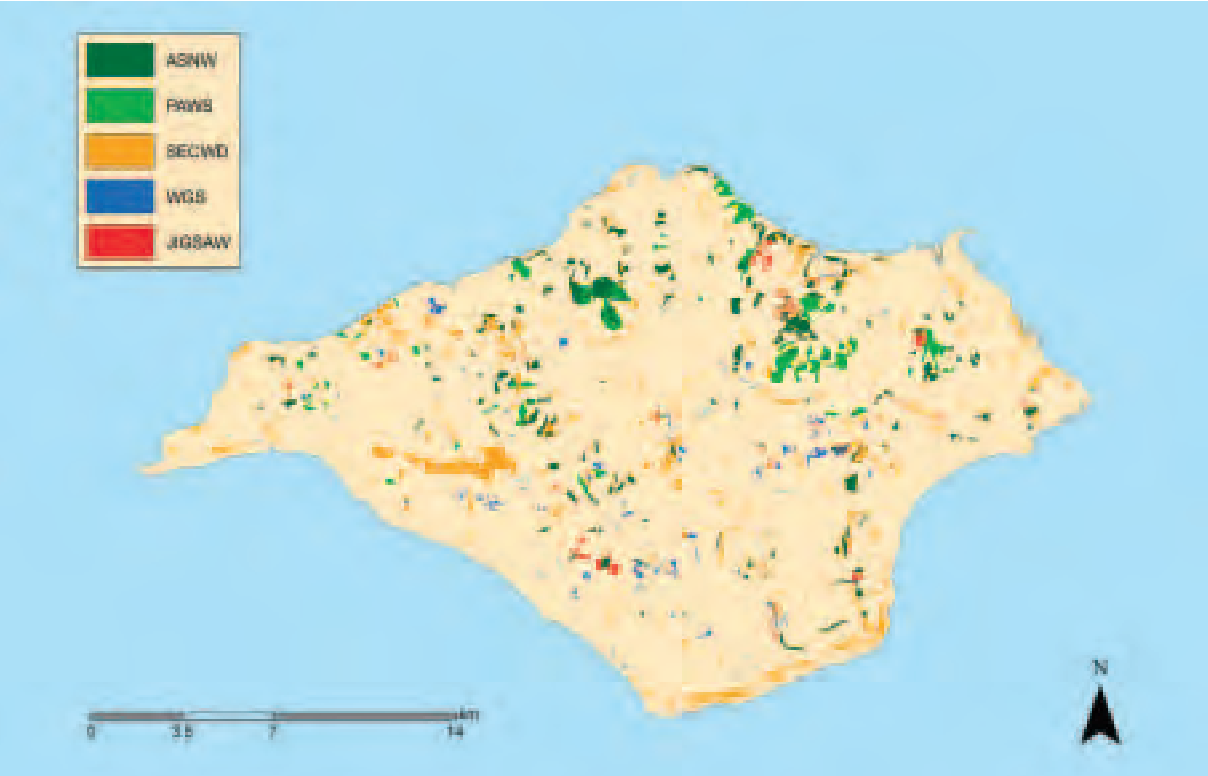

Figure 3

Map showing different woodland assemblages on the Isle of Wight – suitable for analysis of the success of planting schemes using metrics and other landscape evaluation tools. ASNW: ancient and semi-natural woodland, PAWS: plantations on ancient woodland sites, SECWD: secondary woodland – other broadleaved woodlands, WGS: woodlands established under the Woodland Grant Scheme (not spatially targeted at defragmentation), JIGSAW: woodlands established under the JIGSAW grant scheme targeted at defragmentation.

Landscape evaluation

Decision-makers require integrated methods to evaluate alternatives and identify desired future conditions. An approach based on North American landscape analysis was tested in Affric and Sherwood (Bell, 2003). A key driver here was the need to develop the forest design concept to accommodate ecological aspects. The concept was to link an analysis of the structure of the landscape to knowledge of ‘flows’, i.e. movements of animals and resources, and ultimately develop a view of desired future condition. Limitations were exposed due to lack of natural template in highly modified landscapes of Britain – and the complication imposed by cultural dimensions leading to many potential desired future conditions. A similarly subjective, though integrative, approach has been developed for some forest habitat networks.

An emerging approach to evaluation – BEETLE

Experience from the above and developments elsewhere have led us to conclude that we need to give a greater emphasis to assessment of landscape function – but the challenge is how to achieve this! FR ecologists have participated in the development and application of each of the approaches identified in the preceding section (Table 1). The particular focus of our current effort is in developing approaches that assist with decision-making at the strategic or tactical level, namely regional strategies or forest design plans. This has involved the development of an approach called BEETLE – Biological and Ecological Evaluation Tools for Landscape Ecology, which includes the adoption of a functional (rather than simply structural) approach, incorporating the concepts of habitat carrying capacity and landscape permeability. The details of this approach can be found in Watts *et al.* (2005).

Connectivity rather than connectedness

A distinction has to be made between the physical connectedness of habitats, which has often been used in design of networks and is analysed through various metrics, and connectivity which depends upon the ability of species to disperse through landscapes.

Table 2

Example of potential ecological indicators for calculation of anticipated effects of land use change in case study areas within the VisuLands project.

Concept and indicator	Scale	Suggested metric	Other possible metrics	Under pinning ecological assumption	Inference from increase in relative value	Inference from decrease in relative value
Landscape composition: proportion	Class	Class area (ha), number of classes and % of landscape	Shannon’s diversity index	Amount of particular habitat and mix of habitats within a landscape controls available niches	Habitat (class or set of classes) achieving greater dominance – positive if a valued habitat, negative if not a valued habitat	Habitat (class) becoming less common – negative if a valued habitat, positive if not. Are there thresholds?
Landscape composition: patch size	Class, landscape	Mean patch size (ha), standard deviation, and number by class, and for landscape	Average perimeter–area ratio	Amount of contiguous habitat influences its suitability for certain species	Improved conditions for species specialist to that habitat type (class); at landscape scale – increased homogeneity (needs local assessment of positive/negative)	Poorer conditions for specialists, better conditions for generalists, and species of edges
Landscape configuration: patch shape	Class	Perimeter–area ratio	Fractal dimension	Core area of a habitat is the most valuable for characteristic species	Improved conditions for core habitat and species that benefit from those conditions	Poorer condition for habitat and for species that use the core areas of such habitats

Named species or generic species?

A feature of the BEETLE approach is the use of focal species. These are the target for the calculations, but not necessarily of the intended conservation action. They have proved very useful as a discussion device, akin to metrics but enabling assumptions to be more explicit. One particular aspect to the development has been the consideration of whether to use specific (named) species or generic species; species can also be distinguished as habitat generalists and habitat specialists. Each categorisation has its advantages and disadvantages in considering landscape evaluation, and choice may depend upon scale of application, existence of data on real species and on purpose of analysis.

Recent applications

We have developed and applied the approach to a number of case studies which have ranged substantially in scale and objective, as shown in Table 3. An example of the mapped output from this form of analysis is provided in Figure 4.

Key lessons

The science and policy/practice demands have moved rapidly in the past 5 years. Part of the maturing of the debate is to understand that previous simplicity was an illusion, and that with increased knowledge comes an enhanced understanding of the complexity of ecology of landscapes. It seems no longer credible to be working towards a single tool that provides a single form of landscape ecological analysis. Similarly the pursuit of a single metric – or indeed landscape threshold – seems inappropriate. There is a developing conflict between demand for simplification (by policymaker and practitioner) and increasing evidence of complexity. Our evaluation approach attempts to strike a compromise and answer the question posed, without resorting to unnecessary complexity.

It is crucial that the purpose of the evaluation is specifically articulated. The approach to design a simple habitat network in a static landscape at a large scale is very different from the production of a complex spatially explicit population model in a temporal landscape at a very fine scale – they are very different research questions. We have found that evaluation is particularly successful through discussion with a steering group and could be developed further into public participation.

Table 3

Examples of applications of the BEETLE approach.

Purpose	Approach	Location
Analysis of forest expansion scenarios	Relative change, no focal species, metrics appropriate, planned temporal change in landscape	Isle of Wight
Analysis of national habitat network strategy	Extensive scale, limited data availability, general connectivity an objective, static landscape, generic species appropriate	Wales
Analysis of regional habitat network strategy	More spatial/species data, smaller catchment/region scale, specific focal species, static landscape	Borders, West Lothian
Analysis of core sites for special species	Species specific (red squirrel) habitat suitability and defendability analysis	Scotland and north England
Analysis of balance between forest and open ground	More spatial/species data, smaller catchment/region scale, specific focal species	Affric, Sunart, Mull
Analysis of implication of landscape dynamics on rare species conservation (lichen: *Bryoria furcellata*)	Temporal landscape, specific species question, lots of species data, high time, cost, uncertainty	Affric
Analysis of forest design options	Specific focal species, static/temporal landscape, high quality landcover data	Clocaenog, north Wales

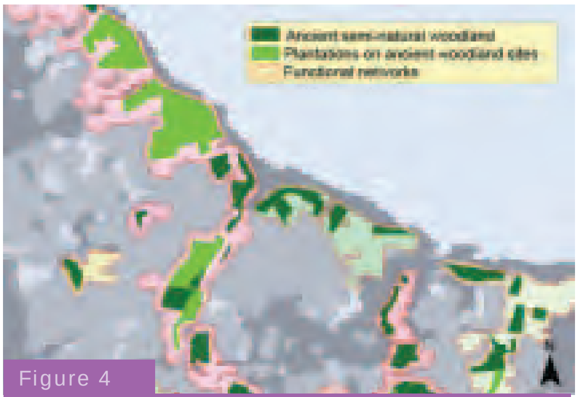

Figure 4

An example from a landscape evaluation using the BEETLE approach showing habitat networks around woodlands in part of the Isle of Wight.

Future development

There are a number of limitations to widespread deployment of our approach, in particular: the availability of data (for example on habitat quality); the lack of species-specific knowledge; the difficulty of providing evidence of model validation; and the technical difficulty of making the process more automated.

We plan to refine the BEETLE approach to address the limitations identified above. Evaluation approaches that integrate such ecological analysis with analysis of other landscape values are likely to be required and are being provisionally examined within the VisuLands project (www.forestresearch.gov.uk/visulands). Other developments also have considerable potential to add to the progression of landscape ecology in Britain, in particular:

- Molecular techniques will facilitate the study of gene flow within landscapes, providing perhaps the best option for validating a number of the models developed on theoretical rather than data-model grounds.
- A broadening of the target species, to include pest and pathogen, may also enhance understanding rather than limiting study to species of conservation concern.
- Remote-sensing and further inventory/census should provide enhanced data availability – not just of extent, but hopefully also of habitat quality.
- There are new methods of integrating multiple data layers and views.

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