Future landscapes and the future of landscape ecology

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Abstract

The future of most landscapes is increasingly being determined by human activities. These activities modify existing landscape patterns and processes either deliberately or inadvertently. It is becoming increasingly apparent that an understanding of these landscape level patterns and processes is essential for rational land use planning and management both for production and biodiversity conservation.

The science of landscape ecology aims to provide this understanding. I argue that landscape ecology has so far failed to integrate the various disciplines it brings together and lacks a coherent theoretical structure and principles of relevance in practical terms. While advances have been made in the study of landscape structure and change, landscape function is often still poorly understood. Flows of biota, water, nutrients and materials across landscapes are determined, in large part, by landscape patterns, but an appreciation of the functional links between patterns and processes has been slow to evolve. If landscape ecology is to provide useful input into land use and conservation issues, greater effort needs to be expended in understanding the functional aspects of landscapes. I suggest that the future of landscape ecology depends on whether landscape ecologists make the decision to take an active part in determining the future of our landscapes. This involves active efforts to produce a truly integrated science, the development of sound landscape design principles and increased interaction with policy, planning and management. Failure to meet this challenge will relegate landscape ecology to being a pleasant academic pastime with little relevance to today's pressing environmental and social problems. © 1997 Elsevier Science B.V. All rights reserved.

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1. Introduction

Landscape ecology is uniquely poised to play a major role in tackling today's major conservation and land-use issues and in developing responses to the pressing problems arising as a result of human-induced global change (Fig. 1). This arises because of the increasing recognition that many conservation and land-use issues can only be tackled in a sensible way within a landscape framework (Saunders et al., 1991; Franklin, 1993). This recognition has resulted in a move away from management directed simply at single sites to considering larger scale patterns and processes. At the same time, it is becoming apparent that the likely impacts of, and responses to, global change have to be considered at the scale of manage-
2. How well is landscape ecology doing?

2.1. Landscape ecology as a science

In 1992, John Wiens surveyed the first five volumes of the journal Landscape Ecology to assess what sort of methodologies and quantification were being used and what sort of topics were being covered (Wiens, 1992). The survey gave an indication that landscape ecology concentrated mainly on the spatial scale of hectares to square kilometres, and consisted of a relatively high proportion of purely descriptive and non-quantitative studies. Of particular note was the fact that few studies contained any experimentation.

To assess whether the situation was changing or not, I surveyed the papers in the next five volumes of the journal, using the same categories as Wiens. The results for volumes 5–10 indicated a shift away from descriptive, non-quantitative studies towards more quantification and use of statistics (Fig. 2). In addition, a greater emphasis on modelling and development of methodology was apparent. Notably, however, there was no increase in the level of experimentation. In his analysis of areas of interest, Wiens concentrated on topics related primarily to biophysical landscape attributes. The results from volumes 6–10 indicate little change in the extent to which these topics received attention in the journal.

While such surveys provide only a partial view of what is going on in landscape ecology, and may partially result from changes in editorial policy of the journal, they do indicate a change towards a more quantitative science, with the development of methodology, and use of statistics and modelling as major trends in the field. The lack of experimentation is seen by some as a weakness in the science, since it precludes adequate hypothesis testing and hard inference. This difficulty dogs all aspects of ecology which deal with large-scale and complex systems, and is either met with calls for increased rigour or with demands for the development of new approaches (Carpenter, 1990; Underwood, 1990; Walters and Holling, 1990; Hargrove and Pickering, 1992). Alternatively, Wiens et al. (1993) suggest that the use of smaller-scale model systems on which to conduct experiments is one way of overcoming these...
problems. Using this approach still leaves us with the question of whether results from these small-scale studies can be reliably extrapolated to larger scales. If not, can we hope to do experiments at a large enough scale? This is undoubtedly difficult, and some questions are not amenable to classical experimental approaches, since it is impossible to deal adequately with problems such as covarying factors (Nicholls and Margules, 1991).

Such considerations could easily lead to an impasse where landscape ecology could not progress because experimental and statistical rigour could not be achieved, and hence the usefulness of landscape ecological research could not be adequately assessed. Recently, however, Pickett et al. (1994) have explored the roots of the problem in terms of the relevance of traditional Popperian methodology, assumptions of simple causation and the use of physics as a model science. Such concerns have been voiced for some time in ecology, apparently to little avail (MacFadyen, 1975). The analysis by Pickett et al. (1994) suggests the need for a reappraisal of the way we do science on complex and large-scale systems. It underscores the need for a flexible and integrative approach which fosters rather than inhibits the development of a greater understanding of landscape processes. This involves the use of all avenues of acquiring information, including classical experiments where possible, natural and other non-classical experiments where available (including management operations: see below), observations, inference (strong and weak) and modelling. We must recognize that novel approaches to the study of complex landscapes are needed. Getting hung up on the quest for classical statistical rigour and strict Popperian falsificationism is not the best way to tackle most of the pressing problems we face. Complexity and uncertainty are inherent characteristics of our subject matter. This must become clear not only to ourselves, but also to those seeking answers from us.

2.2. Understanding landscape structure, function and change

Landscape ecology has been defined in a variety of different ways, but a common theme is the study of patterns, processes and changes at the scale of hectares to square kilometres (e.g. Forman and Godron, 1986; Turner, 1989). Landscape structure (or pattern) can be considered to be the spatial relationship between landscape elements or patches. Landscape function (or process) is, then, the interaction between these spatial elements, and landscape change is the alteration in structure and function occurring through time (Fig. 3). From recent issues of the journal Landscape Ecology, and papers presented at
the Toulouse conference, it is clear that considerable attention has been directed at landscape structure and change, but considerably less at landscape function. Despite Turner's description of landscape ecology as the study of the effect of pattern on process (Turner, 1989), much of landscape ecology is hung up on pattern and largely ignores process.

There are undoubtedly many excellent exceptions to this, in which landscape processes have been explicitly studied. Examples include the integrative work on the bocage system in Brittany (e.g. Baudry, 1984, 1993; Burel and Baudry, 1990; Burel et al., 1993), and on agricultural and fragmented systems (e.g. Saunders et al., 1991; Hobbs and Saunders, 1993; Vos and Opdam, 1993). Further examples are the work on landscape flows within these systems (e.g. Ryszkowski and Kedziora, 1987; van Buuren, 1991; Ryszkowski, 1992; Hobbs, 1993b), and work on the impacts of wildfire on forest systems in Yellowstone (Turner et al., 1994a,b; Pearson et al., 1995) Overall, however, as Turner et al. (1995) comment, "... the ability to quantify spatial pattern and monitor changes in pattern exceeds the ability to interpret its ecological effects".

Part of the problem is certainly that adequate methods of describing landscape structure are still being developed. Also, functional aspects of landscapes are frequently difficult to measure. However, it can be questioned whether there is much value in examining landscape structure without simultaneously considering function. For instance, many metrics have been proposed as descriptors of landscape characteristics such as heterogeneity, connectivity etc., without any consideration of what these metrics actually mean. Cale and Hobbs (1994) have examined the problems arising from trying to use generalized metrics to describe landscape attributes which are likely to be perceived quite differently by different organisms or which affect landscape processes in different ways. Their conclusion was that it made little sense to assess landscape structure without considering the processes about which questions were to be asked.

This problem of ignoring landscape function also finds its way into landscape design. In many instances, design rules are put forward which either deal only with structure and ignore function entirely, or assume that if the landscape "looks OK", it will function OK too (e.g. Forestry Commission, 1992). This approach may be fine when the primary design aim is to satisfy aesthetic values, but is likely to be insufficient when design for particular functions is required. Landscape function may, of course, be viewed differently in different contexts (Hall, 1995). Unfortunately, we often know little about how varying landscape design influences landscape functions in any context (e.g. Hobbs, 1993a). It may often be the case that different functions (e.g. alteration of landscape flows such as water or soil movement, retention of different biotic components) will require different landscape configurations (e.g. Sparks et al., 1994). This, in turn, implies that clear decisions need
to be made about exactly what we want from our landscapes. While these decisions will be made by society as a whole, landscape ecologists have an important role in providing information to aid and influence decision making.

2.3. Landscape ecology as an integrative science

Landscape ecology has often been put forward as a major integrating force between a number of disciplines (Zonneveeld, 1990; Naveh, 1991). How far is this actually the case? After attending the IALE Congress in Toulouse, one might still ask the same question as Wiens (1992) asked, i.e. "What is landscape ecology, really?" Contributions varied greatly in their approach and methods, and there was apparently little cross-fertilization between different streams. There was still an apparent dichotomy between those landscape ecologists with a biophysical perspective and those with a human or sociological perspective. This is despite the increasing recognition that humans are an integral component of most ecosystems and that human activities influence all ecosystems to a greater or lesser extent (McDonnell and Pickett, 1993). Landscape planners, landscape architects, geographers, ecologists, modellers and assorted others frequently viewed each other with some suspicion, and differences in jargon, methods and approaches were frequently in evidence. Rather than capitalizing on the variety of approaches and disciplines brought together under the banner of landscape ecology, there was still a strong tendency for disciplinary rivalry and defensiveness.

There is neither the need nor the time for such divisiveness in today's world. If landscape ecology were just an academic jousting field, where different disciplines could harmlessly engage in verbal battles, then there would be little need to try to rectify the situation. However, the Earth and its landscapes are under unprecedented threat from human activities, and there is an urgent need for rapid action to deal with these threats in a rigorous and effective way. Landscape ecology is (or should be) in the front line of these efforts. This requires a coordination of effort which makes use of all the skills available. This in turn depends on the effective integration of the various disciplines and approaches brought together within landscape ecology. This requires a conscious effort to transcend disciplinary boundaries and to develop mutual respect between disciplines. Nowhere on Earth is now isolated from the impacts of human activities. Solutions to the problems facing our landscapes will never be simply biophysical or simply socio-economic. Solutions developed by the ecologist will not work unless implemented by the planner or the landscape architect. Planned solutions will greatly benefit from input from all parties.

2.4. The practical application of landscape ecology

Landscape ecology lies at the interface of many applied disciplines (Fig. 4). I noted earlier the increasing recognition that global change and conservation biology issues had to be tackled at a landscape level. Similarly, land-use planning decisions frequently involve landscape-scale considerations. Within restoration ecology, too, there are increasing calls for a landscape approach (Aronson et al., 1993; Hobbs, 1993a; Hobbs et al., 1993; Whisenant, 1995). By the very nature of its subject matter, landscape ecology is an applied science. To what extent, then, is it actually applied?

The answer to this unfortunately seems to be "very little". Here, again, there seems to be little cross-fertilization between landscape ecology and other disciplines, even where these have apparent direct points of contact (e.g. Hobbs, 1994b). For instance, in the 350-plus pages of a recent symposium volume on "Large-Scale Ecology and Conser-

Fig. 4. Landscape ecology is relevant to many applications, and interaction between these different disciplines is essential. Landscape ecology potentially has much to offer the fields shown, and others.
At a recent meeting, I heard a well-known conservation biologist comment "Let's not get the landscape ecologists involved—they never contribute anything useful anyway". There is a perception among many in other disciplines that, although the landscape may be the relevant scale at which to study and manage things, landscape ecology has not come up with much that will help.

Certainly, when one peruses recent summations of landscape ecological principles (e.g. Forman, 1995), one wonders how accessible or understandable they are to people who may wish to apply them to real landscapes. The same may be said of much of the modelling work that has gone on. Similarly, when statements such as the following are encountered, it is little wonder that the practical value of landscape ecology is questioned. Referring to a landscape-scale model of northern Majorca, Newbold (1994) stated that, "Co-ordinated management on the landscape scale will involve a number of different agencies and will be difficult to achieve, so that initially the models may be of more theoretical than management value." This is a typical application of the standard scientific practice of developing a model first and then considering its application to management later (if ever). One must question the usefulness of developing a model of landscape management which does not take the practical limitations into account. Also, what about a more proactive approach, where the landscape modelling activity also tries to deal with some of the obstacles to landscape-level management? Management activities can also be used as part of a research program, and can help overcome some of the problems of doing landscape-scale research which are discussed above (Walters and Hilborn, 1978; Walters and Holling, 1990). Many examples are emerging where this type of approach is being used to counter the dual problems of ecosystem degradation and the failure of existing management structures to deal with the degradation (Gunderson et al., 1995). The application of landscape ecology has to involve not only the use of landscape design principles, but also the modification of management regimes and systems to facilitate the implementation of these principles (Hobbs et al., 1993; Mladenoff et al., 1994; Morton et al., 1995).

Although it must be acknowledged that landscape ecology is still a developing science, this does not allow us to develop it in an academic vacuum. How much landscape ecology currently finds its way into land-use planning decisions? Or into landscape design? While much is written about coupling landscape ecology with planning (e.g. Golley and Bellot, 1995; Rookwood, 1995), much more needs to be done by landscape ecologists to foster this linkage. I suggest that the products of landscape ecology (i.e. theory, methodology etc.) are best assessed, not on their intrinsic interest or popularity in the scientific literature, but on the impact they have on the planning and management of real landscapes. This does not diminish the need for good empirical and theoretical research, especially in the area of linking pattern with process: rather it emphasises the need to link this firmly with application.

3. Paths to the future for landscape ecology

Following on from the above analysis of the state of landscape ecology, where does this leave us in terms of future landscapes? I suggest that in its present condition, landscape ecology has surprisingly little to offer those wishing to plan and manage the landscapes of the future. I suggest that several major shifts in emphasis and thinking are required if we wish to change this. These can be summarized as follows:

3.1. The future is not somewhere we are going; it is something we are making

We can simply allow the future to roll over us, accepting change in a fatalistic and powerless way, or we can acknowledge that humanity is making its own future and participate in the process of directing change towards a future that is sustainable.

3.2. We can follow the path to the future, or help in its construction

Landscape ecologists must decide whether they wish to participate in the process of shaping future
landscapes, or simply act as passive recorders of changes in landscape patterns.

3.3. It helps if we know where we want to go

To contribute effectively to the process of shaping the future, landscape ecologists must have some clear ideas about what we want from our landscapes, in terms of their structure and function, and some methods by which these attributes can be achieved.

3.4. Building paths to the future is easier if we all work together

Landscape ecology brings together an impressive variety of disciplines and outlooks. So far, we have failed to capitalize on this variety, and indeed often fail to see the value of different perspectives. Landscape ecology should be able to take the lead in integrating the many biological, geographical and sociological perspectives and the practical and theoretical approaches needed to tackle today’s environmental problems.

3.5. It is much better to build paths that will actually be used

We must ensure that our theoretical constructs, modelling and methodologies are relevant to real-world applications. We must also ensure that they can be used in policy, planning and management. This will be greatly facilitated if policy makers, planners and managers are included in the process of developing the science of landscape ecology.

Everyone with an interest in landscape ecology can play a part in putting these suggestions into action. If we do, landscape ecology really does have a future as a vibrant and useful science.

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