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Forum

Reaffirming Social Landscape Analysis in Landscape Ecology: A Conceptual Framework

DONALD R. FIELD
PAUL R. VOSS
TRACY K. KUCZENSKI
ROGER B. HAMMER
VOLKER C. RADELOFF

University of Wisconsin–Madison
Madison, Wisconsin, USA

Landscape ecology continues to mature as its theoretical grounding is strengthened, its precepts and principles become increasingly accepted in other disciplines, and its broad multidisciplinary perspective becomes adopted as a framework for a growing body of empirical work. The same may be said about a social landscape analysis that draws upon its theoretical foundations in applied demography, human ecology, and rural community studies. In this article, we highlight the theoretical parallels between concepts, principles, and theories in landscape ecology and those in demography. The objective is to expand the scope of landscape ecology by including a more coherent characterization of people, social organizational structure and social relations on the land. We believe an enhanced landscape framework that fully embraces social and demographic processes is essential for obtaining a truly comprehensive understanding of landscape patterns and processes.

Keywords demography, landscape ecology, landscape scale, social landscape

Changing human settlement patterns inevitably alter the landscapes occupied and used by those who settle on the land. From the beginning of European settlement in North America, the initial taming of the land, the inexorable push westward, the sequential conquering of the newest frontiers, the exploitation of natural resources,

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Address correspondence to Donald R. Field, Department of Forest Ecology and Management, University of Wisconsin–Madison, 120 Russell Labs, 1630 Linden Drive, Madison, WI 53706, USA. E-mail: drfield@facstaff.wisc.edu

and the conversion of land to agricultural purposes, all resulted in a social construction of natural resources (Williams and Patterson 1996). Confrontations with indigenous populations who managed to stake out an earlier claim on the land, and the building and expansion of large urban agglomerations, furthered the human imprint on American landscapes. How, and for what purpose, one occupies, transforms, and uses the land results in landscape change. It is the process of analyzing and describing such landscape change that constitutes the focus of our attention.

In particular, we are interested in the process of landscape change in rural areas (although, by extension, the principles outlined here also apply in urban and metropolitan areas). Contemporary migration and settlement in predominantly low-density rural areas with high amenity values such as mountain systems, forests, riverways, and lakes continue to alter the character of such areas in the United States (Johnson and Beale 1994; 1998; Johnson and Fuguitt 2000). As a consequence, issues of sustainable development, biological diversity, ecosystem management, and environmental sensitivity are prime concerns on land parcels adjacent to public lands such as national parks and national forests. Increases in housing stock, often on fragile landscapes like steeply sloping hillsides or littoral lands, are a physical manifestation of human development in these natural systems affecting fragmentation of plant and animal habitats and altering the territorial integrity for threatened and endangered species (Mladenoff et al. 1995).

In the seven states of the U.S. Forest Service's North Central Region, for example, human settlement patterns are generating their most profound effects in the outlying fringes of metropolitan areas and in more remote regions with attractive recreational and aesthetic amenities where recent growth rates have long been high (Gobster et al. 2000). Although the effects of human population growth on forest ecosystems have long been recognized (Ehrlich 1996; Foster 1992; Matlack 1997), most studies have examined regional or global scales (Dale et al. 1993; Fischer and Heilig 1997; Harrison 1991; Kummer and Turner 1994; Mather et al. 1998; Meyer and Turner 1992; Pfaff 1999). Recent attention to eco-regions such as the Pine Barrens of northwestern Wisconsin has documented population growth and housing development in reshaping a landscape once dominated by forest extraction (Radeloff et al. 2000; 2001), a topic to which we return later in the paper.

The purpose of this article is to establish the place of social landscape analysis in landscape ecology. We begin by defining the foundational and organizational principles and definitions of landscape ecology. We then draw comparisons between these principles and their demographic counterparts. We illustrate our perspective by drawing attention to the theoretical and operational comparability of measures such as spatial hierarchy, structure, function, and change from these two fields of study, with examples from our empirical work. We conclude the article by providing some final thoughts on demography and studies of the environment.

A Perspective on Landscape Ecology

Landscape ecology is "the synthetic intersection of many related disciplines that focus on the spatial and temporal pattern of the landscape" (Risser 1987, 3). Studies in landscape ecology can be understood as being constructed from such disparate fields as geology, hydrology, population and community ecology, meteorology, botany, zoology, and limnology, as examples. The purpose of adopting a landscape perspective is not to supersede these separate disciplines, but to demonstrate the hierarchical insights gained when integrating theories and concepts at different scales to obtain a more encompassing understanding of the relationships and flows ongoing between human populations and the biophysical environment.

The history and origins of landscape ecology as a discipline have been traced in several recent publications (see, e.g., Forman 1995), and we do not seek to replicate these efforts. We do wish to emphasize, however, that while landscape ecology is a hybrid discipline, extensively borrowing and generating hypotheses and principles from existing bodies of research, it generally fails to give adequate attention to social processes on the land and to the notion that social change is an integral part of landscape change. For example, insights into landscape structure have been provided by studies of ecological systems (Tansley 1935). Theories and research from phytosociology, island biogeography, and biogeography (including studies of species associations and populations) have been conducted by MacArthur and Wilson (1967). Attention to the effects of human modifications to landscapes (e.g., hedgerow studies in England and France) has been noted by Pollard et al. (1974) and Les Bocages (1976). Only recently have studies in landscape architecture and planning, with explicit attention on aesthetics rather than ecological function, brought attention to human impact on landscapes, opening the door to a more deliberate focus on humans in landscapes. We are aware of the differences in the treatment of the "social" in landscape ecology adopted within the American and European tradition. The European tradition has more deliberately incorporated measures of the human dimension in their landscape analysis. Our discussion here focuses on the American tradition, yet in both traditions there has been a reluctance on the part of natural scientists to incorporate the broad elements of social science and human processes into ecosystem science and processes (Endter–Wada et al. 1998).

The rapid growth of the discipline can be attributed to a number of trends, both technical and substantive, including (1) the ready availability of powerful imaging, remote sensing, and data storage tools; (2) the accumulation of empirical evidence about a wide range of ecological systems (riparian, forest, marine); and (3) the development of scale-consciousness in ecological disciplines. Landscape ecology's importance as a policy tool is likewise broadly recognized. The ongoing debate over land use, so-called smart growth initiatives, and resource allocation and preservation, each made more salient by growing human populations and broad-scale environmental questions, benefits from a landscape perspective.

Forman (1995, 28–29) identifies three broad phases in the evolution of the discipline: (1) independent efforts to understand natural history, ecology, climate, and the physical environment over large areas; (2) the weaving of diverse conceptual threads from several disparate research areas; and finally, (3) the land mosaic or coalescence phase, in which first principles and the importance of a landscape *systems* approach are under development. It is this last phase that characterizes the current state of the discipline, in which researchers are "fitting the puzzle pieces together, and seeing the overall conceptual design of landscape and regional ecology emerge" (Forman 1995, 29).

Landscape ecologists study the interaction of landscape pattern and ecological processes at a variety of temporal and spatial scales (Risser et al. 1984; Risser 1987). Spatial patterning of landscape elements affects the flow of materials, species, and energy in a landscape system; influences the suitability of that landscape as habitat and therefore the presence or absence of species; and impedes or facilitates access to resources and the movement of species. Spatially, a landscape is a mosaic of patches, corridors, and an embedding matrix (Forman 1995, 5–7). Patches consist of relatively small homogeneous areas that differ from their surroundings, which constitute the matrix (Forman 1995, 43). Corridors consist of linear strips, in the form of streams, roads, trails, boundaries, or edges, thus giving physical definition to the patches (Forman 1995, 145). Where identifiable, the matrix is the background or dominant ecosystem in a landscape, and either constrains or supports patch connectivity and the movement of organisms and materials between landscape elements (Forman 1995, 277–282). Landscape ecology studies the spatial relationship between patches, corridors, and the matrix as these landscape elements influence and are influenced by ecological processes.

We note here that the field of landscape ecology can accommodate, as well, the discussion of human landscapes and, more importantly, the organization of human society within the natural landscape. Landscape ecology as a field of study considers humans as actors in, and therefore a part of, the landscape (see Naveh and Lieberman 1994, 9; Risser et al. 1984, 7). Research in landscape ecology frequently acknowledges human impacts on the landscape (Delcourt and Delcourt 1988; Franklin and Forman 1987) and increasingly incorporates human *measures*, both qualitative and quantitative (LaGro 1998; Nassauer and Westmacott 1987; Radeloff et al. 2001; Wear et al. 1996).

We further note, and attempt to demonstrate in the course of this article, that the discipline of demography can similarly accommodate the discussion of *biophysical landscapes* and the organization of the biophysical world within the human landscape. It is our belief that the discipline of demography provides the perspective, the tools and measures, and, critically, the *scale equivalents* to successfully integrate the social with the biological.

A Perspective on Social Landscape Analysis

Social landscape analysis can be defined as the study of the spatial distribution of interrelated social variables in a given biophysical setting. Demography can be defined as the study of the size, territorial distribution, and composition of human populations (Hauser and Duncan 1959). Population study is a field that came of age in the United States with very close links to the field of ecology (Frank, 1959), and it is this historical tie to ecology, generally, that links demography to the core of social landscape analysis (Grove and Burch 1997). Space and time are essential ingredients for understanding human population structure, distribution across the land, and the social organization of rural communities. In the first half of the 20th century, rural demographers in several regions of the nation were able to describe patterns of community growth and decline associated with spatial relations of communities one to another and to metropolitan areas. Examples of these rural demographers include Galpin (1915), Kolb (1933), Chittick (1955), Landis (1933; 1938), Zimmerman (1930), Lively (1932), and later Fuguitt and Deeley (1966), Fuguitt and Field (1972), and Johansen and Fuguitt (1984).

Similarly, environmental features and natural resource attributes contributed to the social organization, growth, and decline of rural communities. Hypes (1944) compared soil quality to farming practices and community well being. He noted, "soil erosion is in essence human erosion, one cannot be solved without the other" (Hypes 1944, 364). Kolb (1921) included a discussion of topography and soils in his examination of the formation and distribution of rural neighborhood social groups. By plotting the location of groups and frequency of contacts between groups on U.S. Geological Service (USGS) topographical maps, Kolb concluded there was a demonstrable relationship between social group activity, vegetation composition, and the contour of the countryside (Kolb 1921).

These two examples illustrate the connection of the social with the biophysical that rural sociologists considered so important to an understanding of the social organization of rural America. In essence, it is the interaction of social patterns on the land and characteristics of the natural resource base and ecological processes that informs social landscape analysis. This form of inquiry at a landscape scale was pioneered by C. J. Galpin in Walworth County, Wisconsin. Galpin utilized social landscape analysis to define measures of community attachment between the rural trade center and its hinterland population, and in doing so was able to map community boundaries in space and time. His work clearly denotes the mutual interdependency of farm and trade center. Social landscape analysis helped social scientists understand the organization and distribution of rural towns across the countryside (Galpin 1915). Landis (1933) mapped the location of all rural towns in South Dakota and reaffirmed the interdependency of rural farm families and trade center viability. He likewise added the variable of change to the spatial relations of farm and town. As farming systems changed from horse-drawn to tractor power, farm size changed and the number of small farm operations began to decline, directly affecting the survival of trade centers. Lively (1932) and Zimmerman (1930), following similar analytical strategies, noted similar trends in Minnesota. Transportation systems such as rail, state highways, and the interstate system (landscape corridors), connecting rural societies with metropolitan America, redefined the spatial relations of rural towns. Vance (1929) examined agricultural regions in the south at a regional scale. One of his contributions to our understanding of human landscape homogeneity or heterogeneity was his focus on crop systems across the southern cotton producing region.

Contemporary demographic studies also illustrate the relationship of human populations to natural resources at a landscape scale. In our own work, for example, Kuczenski et al. (2000) examined the social structure associated with land cover for an entire watershed. In this study the watershed was divided into five natural subwatersheds. Kuczenski selected two subwatersheds with different vegetation cover characteristics and compared the association of occupational structure and work patterns, such as commuting, with land cover. Kuczenski's work was followed by that of Radeloff et al. (2000, 2001) in two articles examining the association of housing density with land cover. He notes the relationship of housing to forest species composition and forest density (in comparison with other vegetation components and presence of water). Similar analyses were carried out by Grove and Burch (1997) for a metropolitan watershed. These articles represent an enhanced conceptual formulation establishing the social element in landscape ecology.

Finding a Common Ground On which to Merge Theory and Method

Diverse and heterogeneous landscapes can be characterized by three fundamental concepts: structure, function, and change (Risser 1987, 5). Landscape has a structure consisting of a web of associations of species and habitat in spatial relationships within distinctive ecosystems. Landscape structural elements include but are not limited to the following: vegetation, birds, fish, invertebrates, amphibians, mammals, soils, hydrology, rocks and minerals, and climate regimes (see Table 1).

At a landscape scale, human population size, composition (e.g., age, gender and ethnicity, income levels and concentration of wealth, labor-force participation) and

TABLE 1 Illustrative Biophysical and Social Landscape Elements

Elements	Biophysical landscape	Social landscape
Structure	Species composition and distribution, habitat suitability, soil type, climatic zone, rainfall abundance, hydrological system	Population size, composition and distribution, housing stock (type, age), socioeconomic characteristics (educational attainment, income, labor force participation), occupation and industry mix, land tenure and land use, transportation and communication infrastructure, energy use
Function	Patch connectivity, biogeochemical cycling, photosynthesis, nitrogen fixation, sediment transfer, decomposition	Production, consumption, government, employment, commuting, education, health, population renewal (fertility, mortality, migration), capital allocation
Change	Species persistence/extinction, disturbances (e.g., fire, insect infestation, disease, flooding), eutrophication, desertification, succession, climate change	Demographic transition, neighborhood succession, economic recession, industrial transformation, urbanization, compositional change, farm consolidation

geographic distribution provide structure to a social system (Hauser and Duncan 1959). The spatial arrangement of these disparate elements gives each landscape its unique pattern, a pattern that shapes and is shaped by that landscape's functions or processes. Landscape functions entail the flows of energy and materials across and among landscape elements. These functions consist of both abiotic and biotic phenomena, including, for example, wind and water flows, disturbance events, the movement of soil and nutrients, photosynthesis and respiration, and species movement, reproduction, competition, and predation. Levy (1966), among others, suggests that social institutions of economy, family, education, and governance represent social functions. Social system functions, which find their expression at a landscape scale, also include nurturing, education, employment, bartering, production, commuting, and migration. Such functions consist of relationships and interactions between and among population members and institutions. These institutional and population components, in concert with the elements of ecosystems described earlier, constitute a landscape's structure and function and determine spatial arrangements and boundaries between and within landscapes. Finally, each landscape will undergo change in both structure and function over time. Changes to the landscape occur seasonally, daily, in response to a climatic event, as a result of natural and human disturbances, and through species extinction or colonization. Societies, too, undergo change in their structure and functions. These changes invariably affect the relationship of that social system to its biophysical environment. Some examples of social changes include population growth or decline, shifts in

TABLE 2 Examples of Scale Equivalence in Demography and Landscape Ecology

Spatial hierarchy	Biophysical landscape	Social landscape
Individual site	Tree, plant, animal, insect Sampling plot, stand, patch, corridor, stream, gap, remote-sensing pixel, species	Person, fence post, well Household, family, land parcel, apartment building, office tower, neighborhood, street, highway, block and MCD boundaries, census block group, town, village, fence, farm, university, manufacturing plant
Landscape	Watershed, local biome, soil district, floodplain, wetland	Community, city, county, census tract, school district, lake conservation district, development/empowerment zone
Physiographic region	North Pacific Border, Upper Sonoran	State, census division, census region
Extended region	Ecoregion, biome	Nation, continent

economy from agricultural subsistence to industry, technological innovation, educational improvement, and aging of a population.

Observable landscape patterns and processes vary with the scale of observation. In landscape ecology and demography, attention is placed on processes, structure, and change at a variety of spatial and temporal scales (see Table 2). The size or extent of the scale chosen for study range from a square meter quadrat, widely used in ecological field studies (see, e.g., Connell et al. 1997, 464), to a watershed, a forest stand, a nation-state, or a continent. Because there is an infinite variety of processes operating on an infinite variety of temporal and spatial scales, the landscape ecologist must pay particular attention to explicitly defining the scale chosen for study (Risser 1987, 10). A researcher's choice of scale will affect the types of questions asked and observations obtained. Landscape ecology has borrowed from hierarchy theory (Allen and Starr 1982) to establish parameters for investigating the structure and function of landscapes at a chosen scale (Risser 1987, 10). Scale in social landscape analysis is often examined at the land parcel (individual), neighborhood, community or region/watershed. Scale equivalence in demography and landscape ecology is outlined in Table 2.

Disturbance events and disturbance regimes are ecological processes and agents of change on which landscape ecology focuses substantial attention. (see, e.g., Connell et al. 1997; Pickett and White 1985; Turner 1987; Turner et al. 1997). Pickett and White define a disturbance as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resource or substrate availability, or the physical environment" (1985). A disturbance, therefore, can include a wind or violent thunderstorm, flood, fire, volcano, pest outbreak, or human-induced conversion of land. These same events can be examined as disturbance in social systems. Disturbances occur at varying spatial extents and recur at varying temporal intervals.

Disturbances in social systems, like biological systems at a particular landscape, can be characterized by the frequency of occurrence, spatial extent, severity, and intensity. Disturbances do not act uniformly upon a landscape, but instead affect complex structural mosaics having differing potential for processes such as recovery or re-colonization (Turner et al. 1997). In the case of social systems, resettlement with structural adaptation to disturbance would be a comparable analysis.

For purposes of this discussion, we adopt a perspective of social landscape analysis in the context of landscape ecology that (1) integrates biophysical and sociocultural elements; (2) analyzes social systems at the landscape at varying scales; (3) accommodates landscape measures such as matrix, patches, corridors, and disturbance events within social landscape analysis; and (4) has relevance to current efforts at ecosystem management (see, e.g., Hawley 1998; McKenzie 1926; Park 1936/1982; Sauer 1925). By employing such a perspective, the interrelationship between demography and landscape ecology becomes clear. The interactions between social structure and function and the structural and functional attributes of the biophysical landscape foster distinctive social-cultural systems and shape the manner in which environmental dimensions are incorporated into these systems. Elsewhere we have integrated and compared social and biophysical structures (Radeloff et al. 2000; 2001). Our approach is illustrated by integrating population and housing census data for very small areas with satellite remote-sensing pixels and by examining housing stock (as a measure of social structure) and land cover (as a measure of vegetation structure). Further, we created a measure of social structure change by examining growth and decline of housing stock from 1940 to 1990.

In Table 1 we attempt to make explicit the comparability and linkages between social and biophysical measures in an integrated social and biophysical landscape ecology. For example, species composition in a given habitat is a measure of structure. Likewise, human population composition is a measure of structure. We are witnessing a growth of retirement age populations moving into high amenity natural resource regions (Johnson and Beale 1994). The structure of communities with growing elderly populations and community attitudes toward nature conservation may be much different from those in a community with a younger age structure composed predominantly by families with school age children. In Table 2, we illustrate the comparability of scale between landscape ecology and demography. Here we can span the smallest scale of forest stand and human land parcel to continents and subcontinents. In both cases there is much to be gained by cross-fertilizing our respective fields with measures from another. A more holistic approach results and places the human actor within the natural resource equation.

The detailed results of our merger of two systems integrating concepts and measures from demography and landscape ecology have recently been reported elsewhere (Kuczenski et al. 2000; Radeloff et al. 2000; 2001). We found, for example, that housing densities (a measure of social structure) were higher where water (physical structure) was more abundant, clearly revealing the presence of seasonal and recreational homes located on the many lakes in these counties in the southern Pine Barrens of Wisconsin (Radeloff et al. 2000). In addition, herbaceous or grassy land cover (physical structure) was associated with medium housing density classes, consistent with the dispersed, separated nature of housing in predominantly agricultural areas. Finally, for purposes of illustration, low housing unit densities were found to be associated with pine forested areas. This is consistent with the extent of pine plantations in the region, many of them part of private industrial holdings, and with county and national forests where the building of housing is prohibited.

The demonstrated ability to quantitatively correlate elements of the biophysical landscape (ground cover) with elements of the social landscape (housing density) reinforces our desire to have a language and a conceptual framework that communicate well the characterization of people and social relations on the land. Each landscape has been long been characterized by structure, function and change. Our research in the Wisconsin Pine Barrens and in the Wisconsin Kickapoo River watershed illustrates in a small first step what can be accomplished in linking a biophysical landscape element with a social landscape element (Kuczenski et al. 2000; Radeloff et al. 2000). This research reflects an enhanced landscape perspective that embraces social and demographic elements and processes as part of the structure, function, and change in landscape patterns generally. It provides the beginning of an encompassing understanding of the relationships and flows between human populations and the biophysical environment. It is a framework designed to facilitate further research in these areas and for better guiding natural resource management and planning.

Our work continues to employ additional measures from the two fields and at various scales. With support from the U.S. Forest Service we are commencing a study to identify specific "hot spots," places where the course of population and housing development in the Forest Service's North Central States is carving up the local landscape at a particularly rapid pace, or where the consequent land fragmentation is threatening specific plant or animal species. The identification of hot spots is essential to landscape or district land management. In addition, we are building forecasting models that incorporate elements of both human populations and the biophysical landscape to anticipate changes in future demographic, social and economic structures and the interrelationships of these changes to change in the biophysical landscape.

Concluding Remarks

The demographic link to social and biophysical ecological process and function has been well documented. For much of the last century the fields of human ecology and animal and plant ecology have been described, dissected and their similarities, differences and potential convergence examined. Grove and Burch (1997) provide an excellent summary of the progression and convergence of the two fields of study and the emergence of an integrated ecological approach to ecosystem analysis. The authors trace the pioneering developments in human ecology, biological ecology and systems thinking. We need not replicate that story here. Rather, we focus on two dimensions of their review. First, the authors note that an integrated ecological approach bridging the social and biological system began to mature in the mid-1980s. Second, they note that many presentations based on the framework of an integrated ecology remain more conceptual and organizing rather than empirical in nature.

With regard to the maturation process of an integrated approach to humans and the environment, credit should also be given to the emergence of natural resource/environmental social science scholarship. For example, Buttel (1996) and later a special issue of *Society and Natural Resources* edited by Buttel and Field (2002) take note of and review the respective histories of natural resource sociology and environmental sociology. Further, the conceptual frameworks and theoretical directions of these fields have been examined by natural resource/environmental sociologists who recommend the inclusion of biophysical variables within a comprehensive integrated social biophysical framework. Burch (1988) and Field and Burch (1988) illustrate the inclusion of "humans as part of an ecological system" in their description of social ecology and the future directions in natural resource research and management. Their call and outline of ideas in an integrated ecological approach to environmental studies was followed by several others proposing more specific conceptual frameworks. Machlis, Force, and Burch (1997) is one such example. Most notable, however, in terms of an empirical reference point, is the conceptual framework presented by Grove and Burch (1997) in their Baltimore work. The authors note:

> [the new human ecosystem framework] provides the basis for using a systems approach to integrate sociocultural and biophysical systems by describing the internal behavior of these systems and their interactions with each other in terms of human ecosystem flows and cycles of critical resources. (p. 263)

The authors go on to identify specific variables from the social and biological world that can be accommodated within an integrated ecological system. Like Grove and Burch, we herein view an integrated approach through the dual lenses of demography and landscape ecology. Both research teams illustrate the power of an integrated approach by focusing on patterns and processes at different scales. Yet Grove and Burch note, as do we, the paucity of empirical work testing the integrated conceptual framework. The Baltimore project is one such effort. Our work in Wisconsin is another. Grove and Burch call for "shared biosocial vocabularies and measures." We agree, and have made this the intent of the present article. We have focused specifically on demography and demographic measures of ecological systems because, more often than not, when empirical representation of the human ecological framework is presented, demographic data form the basis for the analysis. In a sense, demography has been and continues to be a handmaiden of human ecological analysis. In this light, we provide a conceptual framework linking demographic measures and scale with landscape ecological measures and scale. We illustrate the power that demographic measures have for addressing an integrated social/cultural and biophysical ecological system at different landscape scales. Land use planning and management, particularly ecosystem management, applied on public lands will benefit from a strong demographic data base. In this sense we also agree with Grumbine (1997) that ecosystem management must be predicated on inclusion of social data at multiple scales.

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