Chapter 3

Managing Forest Landscapes for Climate Change*

Thomas R. Crow

Abstract Climate change is the defining issue of the day and probably for many subsequent generations of resource managers. Although the public and therefore the policymakers have been slow in grasping the far-reaching consequences of climate change on our social and economic institutions, they are now desperately seeking options for dealing with novel climates, ecological uncertainties, and potential social and economic dislocations. The challenges cannot be overstated, but neither can the role of scientists in helping provide the knowledge for making informed decisions. The science of landscape ecology, with its emphasis on integration and holism, has an important role to play in informing decision makers. In this paper, I explore this role in the context of managing forest landscapes.

3.1 Introduction

Climate change is the most challenging issue confronting contemporary and, for that matter, future resource managers. It affects every aspect of resource management, be it commodity production, biological diversity, land use, forest health, fire, water, invasive species, resource sustainability, and ecosystem services. For some interactions between climate change and resource management, a substantial body of knowledge has accumulated. Stocks et al. (1998), for example, used four current General Circulation Models (GCMs) to project forest fire danger levels in the Canadian and Russian boreal forests. The forecasts for seasonal fire weather severity were similar among all four GCMs – each projected a longer fire season and a large increase in the areal extent of extreme fire danger for both countries under a 2 X

T.R. Crow
Research and Development, Environmental Sciences Staff, USDA Forest Service, Stop Code 1113
1400 Independence Avenue, SW Washington DC 20250-1113 USA
e-mail: tcrow@fs.fed.us

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CO_2 climate scenario. Likewise, climate is a fundamental driver of the water cycle and so significant changes in precipitation patterns, storm intensity, evaporation, transpiration, timing of snowmelt, snow vs. rain events, and groundwater level can be expected with climate change (Houghton et al. 2001). With water, it is not only quantity but also quality and securing sources of safe drinking water that are of concern. The vulnerabilities of supply are linked not only to climate change, but also changes in demand related to a growing human population and economic development (Vörösmarty et al. 2000).

For other interactions, little is known. Although the potential for impacts of climate change on fire, water, forest health and productivity are widely acknowledged, how these impacts will play out in time and space is not well understood. Because of its emphasis on understanding ecological processes in time and space, the science of landscape ecology can play an important role in improving our understanding about the possible impacts of climate change on natural and human capital.

The movement toward investigating large systems reflects, in part, new technologies that enable scientists to study them. It also reflects an appreciation in the scientific world that phenomena observed and studied at small scales are part of larger systems. A corollary to this in the realm of resource management is the recognition that informed decisions can not be based solely on a single species or local site, but they require the context provided by larger spatial areas that encompass many species and multiple ecosystems (Turner et al. 2002).

Although the terms "managing landscapes" and "landscape management" are a common part of the lexicon for resource managers (Crow 2005; Rolstad 2005), the meaning of these terms is not always clear. For purposes of this paper, a landscape is defined as consisting of a mosaic of interacting ecosystems, both aquatic and terrestrial, that occupy a geographic space somewhere between the local and regional levels. While this may seem rather imprecise, the defining characteristic is clear – two or more interacting ecosystems constitute a landscape. Thus ecosystems are the fundamental unit defining landscapes. The ecosystem concept has deep roots in both science (Tansley 1935; Odum 1969; Golley 1996) and management (Schultz 1967; Crow and Gustafson 1997). It is a spatially-explicit unit for which the standards for identifying and classifying are in place (e.g., Rowe 1962; Bailey 1983; Host et al. 1996; Cleland et al. 1997), and for which boundaries can be identified and mapped (e.g., Spies and Barnes 1985; Albert 1995; Keys et al. 1995). By integrating the biota or biosphere with landform, soil, and atmosphere, the physical environment or geosphere, the ecosystem concept provides a useful and powerful tool for understanding and managing complex natural systems (Rowe and Barnes 1994).

In their August 2007 report, the Government Accountability Office (GAO) identified the challenges facing federal resource management agencies such as the USDA Forest Service, National Park Service, Fish and Wildlife Service, Bureau of Land Management, and National Oceanic and Atmospheric Administration in addressing climate change (GAO 2007). Specifically the GAO states that "resource managers have limited guidance about whether or how to address climate change and therefore, are uncertain about what actions, if any, they should take." The GAO further asserts that "resource managers do not have sufficient site-specific information to plan for and manage the effects of climate change on the federal resources they oversee."

The purpose of this paper is to explore the value of a landscape perspective when addressing climate change. My intent is to provide general principles for managers as they consider strategies for adapting to a changing climate. Although these principles are not the specific prescriptions needed by managers, they are an important first step toward developing them.

3.2 Including People

This general principle is listed first because it is the most important. Although it seems rather obvious, never-the-less including people when managing landscapes for climate change needs to be stated explicitly.

People are part of the landscape and they are being affected by climate change. As stated by Allen (2004), landscape management "will not work unless it involves explicitly giving people options that they are prepared to use, and a sound basis to select among them." In other words, we as scientists and managers need to understand what motivates people to act and how they make choices and assess risk while conducting their lives in the biological and physical worlds that we study and manage. The key is being responsive to society's changing and diverse values and expectations (Bengston 1994).

3.3 Looking Beyond the Forest

The second principal deals with the scale at which resource management occurs. Scale is a characteristic dimension for both space and time which deals with the relative size, extent, or level at which an object, process, or action occurs (Lovell et al. 2002). The fundamental issue is this: focusing on a single scale in time or space obscures important processes or properties that are obvious at larger or smaller scales. In many respects, climate change is the perfect example for illustrating the need to consider multiple scales. Although climate change is a global phenomenon, it affects processes occurring at all spatial scales.

From a management perspective, this need to consider multiple scales in time and space complicates the already difficult task of managing natural resources. But there are some practical approaches that can be used when a landscape perspective of the forest is employed. The first is to make local management decision within the context of landscape, regional, national, and even global information. The USDA Forest Service and many other federal and state agencies have conducted numerous broad-scale biophysical and social assessments in response to a variety of issues and needs (Johnson et al. 1999; Jensen and Bourgeron 2001). Perhaps the best know of these assessments is the Northwest Forest Plan which is a bold attempt to implement adaptive resource management on the west side of the Cascades in the states of Washington and Oregon. Assessments for other regions of the United States exist as well – e.g., Southern Appalachian Assessment, Great Lake Ecological Assessment, Sierra Nevada Ecosystems Project, and Southern Forest Resource Assessment (Crow 2006). Although few of these sources currently deal explicitly with global change, you can expect much more emphasis given to this topic in the near future.

Within the United States, the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 requires the USDA Forest Service to conduct periodic reviews of the nation's renewable natural resources. These reports, another good source of contextual information, include analyses of present and projected trends in the resource base at the national level. For example, in their RPA publication entitled *Land Use Changes Involving Forestry in the United States: 1952–1997, with Projections to 2050,* Alig et al. (2003) project a 3% or 23 million acre reduction in total forest area in the United States by 2050 compared to 1997. Most of these changes are due to projected increases in population and income that will likely result in demands for converting forests into urban and other developed landscapes. Other assessments such as the Heinz Center's *The State of the Nation's Ecosystems* or the United Nations' *Millennium Ecosystem Report* involve the efforts of many experts.

Collectively, these reports provide a state-of-the-knowledge about the conditions and trends of the world's ecosystems and the services they provide. When available, these assessments provide an excellent source of contextual information for making local management decisions.

3.4 Reading the Landscape

Interactions among soil, landform, climate (i.e., the physical environment) and human land use profoundly affect the composition and structure of the landscape (Crow et al. 1999). Landscape composition can be obtained using remote sensing, ecosystem classification, and mapping of natural features such as vegetative cover types or lakes and rivers as well as features resulting from human land use such as agricultural lands, urban and industrial lands, reservoirs, and transportation networks. Landscape structure is a measure of spatial heterogeneity. The spatial configuration as defined by the size, shape, and arrangement of cover types or patches create structure on the landscape. For managers, the size-class distribution of patches is a useful metric for characterizing landscape structure. Typically a landscape contains many small patches and a few large patches. The large patches serve an important "connecting" function that facilitates the flow of materials and organisms through a landscape.

Because of the physical linkage between the earth's surface and the atmosphere, changes in the composition and structure of the landscape can have pronounced effects on weather and climate (Pielke and Avissar 1990). Both observation and modeling demonstrate the influence of landscape characteristics on atmospheric conditions. Numerous studies document changes in near surface microclimate conditions with changes in surface conditions (see, e.g., Chen et al. 1999), so it is reasonable to conclude that changes in surface properties can affect the regional atmosphere (Pielke and Avissar 1990; Pielke 2005). The physical linkage between the surface and the atmosphere has to do fundamentally with albedo and the fractional partitioning of atmospheric turbulent heat flux into sensible and latent fluxes. Parameters in these budgets are directly dependent on the surface properties (e.g., an asphalt surface compared to forest cover) and the vegetation characteristics such as height, aerodynamic roughness, displacement height, percentage cover, and photometric properties. Both empirical and modeling studies suggest that even small changes in land use and changes in their spatial distribution can cause major alterations in local and regional atmospheric conditions. Much less is known, however, about the cumulative effects of the present surface properties (both amount and distribution) on global climate (Pielke and Avissar 1990).

Just as foresters can walk through a forest and make judgments about its suitability for a commercial harvest or for providing suitable habitat for deer or grouse, managers also need to read the landscape in which the forest exists in order to make judgments about the quality and quantity of goods and services that the landscape is capable of providing. Given the number of road crossing over streams, is it likely the landscape will produce clean water? Are critical habitats present in the landscape for threatened and endangered species? Are old as well as young age-classes for trees included in the landscape? Are undeveloped lakeshores present? What is the density of roads and trails in the landscape? Do the ephemeral ponds exist within the landscape and, if so, where? Given the soil types and landforms, what is the productive potential of the land? What forests types are present? What proportion of the landscape is forested compared to agriculture or urban and how are these different land covers arranged? By addressing these and similar questions, the resource manager and planner gains an understanding of the ecosystem services that the landscape can provide. By answering these and similar questions, the resource manager and planner are reading the landscape.

3.5 Managing Composition and Structure

Principle three, reading the landscape, is the antecedent to managing composition and structure. Desired changes in goods and services based on reading the landscape are derived from manipulating landscape composition and structure. Because of the demands humans are placing on the lands and waters, greater emphasis will be placed on designing landscapes to meet specific management objectives that, in combination, provide the array of goods and services desired by society. One example of manipulating structure relates to providing conductivity within the landscape. The migration of species during climate change is critical to their survival. The combination of land use and climate change place many species at risk unless migration is possible. Current land use patterns (especially habitat fragmentation) create barriers to migration and increase the isolation of some populations. As the landscape becomes dissected into smaller parcels of habitat, landscape connectivity (the functional linkage among habitat patches) may become disrupted. This limits the distribution and persistence of populations.

Corridors are one of many structural features that have been being studied within the landscape. Within the scientific community, a robust discussion is ongoing about the effectiveness of corridors to facilitate the movement of species and their populations in response to habitat fragmentation (e.g., Simberloff and 1987; Simberloff et al. 1992; Beier and Noss 1998). Corridors have been shown to maintain and enhance biological diversity, but corridors also facilitate the movement of invasive species, pests, diseases, as well as increase the risk to predation and the spread of disturbance. The effectiveness of corridors depends on many factors, including a species' habitat requirements, the dispersal ability of a species, and local environmental conditions. Habitat specialists with limited dispersal capabilities will likely have a much lower tolerance to habitat fragmentation (and climate change) compared to highly mobile, generalist species.

With the goal of creating forests that are resilient to a changing climate, greater emphasis is needed on the relation between landscape structure and the distribution and persistence of plant and animal populations. Spatially-explicit population and habitat models are useful tools for understanding species movement, their patterns of extirpation, and the processes that promote recolonization within a landscape. Gustafson and Gardner (1996) used an individual-based dispersal model to measure immigration and emigration rates between habitat patches within heterogeneous landscapes. The model was used to estimate the probabilities of disperser transfer between patches by varying the *a priori* probabilities of movement into each habitat type in order to estimate the effect of changing landscape heterogeneity on the transfer probabilities, and to visualize dispersal corridors and barriers as perceived by model organisms operating by specified rules and at specific scales. The results show that 89% of the variability in dispersal success can be accounted for by differences in the size and isolation of forest patches, with closer and larger patches having significantly greater exchanges of dispersing organisms (Gustafson and Gardner 1996). Further, their results suggest that corridors are often diffuse and difficult to identify from structural features in the landscape. Understanding how landscape structure, including well-defined corridors and other structural features, affects the movement of species will be critical to devising strategies that mitigate the effects of climate change (Taylor et al. 1993).

3.6 Designing the Landscape

This principle is an extension of the previous two principles. Designing landscapes deals fundamentally with managing the composition and structure of the landscape in order to meet some socially-defined outcomes and benefits. Most design principles utilized in land planning and management are directed at gaining economic efficiency or for providing aesthetic appeal rather than sustainability. Although there is increased recognition that more sustainable approaches are needed for planning and managing landscapes, much of the available information is conceptual and theoretical, and little of it deals directly with adapting to climate change. Leitão and Ahern (2002) present a conceptual framework for sustainable landscape planning through the application of ecological knowledge in the land planning process. Designs for local adaptation in which the behavior of resident individuals is guided by feedbacks from their immediate environment (e.g., Levinthal and Warglien 1999), based on organizational theory and behavior of complexity systems, certainly have implications for adapting to climate change. In the realm of urban planning, concepts such as "smart growth" to reduce urban sprawl can also reduce the greenhouse gases that are, in large part, responsible for climate warming.

The challenge is to relate the composition and structure of landscapes to the ecosystem services they provide. Ecosystem services are defined as those benefits people obtain from ecosystems (Mooney and Ehrlich 1997). Undeveloped forestlands provide clean drinking water, wood products, wildlife habitat, and recreational opportunities that may not be available in the developed landscape. In order to maximize these ecosystem services, Forman (1995) suggests arranging land uses based on what he calls the aggregate-with-outliers principle in which aggregates – contiguous areas of natural vegetation – are maintained along with smaller outliers distributed throughout the developed (i.e., agriculture, urban, industrial, infrastructure) landscape. The undeveloped forestland or aggregate provides unique ecosystem services and these services are supplemented by the dispersed outliers embedded in the developed landscape. Unfortunately, as lands become subdivided and developed, the likelihood for providing high quality ecosystem services such as clean water and air or the production of wood declines. Clearly, no one ownership class – public or private – can provide all the desired goods and services that can be derived from the forest. New mechanisms for coordination and collaboration are needed in order to make stewardship across boundaries possible (Yaffee 1998). Further, no one collaborative model will fit all cases; instead, many different partnerships, each tailored to meet local and regional needs, are likely.

3.7 Embracing Complexity

Landscapes are comprised of discrete, bounded patches that can be differentiated using either biotic or abiotic features (Pickett and Cadenasso 1995). The origins of this landscape mosaic relate to the interaction between the physical environment and human land use. Understanding how this spatial variation and changes in these patterns affect movement of organisms and fluxes of materials and energy is a centerpiece of landscape ecology. Because ecological phenomena respond to spatial heterogeneity, the response of ecosystems to climate change is likely to differ depending on the type of ecosystem and where that ecosystem occurs in the landscape.

Just as the responses to climate change will vary in space, ecosystem responses to climate change will vary with time. Some changes are likely to occur quickly and will become readily apparent, while other changes appear to occur more gradually and uniformly through time and thus will be less apparent in the short term. Some events such as an acute regional expose to ozone due to atmospheric conditions are episodic in their occurrence, while others such as seasonal monsoon rains are more cyclical in their temporal pattern. A 100-year drought may be stochastic when viewed in the short term, but are periodic when viewed in the long term. Other patterns are ephemeral (e.g., an intermittent stream) or continuous (e.g., groundwater movement) through time. Each of these varied responses adds temporal heterogeneity that necessitates considering many different time scales in order to understand the responses of ecosystems to climate change or any other disturbance.

Throughout much of its history, ecologists sought to minimize the variation in the systems they studied. Perhaps more insights would have been gained if just the opposite strategy had been employed. Likewise, resource managers have attempted to reduce the variation in the structure and composition of managed forests due largely to operational and economic considerations – creating a forest that is homogeneous in its composition and structure reduces the costs associated with extracting and processing wood. The cumulative effects of forest management at the landscape and regional scales tend to simplify the compositional and structural complexity of forest ecosystems (Schulte et al. 2007). Managing for complexity is likely to result in greater resilience and to promote adaptability of forest ecosystems to climate change.

3.8 Confronting Uncertainty

Resource managers are always making decisions under circumstances with high degrees of uncertainty. It is simply the nature of the job when we lack understanding about complex systems and given our inability to predict the future. This is the case with climate change. As previous mentioned, there is a high degree of uncertainly associated with how climate change will play out in both time and space. In their short but remarkable paper *Uncertainty, Resource Exploitation, and Conservation: Lessons from History*, Ludwig et al. (1993) provide useful suggestions for taking uncertainty into account. They remind us that although there are well-developed theories supporting decision-making under uncertainty, most times it is more about using common sense.

In their words:

> We must consider a variety of plausible hypotheses about the world; consider a variety of possible strategies; favor actions that are robust to uncertainties; hedge; favor actions that are informative; probe and experiment; monitor results; update assessments and modify policy accordingly; and favor actions that are reversible.

3.9 Conclusion

Adapting to climate warming will be the defining challenge for forest managers now and into the future. The challenges are enormous given the complexity of the underlying biological, physical, and social systems. Our science and therefore our management historically have featured reductionism in which the pieces are featured at the expense of the whole. While reductionism has its place, it alone is not sufficient to address the many complex, large-scale problems facing society. A landscape perspective is helpful for resource managers when developing adaptive strategies for climate change because it: (1) places humans at the center because they effect and are affected by climate change; (2) provides social, economic, and ecologic context for local decisions; (3) improves understanding of the cumulative impacts of multiple treatments and multiple stresses at large scales; (4) supports adaptive management when combined with monitoring; and (5) encourages a more holistic and integrated approach to science and resource management.

Climate change is but one compelling reason for conducting landscape-scale research. Success depends on our ability to understand interactions among biophysical components and between biophysical and social systems (Mills 2004). Landscape ecology provides a formal framework in time and space as we hedge, experiment, probe, monitor, assess, and finally adjust our actions as we learn more about the changing world in which we live.

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