Chapter 9

Tools for Understanding Landscapes: Combining Large-Scale Surveys to Characterize Change*

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Abstract All landscapes change continuously. Since change is perceived and interpreted through measures of scale, any quantitative analysis of landscapes must identify and describe the spatiotemporal mosaics shaped by large-scale structures and processes. This process is controlled by core influences, or "drivers," that shape the change and affect the outcome depending on their magnitude and intensity. Our understanding of landscape change and its drivers depends upon many different sources of information of varying quality and breadth – some quantitative, some systematic, others anecdotal or qualitative. In this respect, large-scale surveys and inventories capable of documenting landscape composition, structure, and dynamics, both past and present, can prove to be vital tools for addressing contemporary resource issues. This chapter examines the role of large-scale inventories in identifying landscape change and developing hypotheses about the underlying drivers. Although a number of such sources exist, we shall focus on two from the United States: the Public Land Surveys (1785–1900), and the US Forest Service's Forest Inventory and Analysis program (1930s-present). After defining landscapes and providing definitions and examples of landscape change, we evaluate these surveys with respect to their potential use for ecological analysis, and present examples of their use for ecosystem reconstruction. These longitudinal comparisons are a good first step in understanding the biophysical processes that drive landscape change, but determining the influence of other drivers – social, cultural, or economic – requires other sources of information that are rarely systematic or conclusive. To this end, cautious analysis and conservative conclusions are essential when employing this mix of data sources.

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9.1 Landscapes and Landscape Change

Landscapes are the expression of the inherent productive capability of any given area as shaped by climate, parent materials, the biota, and environmental history and as influenced by continuums of endogenous and exogenous biophysical drivers (Bolliger 2005; Bolliger et al. 2003). As a result, landscapes continually change over time and space. While these changes may or may not be desired, particular outcomes are certainly preferred. To this end, understanding landscape change can help society mitigate the effects of change or at least identify undesirable patterns and processes to be avoided. This chapter examines the role of large-scale surveys in defining landscapes and, by inference, landscape change. After a brief introduction to the concept of driving forces, three examples of landscape change analysis are presented that compare landscapes separated by almost 2 centuries.

For recent changes, evidence tends to be well documented and relatively easy to investigate. This, however, is not the case with historical landscape change. Given fewer and often less accurate sources of information, discerning the mechanisms behind past landscape change becomes more challenging. Not that historical information is without value – prior events and observations can contribute towards the understanding of previous environmental conditions (Fei 2007; Goforth and Minnich 2007). Rather, more exacting research is needed to identify processes and consequences of prior land use to foster collaboration with fields other than ecology to ensure interdisciplinary science (Wu and Hobbs 2002; Bürgi et al. 2004; Bürgi et al. 2007). After all, the factors driving past environmental change, though often the same as those occurring nowadays, can have fundamentally different consequences on modern landscapes.

Furthermore, assessment of landscape change involves looking beyond the local landscape or research question to search for general properties that can be applied elsewhere (Bürgi et al. 2004). Are there common drivers that might explain landscape change across ecoregions or even climatic zones? If so, are these drivers temporally extensible? Assuming that at least some of the factors that shaped past landscapes still affect those observed today, what does this tell us of future conditions? For instance, natural disturbances continue to resonate across forests, with concurrent biotic responses to these alterations. Knowing how the environment responded to perturbations in the past should provide at least a hint about how a landscape may respond to similar disturbances.

Another challenge in understanding landscape change lies in the linkage of data of inherently different origins, structure, and quality. Bürgi et al. (2004) emphasized this point by comparing data from unique disciplines. However, even the comparison of information collected within a given field can prove challenging. As an example, natural resource surveys conducted a century or more ago are noticeably different from current ones. This difference arises from differences in the data being measured, the tools available to assess the resource, and our ability to understand the available information. While some attributes, such as species composition, are still utilized, many attributes now considered important were rarely incorporated in inventories even a few decades ago. For instance, measurements of large woody debris (Woodall and Williams 2005) or vertical forest structure (Ferris and Humphrey 1999) are now common in ecological surveys.

Finally, we must consider societal influences as an explicit and prominent portion of any model of landscape change (Bürgi et al. 2004). While environments can change dramatically under natural processes, few have proven to be more pervasive and intensive than human activities, which typically result in simpler conditions than those caused by natural disturbances (Skånes and Bunce 1997). For example, the globalization of the forest products industry has resulted in many natural forests being replaced by even-aged, short rotation monocultures. Hence, a purely economic driver (fiber production) has supplanted established patterns of natural disturbance, plant succession, soil development, and carbon accumulation, amongst others.

9.2 What Are Drivers of Landscape Change?

Even though our understanding of change in the face of uncertainty challenges any model we may wish to construct, the measured analysis of data in light of known landscape drivers has been remarkably successful in explaining large-scale pattern and processes. This understanding of pattern and process is possible because driving forces are considered to be the most "...influential processes in the evolutionary trajectory of the landscape..." (Bürgi et al. 2004, p. 858). Like the large- and small-scale disturbances impacting the dynamics of a forest stand, these forces shape and change landscapes over time (Oliver and Larson 1996). Driving forces may be natural or socioeconomic (including political, technological, and cultural factors (Brandt et al. 1999)), and are often exceedingly complex and inextricably intertwined, making it impossible to consider them as discrete phenomena.

Most ecologists are familiar with natural driving forces, which can be either directly observed or inferred from biotic responses to certain environmental conditions. The former is self-evident, while an example of the latter can be taken from the presettlement forests of the Ozark Plateau of Missouri and Arkansas (U.S.A.). These *Quercus*-dominated woodlands were primarily composed of low density stands or isolated denser groves in sheltered coves or narrow strips along riparian zones (Beilmann and Brenner 1951; Schroeder 1981; Foti 2004). The historically low forest density and species composition of Ozark landscapes are usually attributed to frequent fires (Batek et al. 1999; Guyette et al. 2002) and extensive areas of poorly suited soils (Schoolcraft 1821). Applying the landscape drivers model, we find that the historical driving forces of poor soils and fire imposed upon vegetative patterns, producing a feedback loop that helped sustain presettlement landscape patterns.

From the previous example, we can see how individual drivers can combine to effect landscape change. These drivers can also act in concert with each other over time. In eastern North America, for example, forested landscapes changed following the evolution of human economic activity from hunting and gathering to row-crop agriculture, government-promoted settlement of lands, the influence of the railroad in timber harvesting, and a trend towards maximizing economic productivity (Beilmann and Brenner 1951; Kersten 1958; Fitzgerald 1991; Benac and Flader 2004). This final industrialization driver is witnessed in the growing prominence of loblolly pine (*Pinus taeda* L.) plantation monocultures across the southern U.S.A. Over much of this region, the potential for increased financial returns has encouraged many landowners to significantly intensify their silvicultural practices (Stanturf et al. 2003; Rousseau et al. 2005). As a result, much of the region has been cleared of the existing timber and converted to short-rotation (15- to 30-year) loblolly pine plantations (Wear and Greis 2002; Allen et al. 2005). Older and larger tracts are most susceptible to conversion, greatly simplifying landscape composition and structure (Rogers and Munn 2003; Arano and Munn 2006). These alterations also affect other large-scale phenomena, such as variations in site quality or the frequency of damaging storms (Read 1952; Rebertus et al. 1997).

9.2.1 Using Large-Scale Data to Identify Landscape Change

Given the lasting legacy of past events and conditions on current systems (Bürgi and Turner 2002; Bürgi et al. 2007), an understanding of historical environments is a valuable asset in natural resource management (Landres et al. 1999). Knowledge of past conditions can provide a baseline for assessing change, help us understand important processes associated with ecosystem conditions, and provide potential targets for restoration activities (Bolliger et al. 2004). Fortunately, many types of information are available on past conditions and processes, including diaries, newspaper reports, official forest and agricultural statistics, maps, photos, and public and private archives (Russell 1997; Bürgi et al. 2007; Fei 2007; Goforth and Minnich 2007). Note that these data sources can be either quantitative or qualitative in character, represent different spatial or temporal extents, and vary in their accuracy regarding past conditions, so their interpretation must be carefully undertaken.

A critical prerequisite for the study of landscape change and the drivers propelling it is knowing how to acquire accurate baseline information. With this in mind, Antrop (1998) provided the following questions:

1) What is being changed?
2) How often does the change occur?
3) How significant is the change? and
4) What is the reference period the changed environment is compared to?

Large-scale inventories can provide answers to these questions. However, the longer the time between measurements, the more that differences in inventory design – such as the scale and resolution of sampling, individual performance in data collection and taxonomic identification, variation in the units of measurement, and lack of consistency in quality control – make the comparison complex and uncertain. Furthermore, some drivers such as natural ones (severe wildfires or landscape-level soil productivity) or political ones (government support of land settlement) are more easily documented than others (e.g., changing cultural attitudes towards land use or the rate of technological progress).

The appropriateness of large-scale data depends in part on the analytical method(s) employed. Whereas documentation of a particular landscape condition based on anecdotal descriptions may suffice for qualitative analysis, quantitative analyses of past conditions require spatially- and temporally-representative data. Surveys and inventories across multiple levels are used to inform this process by cataloging the current state of the landscape, flora, or fauna, and can be used to assess the likely consequences of environmental change. For instance, contemporary land-cover and land-use surveys usually employ remotely-sensed data from aerial photographs or satellites to develop geospatially and chronologically comparable datasets.

Examples of landscape change detected by land-cover and land-use surveys can be seen in the large-scale trends affecting agricultural regions. The primary drivers influencing these agricultural lands are associated with economic and technological changes in crop production. In many parts of the world, particularly in mountainous and other marginal areas, farmlands are being lost to other land uses, driven by declines in the economic significance of agriculture (Bolliger et al. 2007; Laiolo et al. 2004). Often, this results in the reforestation of formerly open land, which may lead to a short-term increase in species richness due to an increase in the variety in landscape structure (Söderström et al. 2001) and the offset of forestlands lost to urbanization (Wear 2002). However, there are instances of pastoral abandonment that result in significant habitat loss for open-land species (Dirnböck et al. 2003; Bolliger et al. 2007) and can potentially threaten species diversity (Tilman et al. 2001). The trend in North America has been toward simplified agricultural landscapes, with a diminishing number of cover types arranged in fewer and larger patches (Schulte et al. 2006). In central North America, this simplification has been linked to a decline in populations of grassland birds (Murphy 2003) and degradation of water quality (Turner and Rabalais 2003).

Models are also gaining importance in formulating spatiotemporal interactions within and between landscape elements. A range of quantitative model types can be distinguished based on various aspects of the modeling approach. Models differ in the way landscape heterogeneity is taken into account, based on the research focus and the availability of data on exogenous and endogenous factors and processes (for reviews see Guisan and Zimmermann 2000; Lischke et al. 2007). Yet, whether it is a stochastic Markov analysis of potential transitions between differing species mixtures (Moser et al. 2003), detailed modeling of individual driving forces, or qualitative Delphi-type techniques that incorporate all of the underlying driving forces into one category of change magnitude (Moser et al. 2006), each method describes the transition of a landscape from one state or condition to another. However, quantitative methods do not provide certitude by themselves. Ecologists increasingly need to incorporate ancillary data, circumstantial evidence, and inferential reasoning from other information for their analyses to avoid misinterpretations of landscape change (Bürgi and Russell 2000), or to combine data from different resources to optimize spatial information (Edwards et al. 2006).

The combination of such information from drastically different sources is fraught with challenges. For instance, taxonomic data (particularly for infrequent species) are often acquired via purposive sampling (Edwards et al. 2006; Lütolf et al. 2006). This type of sampling, which is generally not statistically or spatially representative, provides information on species presence. While the presence of a species may be easily determined in the field, absences are more difficult to confirm (Kéry 2002). A species may be absent for any number of reasons, but only unsuitable habitat is considered a real absence in habitat modeling (Lütolf et al. 2006). Thus, many species surveys include presence-only data (i.e., data with confirmed presences, but unconfirmed absences). Although there are ways to model species distributions with presence-only data, the generation of pseudo-absences should be made a priority in habitat distribution modeling, e.g., by using auxiliary species whose habitat(s) resembles that of the focus species (Lütolf et al. 2006). Another option would be to pool taxonomic information from other sampling strategies. However, it has been demonstrated that the overall sampling design has significant influence on the validity of the statistics (Edwards et al. 2006) and, hence, on the interpretability of the habitat distribution patterns. A comparison of purposive sampling and design-based strategies shows that the model performance from simulations originating from the former method is lower compared to those from the latter (Edwards et al. 2006).

The conflict between data types (whether sampled or modeled) and reliability shows that when they are integrated to address landscape-to-regional questions, close attention should be paid to their limitations. The data, analytical methods, and resultant interpretation must be carefully evaluated so that conclusions are not tied more to the inherent tendencies of the source than to the ecology of the system. Diary records, newspaper reports, or personal photos may provide details for a particular time and location, but are heavily influenced by the writer's perception of what conditions were noteworthy. Hence, this source of information is likely to over-represent sensational, large, or unique landscape features. Examples of potentially misleading ecological information in generally reputable outlets are historical photographs of old-growth timber or large "trophy" trees in lumber trade journals (Bragg 2004) and dramatized newspaper reports of large-scale fires in the California chaparral (Goforth and Minnich 2007). Official historical surveys, maps, or land statistics may be more representative over broader spatial scales (Manies and Mladenoff 2000), but should be carefully examined to minimize interpretation errors or spurious correlations. It is also critical to avoid observer biases made from contemporary experiences with modern-day landscapes. For example, the current distribution of species such as red maple (*Acer rubrum* L.) and loblolly pine has drastically increased from what existed in presettlement times as natural disturbance regimes and land use patterns have changed (Abrams 1998; Bragg 2002). On the other hand, some once dominant taxa have declined precipitously (e.g., American chestnut [*Castanea dentata* (Marsh.) Borkh.] or American elm [*Ulmus americana* L.]) because of introduced diseases.

9.3 Examples Using Historical Data and Current Large-Scale Surveys

Ecologists and other resource professionals in North America trying to establish criteria for sustainability have looked to pre-European settlement landscapes as a contrast to today's highly altered landscapes (Swetnam et al. 1999; Foti 2004). Although these early landscapes were known to be disturbed by indigenous peoples (Guyette et al. 2002) and biotic and abiotic forces (Schulte and Mladenoff 2005), many people believe that they represent examples of "natural variability" (Landres et al. 1999). Yet, serious questions remain. For instance, how does one define the nature of these presettlement landscapes? Given that historical surveys were rarely collected specifically for the study of the biota, how must the information contained within them be interpreted? What sources are best suited for this task?

Probably best known among the official historical resource surveys of the U.S.A. is the General Land Office's public land surveys (PLS). Implemented across most of the country during the 19th century, the PLS was a rectangular, rule-based system of land subdivision that opened the public domain to private ownership, provided a key source of revenue to a growing federal government, and brought development to heretofore "wild" landscapes (Linklater 2002). These north-south and east-west running demarcations divided the land into nominal 9,324 ha (36 mi^2) squares called "townships," which were then further subdivided into 259 ha (640 ac) "sections" (Stewart 1935; White 1983). At corners and selected points in between, the surveyors recorded information (e.g., species, estimated diameter, and distance) on two to four trees near the posts. In addition to these witness trees, the PLS field notes also usually recorded conspicuous features, such as stream and river crossings, the predominant trees, and obvious changes in forested condition or geology. Furthermore, the surveyors also drew geographic plat maps of many of the features (e.g., streams, lakes, springs, bluffs, prairies, early settler improvements) reported in the field notes.

Despite many shortcomings (e.g., Bourdo 1956; Manies and Mladenoff 2000; Schulte and Mladenoff 2001; Foti 2004), the PLS records provide useful large-scale information on vegetation composition and structure due to their resolution, extent, and detail. In part, this is because the PLS field instructions have been thoroughly documented in the literature (Stewart 1935; White 1983), allowing users to evaluate their applicability to the question at hand and interpret the surveys accordingly. Decades of experience have resulted in the PLS' being used to interpret (1) local and regional vegetation patterns using both descriptive and quantitative approaches (Batek et al. 1999; Schulte et al. 2002; Bolliger et al. 2004; Bolliger and Mladenoff 2005); (2) the characteristics of historical disturbance events (Zhang et al. 2000; Schulte and Mladenoff 2005); (3) landscape change (Radeloff et al. 2000); and (4) land-use change (Foster et al. 1998; Bürgi et al. 2000). They have also been used with spatially dynamic landscape models to evaluate relationships between pattern and process (Bolliger et al. 2003; Bolliger 2005) and have revealed early socioeconomic trends (Silbernagel et al. 1997).

The following examples present very different approaches to using historical and contemporary large-scale survey data to examine issues of landscape change and their drivers. Each uses PLS and Forest Inventory and Analysis (FIA)[1] data to address the topics. First, a series of resource inventories was used to reconstruct a shift in dominance between two native pine species in the southern portions of Arkansas. Here, the study specifically examined the drivers that propelled the landscape change. A second example addresses the problem of conforming two different inventories to a common metric capable of summarizing landscape change and guiding restoration priorities. Acknowledging the drivers that promoted landscape change, this study amalgamates the driving influences into a dimensionless restoration-suitability category.

9.3.1 Shifts in Pine Dominance Across the Gulf Coastal Plain of Arkansas

In the early decades of the 20th century, foresters were concerned about an apparent decline in pine abundance across the Upper West Gulf Coastal Plain (UWGCP) (Chapman 1913; Hall 1945). Bruner (1930) reported that the forested lands of Arkansas had dropped from almost 13 million ha before settlement to 8.9 million ha, and standing volume had declined from an estimated 0.9–1.4 billion m^3 in the original forests to about 0.2 billion m^3 in 1930. In addition, a variety of less valuable hardwood species had markedly increased their presence across the landscape (Reynolds 1956). Over the intervening decades, it became obvious that agricultural abandonment and the spread of scientific forestry had stemmed the loss of pine-dominated timberlands (Hall 1945). Indeed, as silviculture became increasingly lucrative following World War II, management of a greater proportion of the land was driven by the interest in a single species – loblolly pine. Over the years, structurally-complex, naturally-regenerated mixed pine-, pine-hardwood-, and hardwood-dominated stands have been replaced with increasingly loblolly-dominated, intensively-cultivated stands (Bragg et al. 2006).

Evidence suggests that shortleaf pine (*Pinus echinata* Mill.) was considerably more abundant in presettlement times over much of the UWGCP in southern Arkansas (Mohr 1897; Bragg 2002). Estimates of the shortleaf pine composition of the pine-dominated presettlement upland forests of the UWGCP in Arkansas ranged from approximately 25–50 percent shortleaf pine, with an increasing representation of shortleaf as one traveled from east to west and localized pockets of

[1] The national inventory conducted by the US Forest Service FIA program uses permanent sample plots located systematically across the U.S.A. at an intensity of approximately one plot every 2,400 ha to produce a random, equal-probability sample. Over the years, other types of environmental measurements, such as forest health monitoring or state-based assessments, have been tied to the FIA plot system, and therefore share considerable concordance in the statistical nature of the data collected (McRoberts 1999). Complete documentation of the plot design and all measurements can be found at http://socrates.lv-hrc.nevada.edu/fia/dab/databandindex.html.

"pure" (>80 percent) shortleaf pine across the UWGCP. Loblolly pine's abundance in historical upland forests also varied considerably, but in general the species was considered prominent only in smaller bottomland or on more mesic sites protected from frequent fires (Mohr 1897; Olmsted 1902; Chapman 1913; Bragg 2002).

Modern-day assessments of forest cover in the UWGCP of Arkansas reveal that loblolly pine is now the most dominant species (e.g., Rosson et al. 1995). Documenting the shift from shortleaf to loblolly pine, however, is not a simple matter. The PLS surveyors did not differentiate between the pine taxa of Arkansas, although other sources of historical information report considerable differences in pine abundance by species, geography, and landform (e.g., Bragg 2002). Furthermore, the PLS represents vegetation conditions at an instant in time, and thus does not reflect changes in pine dominance.

However, combining PLS data with the US Forest Service's FIA data can be used to derive long-term species dynamics across large geographic regions. Using periodic inventories of the 22 counties conducted since the late 1930s (Eldredge 1937; Duerr 1950; Sternitzke 1960; Hedlund and Earles 1970; Quick and Hedlund 1979; Hines 1988; Rosson et al. 1995), the long-term relative trends of shortleaf pine, loblolly pine, and hardwoods were determined over the last seven decades for southern Arkansas (Fig. 9.1). From its peak abundance during presettlement times, shortleaf pine abundance dropped following the historical logging, burning, and agricultural clearing of the forests of southern Arkansas. Up until 1970, however, shortleaf pine maintained a respectable presence in the overstory, comprising between 20 and 25 percent of the standing sawtimber. Over the last 35 years, shortleaf pine has declined dramatically, dropping to less than 7 percent of all sawtimber-sized trees in the latest FIA information available for this region (Moser et al. 2007b).

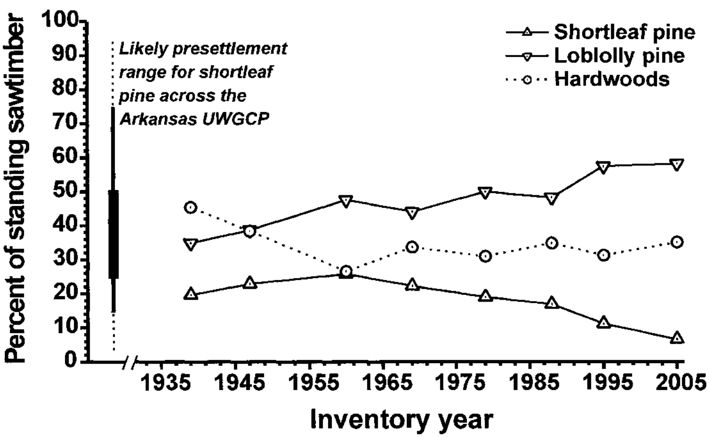

Fig. 9.1 Long-term trend in loblolly pine, shortleaf pine, and hardwood species in southern Arkansas compiled from multiple inventory reports. The presettlement abundance of shortleaf pine has been adapted from several historical references, and the thickness of the bar indicates the relative likelihood of that proportion of shortleaf in the Upper West Gulf Coastal Plain (UWGCP)

Loblolly pine, on the other hand, has steadily increased from about 35 percent of the overstory volume in 1937 to over 58 percent in 2005.

9.3.2 *Comparing Current and Historical Resource Surveys as a Tool for Targeting Landscape Restoration in Missouri*

In 2003, a team of natural resource professionals from the Missouri Department of Conservation and the University of Missouri developed a forest classification scheme based on current and potential forest-type groups with the suitability (and, by implication, the ease) of conversion from one type to another based on site index (Moser et al. 2006).[2] This system, excerpted in Table 9.1 (Nigh et al. 2006), is analogous to a "state and transition" approach to restoration (Fig. 9.2, Hobbs and Norton 1996).[3] Although the categories of suitability presented in Table 9.1 refer to all management activities (not just restoration), the overall concept applies.

To evaluate historical forest land structure, 1815–1855 PLS data from Missouri were used. Current data was obtained from the annualized inventory of Missouri's forest resources, collected by the FIA program between 2001 and 2005 (Moser et al. 2007a) to assess the present-day landscape. The study employed a "moving window" analysis – where each pixel was assigned a value based on a function of the ground observations within a particular radius (similar to what was employed in Moser et al. 2006). Because of the different sampling intensities of the two surveys, each analysis required different-sized windows: a 2000 m radius for the historic (PLS) data and a 4000 m radius for the current FIA data. The two datasets were then reduced to a common data structure to facilitate analysis (Table 9.1).

The output from the classification scheme was a conversion suitability map that estimated the effort required to restore the landscape of the 1820s (Fig. 9.3). Of the 1.4 million ha in the study area, 11 percent was classified as low-effort sites, 11 percent as medium-effort sites, 6 percent as high-effort sites, 2 percent as maximum-effort sites, 12 percent as non-forest and 45 percent as not possible (Table 9.2). The remaining 12 percent was classified as having no information. The large number of hectares considered unsuitable or for which there were no data resulted largely from an inability to delineate particular combinations of present-past forest types. Among these was savanna, for which there was no definition in the conversion matrix. As savanna represented a considerable portion of the historic landscape,

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[2] The effort required to maintain a particular composition and structure depends upon many factors, including the dynamics of the current forest, the degree of difference between current and desired states, and site factors such as soil productivity and climate.

[3] In their article, Hobbs and Norton defined State 1 as a non-degraded ecological state, States 2 and 3 as partially degraded states, and State 4 as a highly degraded state. Stressors or some other debilitating agent caused the transition from State 1 to States 2, 3, and 4. Removing the stressor in States 2 and 3 can result in an unaided return to State 1, analogous to natural resiliency. However, additional management action beyond merely removing the stressor will be required in State 4, as the threshold represents a level of degradation that would preclude any unaided restoration.

Table 9.1 Classification system and management options for upland forest/woodland types in Missouri, excerpted from Nigh et al. 2006. Numbers associated with each site quality class indicate degree of suitability and effort from 1 = highly suitable and low effort to 4= low suitability and maximum effort. An "X" indicates a very unlikely occurrence

Present	Suited	Site Quality			
Forest Type	Forest Type	1	2	3	4
		12–16 m (40–54 ft)	16–19 m (55–64 ft)	19–22 m (65–74 ft)	22 m+ (75 ft+)
Post oak woodland	Post oak woodland	1	2	4	X
	Mixed oak woodland	2	1	1	X
	Mixed oak forest	X	2	1	X
Mixed oak woodland	Post oak woodland	1	2	4	X
	Mixed oak woodland	1	1	2	4
	Pine-oak woodland	1	2	3	X
	Mixed oak forest	X	3	1	2
	Pine-oak forest	X	2	1	3
	White oak forest	X	3	2	1
	Pine woodland	1	2	4	X
	Pine forest	2	1	3	X

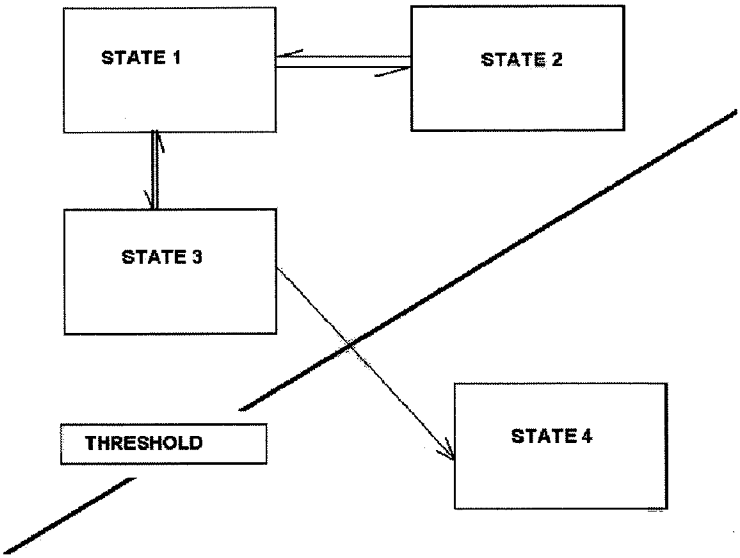

Fig. 9.2 A state and transition approach to restoration (Hobbs and Norton 1996). States 2 and 3 represent conditions that could naturally return to the predisturbance state 1 once the stressor is removed. State 4 is beyond the limit of natural resiliency and additional restoration efforts must occur for this state to be returned to State 1

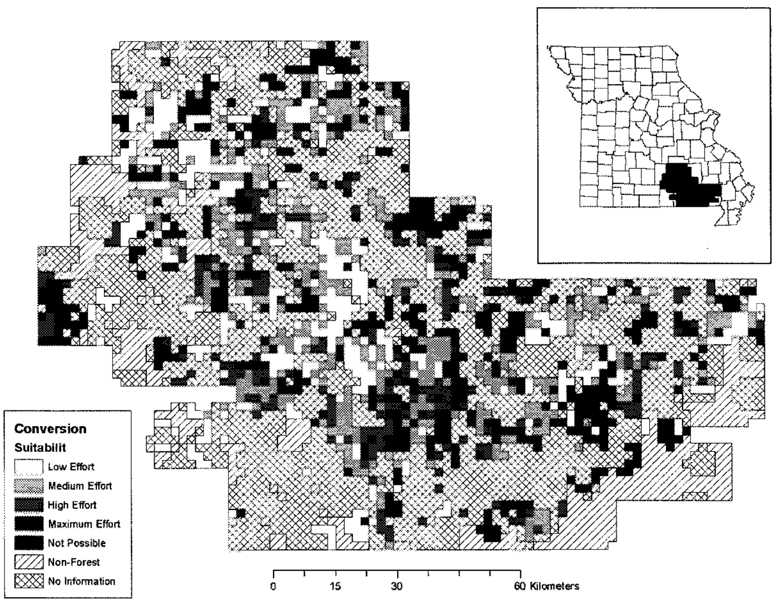

Fig. 9.3 Map of categories of conversion suitability and effort. The scale is from "low effort" (a "1" in the matrix in Table 9.1) to "maximum effort" (a "4" in the matrix in Table 9.1)

Table 9.2 Summary of categories of conversion suitability in the study area, Missouri Ozark region. Percentages do not add up to 100 due to rounding

Suitability	Hectares	Percentage of Total
Low Effort	158,800	11
Medium Effort	153,200	11
High Effort	86,400	6
Maximum Effort	34,800	2
No Information	165,200	12
Non-Forest	168,000	12
Not Possible	636,800	45
Total	1,403,200	

omitting it meant that a substantial segment went "unclassified" ("no information" in Table 9.2). Nevertheless, the results are consistent with other analyses that use a more disturbance-based protocol (e.g., Guyette et al. 2002). Hence, an understanding of landscape change via analysis using large-scale inventories can be used to develop drivers to predict potential future conditions.

9.4 Conclusions

Recognizing the presence and influence of drivers of landscape change improves the ability to predict outcomes from current and future resource management activities, especially large-scale restoration work. Practitioners documenting landscape change with an eye toward restoration should first determine the primary historical structures and functions, followed by a series of inquiries patterned after the questions posed by Antrop (1998) to identify and quantify landscape protection:

1) How often must the landowner invest in restoration? Is this a one-time effort, or will there need to be continued maintenance?
2) How much effort will it take to restore the landscape to the desired state? Is the restoration effort worth the perceived benefits? Will the investment in restoration be rewarding to the landowner, perhaps as a result of a subsidy?
3) What are the criteria for success?

In conjunction with these questions, landscape analyses can help identify practical constraints in restoration activities (Bell et al. 1997). For instance, environmental degradation can result from extensive and intensive causes (Hobbs and Norton 1996), so effective, sustainable restoration efforts should also be at a comparable scale.

Characterization of landscape attributes involves more than just comparing patterns over time and space. Rather, it involves explicitly connecting past environments with the underlying processes that drive them towards specific patterns. Not surprisingly, the more complex the processes influencing the landscape, the more important it is to understand them and their role in landscape change. However, models of landscape change should follow "Occam's Razor" and be only as sophisticated as needed to answer the question – if for no other reason than that simpler models will likely fit the available data better than more complex ones. After all, surveys such as the PLS of the 19th century or FIA in the 21st collect a limited set of information. The apparent changes noted between these surveys are the result not only of biophysical processes but also cultural, technological, social, and economic drivers that frequently go undocumented.

Effective analysis of these drivers requires that scientists move beyond mere comparisons of two inventories at different points in time to a more holistic analysis that incorporates different types of information reflecting the different influences upon landscape change. Balanced against this goal is the reality that our understanding of the influences – human and environmental – is limited not only by our personal understanding of the subject but also by the data available. Large-scale inventories are a good first step, but they are, by themselves, incomplete. The scientist gains understanding of the past as tidbits of information are revealed: a settler's account of the land he cleared, fire scars on those few surviving trees, commercial records two centuries old, remnants of an old cord road or a railroad line. In the end, scientific honesty demands that one be conservative in the analyses in order to take into account the fractured and incomplete nature of the evidence.

Despite the humbling reality of the available information, landscape ecologists are still able to discern interesting patterns of change that hold lessons beyond the region, watershed, or process in which they were found. As scientists become even more practiced in integrating qualitative and quantitative information, they will improve their ability to assemble mechanistic relationships from survey information and to incorporate knowledge from other ancillary sources as different as cultural surveys, historical accounts, and satellite imagery. The ultimate objective, to gain an understanding of agents of landscape change, is then within their grasp.

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