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Long-Term Trends in Ecological Systems:

A Basis for Understanding Responses to Global Change

Contents

Chapter 15

Management and Policy Implications of Cross- and Within-Site Long-Term Studies

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Management is defined as a set of processes that guide and evaluate actions required to implement a program. In the management of natural resources, it is understood that these processes are guided not only by science, but also by experiences learned by or conveyed to a resource manager over time. We recognize that information based on scientific studies and available through the peer-reviewed literature is often lacking or inadequate to address many of today's complex resource management issues.

Fortunately, long-term datasets are now becoming available that can provide useful information with application to natural resource management and policies. For example, climate, and particularly the occurrence of long-term drought, is a major driver of ecosystem dynamics across the United States. Long-term data provide a basis for evaluating not only the likelihood of drought, but resilience of drought within managed landscapes. Drought records, such as annual Palmer Drought Severity Indices (PDSI; figure15-1), provide these utilities to managers of both public and privately held natural resources. To illustrate, the historical record of PDSI for southern New Mexico (figure 15-1; JRN ARS-LTER) informs managers that over 75 percent of the years during this 50-year period were recorded droughts and that the drought of 1951-1956 was the most severe of its time. Management actions based on resource inputs, such as reseeding native grasses, implemented during this period would likely be failures, and the interpretation of their usefulness needs to be judged within this context of perpetual drought.

Another driver that strongly influences resource management is the increasing human population and the increased landscape fragmentation accompanying these population increases. Census data collected since the late 18th century show an increase in population density across the continental United States that can seriously impact natural resources and their management (figure 15-2). These long-term data reflect the heterogeneous nature of population dynamics across the country. For example, in the late 20th century, growing population demands on water resources in the Southwestern United States are quite evident (Jackson et al. 2001). Conversely, decreases in human population densities across rural counties of the Central Plains will likely result in a loss of knowledge and experience in natural resource management.

These examples illustrate the value of long-term data beyond their contribution to our understanding of important ecological processes. Specifically, the value of long-term data to management of natural resources includes a basis for the development of—

- conservation practices which have direct application to natural resource management,
- policies and programs that can be instrumental in guiding that management, and
- adaptive strategies required to contend with both the spatial and temporal heterogeneity that are characteristic of natural resources and managed landscapes.

These values emerge from analyses of long-term data based on two key attributes: our ability to examine data retrospectively to identify temporal and spatial sensitivities and our ability to build those historical perspectives into predictive models with which we can objectively evaluate potential future scenarios. Both attributes provide the needed perspectives to manage our natural resources and to adapt our management practices to conserve those resources and mitigate the effects of our actions.

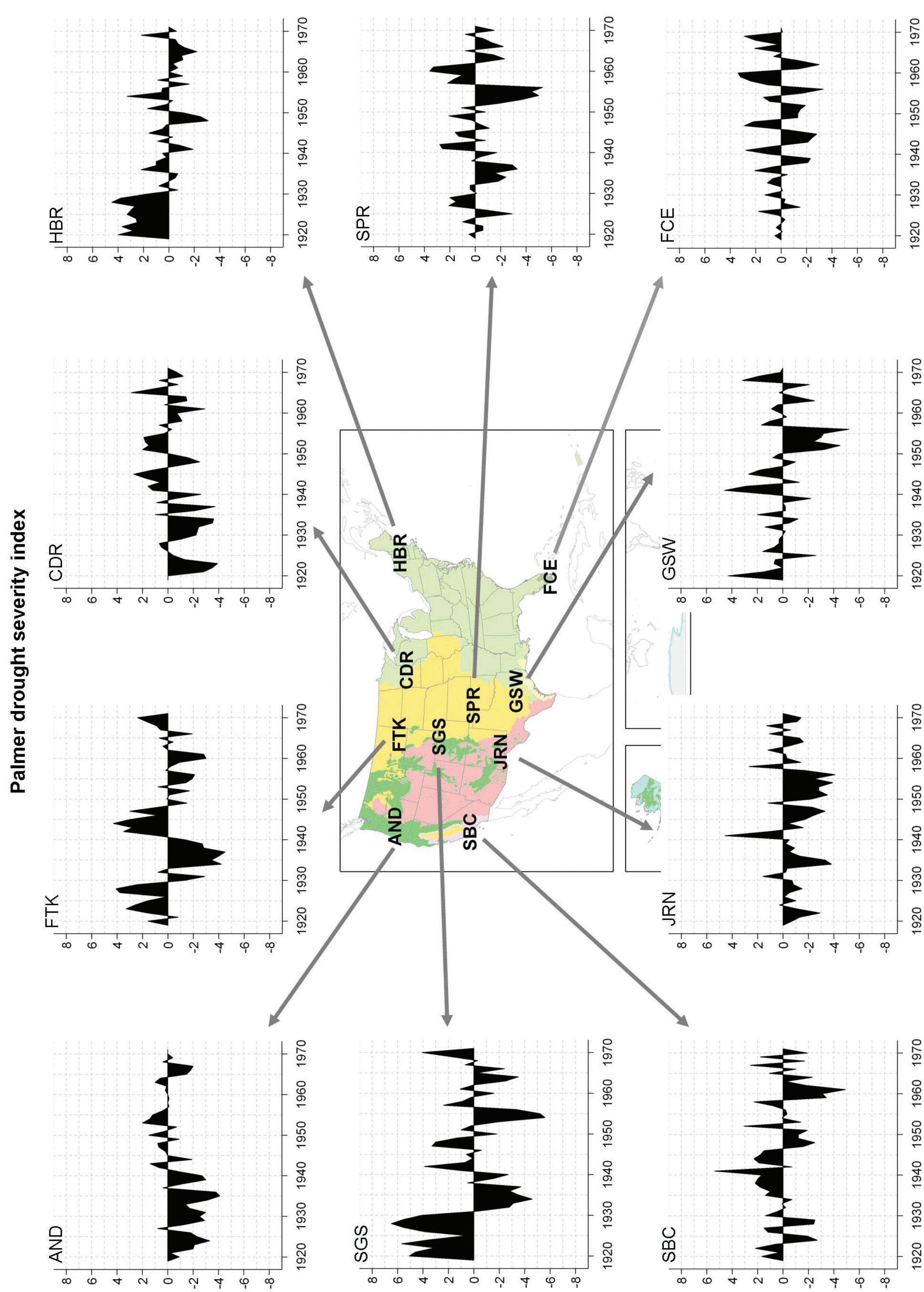

Figure 15-1. Fifty years of annual Palmer Drought Severity Indices for 10 key locations across the continental United States. Original data from http://www.ncdc.noaa.gov. Synthesized data from http://www.ecotrends.info.

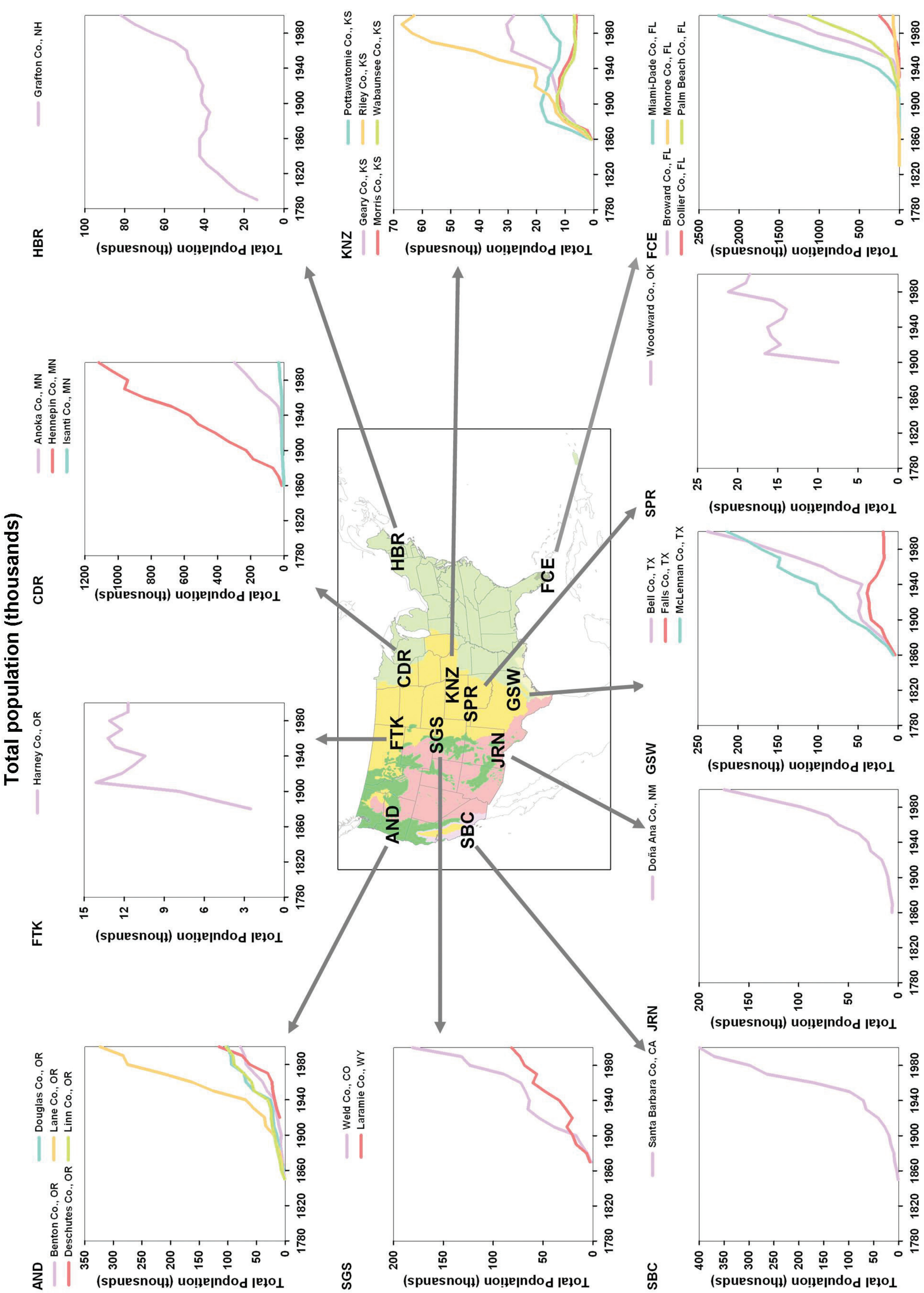

Figure 15-2. Long-term census data for 10 key locations across the continental United States. Original data from http://www.census.gov. Synthesized data from http://www.ecotrends.info.

Historical Perspectives

Long-term data provide three important perspectives that are useful in management of natural resources. First, we are able to quantify temporal dynamics characteristic of natural systems. For example, in the St. Lawrence River watershed of Canada, 100 years of agricultural census data have allowed calculation of phosphorus accumulations in soils within that large basin (MacDonald and Bennett 2009). These long-term data document the periodic pulses that characterize soil phosphorus dynamics over decades and provide a basis for development of management strategies to contend with environmental issues associated with phosphorus accumulation, such as eutrophication.

Long-term data on soil nitrogen and carbon cycles in response to climatic drivers in the Hubbard Brook Ecosystem Study in New Hampshire provide a basis for modeling ecosystem responses to key environmental factors, such as temperature and snow levels, and to possible future climate scenarios (Groffman et al. 2009). These models also illustrate different responses of carbon and nitrogen to future changes in temperature and soil moisture and provide a basis for forest management policy decisions.

Data collected for nearly a century in south-central New Mexico have been analyzed to identify the climatic variables and rangeland management factors that contribute to vegetation dynamics over time (Yao et al. 2006). Repeat photos beginning in 1937 have been analyzed to characterize vegetation dynamics in this desert system (figure 15-3). Collection of these types of data and their subsequent analyses provide insight into the influences of extreme climatic events and provide a basis for projecting responses under future climatic scenarios. The data illustrate the episodic nature of invasive species dynamics and changes that often respond to co-occurrence of disturbance factors, such as overgrazing by livestock during multiyear droughts (Fredrickson et al. 1998). These data have informed grazing management practices and policies at the State and regional scale.

Forty years of data on vegetation responses to landscape modifications in an Atlantic forest showed a time lag in responses of numerous species to those modifications (Metzger et al. 2009). These long-term data demonstrate the importance of landscape history in affecting species presence and diversity within a region and the effects of species attributes on important aspects of ecosystem function (such as carbon storage) and resilience.

Long-term data also provide opportunities to evaluate responses to management actions over time. In another example drawn from southern New Mexico, we have been able to track vegetation responses over time to specific vegetation management practices (figure 15-4). In numerous other examples across the United States, historical treatment areas can also be evaluated from either ground-based records or from archived aerial photography.

Similar experiments conducted on several sites across the continent can provide insights into the effects of management on ecological processes. For example, rangeland grazing management practices have been studied on numerous sites across the Western United States throughout much of the 20th century. Recent analyses from these studies show that two common types of grazing systems showed similar responses in plant production for 89 percent of studies: 36 percent of studies showed greater animal production per head for continuous grazing than for rotational grazing, while 57 percent of studies showed no difference between grazing systems (figure 15-5a) (Briske et al. 2008). Studies were conducted at locations across the Western United States (figure 15-5b).

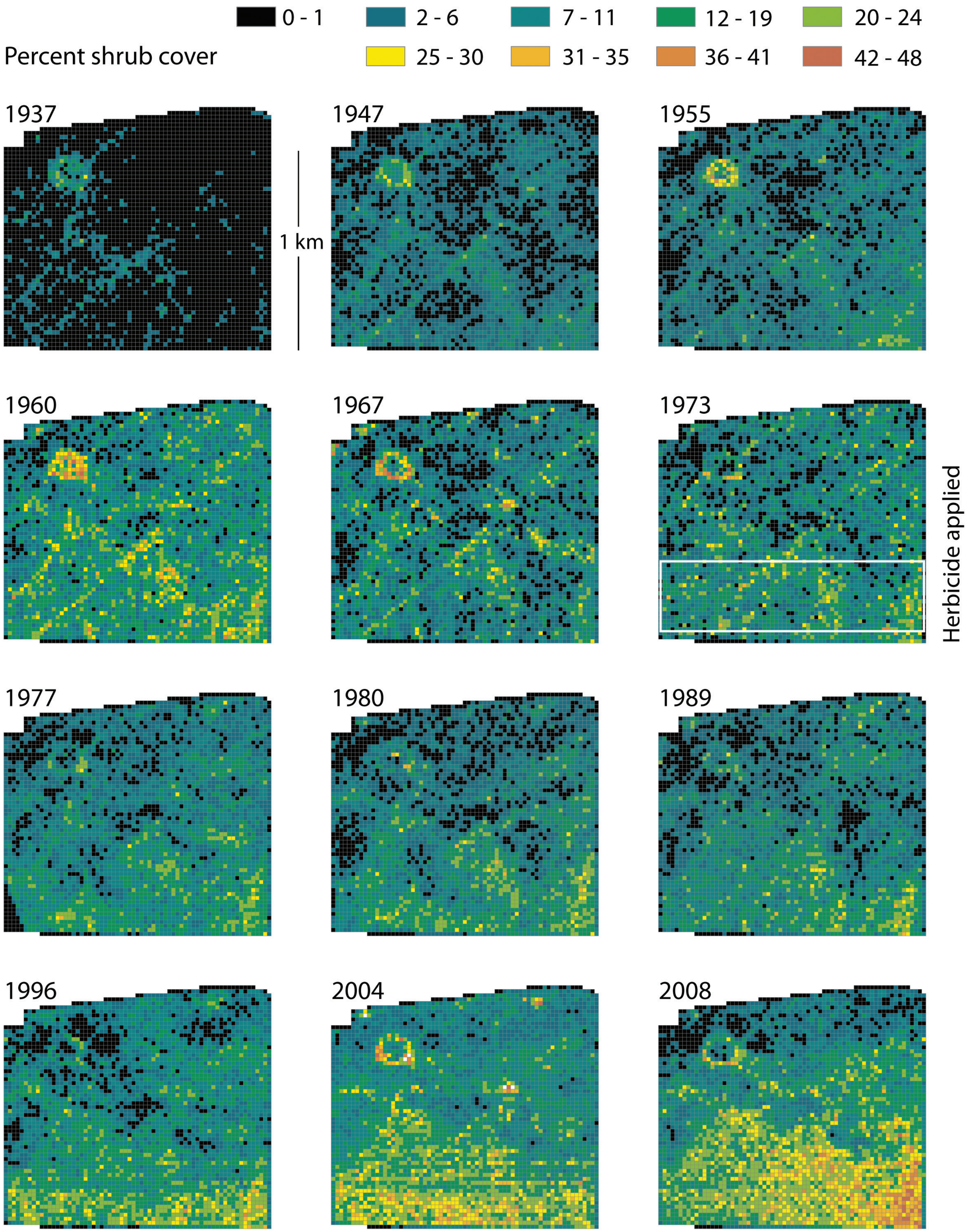

Figure 15-3. Repeat time series of aerial photographs over a 71-year period in southern New Mexico illustrating a variable increase in percentage of shrub cover through time as a result of extreme climatic events. Shrubs increased dramatically between 1937 and 1947 and again between 1996 and 2008. (D. Browning, unpublished data.)

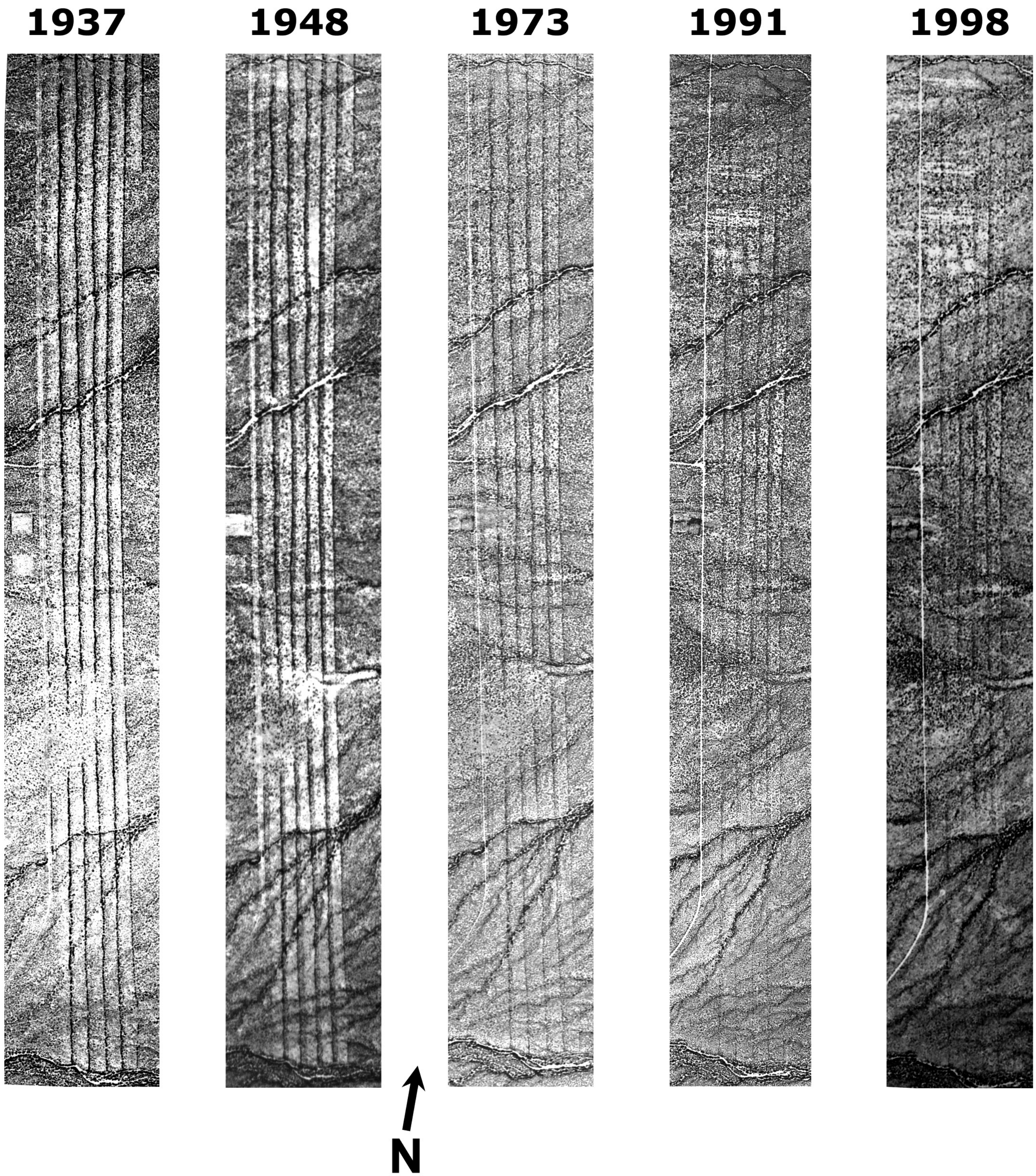

Figure 15-4. Temporal sequence over a 61-year period of alternating grubbed (shrubs physically removed at the ground-surface level; light-colored strips) and control areas (dark strips) in a predominantly creosotebush-dominated shrubland in southern New Mexico. Original grubbing was performed in 1936. Aerial photos were taken from flights in 1937, 1948, 1973, 1991, and 1998 (Rango and Havstad 2003). Reprinted with permission from Cambridge University Press.

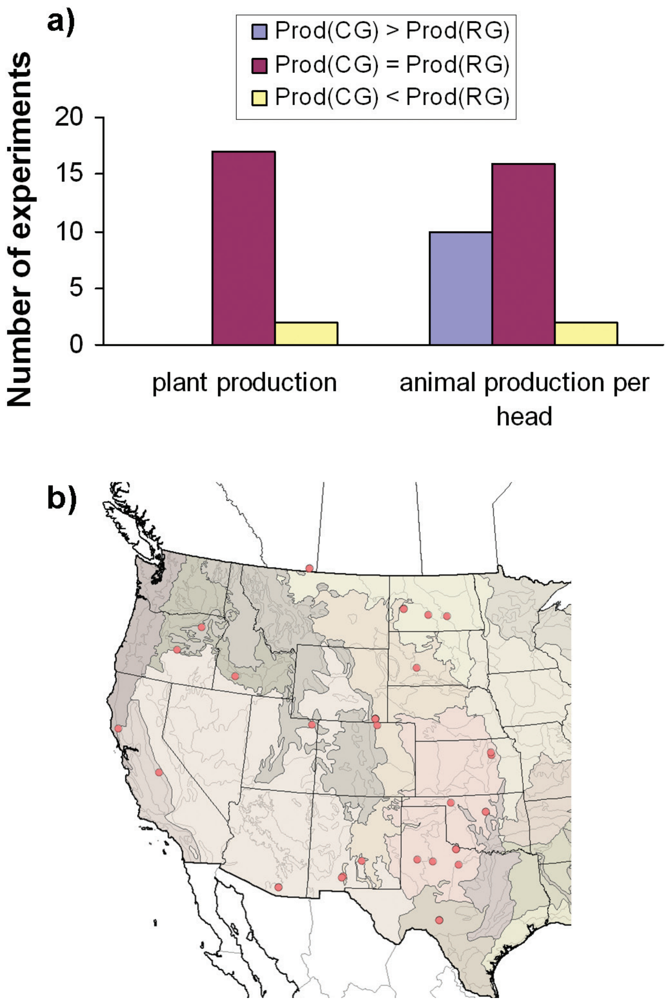

Figure 15-5. (a) Synthesis of research results from long-term studies of the response of plant and animal production to two common types of grazing systems: continuous grazing (CG) and rotational grazing (RG). When stocking rates were similar, 89 percent of the studies showed no difference in plant production between grazing systems, 36 percent of the studies showed greater animal production per head for CG than for RG, and 57 percent showed no difference between CG and RG. Redrawn from Briske et al. 2008. (b) Studies were conducted at locations (represented by red dots) across the Western United States. Map by Shawn Salley.

Predictions

Another important application of long-term, cross-site data collection is to develop and run mathematical models of ecosystem behavior, especially to predict responses of ecosystem services (such as water quality, carbon flux) to changes in climate, land use, and management. As the solutions to environmental issues become more contentious, the effects of human activities become more extensive in both space and time. In addition, the cost of conducting long-term, multisite field experiments increases. A reliable set of predictive models that can be used to estimate the effects of a variety of climatic and management scenarios are critical to informed decisionmaking and effective communication.

Examples exist of the application of complex models to integrate a small set of land management options and climate scenarios for the purpose of predicting a limited range of ecological and socioeconomic response variables (an example is the USGS's Land Carbon Project [USGS 2009]). However, consistency and transparency remain critical problems. The foundation for improving modeling approaches is ready access to data from well-designed, replicated experiments that can encompass the ecological, social, and economic questions of interest. Few experiments are currently designed, conducted, and analyzed with a focus on improving the performance of a mathematical model. Experiments often lack the range of treatments necessary to confidently predict beyond a fairly narrow set of circumstances. As a result, the use of some popular models to predict ecosystem response is ill advised (Brown et al. 2010).

Traditional comparative treatment experiments should be continued in order to more efficiently develop existing and new models. Improving the performance of models with the use of long-term data from multiple locations will remain a challenge and will require serious thought and commitment of resources to ensure that the sometimes conflicting goals of hypothesis testing and model development are met. However, the value that long-term, multisite data have already contributed to the use of mathematical models that predict ecosystem behavior and that guide policy and land management decisions demands that serious efforts be mounted to organize existing data and to cost-effectively collect new information.

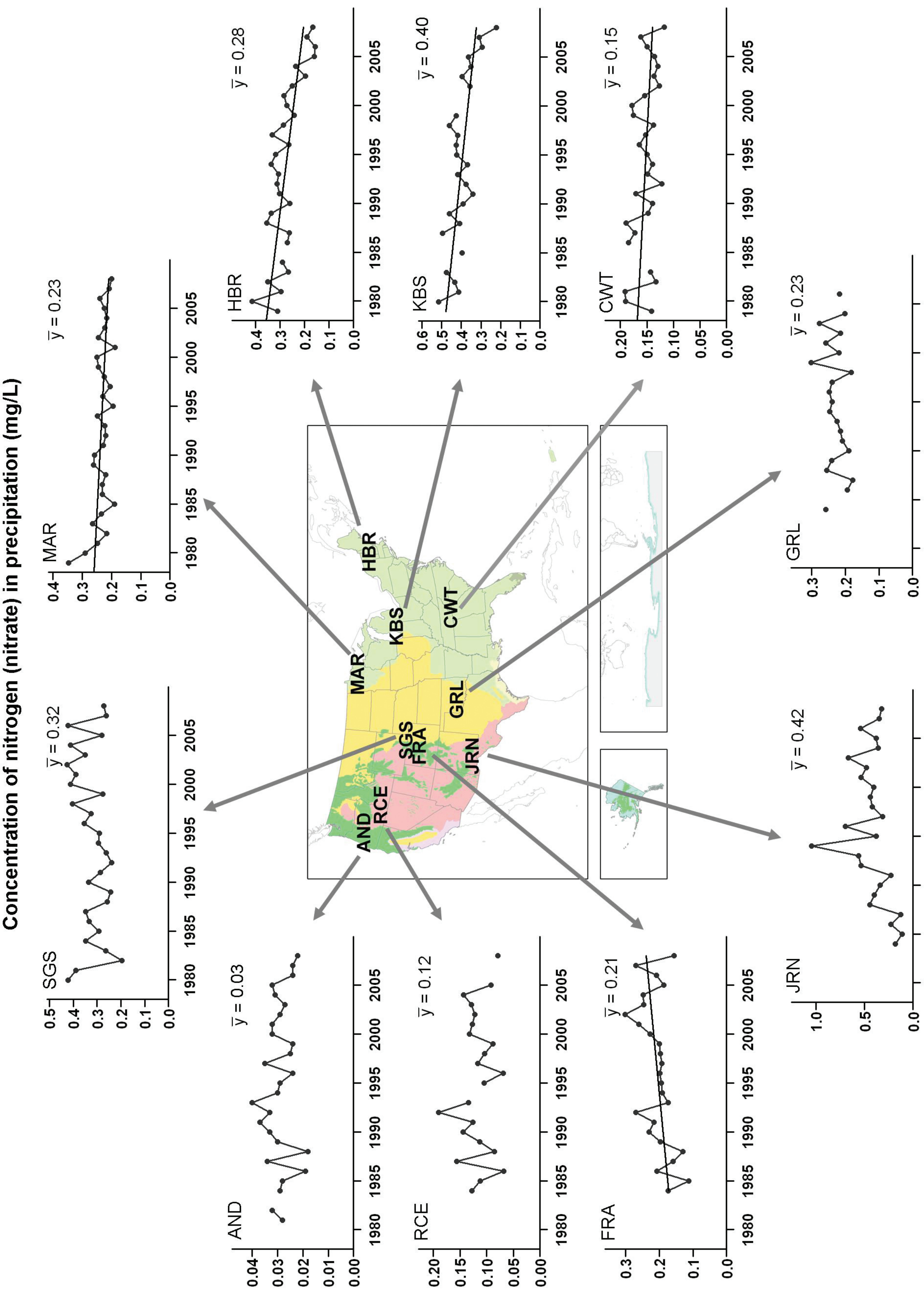

Figure 15-6. Nitrate concentrations recorded in precipitation (mg/L) over a 25-year period following Federal clean air policies enacted in the 1970s. Original data from http://nadp.sws.uiuc.edu/. Synthesized data from http://www.ecotrends.info.

Summary

Long-term data and their collection at specific sites across the United States have provided three distinct, but complementary, values to management of natural resources.

First, these data provide an opportunity to understand the temporal and spatial variability of many ecological patterns and processes. This value is important because many management actions, such as prescribed burning or reseeding of degraded land, incorporate key ecological processes and are sensitive to both location and time. For example, the timing of synergistic environmental conditions, such as periods of dryness for prescribed fires or periods of subsequent moisture for reseeding practices, is an important constraint on the success or failure of management actions.

Conversely, most management actions are highly dependent on site features. It is commonly understood that no single management practice will work in all locations at all times. Without long-term data across numerous sites, we cannot identify this array of temporal and spatial sensitivities nor develop data-based guidelines to direct the appropriate timing and application of management practices.

Second, long-term data provide the opportunity to evaluate policies and programs that have been implemented for resource conservation. Often, policies are developed and enacted with incomplete knowledge of ecological ramifications. The ability to evaluate environmental responses after policy implementation provides the data necessary to validate policies or may lead to their subsequent revision. Of additional importance is the value of long-term data in assessing and monitoring ecological responses to implemented policies. For example, nitrate concentrations in precipitation collected at locations across the United States reflect the positive effects of federally mandated clean air policies enacted in the 1970s in reducing nitrate concentrations in the industrialized upper Midwest and the Eastern United States (figure 15-6). Areas of the less industrialized West and Southwest reflect negligible effect of these policies, as would be anticipated.

In another example, a key technology for management of rangeland resources is an ecologically based system for delineating landscapes into units of similar vegetation potential that are expected to respond similarly to a management practice. The principal provider of this technology since the mid 20th century is USDA Natural Resources Conservation Service (NRCS). For decades, this technology was described as “range sites,” where the condition of a site is characterized by its linear departure from a potential determined by the combination of climate and soil properties. This technology was based on an assumption that state changes are reversible and that the potential of a site is consistent over time. In the 1990s, NRCS revised this management technology in an effort to incorporate an understanding drawn from long-term data which state that changes may be irreversible and that site potentials are not permanent over time (Bestelmeyer et al. 2003). The new technology, known as “ecological sites,” represents an improved tool that is more firmly rooted in a data-based understanding of the ecological dynamics of arid and semiarid ecosystems (Bestelmeyer et al. 2009).

Third, long-term data collection provides the opportunity for clients, partners, and stakeholders to be engaged in scientific processes. Often, long-term study sites, such as those that contribute to EcoTrends, are platforms for cooperative and collaborative activities with users of the information. These interactions create opportunities not only for technology and information transfers but for users to inform the science and its research directions. This kind of involvement increases the likelihood for research to be conducted that has impact and enhances the utility of long-term data.

It would be difficult, if not impossible, to adequately estimate the economic cost of developing today the network of sites and their long-term data sets that exist across the continent. As a reference point, the National Science Foundation has committed over $300 million to develop the soon-to-be-established National Ecological Observation Network (NEON) at 60 locations across the country. This network will be a sensor- and tower-based system; and though highly advanced scientifically and technologically, NEON is not as expansive as the land-based network of research sites currently in existence that form the basis for data in this book. The investment required today to develop the long-term data system currently in place would likely require many billions of dollars, if sites could even be selected and secured from existing land uses. Fortunately, these sites and data sets are in place, and their value to management of our natural resources is both evident and real.

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