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Long-Term Trends in Ecological Systems:

A Basis for Understanding Responses to Global Change

Contents

Chapter 8

Long-Term Trends in Human Population Growth and Economy Across Sites

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Human activities play profound roles in ecosystem dynamics, both directly through land use change, spread of invasive species, and increases in air and water pollution and indirectly through increases in atmospheric carbon dioxide (CO_2) and trace gases that modify climate and weather patterns. Rapid growth in the global human population during the last century, from 1.6 billion in 1900 to 6.7 billion in 2008, has increased demands for resources with subsequent effects on biotic (plants, animals, microbes) and abiotic (soils, atmosphere, water) properties of ecosystems. These changes in ecosystem properties result in modifications to the goods and services provided to humans. Thus, a feedback loop exists between human populations and their environments that makes it imperative that trends in human populations be examined as both a key driver to changes in ecosystems, and as a key responder to changes in those same systems.

Although human population is rising globally, the distribution is not uniform and varies spatially, even across the United States (figure 8-1). The Eastern United States is more heavily populated than the West, although parts of the West have experienced some of the highest rates of increase over the past 50 years (chapter 13). In particular, between 1990 and 1998, the Phoenix metropolitan area grew faster—a 31-percent rate of increase—than any other metropolitan area in the United States. (National average rate was 8.7 percent.)

Figure 8-1. Night lights show spatial variation in human population density across the United States. (Http://veimages.gsfc.nasa.gov//1438/land_lights_16384.tif.)

These increases in human populations throughout the country influence the ecological dynamics of research sites adjacent to urban areas as well as noncontiguous sites. Many research sites in this book were originally located in relatively pristine areas with low direct human impacts. As human populations have increased through time, housing and urban developments are moving closer to these formerly pristine areas. Although most research sites allow restricted or limited access to the public, the spread of native and exotic plants and animals from residential areas to nearby research areas is difficult to control. In addition, human activities upslope or upwind of research areas can influence those ecosystems through the transport of seeds, particulates, chemical compounds, water, soil, and nutrients by water, wind, and animals. This transport of materials can occur locally from a nearby city (figure 6-4) or over large distances, such as sediment loads from the upper Mississippi River deposited in the Gulf of Mexico.

Thus, we need to understand how human populations are changing in demographic and socioeconomic variables that directly influence nearby research sites. We also need to know the broader context of change in these variables across the country and how these changes influence patterns in migration and economic policies that can influence noncontiguous areas. Comparing human population and economic variables through time and across space (chapter 13) for the same set of sites where detailed ecosystem properties are measured (chapters 11, 12, 14) provides an opportunity to directly link these important elements of coupled human-natural systems.

In this chapter, we illustrate the value of long-term data in testing two important hypotheses related to spatial variation in trends in coupled human-natural systems and present a case study of cross-site comparisons made possible with population and economic data from different locations across the country. Long-term graphs of human population and economy data by site are in chapter 13.

Hypothesis 1. Tree Canopy Cover and Socioeconomic Status Are Positively Correlated in Both Urban and Suburban Counties

Tree canopy cover in both urban and suburban areas is largely a function of human population density, socioeconomic status, and lifestyle preferences. Although ecosystem properties such as water or soil nutrients can be limiting factors, these limits can be overcome through human intervention, including infrastructure, such as amendments to soil and irrigation, and management regimes including fertilizer application. These interventions along with maintenance of trees and available land for planting require resources. We hypothesize that variability of canopy cover in urban and suburban neighborhoods is explained primarily by the demographic and socioeconomic characteristics of those neighborhoods (Troy et al. 2007). A complementary hypothesis is that present-day canopy cover is a function of past socioeconomic characteristics of neighborhoods and that a “lag effect” can be detected through appropriate analysis of historic census data. Both long-term ecological data on canopy cover and human economic data collected by a suite of sites can be used to test this hypothesis (Boone et al. 2009).

Hypothesis 2. Health-Related Ecosystem Services Follow an Inverted U Relationship

Environmental conditions that affect human health, such as air pollution, are significantly affected by changes in the economy. We hypothesize that as the economy transitions from agriculture to manufacturing, either in locations or over time, air pollution will worsen. By contrast, as the economy shifts from manufacturing to a service economy, air quality will improve. The same inverted U relationship (known as the Environmental Kuznets Curve) is expected to develop with increases in income per capita. This hypothesis could be tested using air quality data obtained as the number of EPA nonattainment days per year for criterion air pollutants or as atmospheric deposition data in chapter 12 combined with economic data in chapter 13.

Case Study: Patterns in Human Population Growth Across the Country

Prior to this project and book, patterns in human population and economy variables had not been systematically examined for ecological research sites. Historically, most sites focused on collecting ecological data. In 1994, two LTER sites, NTL and CWT, were funded to incorporate a regional human dimension. In 1997, two LTER sites, BES and CAP, were funded as coupled human-natural systems with objectives directly related to studying human systems as part of the ecological system. More recently, the LTER Network published a document that describes a critical need for coupled human-natural systems research at all LTER sites (LTER 2007). This new direction for the LTER Network reflects an increasing recognition that humans are an integral part of all ecological systems. Thus, effects of both direct drivers (such as land use) and indirect drivers (such as climate change) of human systems on their environment must be studied in addition to studying feedbacks from ecological systems to human systems.

As a first step in studying these coupled systems, we examine spatial variation in trends in human populations with a focus on the percentage of the population that is urban. Although the United States in general is becoming more urban (Brown et al. 2005), we expect that the rate of change in urbanization varies across the country. We also acknowledge that some parts of the country are less urbanized than others. We selected six sites in different parts of the country to illustrate spatial variation in demographic change. Three of these counties were mostly urban in 2000: Santa Barbara, CA; Maricopa, AZ; and Miami-Dade, FL. The population data obtained from the U.S. Census Bureau show that these counties had very different patterns in the rate of change in urbanization through time (figure 8-2). Miami-Dade county in the southeastern United States, where the FCE LTER site is located, was more than 60 percent urban by 1920, whereas counties in the West became urbanized later: Santa Barbara County (SBC LTER) by 1930 and Maricopa County (CAP LTER) by 1950.

Three other counties were selected that were less than 80 percent urban in 2000—Dona Ana, NM; Grafton, NH; and Weld, CO (figure 8-3). These counties had similar rates of change until 1970 even though they are in different parts of the country. The increase in the populations of Doña Ana County (JRN LTER) and Weld County (SGS LTER) starting in 1970 reflects the migration of people from the north and west to the moderate climate of the Southwest and the Front Range of the Rocky Mountains. The county in New Hampshire surrounding the HBR LTER site remains mostly rural. These differential patterns in urbanization provide a template and stratification for future studies that link human populations with their environment.

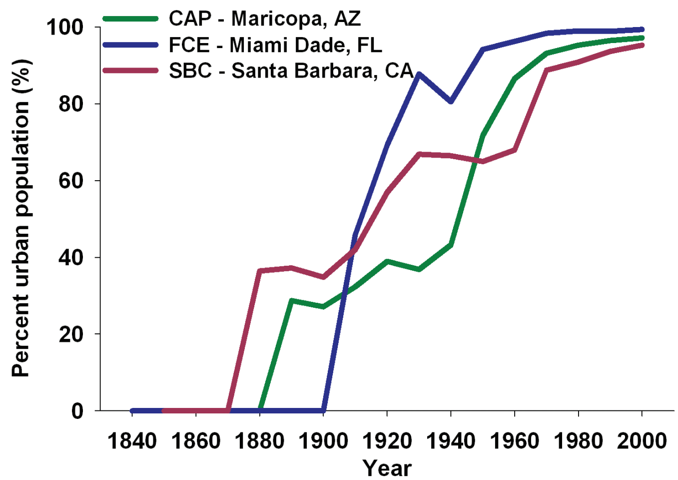

Figure 8-2. Percentage of the population in each county that was urban in each year of the U.S. census for three counties associated with LTER sites that are currently nearly 100 percent urban: Central Arizona-Phoenix (CAP), Florida Coastal Everglades (FCE), and Santa Barbara Coastal (SBC). (Original data from http://www.census.gov. Synthesized data from http://www.ecotrends.info.)

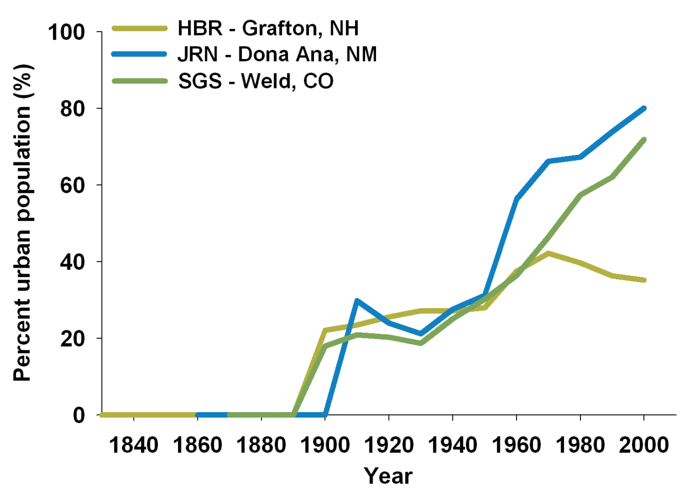

Figure 8-3. Percentage of the population in each county that was urban in each year of the U.S. census for three counties associated with LTER sites that are currently less than 80 percent urban: Hubbard Brook Ecosystem Study (HBR), Jornada (JRN), and Shortgrass Steppe (SGS). (Original data from http://www.census.gov. Synthesized data from http://www.ecotrends.info.)

Summary

Since 1920, the majority of the human population of the United States has lived in urban areas. In the past few decades, urbanization rates have been particularly rapid in the West. Timing of growth affects the nature of urban expansion across the country because of the variation in policies, availability of technologies, and cultural norms that dominate over time. Especially since World War II, urban growth has been characterized by low-density development on the periphery of cities. This urban expansion can have direct effects on surrounding ecosystems through land use change and indirect affects through resource consumption, nutrient transport, and waste generation. In turn, alterations to ecosystem structure and function can affect availability of ecosystem services and human outcomes and behavior. Therefore, integrating human and ecological systems is critical to understanding the feedbacks and linkages that affect both and to develop better management systems.

Long-term demographic data are valuable for testing variations in social-ecological systems across space and time. We hypothesize that variation in vegetation cover in urban areas reflects demographic characteristics more than biophysical limits and that past demographics may be better predictors of vegetation, especially tree canopy cover, than present population characteristics. Long-term census data coupled with ecological data could be used to test the Environmental Kuznets Curve hypothesis, that as the economic base shifts from agriculture to manufacturing to services, air quality will worsen then improve. Variability across LTER sites through time provides a rich dataset for testing socioecological dynamics.

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