# Changing Conditions and Changing Ecosystems: A Long-Term Regional and Transcontinental Research Approach on Invasive Species

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Two conundrums: "*Biological invasions are natural and necessary for persistence of life on Earth, but some of the worse threats to biological diversity are from biological invasions. ... One can either preserve 'a natural' condition, or one can preserve natural processes, but not both*." (Botkin 2001: 261)

## Abstract

Emerging new ecosystems are products of human activity. They occur everywhere but particularly in degraded sites and abandoned managed lands. These ecosystems have new species combinations and dominance by invasive species and appear to be increasing in land cover. As new ecosystems emerge on landscapes, issues of social values and attitudes toward alien species and naturalness increase in relevance. Despite their ecological and socioeconomic importance, however, very little empirical information exists about the basic ecology and social relevance of these ecosystems. We propose regional and transcontinental ecological and socioecological research to address questions about the structure, functioning, and ecological services of new ecosystems.

## Introduction

This paper addresses the subject of land use and land cover change in relation to invasive species and the emergence of new ecosystems. Its purpose is to propose the elements of a national invasive species research program that would anticipate issues and provide objective information to inform policy and management actions regarding the Nation's forests and rangelands.

## The Challenge

Dramatic environmental change—some say unprecedented change—is anticipated in the United States. Such a level of environmental change is a challenge to land managers because it tests their capacity to react and adapt their conservation activities in the face of evolving conditions. These changing conditions involve changes in the gaseous composition of the atmosphere, air temperatures, rainfall patterns, land covers, disturbance regimes, and species composition. Unfortunately, we do not understand the effects of these expected changes on ecosystems, and the tendency is to concentrate management approaches on preventing change for fear of the ecological and economic consequences. This fear, however, leads our policies to the conundrums in the previous quotation. The challenge is compounded by the need to deal with invasive species while also keeping track of ecosystem-level changes caused by species invasions and their implications to the overall functioning of landscapes. The scope of a national invasive species research program must transcend the individual species and focus on the whole biotic spectrum, including community-, ecosystem- and landscape-level processes.

## Future Environmental Setting

The Forest Service Resource Planning Assessment Report (USDA Forest Service 2006) anticipates a greater urban land cover, denser and increasingly urban human populations, greater exchange of species and connectivity between continents, and greater anthropogenic effects than exist today. Alien and native species are expected to become more invasive as community composition shifts away from the familiar ones of yesterday and today. Potential climate change and changing disturbance regimes add uncertainty to the mix. One critical

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aspect of these future environmental settings is the nature of the habitat modification by humans. Human activity can alter or disturb ecosystems in novel ways relative to natural disturbances. A clear example is the introduction of toxic substances to the environment. Subtler are land degradation activities over large areas, which preclude native species regeneration.

## Emerging Patterns

The change in species composition of ecosystems influenced by human activity will be the most daunting ecological issue in the 21st century. Already this issue is dividing ecologists in a number of manifestations of the same phenomena (Ewel et al. 1999). For example, ecologists argue about whether we are at the onset of an extinction crisis of equal proportions as the ones caused by asteroid effects. Ecologists also argue about whether alien species cause extinctions and the discussion turns more controversial when the debate focuses on whether the presence of aliens "destroys," "disintegrates," or changes ecosystem functions and processes. Ecologists also cannot agree on whether the expansion of alien species homogenizes or diversifies landscapes. Finally, ecologists cannot predict or do not understand what makes some species become invasive, and they argue about whether these invasive species are the causes of environmental change or the reflections of environmental change.

While ecologists are developing consensus to these fundamental questions, they have no disagreement on the following important aspects of the unfolding scenario:

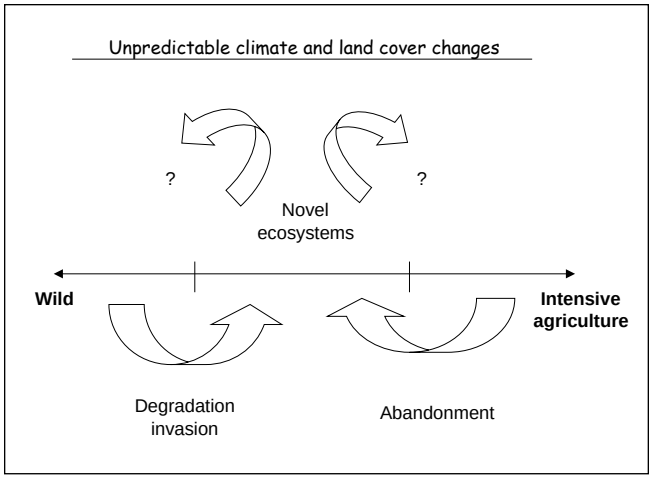
- The level and intensity of human activity is increasing.
- Land degradation continues.
- Species extinctions are occurring.
- Climate change appears more certain.
- Whole landscapes are changing.
- Many familiar ecosystems are not so familiar anymore.
- A larger number of alien and invasive species appear in most ecosystems.
- The cost of mitigating the effects of these species on agriculture and other land uses is increasing.
- Many alien species are becoming naturalized.
- The invasion and naturalization of alien species are leading to the formation of new species combinations (new ecosystems).
- Increased competition and symbiosis are emerging between native and alien fauna and flora.

All these trends have the same outcome: They result in changes in species composition of ecosystems. Clearly, as the 21st century unravels, changes in species composition of communities will become the dominant ecological phenomena that scientists and land managers must face. For the Forest Service to maintain a position of leadership in the 21st century, it must provide society with clear and reliable information for dealing with the changes in the biota that human activity is causing. At least two factors contribute to the confusion about invasive species issues: (1) lack of empirical understanding of the ecological changes taking place and (2) a clash of values in society. We discuss these two factors next.

## Emerging Ecosystems

Ecologists lack empirical understanding of the phenomena that will drive 21st century ecology because, for decades, ecological attention was centered on balanced or steady-state native and mature ecosystems. Ecologists gave less attention to anthropogenic disturbances and modified ecosystems. As a result, the science of ecology has a lot of catching up to do in the area of acquiring empirical information about the new ecosystems on Earth. New, emerging, or novel ecosystems are those with novel combination of species and human agency; i.e., they are the result of deliberate or inadvertent human action (Hobbs et al. 2006, Lugo and Helmer 2004). These ecosystems emerge naturally in response to such human actions such as land degradation, enrichment of soil fertility, introduction of invasive species, and abandonment of lands previously managed. Hobbs et al. (2006) suggest that emerging new ecosystems developed in a zone between two land cover extremes: (1) "wild" and (2) intensively managed or even urban covers (fig. 1). In reality, novel ecosystems develop anywhere species invasions occur. Within this broad geographic expanse, ecosystems are subjected to a broad range of modification and recurrent disturbances that induce species succession and competition and the resulting modification of the original community.

Figure 1.—*The interface between land covers on which novel or emerging new ecosystems occur* (*details in Hobbs et al. 2006*). *Novel ecosystems arise from either the degradation and invasion of "wild" or natural/seminatural systems or from the abandonment of intensively managed systems. They also arise when alien species invade nondegraded or otherwise intact ecosystems.*




At least four processes leading to invasiveness and species composition change can be identified:

1. Severe alteration of site conditions because of land cover change or degradation can preclude historical succession patterns and favor species invasions.
2. Ecosystems are subject to invasion by alien species that exploit unused resources.
3. Invasive species can outcompete native species, even when the environment has not changed.
4. Each of these processes requires a different management strategy to mitigate it, because the ecological processes and consequences are different. Research is needed to unravel those differences and consequences.

## Socioecology

A value issue is involved in how humans react to environmental change. We value familiar ecosystems and surroundings and naturally repudiate change, particularly when change is happening as fast as it is happening today. If we do not value an alien species, we are unlikely to accept information that suggests that that an alien species is acceptable, ecologically speaking. It appears that a need exists to combine empirical science with social science to explore the role of values in the interpretation of empirical data and the use of social science principles to influence how empirical information is transmitted to people to make its use more effective. Although the need to merge ecological and sociologic knowledge is not new, the impetus for socioecology has gathered momentum. This momentum is fueled by expected global environmental change scenarios and the new emphasis on ecosystem services as a way of demonstrating the value of natural ecosystems to economic sustainability.

## Research Approach

Research on invasive species must address multiple levels of biotic organization (from species to ecosystems and landscapes), be multidisciplinary, include a combination of natural history and experimental approaches, and encompass a long-term perspective over large spatial scales. We recommend a research program at two spatial scales to take advantage of the scope of the Forest Service Research and Development (R&D) organization and to address questions at the spatial level at which they occur. The two spatial scales are regional and transcontinental.

### Regional Research

We suggest interdisciplinary long-term study of the intersection of values and empirical science in new ecosystems, such as plantation forests, urban rivers, polluted lakes and reservoirs, new forests on abandoned agricultural lands, invaded forests and rangelands, and vegetation on brownfields. Our suggestion involves collecting information on the functioning of these ecosystems and evaluating them empirically as to their role in the modern landscapes. Their functioning should be compared with familiar native ecosystems not invaded by alien species. Simultaneously, we suggest socioeconomic and anthropological studies to determine people's attitudes toward new ecosystems. Such studies must include people from many locations and professions, including ecologists. The objective is to uncover values at different geographic and intellectual distances from the location of ecosystems and ecological understanding, respectively. One aim is to find out to what degree science can inform society and modify its values. A hypothesis could be that informed science leads to informed decisions and modifies values. The questions embedded in figure 2 are as follows:

Q1a. To what degree are new ecosystems a product of new disturbance regimes?

Q1b. What is the relative importance of disturbance and the external genome in the formation of alien-dominated ecosystems?

Q2. What are the ecological characteristics of alien-dominated ecosystems?

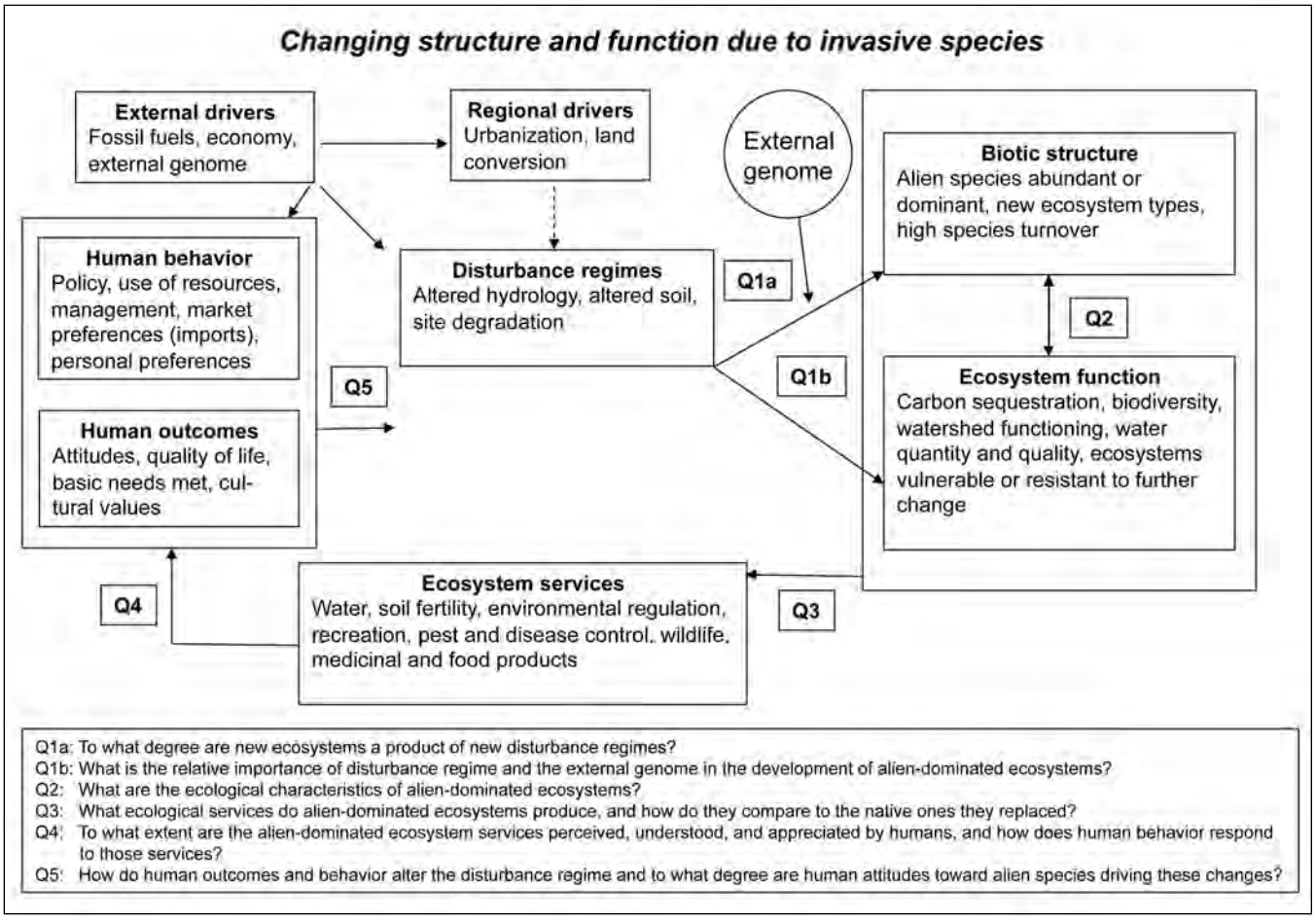
Q3. What ecological services do alien-dominated ecosystems produce, and how do they compare to the native ones they replaced?

Q4. To what extent are the alien-dominated ecosystem services perceived, understood, and appreciated by humans, and how does human behavior respond to those services?

Q5. How do human outcomes and behavior alter the disturbance regime and to what degree are human attitudes toward alien species driving these changes?

The larger question is this: What determines dominance in ecosystems and how do ecosystem structure and process reflect that dominance across gradients (Denslow and Hughes 2004)?

Figure 2.—*A sociecological system with key research questions on invasive species. This diagram, which was developed as part of an exercise within the Luquillo LTER, relates the ecological drivers and consequences of alien species invasions* (*right*) *with the related socioecological drivers and consequences* (*left*) *and lists possible research questions.*




*LTER = Long Term Ecological Research Network.*

## Transcontinental Research

Forest Service R&D units have access to many transcontinental gradients involving tropical to boreal (temperature), desert to rain forest (rainfall), lowland to montane (multiple gradients including atmospheric variation), etc. By focusing on gradients, researchers can quickly envelop the range of conditions that ecosystems face and can anticipate ecological behaviors at specific localities due to geographic shifts in the ecological gradients. Within these gradients (fig. 3a), they can find pristine to highly degraded examples of forests and ranges. Forest Service R&D is in a position to take advantage of the gradient space implicit in figure 3b to advance understanding of the mechanisms and consequences of emerging new ecosystems. We recommend a simple gradient approach to begin developing a research network with unified research questions. Whether the subject of research is at the species, group of species, or ecosystem level, studies across stations will benefit if they are conceived in the context of a gradient involving other stations or collaborators. Through commonality of methodology and types of questions asked, it will be possible to advance regional and transcontinental objectives simultaneously.

Some of the questions to address include the following:

- How do functional and structural attributes of emerging ecosystems vary along temperature, rainfall, and/or elevation gradients?
- How do ecosystem services change along temperature, rainfall, and/or elevation gradients?
- How does the dominance of invasive species change across these gradients?
- What are the patterns of plant life form dominance (e.g., trees vs. grasses) across emerging ecosystems and what are the implications to ecosystem functioning?
- Do plants, animals, and microbes follow the same patterns of response to human activity across the gradient?

Figure 3a.—*Temperature, precipitation gradients in watersheds within and without experimental forests and ranges. These gradients were developed as part of a NEON exercise among three Federal agencies: The USDA Forest Service, U.S. Geological Survey, and USDA Agriculture Research Service. Open dots illustrate sites that fall within steep temperature and precipitation gradients.*

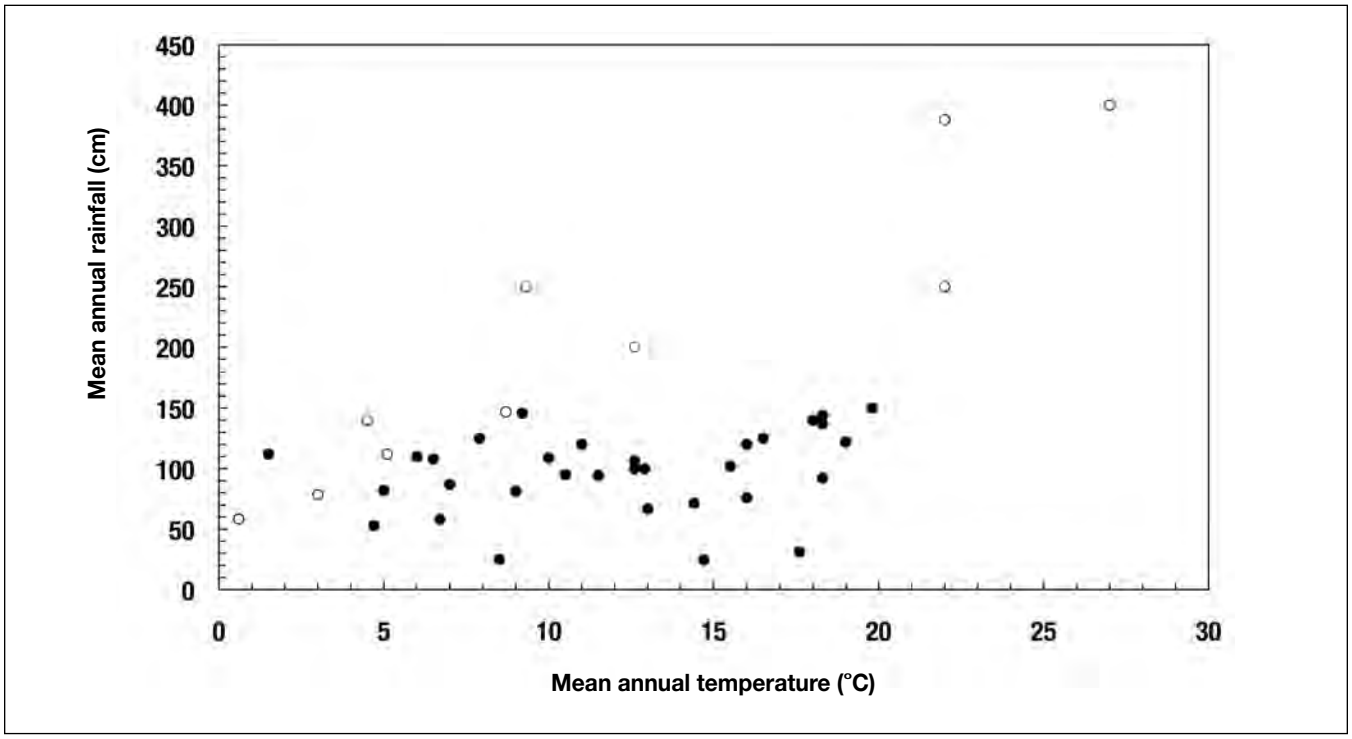
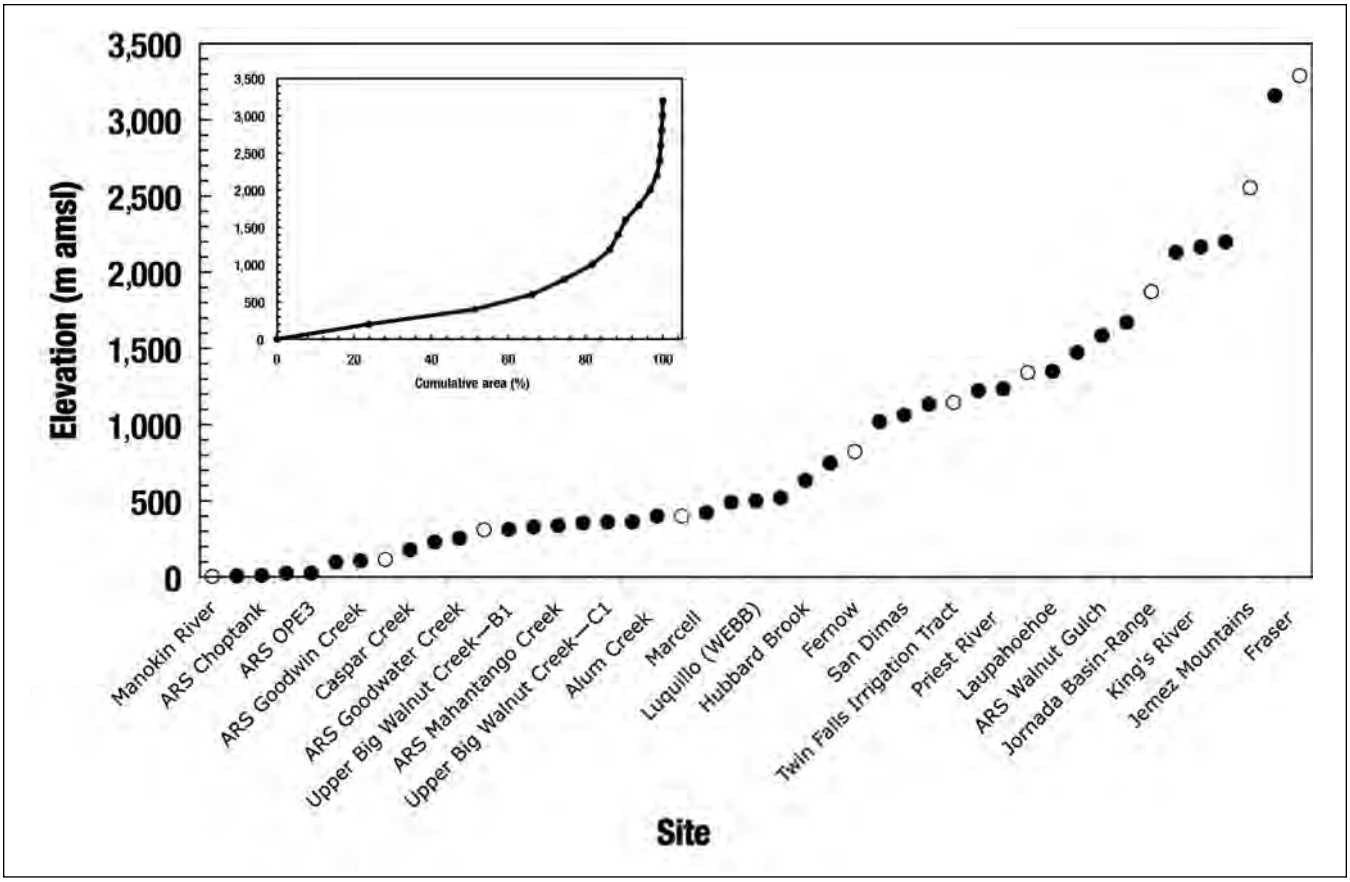


Figure 3b.—*Elevation gradients in watersheds within and without experimental forests and ranges. The insert in the elevation gradient represents the elevation gradient for the whole United States. These gradients were developed as part of a NEON exercise among three Federal agencies: the USDA Forest Service, U.S. Geological Survey, and USDA Agricultural Research Service. Open dots illustrate sites that fall within steep elevation gradients.*




*amsl = above mean sea level. ARS = Agricultural Research Service. NEON = National Ecological Observatory Network. USDA = U.S. Department of Agriculture. USGS = U.S. Geological Survey.*

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