

# The relevance of resilience

## *A forest manager's primer on linkages between biodiversity and forest resilience*

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**Phoenix:** Biodiversity underpins forest resilience. *Photo: iStockphoto/vicm*

**B**iodiversity underpins most forest ecosystem goods and services and many tropical forests maintain high levels of biodiversity. Loss of biodiversity has considerable consequences for the productive capacity of the forest resource. Maintaining these goods and services and the biodiversity is a cornerstone of sustainable forest management.

Forests have many unique properties, related to their high rates of primary productivity and biodiversity, which distinguish them ecologically from other ecosystems. Some of these properties include biological structures that develop in vertical and horizontal layers of live and dead plants, complex processes at multiple vertical levels from within the soil layers up to the canopy, the capacity for self-renewal in the face of constant small and large disturbances, plant-animal and plant-plant interactions, and the influence forest

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landscapes can have on micro- and regional climates, especially in large areas of closed-canopy tropical forests. Forests are comprised of multiple ecosystems that are associated with variable edaphic and microclimate conditions across broad landscapes. To sustain the goods and services we derive from forests, forest ecosystems must recover after disturbances and not become degraded through the loss of biodiversity. In large part, this means maintaining the resilience of forests through careful management with the clear recognition that the global climate is changing.

## **Resilience and forests**

Resilience is a quality that is commonly associated with people, companies, sports teams, and also forests. In all cases, being resilient has to do with an inherent capacity to recover from adversity. In forests, resilience is the capacity to recover from severe disturbance, such as fire or logging, to the original state. Forests are generally resistant to change, that is, they change little within bounds as a result of non-catastrophic disturbances such as insect herbivory or minor blowdown. Canopy gaps created by the death of individual or small groups of trees are quickly filled by new young trees. Forests may also be resistant to certain environmental changes, such as weather patterns over time, owing to redundancy among functional species (where redundancy refers to the overlap and duplication in ecological functions performed by the diversity of species in an ecosystem, see below). Redundancy can also confer system resilience and/or resistance in response to the impact of disease and pests. Ecosystems may be highly resilient but have low resistance to a given disturbance. For example, grasslands are not resistant to fire, but they are highly resilient and recover quickly after fire. Generally, most well-developed forests, especially primary old forests, are both resilient and resistant to changes.

As forests change after logging, insect attack, or under global warming, managers need to be concerned with bringing the forest back to a condition that will supply the goods and services that were desired from that forest. There is strong evidence that forest resilience is tied to the biodiversity that normally occurs in the ecosystem. In particular, certain species perform key functions in forests and so are essential for the forest to maintain all of its processes. Pollinators, some insects, bats and birds, are excellent examples of

highly functional species in ecosystems; without them many plants could not propagate. Similarly, bird predation can maintain insects at low abundances, reducing insect herbivory and hence increasing tree productivity. Forest resilience depends, in large part, on these key species and functions being maintained especially after forest management.

In the absence of biodiversity there would be no ecosystems and no functioning. There is evidence that complex forest ecosystems are more productive than less diverse ones (under the same conditions), and more productive ecosystems are more resilient than less productive ones. Forests comprised of few species supply few goods and services and are highly prone to various catastrophes including disease and invasion. Resilience in forest ecosystems comes from several different kinds of biodiversity in forests. First, the genetic make-up of species enables a range of tolerance to climate, moisture, and soil conditions. So, for example, the same species of tree growing under different site conditions may differ slightly in their DNA, as a long-term response to their environment. Similarly, species may differ in their relative abundances in the same kind of ecosystem depending on local conditions. For example, conditions might change sufficiently to favor one functional species over another such that, under those different conditions, the function of the system would not be lost but the species performing the primary functional roles might have changed. Finally, across large landscapes, certain species might replace others entirely in a forest system owing to different conditions. This 'landscape level' of resilience is common to many forest types, especially among animal species. So, forest resilience is a consequence of multiple aspects of biodiversity, and an emergent property of the ecosystem.

### **Climate change impacts**

Superimposed on the many other human impacts on forest ecosystems noted above is global climate change. Most evidence suggests that tropical forests may not be resilient to climate change over the long term, primarily owing to a predicted reduction in rainfall and increased drought. Climate has a major influence on rate of production, respiration, and other forest processes, acting through temperature, radiation, and moisture regimes over medium and long time periods. Climate and weather conditions also directly influence shorter-term processes in forests, such as frequency of storms and wildfires, herbivory, and species migration. As the global climate changes, forest ecosystems will change because species' physiological tolerances may be exceeded and the rates of biophysical forest processes will be altered. If climate change results in a significant reduction in water availability, then the forest ecosystem will naturally change species composition and hence, the state (the recognizable condition) of the ecosystem will be different. For example, conditions may reach a threshold beyond

which the vegetation structure is not sufficiently tall and dense to comprise a closed-canopy forest, and there will be changes in the dominant composition of the plant community. Under severe drying conditions, forests may be replaced by savannahs or grasslands (or even desert).

The synergistic effects of biodiversity on primary productivity are also most evident in primary tropical forests with respect to nutrient cycling. Many tropical forests naturally form on nutrient-poor substrates but these ecosystems have developed through natural selection such that they can harvest from rainwater the nutrients lacking in the soils. Furthermore, through retention and recycling they build up the stock of nutrients needed to support the high levels of plant growth enabled by moist tropical climates. Plants have special adaptations that serve to conserve nutrients and a myriad of other fungal, bacterial and animal species aid in their efficient and rapid recycling. Overall, biodiversity-related processes serve to increase the productivity and resilience of carbon dynamics in tropical forests.

Ecosystems and forests are comprised of assemblages of species. Across regions, individual species' ranges reflect their physiological and ecological niches, with the latter reflecting where the conditions are advantageous. Species with broad physiological niche requirements may be highly resilient to even significant global climate change. Likewise, species with narrow ecological niches might be more resilient than they appear, if changed conditions provide them with an advantage at the expense of competitors. In either situation, this capacity only applies to species which have large enough gene pools and/or the ability to migrate but for many species this is not the case. Where population sizes and genetic diversity have been reduced, or the mobility of species is restricted through habitat fragmentation or by natural lack of species mobility, the likelihood of successful adaptation to environmental change, such as climate change, is diminished. In some cases, populations exposed to a rate of environmental change exceeding the rate at which populations can adapt, or disperse, may be doomed to extinction. In the biological realm, maintaining species and genetic diversity addresses the need to be prepared for whatever environmental changes might happen, and this is fundamental to the concept of resilience.

Forests can also influence regional climates, depending on their extent and this is particularly true of the Amazon forest because of its huge area. As the climate changes, numerous feedbacks will occur between climate and forests, mediated through albedo, carbon cycle dynamics, energy fluxes, and herbivory. Hence, maintaining forest resilience can be an important mechanism to mitigate and adapt to climate change.

## Managing for forest resilience

A large part of a forest manager's job is helping a forest recover after timber harvesting, through sustaining the properties of the ecosystem over the long term. However, this job is now more complicated by the additional stress of climate change. Maintaining biodiversity is a key to maintaining forest resilience. The biodiversity in a forest is linked to and underpins the ecosystem's productivity, resilience, and stability over time and space. Biodiversity increases the long-term resilience and resistance of forest ecosystem states, increases their primary production, and enhances ecosystem stability at all scales. Forests have a capacity to resist environmental change owing to their multiple species and complex multiple processes. However, a reduction in biodiversity in forest systems has clear implications for the functioning of the system and the amounts of goods and services that these systems are able to produce. While it is relatively simple to plant trees and produce a short-term wood crop, the lack of diversity at all levels (i.e., gene, species of flora and fauna, and landscape) in these systems reduces resilience and resistance to disturbances, degrades the provision of goods and services that the system can provide, and renders it vulnerable to catastrophic disturbance.

The application of ecological sustainability principles in forest management will provide part of a long-term approach to mitigating and adapting to climate change. While proper sustainable forest management is a major part of maintaining forest resilience, response to climate change requires some extra planning and actions. The capacity to conserve, sustainably use, and restore forests rests on our understanding and interpretation of pattern and process at several scales, the recognition of thresholds, and the ability to translate knowledge into appropriate management actions in an adaptive manner. Part of the adaptation component is to develop an understanding, based on predictions and observations, of what the plausible future scenarios may be. The following suggestions are developed from ecological principles that can be employed to maintain and enhance long-term forest resilience, especially under climate change:

1. Plan ahead to maintain biodiversity at all forest scales (stand, landscape, bio-regional) and of all elements (genetic, species, community) based on expected future climate conditions.
2. Maintain genetic diversity in forests through management practices that do not select only certain trees for harvesting based on site type, and their growth rate or form.
3. Maintain stand and landscape structural complexity using natural forests as models and benchmarks. Managers should try to emulate the natural stands, in terms of species composition and structure, by using

silvicultural methods that relate to the major functional tree species.

4. Maintain connectivity across forest landscapes by reducing fragmentation, recovering lost habitats (forest types), and expanding protected area networks.
5. Maintain functional diversity (and species redundancy) and eliminate conversion of diverse natural forests to monotypic or reduced species plantations.
6. Reduce non-natural competition by controlling invasive species and reduce reliance on non-native tree crop species for plantation, afforestation, or reforestation projects.
7. Reduce the possibility of negative outcomes by apportioning some areas of assisted regeneration with trees from regional provenances and from climates of the same region that approximate expected conditions in the future. For example, compile a list of tree species that may be more drought-resistant than local species, and that provide similar wood value, and supplement re-planting using some of these.
8. Protect isolated or disjunct populations of organisms (populations at margins of their distributions) as source habitats. These populations represent pre-adapted gene pools for responding to climate change and could form core populations as conditions change.
9. Ensure that there are national and regional networks of scientifically designed, comprehensive, adequate, and representative protected areas. Build these networks into national and even regional planning for large-scale landscape connectivity.
10. Develop an effectiveness monitoring plan that monitors climate conditions and results of post-harvest silvicultural actions, and adapt planning and implementation as necessary.

A key aspect of any plan to maintain a flow of forest goods and services is a good understanding of local forest ecology on which to base sustainable forest planning and management.

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