Chapter 7
Conclusions

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Introduction

Forest ecosystems in the United States in the year 2100 will differ from those of today as a result of a changing climate. Those differences will be superimposed on the human imprint of forest management and the legacies of other land use activities, stressors, and disturbances of the 19th and 20th centuries. Future changes in forest ecosystems will occur across both public and private lands and will challenge our ability to manage forests sustainably, especially as the human population continues to grow, demands for ecosystem services increase, and fossil fuel supplies decrease. We summarize below the most important inferences from the preceding chapters, with emphasis on issues most relevant to land managers.

Forest Disturbance

Although increases in temperature, changes in precipitation magnitude and seasonality, higher atmospheric carbon dioxide (CO_2) concentrations, and higher nitrogen (N) deposition may over time modify ecosystem structure and function, the fastest and most significant effects on forest ecosystems will be caused by altered disturbance regimes. A warmer climate will increase the area burned by wildfire and the area affected by bark beetles and other insects. These two factors, individually, in combination, and as components of broader stress complexes, may lead to permanently altered species composition, distribution of forest age and structure, and spatial patterns across large landscapes.

An increase in wildfire throughout the United States, which will likely include at least a doubling of area burned by the mid-21st century, will challenge government agencies and social institutions. Fire directly affects human communities near wildlands, but it is also stretching the ability of federal and state agencies to pay for fire suppression. Expanded efforts to reduce hazardous fuels can reduce the severity of wildfire on a local basis, but if the current investment in reducing stand densities and fuels does not increase significantly, it will be impossible to mitigate the effects of increasing crown fires.

The current advance of bark beetles in forests throughout the Western United States and Canada is unprecedented and often affects more land area than wildfire on an annual basis. Similar to wildfire, insects cause a rapid change in forest structure and function but with a slower return of carbon (C) to the atmosphere. Insects appear to affect fire severity in some cases and are a component of stress complexes that include prolonged drought. The prospect of bark beetles affecting higher elevations and different tree species than in the past portends major changes in forest ecosystems previously considered unaffected by beetles. Reducing stand densities and improving stand vigor can reduce impacts at the local scale, but it will be challenging to implement effective mitigation across large landscapes. A strategy of modifying the spatial pattern of age and structure in forests affected by beetles may provide some hope for controlling the spread of insects in the long term.

Invasive plants are another important component of stress complexes throughout the United States, and although the exact trajectory of this stressor in forest ecosystems is difficult to project, invasive plant species will likely become more numerous and widespread in the future. Many invasive species are more competitive in a warmer environment with elevated CO_2. However, increased disturbance from fire, insects, and land use change are among the most important factors facilitating their dispersal and population growth. This risk may be highest in mountain ecosystems, where cooler temperatures have historically limited the spread of invasives.

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Geomorphic disturbance will also increase if storms become more intense as is projected by many climate models. Concentrating precipitation in shorter periods of time increases erosion and mass wasting during and following storms, and increases the duration and intensity of low soil moisture (drought) during the rest of the year. Pulses of erosion and movement of sediment into streams are difficult to predict, but if they do indeed increase, they will affect decisions about management of roads and other infrastructure, as well as access for users of forest land. Increased drought will exacerbate stress complexes with insects and fire, leading to increased tree mortality, slow regeneration, and changes in species assemblages at some forest ecotones.

Forest Processes

Stabilizing greenhouse gas concentrations in the atmosphere is a major goal for slowing global warming and buying time for implementation of alternative energy strategies and adaptation of forest ecosystems and human institutions to climate change. Forest growth and afforestation in the United States currently account for a net gain in C storage and offset approximately 13 percent of the Nation's fossil fuel CO_2 production. Overall, forest area has been stable since 1950, while C density (C per unit area) has increased. This assimilation of C is a function primarily of forest regrowth following timber harvest and land clearing in the previous two centuries and is projected to continue to around 2040, at which point U.S. forests could become a net emitter of C. The majority of this C is in live aboveground biomass and soil organic C, so anything that affects these two components will significantly affect total C storage. During the next few decades, Eastern forests are expected to continue to sequester C through favorable response to elevated CO_2 and higher temperature, while Western forests may begin to emit C through expanded fire and insect disturbance. At large spatial and temporal scales, reduced in forest land cover may offset some of the C gains expected in Eastern forests.

No standard evaluation framework exists to aid decisions about which management approaches—encompassing both biological and social processes—would be most effective in maximizing C storage (reducing emissions) while minimizing risks. However, five approaches guide strategic and tactical management of forest C: (1) increase forest area and avoid deforestation, (2) manage C in existing forests, (3) use wood as biomass energy, (4) use wood in place of other building materials, and (5) use wood products for C storage. These approaches differ considerably based on local forest productivity, management objectives, and economic conditions.

No-regrets strategies for enhancing C storage include preventing conversion of forest land to other uses and extending the life cycle of wood products. Avoided deforestation protects existing forest C stocks with low risk and has many co-benefits, although incentives to avoid deforestation in one area may increase removal of forest in other areas, as well as decrease economic opportunities for timber, agriculture, and urban development. Evidence for the benefits of fuel treatments (thinning plus surface fuel treatment) for C storage is equivocal, and the value of C offsets would be higher if thinning material had higher commercial value as long-lived products that yield substitution benefits and not just as bioenergy. The benefit of stored C in wood products is multiplied when wood is used in place of materials that require much higher C emissions to produce (e.g., concrete and steel). Careful management of forest products has potential for C mitigation that accrues over time and complements strategies for increasing forest C stocks, but effective strategies need to ensure that energy offsets are attained in an acceptable period of time and that substitution effects are attained.

The effects of climate change on water resources and biogeochemical cycling will differ by forest ecosystem and local climatic conditions, as mediated by local management actions. Large-scale disturbances such as fire, bark beetle outbreaks, and defoliating insects will reduce water uptake, causing a near-term increase in runoff and potentially erosion. In systems with a long regeneration time, as in low-elevation forests and woodlands of the Southwest, erosion may be high for years to decades following disturbance. Increased temperature during the past few decades has decreased snow cover depth, duration, and extent, a trend that will likely continue with further warming. Decreased snow cover will alter the seasonal timing of runoff and exacerbate soil moisture deficit in some forests, which may decrease tree vigor and increase susceptibility to insects and pathogens. In addition, fuels may remain dry and flammable for a longer period of time, leading to higher fire hazard and a longer period of time during which wildfires will burn. Less snow and drier fuels may also extend the time during which prescribed burning can be conducted, a potential benefit to resource managers.

Elevated CO_2 may increase the water use efficiency of some tree species, thus reducing evapotranspiration, but the effect on hydrologic dynamics will likely be modest. Warmer temperature may also modify tree phenology, although the effects on evapotranspiration are uncertain. If species and genotypes that grow fast are widely planted in the future, their demand for soil water could reduce streamflow in some locations. Warmer temperature may also accelerate the rate of nutrient cycling in some systems, promoting increased forest growth and elevated N levels in streams.

Species Distributions

It has been difficult to infer if changes in forest species distribution and abundance are occurring in response to climate change, partly because of the lack of long, high-quality time series on species distribution, and partly because the legacy of widespread land use actions are so persistent in most landscapes. Most models predict that suitable habitat for many species will move upward in elevation and northward in latitude and be reduced or disappear from current habitats in lower elevations and lower latitudes. This is supported by both process-based and empirical modeling, although the different assumptions and resolutions of the models lead to rather different spatial and temporal inferences about habitats and species. It is possible that new climatic conditions will “move” faster in some locations than tree species can disperse, creating uncertainty about the future vegetation composition of these new habitats. It is also possible that topographic diversity, and thus microclimatic diversity, in mountainous regions will be sufficient to support most current species but with different spatial distributions and abundances. Despite the uncertainty of current modeling, the paleoecological literature suggests that major changes in species distribution and abundance, often mediated by disturbance, are possible with small but persistent changes in temperature and precipitation.

Risk and Social Context

The Intergovernmental Panel on Climate Change (IPCC) and U.S. Global Change Research Program (USGCRP) currently emphasize that risk and uncertainty should be clearly articulated in order to provide a realistic context for interpreting scientific data and inferences. Risk assessment considers both the magnitude of a particular climate-change effect and the likelihood that it will occur. A risk management framework for natural resources means that risks are identified and that magnitude and likelihood of effects are quantified to the extent possible. Although risk management has been used (often informally) in natural resource management for many years, it is a new approach for projecting climate-change effects, and some time may be needed for both scientists and resource managers to feel comfortable with it. Risk assessment for climate change should be specific to a particular region and time period, and needs to be modified by an estimate of confidence in the projections being made.

The IPCC and USGCRP also emphasize that climate-change effects need to be considered in light of ecosystem services provided to local communities and human enterprises. Climate-change effects in forests are likely to reduce ecosystem services in some areas and increase them in others. Some areas may be particularly vulnerable because current infrastructure and resource production are based on past climate and steady-state conditions. For example, increased fire and insect attacks will, at least temporarily, reduce productivity, economic benefits from timber harvest, and C storage, and, in some cases, will increase surface runoff and erosion. In this case, potential losses of resource value and economic value are large, exclusive of the huge economic cost of fire suppression that may be required. Any change in forest ecosystems that affects water resources will result in a significant loss of ecosystem services.

Preparing for Climate Change

Federal agencies, and the U.S. Forest Service in particular, have made significant progress in developing scientifically based principles and tools for adapting to climate change. Adaptation builds on a sequence of activities that starts with education, continues with an assessment of vulnerability of natural resources to climate change, and culminates in development of adaptation strategies and tactics. This process is most effectively conducted through a science-management partnership in which scientists lead the education and vulnerability assessment phases, and resource managers provide most of the input for adaptation. Tools and techniques available to facilitate this process are readily available in recent materials developed by the Forest Service, and can be applied to both public and private lands. In addition, several case studies of adaptation for national forests and national parks, individually and in collaboration with other stakeholders, are now available and can be emulated by other land management organizations. Collaboration across multiple land ownerships over large landscapes will ultimately lead to the most effective adaptation strategies and plans.

Although uncertainty exists about the magnitude and timing of climate change effects on forest ecosystems, sufficient scientific information is available to begin taking action now. However, on-the-ground implementation of adaptation plans and carbon management are rare in both public and private forest sectors. This is due to a perceived lack of urgency, a limited number of personnel trained in climate change science, inadequate guidelines and protocols, and inadequate resources to implement another “unfunded mandate.”

Fortunately, land managers who are currently managing forest ecosystems in a sustainable manner are often already using “climate smart” practices. For example, thinning and fuel treatments implemented to reduce fire hazard also reduce intertree competition and increase resilience in a warmer climate. Increasing culvert size under roads reduces the risk of damage to roads and downstream resources that may occur in response to higher flood frequency and magnitude. Building on practices compatible with adapting to climate change will provide early successes and experience for resource managers who may want to start the adaptation process but do not have sufficient money, time, or personnel to initiate a major effort. We anticipate that climate change will be a standard component of sustainable resource management by the end of the decade, and that C management and adaptation will be fully embraced by forest management organizations. Building the foundation for this new management context as soon as possible will ensure that a broad range of options will be available for managing forest resources sustainably.