Impacts of Climate Change on Forests

I N T E R N E T   E D I T I O N

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INTRODUCTION

Experts generally (though not universally) agree that increased concentrations of greenhouse gases (GHGs) in the atmosphere will result in changes in the earth's climate. There is much less agreement about how such climate change could affect the earth's forests. The question is important because forests are an important global source of both valuable market goods (especially timber) and environmental benefits (such species habitat, biodiversity, and soil and climate stabilization). Additionally, it is important because the recent Kyoto Protocol requires significant reductions in net GHG emissions over the next ten years and provides "sink" credit only for deliberate human actions in forest that sequester carbon. This paper identifies potential sources of forest damage from climate change and evaluates the socioeconomic consequences. We conclude that the effects of climate change on forests generally and on timber harvests in particular are likely to be positive, meaning that previous research warning of severe consequences has overstated the risk. We also conclude that effects of climate change on ecological values associated with forests are a source of concern in specific places but need not be large overall, especially if climate change is relatively gradual and adaptation to climate change is enhanced. Although the sink function of forests is important, that topic will be developed in a future paper.

FOREST-CLIMATE INTERACTIONS

Forests thrive in a variety of climatic conditions, ranging from wet tropical forests to the forests of dry boreal (high-latitude) regions. The vegetative transition from deserts to grasslands to forests is commonly determined by moisture conditions. In extreme conditions the vegetative transition reverses course and forests are displaced by grassland. Forests generally flourish best in warm, wet environments and do progressively less well as temperature and moisture decrease. Thus forests would be expected to respond to changes in temperature and to increases or decreases in precipitation brought on by climate change. The types of trees growing at a given site might give way to those more suited to the new climatic conditions, or a forest might cease to exist altogether. However, the socioeconomic impact would depend not only on what disruptions occurred in the established relationships between forests and climates, but also on how human beings adapted to the consequences.

Ecological predictions of the impact that climate change might have on forests are generally based on the outputs of General Circulation Models (GCMs). Virtually all GCMs predict increased precipitation overall as a consequence of warming, but the pattern of regional increases and decreases in precipitation is more complex (for example, midcontinental areas could become significantly drier). Moreover, the amount of temperature change is likely to be smallest at the equator and progressively larger toward the poles.

The most recent GCMs point to an expansion in forest area from global warming, in contrast to studies in the 1980s that suggested a contraction. In light of the expected pattern of temperature changes, tropical forest areas would be less affected while boreal forests found in higher latitudes would be more affected. If higher moisture levels were generally to accompany the higher temperatures, as the GCMs now suggest is likely, increased growth and productivity would be expected to occur in the boreal forests, as would their expansion into the tundra regions of the North. The forest type and mix of species that now exist in temperate regions would give way to types and species better adapted to the new climate.

Climate change could have significant negative impacts on existing forests where there was a widespread decrease in soil moisture. This could occur where climate change caused precipitation to decline (or where warming occurred in conjunction with constant or only slightly elevated precipitation). Where a drier climate ensued, existing forests would give way to ones more suited to the new conditions, or even to other vegetation altogether, such as grasses or shrubs. However, increased carbon dioxide can improve water-use efficiency of individual trees, thereby to some extent offsetting the effects of the drier climate by making forests more tolerant to drought.

A recent modeling study by Bowes and Sedjo (see Further Readings) of the prairie-forest interface in the U.S. Midwest illustrates the sensitivity of forests to climate. These researchers showed that the condition of natural forest was critically dependent on precipitation. Where warming and drying coincided, the productivity of the forest declined and some of it was overtaken by prairie. However, where warming coincided with increased precipitation and thus decreased stress on trees, forest productivity increased and trees displaced some grass. In the short term (by forest standards—thirty years), the species mix of the forest changed only minimally. In the long term, however, the mix underwent considerable change as trees suited to the new climate conditions displaced those that could not adapt.

Other studies have shown that a higher level of atmospheric carbon dioxide generates a “fertilization effect” causing an increase in biological growth rates for certain types of plants, including trees. The evidence on carbon fertilization, however, is not complete. Moreover, carbon is often not the “limiting factor” in forest growth. If some other nutrient such as nitrogen were the limiting factor, productivity gains would be minimal. Species competition might also constrain overall productivity, so that total forest biomass at maturity might not increase.

CONCERNS ABOUT FOREST IMPACTS

Some analysts are concerned that climate change would mean a global environment less hospitable to forests, one where conditions would be rife for “dieback” — a high incidence of decline and individual tree death because the change in climate conditions would make them vulnerable to disease and insect predation. Alternatively, weakened or nonadaptive species might simply be overwhelmed by competition from tree species or vegetation more suited to the site in the wake of climate change.

A related concern is that any transition from one type of forest to another, or to another type of vegetation altogether, could be difficult and disruptive, perhaps leaving a site barren for years to come.

Even without climate change, a forest may not be able to migrate effectively over a landscape. Although forests can and have migrated, the rate at which they do so is not well understood, although pollen evidence provides some information about past forest migrations. The capacity to do so appears to vary with tree species. In addition, the heavy impact of human activities, such as agriculture and urbanization that involve the conversion and fragmentation of land, could hinder transition and replacement. If the climate change were modest and gradual, species more suitable to a site would probably infiltrate relatively easily and gradually displace forest types no longer able to thrive in the changing conditions. Should the change be rapid, however, greater forest transition problems might be expected. Replacement species would have difficulty migrating fast enough to replenish a dying site. Dead and ailing forest areas might not be overtaken and land with the look of a moonscape might appear.

However, the likelihood of this latter scenario is fairly low. Mature trees can survive in inhospitable habitats outside their normal range, although often they cannot procreate. Such stands of trees might well endure until more appropriate species replaced them at a more or less normal rate of mortality. Grasses and shrubs might also fill the space during the interim. Moreover, most of the updated GCMs suggest that temperature increases are likely to be smaller and more gradual than anticipated by earlier GCMs. This bodes well for a relatively orderly natural transition.

Some ecological models predict a difficult transition because of the unavailability of seeds from appropriate species. However, most forests consist of many species, which overlap each other’s natural range. Thus, while climate change may seriously impact some species, all the forest’s species are unlikely to be impacted negatively and seed sources may not be a problem. Additionally, human intervention could make a big difference in ameliorating this problem when it did occur, either through low-cost aerial seeding or costlier on-site sowing and replanting. Recent economic research that we conducted with colleagues (see Further Readings) suggests that in many cases, economic incentives would be sufficient to justify various types of forest regeneration investments during climate change. Typically, these investments would occur after timber stands were harvested or logs salvaged in cases where forests were experiencing dieback.

Among the many unanswered questions is whether forests would act more as a sink or a source of carbon as the world's climate changed. Models demonstrate that forests have the potential to be either, depending on the underlying ecological scenario. Some early analyses suggest that forests would be sources, emitting large quantities of carbon in the transition period. More recent analyses, however, suggest that forests would expand and thus absorb more carbon in the process, particularly when human activities in response to anticipated climate change are taken into account.

SOCIOECONOMIC CONSEQUENCES: TIMBER HARVEST AND NONHARVEST VALUES

Economic studies of U.S. and global timber markets indicate that global forests—both natural and cultivated—can be expected to expand with climate change, based on a large number of alternative assumptions about climate and ecology. The transition to new forest types could occur through interspecies competition or through dieback. Foresters are presumed to invest in reforestation where it is economically justified. In either case, future timber supplies would be larger and timber prices lower than in the absence of climate change.

This result contrasts sharply with some earlier studies. One reason is that more recent ecological models indicate less stress from climate change, as discussed above. More recent analyses also take into account the possibility of long-term human intervention and adaptation in forest management.

Forests are valued not only for their timber production, but also for their ecological services and recreational values. If forest dieback were to occur so rapidly that new forest had difficulty replacing existing ecosystem services (such as water protection and erosion control), the damage could be substantial. However, such a result appears unlikely. When forests experience catastrophic damage from natural disasters (e.g., major wildfires, volcanic eruptions, and serious pest infestations) natural systems typically respond with resilience. Because tree and plant species have different climatic ranges, the absence of one or several of them need not condemn a site to desolation. The horse chestnut tree, for example, was common in the eastern United States until the end of the nineteenth century when disease eradicated it. Yet the forest continued to perform its ecosystem functions unhindered as other tree species (in particular, hickory) filled in for what was lost. Similarly, a forest's recreational services—providing places for hunting, fishing, hiking, bird watching, and skiing—presumably could continue as the forest cover changed gradually over time.

In the case of wildlife, perhaps the major challenge would not be climate change per se, but the need to preserve a landscape that provided for adaptation. The migratory capacities of many species allow for relatively easy adaptation. The important caveat is that the necessary habitat areas and migratory pathways have to remain available.

Perhaps the most challenging problem associated with climate change and forests is the probable loss of biodiversity. Even without climate change, there is concern that substantial numbers of genes, species, and ecosystems are being lost in ongoing deforestation. It appears likely that climate change would add to the problem by disrupting certain delicate relationships within forests.

Some experts argue that more species on a site is better, because the site is filled more completely and the redundancy provides for rapid adaptation in case of external disturbances and changes. But other experts disagree. They counter that, beyond a certain number, species add nothing to the productivity of a site. They point to the fact that nature limits to a very few the number of species on certain sites, (e.g., eastern salt marshes and boreal forests). These experts conclude (see Further Readings) that neither evolutionary theory nor empirical studies present convincing evidence that species diversity and ecosystem function are consistently and causally connected.

Whether less diversity is a problem or not, a forest that is adapting to climate change is likely to experience losses. Endemic species in particular could disappear, since they are not widely distributed and may not migrate. However, tropical areas, which are the richest in biodiversity, are predicted to experience the least amount of climatic change.

CONCLUSIONS

Although climate change is not necessarily a pleasant prospect to consider, its impact on global forests in their entirety would in all likelihood be modest. However, its impact on individual forests could be substantial as they adapted to new climate conditions. New forests might rise up in the tundra. Others might wane in places where moisture levels declined. Overall, the impacts would likely be greatest in the higher latitudes, where more warming is expected.

The effect of climate change on the industrial wood supply would probably be positive. The negative effects on most ecological, environmental, and recreational services would not be large, provided that climate change occurred gradually, as most of the recent GCMs now predict. The major negative impact would likely be on biodiversity, particularly on endemic species that would have difficulty migrating. Mitigating the negative impacts of climate change on forests will depend on enhancing the capacity for adaptation.

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