Considerations for Forest Adaptation to Climate Change in Sustainable Production of Wood/Fiber/Biomass and Ecosystem Services

Roger A. Sedjo

Senior Fellow, Resources for the Future, Washington, DC

Abstract: *Climate change is expected to affect forests into the future. Although forests have an inherent resiliency that allows them to adapt to various disturbances, including past climate change, concerns are expressed that the rate of change of current and future climate may be more rapid than the ability of many forests to adapt. This paper examines the background of forest challenges to natural disturbances. Recent research on the ability of forests to adapt is cited, as are their general projections. This paper notes that most research suggests that while some areas are likely to experience dieback, other forests may flourish. Various tools available for humans to assist the adaptation process are discussed, with the management options for both timber-production and non-production forests discussed.*

BACKGROUND

Throughout most of human history, forests were largely a gift of nature, and human management was absent or modest at best. Wild forests are resilient, so they have persisted despite the numerous disturbances and threats. They have been adapting to modest climate changes since the last ice age (Shugart and others 2003). In much of the world, it is only in the past several decades that forest management has become important.

Today, forestry involves two types of forests: natural wild forests, and planted and intensively managed forests. The first type provides a host of environmental services, e.g., water values, wildlife habitat and carbon sequestration, while the latter tends to focus on the commodity timber production, as well as providing many environmental services. Forestry has changed a great deal since the mid 20th century. Humans now have a better understanding of forests' inherent resiliency and their ability to adjust and adapt to changing conditions. We also have learned a lot about managing forests. However, forests face tremendous pressures. Although they are a source fiber, fuel, and fodder, forests were often viewed as a hindrance to economic development. In the United States, forestland was converted to agriculture, and the land was converted to living space for expanding populations. Although some may view this conversion as unsustainable, and indeed it was, economists would view this movement as an adjustment from one equilibrium to another. This was true worldwide, but especially in New World and the United States.

As early as the 1870s Secretary Schurz raised concerns about the long-term viability of the U.S. forests to continue to provide water and timber, and throughout most of the 20th century, forecasts regularly predicted a coming "timber famine" (see Clawson 1979). However, even long-term trends rarely last forever. In the early 20th century, the forest area of the United States stabilized, and the forest stock started to expand as most of the land conversion was complete, agriculture in some areas declined as it lost its competitive position, e.g., New England. Many logged-over forests on sub-marginal agricultural lands experienced natural regeneration, e.g., part of the Lake States. Since 1952, the USDA Forest Service has undertaken systematic timber inventories, through what is now known as the Forest Inventory and Analysis (FIA) program. They found that for each inventory, the forest stock was greater than in the previous inventory. Forest stock cannot expand forever, but according to FIA it has not yet reached its biological peak in forest biomass on currently forested lands. This trend has been encouraged by the advent of forest management and particularly tree planting and planted forests.

Before the 1950s, little commercial tree planting was done, although the "make work" projects during the Great Depression did begin the tree-planting process. However, the 1950s saw the advent of the "soil bank" program, which evolved into the modern Conservation Reserve Program, with its emphasis on tree planting. In the following decades, the greater ability to control wildfire made commercial planted forest a less risky investment. Once managers began to incur the costs of planting trees, it made sense to strive to identify and develop superior trees (Sedjo 1983). During the latter decades of the 20th century, the era of plantation forestry emerged broadly across much of the globe. In the United States, most years between 1970 and 2000 saw tree-planting levels exceeding 2 million acres (Moulton and Hernandez 2000).

The ability to plant and manage forests effectively offers promise of aiding humans in their ability to address major crises including forest regeneration, and perhaps, future forest dieback that may be associated with climate change. Today we rarely, if ever, hear concerns expressed over a "timber famine." Some have characterized the situation at the beginning of the 21st century as facing a "wall of wood." Although the harvest within the National Forest System has declined dramatically as a result of political considerations, from about 12 billion board feet (BBF) in the late 1980s to 2 BBF annually since the early 1990s, no shortage of industrial wood has occurred. Concerns with the national forests now focus on ecosystem values and wildfire control, with relatively little attention given to timber production.

In summary, while forests may be subject to many pressures, historically they have proved to be extremely resilient systems. However, they are now believed to be threatened by a new foe—human-induced rapid climate change. But humans need not rely solely on the ability of natural systems to address forest challenges. Human activities can assist in confronting the challenges of climatic change facing wild forests and also provide for the production of industrial wood from planted and intensively managed forests during these challenging times.

FORESTS UNDER CLIMATE CHANGE: SOME PROJECTIONS

The current focus of concern is increasingly on the effects of climate change on forests. Will a warmer world threaten global forests? Clearly, trees have demonstrated that they can prosper in many environments. From the tropics to the tundra, from seashores to mountaintops, trees flourish.

As the climate changes, forests must find ways to adapt, and adaptations have been tracked in earlier periods (Shugart and others 2003; Smith and Shugart 1993). Forests can adapt to climate changes by migrating to areas with a more favorable climate either through natural seed dispersal or human intervention. For example, forecasters predict that the most dramatic increases in temperatures will occur in high latitudes. Thus boreal forests of the northern latitudes may migrate to the north and occupy large areas that were previously tundra. As they depart from the warming temperatures at the southern edge of their range, temperate forests of the middle latitudes may expand into the lands formerly occupied by boreal forests.

A host of studies have systematically questioned the implications of climate change, specifically warming and corresponding precipitation changes on vegetation and forests (e.g., Haxeltine and Prentice 1996; King and Neilson 1992; Neilson and Marks 1994; VEMAP Members 1995). These studies have generally found that many future climates are likely to be conducive to forests. Studies generally agree that a warmer (and wetter) globe, as anticipated for many parts of the globe, is likely to be as accepting of forests as the global climates of recent decades. However, these studies also project warmer and drier areas where forests are unlikely to flourish. Studies suggest that brush and grasses are likely to replace forests in some warmer and drier climate (van Mantgem and others 2009; Bowes and Sedjo 1993). In fact, many studies suggest that forests overall may flourish and perhaps expand in a warmer and wetter world (e.g., see Haxeltine, unpublished dissertation; Haxeltine and Prentice 1996; VEMAP Members 1995).

Projecting these changes on a regional basis, however, may be difficult. Regional climate change projections are usually done using general circulation models (GCMs) that focus on regional climate change. However, for many regions, the different models project different climate outcomes (Watson and others 1998; VEMAP Members 1995). As noted above, temperature is important, but so is precipitation. A warmer and wetter climate will support a very different forest than a warmer and drier one (e.g., Bowes and Sedjo 1993). Although GCMs often generate similar regional temperature projections, their variability regarding precipitation projections is much greater.

For the continuation of the forest, the challenge likely will be to get the right species in the right locations. As the climate changes, forests must find a way to adapt. Although forests have demonstrated mobility, researchers have often estimated range shift to be relatively quite slow (e.g., Davis and Shaw 2001). However, this issue is not wholly resolved (Clark 1998), and it appears that migration rate varies with tree type and species, as well as the severity of climatic change. Of course, no one is quite sure how rapidly climate change will occur either. We can conceive of climate change outrunning the mobility of forests (Solomon and others 1996), but most researchers now believe a moonscape outcome is unlikely. Not all plant and tree species demonstrate the same degree of mobility, however, so many of the resulting forests will likely experience changes in composition, thereby changing the broad forest ecosystem (Shugart and others 2003).

We humans believe, in principle, that we can limit the extent of climate change by controlling greenhouse gas emissions. Otherwise, why would we bother with a climate policy? But the jury is still out—and is likely to be out for most of this century—as to how effective human mitigation of climate change will be and thus how much global climate change will subsequently occur.

Beyond the question of future forests is that of the potential of these forests—wild and managed—to provide industrial wood to society. Based on the various projections of forest changes, numerous studies have examined the implications of these changes on global forest area and particularly on future industrial wood production potential (Joyce and others 1995; Perez–Garcia and others 2002: Kirilenko and Sedjo 2007; McCarl and others 1999; Sohngen and others 2001). Generally, the results have been encouraging for global wood production and for meeting the world's wood consumption requirements.

WHERE ARE WE TODAY?

Our generation has inherited a global forest of about 4 billion hectares (FAO 2012a). These forests provide a host of ecosystem services, as well as industrial wood, of which the world consumes about 2 billion cubic meters annually (FAO 2012b). That computes to about 0.5 cubic meters per hectare per year. Achieving an average growth rate equivalent to this rate of consumption does not appear to be too daunting a task. There are many places in the world where a managed forest can yield an average of 10 cubic meters per hectare per year. At this growth rate, which assumes appropriate climatic conditions, it would require only 200 million hectares of sustainability managed forests—5 percent of the existing forest area—to produce this volume indefinitely (Sedjo and Botkin 1997). Thus, in facing a world of climate change, humans have been dealt an apparently strong hand with respect to industrial wood production.

Although the world is still harvesting from natural forests, the portion harvested from planted or managed forests today is about 50 percent, and this is projected to rise to 75 percent by 2050 (Sohngen 2007). Importantly, the fact that we can produce most of the world's industrial wood on a small fraction of the world's forested area provides opportunities in addition to presenting challenges. Having these large forested areas allows for many opportunities for forests to adapt to changing climate, both through natural processes and with human assistance.

FOREST MANAGEMENT AND ADAPTATIONS

Forest managers now have a significant ability to control the production and location of much of the industrial wood supply, and a variety of management activities can be used to help forests adapt to a changing climate (Seppala and others 2009; Sohngen 2007). When trees are planted, as they are now for nearly half of the world's industrial wood (Sohngen 2007), managers can choose seedling types based on the expected future climate conditions of the site. Furthermore, shorter rotations enhance the forest manager's flexibility and ability to adapt to unforeseen changes. Humans can assist this inherent adaptive ability through activities such as providing vegetative corridors and aerial seeding.

Additionally, as in agriculture, biological breeding can customize tree genetics to make a species more tolerant to the conditions it is expected to face (Sedjo 2004). Genetic modifications can make a tree more resistant to climate-related challenges such as drought or higher or lower temperatures, and genes can also be modified for greater growth rates. Planting, as opposed to natural regeneration, allows for the customization of tree species and genetics to the particular site, as well as to current and expected future climatic conditions.

Carbon dioxide (CO_2) itself will likely assist forests in adapting to climate change. Higher levels of CO_2 will generate a "fertilization effect" that is expected to accelerate the growth of trees (Norby and others 2005; Shugart and others 2003). Evidence shows that this effect may already be occurring (Boisvenue and Running 2006).

A STRATEGY FOR FOREST MANAGEMENT IN AN UNCERTAIN WORLD

Forestry, like agriculture, has always been plagued with a high degree of uncertainty and risk due to droughts, storms, diseases, infestations, and other threats. For forests, wildfire can be added to the list. Nevertheless, humans can anticipate changing climate conditions and begin to undertake mitigating activities.

If we view the world's forest as consisting of two groups—natural, largely wild forests and managed planted forests—the climate strategy for each might be different. Where management and planting are common, harvest of existing forests can be followed by planting trees expected to be appropriate to the newly emerging climate (Sedjo 2010). Adaptations can be achieved via using different provenances, different species, or trees bred to deal specifically with the anticipated environment. Even without climate change, planting, although expensive, commonly makes economic sense for commercial plantations in many regions. When facing predicted climate change, managers can make judicious choices as to planting stock to anticipate that change.

More broadly, for largely planted forests, management has a variety of tools (see Seppala and others 2009; Sohngen 2007). Managers can control the choice of site, species, and genetics of what is planted. They also can control the timing of planting and harvests and can vary the rotation period as desired. If managers have confidence as to the nature of the future regional climate, they can adjust species, planting, management, and harvesting cycles accordingly.

In regions where the future climate is viewed as quite uncertain, managers may stress flexibility recognizing that their best analytical speculations may be incorrect in some aspects. For example, if uncertainty exists as to the speed or direction of climate change, the manager might adapt by reducing the harvest rotation period or by modifying a planned sawtimber rotation to a pulpwood or fuelwood rotation. This approach, while not satisfactory for all situations, might be appropriate for many climate change situations, particularly for planted forest.

For existing wild forests, other approaches may be more judicious. Many plants, including trees, have a natural mobility, but this mobility can be inhibited by various barriers, such as intervening cropping modes, industrial developments, or roads. Humans can act to keep mobility channels open for trees and other indigenous plants in much the same way that channels for wildlife mobility are maintained. Additionally, other human interventions can be undertaken. For example, aerial seeding is a fairly inexpensive method that can be used to assist nature in enhancing forest mobility.

Finally, wildfire is an especially important component of the threats and uncertainties facing forests. For example, although fire suppression is useful in allowing new types of more suitable stands to become established during a transition to the new climate, fire can also be useful in facilitating the species transition in natural forests by creating openings in previously well established older forests (Sedjo 1991).

SUMMARY AND CONCLUSIONS

In summary, climate change is likely to have a substantial effect on forests. Although some individual trees and species will likely experience decline and dieback, many forest types may flourish in modified forms in the anticipated modified global climate.

However, a huge amount of adaptation will be necessary as forests adjust to a rapidly changing climate. Wild forests will see migration and dieback of many of their tree species, and the broader forest ecosystems will change as tree types migrate into and out of various regions as the local climates change. The fate of individual forests will depend on the interaction of several variables, including temperature, precipitation and moisture, changes in natural disturbances such as fires and infestations, and importantly, the type of human interventions. Humans can play a role in aiding wild forest transitions by reducing barriers to tree migration and perhaps establishing plant corridors, aerial seeding, and other facilitating activities.

The global industrial wood industry is probably relatively well-positioned to address climate change, although not without costs. Highly managed and planted forests are providing increasing portions of the industrial wood supply. Forest managers have a number of tools they can use to adapt industrial wood production to a changing climate, including choice of species, genetically modified stock, selection of location, timing of planting and harvest, and various other silvicultural practices. Although it is generally believed that humans can predict warming with some confidence, predicting regional precipitation is more problematic but no less important to forest success. In the absence of highly confident outcomes, flexibility in the timing and application of management tools is probably the key to industrial forest management success.

REFERENCES

Boisvenue, C.; Running, S.W. 2006. Impacts of Climate Change on Natural Forest Productivity—Evidnece since the Middle of the 20th Century. Global Change Biology. 12: 1-21.

Bowes, M.; Sedjo, R. 1993. Impacts and Responses to Climate Change in Forests of the MINK Region. Climatic Change. 24: 63-82.

Clark, J.S. 1998. Why trees migrate so fast: confronting theory with dispersal biology and the paleorecord. American Naturalist. 152: 204-224.

Davis, M.B.; Shaw, R.G. 2001. Range Shifts and Adaptive Responses to Quaternary Climate Change. Science. 292: 673-679.

FAO. 2012a. Forest Products. Rome: Food and Agricultural Organization of the United Nations.

FAO. 2012b. State of the World's Forests, 2012. Rome: Food and Agricultural Organization of the United Nations.

Haxeltine, A. 1996. Modelling the Vegetation of the Earth. Unpublished Ph.D thesis. Faculty of Science, Plant Ecology. Lund, Sweden: Lund University.

Haxeltine, A.; Prentice, I.C. 1996. BIOME3: An Equilibrium Terrestrial Biosphere Model Based on Ecophysicological Constraints, Resource Availability, and Competition among Plant Functional Types. Global Biogeochemical Cycle. 10(4): 693-709.

Joyce, L.A.; Mills, J.R.; Heath, L.S. [and others]. 1995 Forest Sector Impacts from Changes in Forest Productivity Under Climate Change. Journal of Biogeography. 22: 703-713.

King, G.A.; Neilson, R.P. 1992. The Transient Response of Vegetation to Climate Change: A Potential Source of CO2 to the Atmosphere. Water, Air, and Soil Pollution. 94: 365-383.

Kirilenko, A.; Sedjo, R.A. 2007. Climate Change Impacts on Forestry. Proceedings of the National Academy of Sciences. 104: 19697-19702.

McCarl, B.A.; Adams, D.M.; Alig, R.D. [and others]. 1999. The Effects of Global Climate Change on the U.S. Forest Sector: Response Functions Derived from a Dynamic Resource and Market Simulator. Climate Research. 16: 255-259.

Neilson, R.P.; Marks, D. 1994. A Global Perspective of Regional Vegetation and Hydrologic Sensitivities from Climate Change. Journal of Vegetation Science. 5: 715-730.

Norby, R.J.; DeLucia, E.H.; Gielen, B. [and others]. 2002. Impacts of Climatic Change on the Global Forest Sector. Climatic Change. 54: 439-461.

Sedjo, R.A. 1983. The Comparative Economics of Plantation Forestry: A Global Assessment. Washington, DC: Resources for the Future.

Sedjo, R.A. 1991. Economic Aspects of Climate, Forests, and Fire: A North American Perspective. Environment International. 17 (2/3).

Sedjo, R.A. 2004. The Potential Economic Contribution of Biotechnology and Forest Plantations in Global Wood Supply and Forest Conservation. In Strauss, S.H.; Bradshaw, H.D., eds. The Bioengineered Forest: Challenges for Science and Society. Resources for the Future, Washington, D.C.: 22-35.

Sedjo, R.A. 2010. Adaptation of Forests to Climate Change: Some Estimates. RFF DP 10- 06. http://www.rff.org/RFF/Documents/RFF-DP-10-06.pdf

Sedjo, R.A.; Botkin, D. 1997. Using forest plantations to spare natural forests. Environment. 30: 15-20, 30.

Seppala, R.; Buck, A.; Katila, P., eds. 2009. Adaptation of Forest and People to Climate Change—A Global Assessment Report. IUFRO World Series Vol. 22.

Shugart, H.H.; Sedjo, R.A.; Sohngen, B. 2003. Forest and Climate Change: Potential Impacts on the Global U.S. Forest Industry. Report prepared for the Pew Center on Climate Change.

Smith, T.M.; Shugart, H.H. 1993. The Transient Response of Terrestrial Carbon Storage to a Perturbed Climate. Nature. 361: 523-526.

Sohngen, B. 2007. Adapting Forest and Ecosystems to Climate Change. http://www.iccgov.org/files/ADAPTATION/Sohngen_ccforest_4_2009.pdf

Sohngen, B.; Mendelsohn, R.; Sedjo, R.A. 2001. A Global Model of Climate Change Impacts on Timber Markets. Journal of Agriculture and Resources Economics. 26 (2): 326-343.

Solomon, A.; Ravindranath, N.H.; Steward, R.B. [and others]. 1996. Wood Production under Changing Climate and Land Use In R.T. Watson (ed.), Climate Change 1995: Impacts, Adaptation & Vulnerability.

van Mantgem, P.J.; Stephenson, N.L.; Byrne, J.C. [and others]. Widespread Increase of Tree Mortality Rates in the Western United States. Science. 323: 521-524.

VEMAP Members. 1995. Vegetation/Ecological modeling and analysis project (VEMAP): comparing biogeography and biogeochemistry models in continental scale study of terrestrial ecosystems responses to climate change and CO2 doubling. Global Biogeochemical Cycles 9: 407-437.

Watson, R.T.; Zinyowera, M.C.; Moss, R.H. 1998. The Regional Impacts of Climate Change: An Assessment of Vulnerability. Cambridge: Cambridge University Press.

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