Valuing the impacts of climate change on forestry

Brent Sohngen (Ohio State University)

1. Briefly review the existing estimates of the value of climate change impacts on forestry. In addition to the best central estimates, also describe the wider range of possible outcomes—including those that may arise from potential economic catastrophes—and the relative likelihoods of these outcomes.

Current estimates suggest that forestry outputs are likely to increase globally over the century (see Table 1). As a result, consumers will gain from increased timber output and lower timber prices. Producers could gain if timber production increases due to climate change, although lower prices could have negative impacts in some regions (for discussion of overall welfare impacts, see Sohngen et al., 2001). The strongest gains are projected for subtropical regions where producers are able to adapt more quickly with faster growing timber types.

Table 1: Estimates of impacts of climate change on timber outputs by region (reproduced from Table 4.2 in Seppala et al., 2004).

Region	**Output**		**Producer Returns**
	2000–2050	2050–2100	
North America[1]	-4% to +10%	+12 to +16%	Decreases
Europe[2]	-4% to +5%	+2 to +13%	Decreases
Russia[3]	+2 to +6%	+7 to +18%	Decreases
South America[4]	+10 to +20%	+20 to +50%	Increases
Australia/New Zealand[4]	-3 to +12%	-10 to +30%	Decreases& Increases
Africa[5]	+5 to +14%	+17 to +31%	Increases
China[5]	+10 to +11%	+26 to +29%	Increases
South-east Asia[5]	+4 to +10%	+14 to +30%	Increases

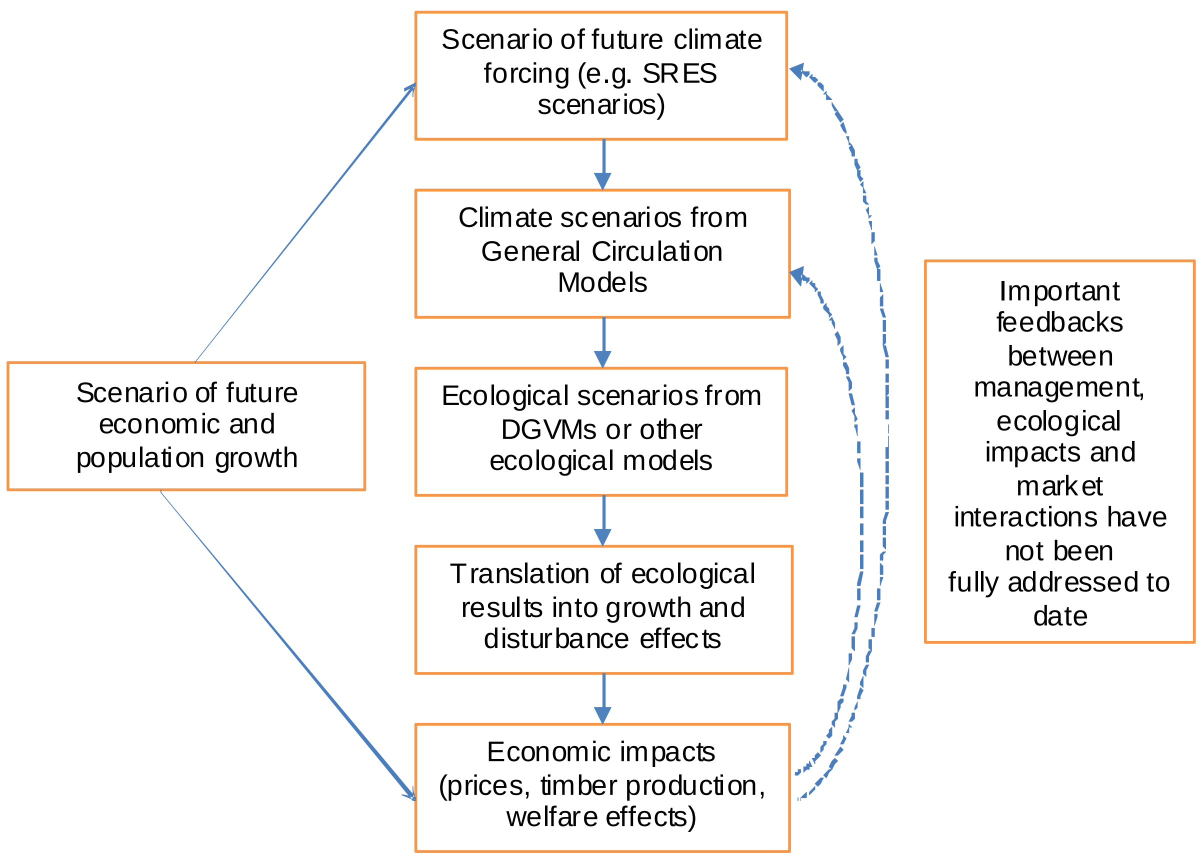
[1] Alig et al. (2002), Irland et al. (2001), Joyce et al. (1995, 2001), Perez-Garcia et al. (1997, 2002), Sohngen et al. (2001), Sohngen and Mendelsohn (1998, 1999), Sohngen and Sedjo (2005)
[2] Karjalainen et al. (2003), Nabuurs et al. (2002), Perez-Garcia et al. (2002), Sohngen et al. (2001)
[3] Lelyakin et al. (1997), Sohngen et al. (2001)
[3] Lelyakin et al. (1997), Sohngen et al. (2001)
[4] Perez Garcia et al. (1997, 2002), Sohngen et al. (2001)
[5] Sohngen et al. (2001)

Although the general results suggest higher output in forestry, there is large uncertainty about these results. The ranges shown in Table 1 are not uncertainty bounds, but they are instead ranges based on different studies in the literature. These do not reflect the full set of uncertainty that would be expected to affect estimates of economic impacts, but they are illustrative of the current state of knowledge.

One of the difficulties of measuring uncertainty in economic outcomes relates to method used to conduct integrated assessment modeling of forestry impacts. Figure 1, for example, represents the typical modeling steps that are undertaken to calculate the impacts of climate change on forestry. Modelers start with the climate models, which are linked to ecosystem models, which are in turn linked to economic models. All of the models have their own uncertainties, and researchers will handle these uncertainties in different ways, depending on the resources they have to conduct a study.

For example, uncertainty in climate outcomes from the climate models can be incorporated, at least tentatively, by utilizing several different models. There are a large number of climate models, and if researchers have access to many of them, they can choose them in order to represent the range of potential outcomes from the models. The ecosystem models, nowadays the Dynamic Global Vegetation Models (DGVMs), also contain uncertainty. There are fewer ecosystem models than climate models, but in the past, research teams have collaborated to prepare results across different ecosystem models based on common climate inputs (e.g., VEMAP Members, 1995). In these cases, the research teams have represented at least some of the uncertainty in ecosystem outcomes by using results from several models.

Figure 1: Flow of forestry integrated assessment models of climate change impacts (from Seppala et al., 2009)



2. How do these estimates vary across regions? Characterize the uncertainty / robustness / level of confidence in these estimates, on average globally and by region.

The results in table 1 suggest potential negative effects in the shorter-term in temperate regions like the United States, Canada, Europe, Russia, etc. There are several reasons for this. The ecological models utilized in the studies in Table 1 suggested that climate change could cause relatively large disturbances in forests over the next several decades, and these disturbances could negatively influence outputs. While the impacts are mitigated to some extent by adaptation through salvage harvesting, the changes in disturbance patterns modeled by the ecological models were large enough to have important impacts.

In contrast, most subtropical and tropical regions are projected to potentially benefit from climate change according to the results in Table 1. These trends are anticipated to continue. Over the past half century, there has been a continued increase in the area of fast-growing timber plantations in subtropical regions world-wide. Current estimates suggest that there are 90-100 million hectares of fast-growing timber plantations globally with20-40 million of these hectares located in subtropical regions (ABARE-Jaako-Poyry, 1999; Sohngen, 2010). They are estimated to provide 15-25% of global timber supplies currently (Daigneault et al., 2008; Sohngen, 2010), and are expected to provide much of the growth in output in the coming decades. The fast-growing plantations have timber species that can be harvested in 10-25 year rotations and produce 10-20 m^3 per hectare per year in wood (Cubbage et al., 2010).

Economic studies suggest that managers are able to adapt to climate change relatively rapidly with these fast-growing plantation species. As supplies in temperate zones are affected by disturbances, supply of timber from plantations expands to limit any shortfalls globally. In fact, managers of plantation forests appear to be able to take advantage of some of the impacts of climate change in forests that have longer rotations. Furthermore, ecosystem models used in the earlier economic studies did not suggest as large of disturbance patterns in subtropical regions as in temperate regions, so plantations were exposed to less risk than their counterparts further north.

As noted above, it is difficult to quantify the uncertainty in economic outcomes. Most of the studies conducted so far are greater than 5 years old, and thus are reliant on climate and ecosystem modeling that occurred in the early to mid-1990s. This constitutes an important limitation to the robustness of the result described above. Utilizing more recent climate and ecological modeling may lead to very different estimates of economic impacts.

3. Briefly review the models and data used to estimate the value of climate change impacts on forestry.
    a. What types of natural science models and data are used to inform these estimates, and what categories of values have been included?

A number of different ecosystem models have been used to date by economic modelers. For example, the models in the study by VEMAP Members (1996) have been used by a number of different modelers to examine economic effects of climate change. These earlier models have been supplanted by more recent Dynamic Global Vegetation Models (e.g., Fischlin et al., 2007;

Bachelet et al., 2003, Bachelet et al., 2004). These models project changes in ecosystem type, changes forest productivity (net primary productivity, net ecosystem productivity, and net biological productivity), and in some cases changes in carbon content due to fire or other disturbances. The models can be implemented at a range of scales depending on the inputs. Often, for example, they are implemented globally at the 0.5 degree grid cell basis; however, they can be implemented at a finer scale for more specific regional analysis. For climate analysis, however these models all rely on climate model inputs, which are often provided at a much more aggregate level.

b. What physical and economic factors make some regions more or less vulnerable to the impacts of climate change on forestry than others?

The most vulnerable regions to climate change in forestry appear to be regions that currently produced the greatest share of output. For instance, in the United States, the Southern US produces the greatest share of output nationally and is also projected to be the most vulnerable in analyses to date (e.g., Sohngen and Mendelsohn, 1998, 1999; Sohngen et al, 2001; Bachelet et al., 2003; Bachelet et al., 2004). In a global context, the study by Sohngen et al. (2001) suggests that North America, Europe, and Russia are more vulnerable to climate change than other regions due to ecological and economic factors. Note that these regions currently constitute over 65% of industrial timber outputs. Ecologically, the models suggested that these regions would experience greater disturbance with climate change. Economically, these temperate regions could adapt, but because other regions were able to adapt more rapidly, prices fell, and the lower prices reduced welfare for landowners in temperate regions.

The physical factors that make a region more or less vulnerable relate mainly to the growth rate of the timber stocks and the area of fast-growing plantations. Regions with faster growing species appear to be more able to adapt to climate change, whereas regions with slower growing species appear to be more susceptible to damages from forest fires and other impacts.

c. How are the values of forestry impacts projected into the future, accounting for changes in other economic and environmental conditions?

For the most part, process based economic models are utilized. These models used either dynamic optimization approaches, or other static simulation approaches to projection timber harvests. Most studies have made timber price endogenous so they are able to account for other factors that influence timber demand, such as changes in population and income.

4. What are the most important gaps or uncertainties in our knowledge regarding the value of forestry impacts? What additional research in this area would be most useful?

There are a number of important gaps. Three potential gaps and additional research topics are listed below:

- The pace of change in ecosystem and climate models appears to be much more rapid than the pace of change in economic modeling. For example, new scenarios of climate models and new scenarios of ecosystem models seem to appear about every 5 years, while new economic analysis emerges much more slowly.

There may be a number of reasons for this. One possible explanation is that the effect of humans on forested ecosystems is changing dramatically. The economic studies reviewed above focus on timber demand as the driving human influence; however, timber demand may not be the most important demand of forest resources in the future. For example, future demand for natural ecosystems may be driven by non market vaues or recreational values, or it may be driven more importantly by land-use change (e.g., conversion of productive timberland to private recreational land). Alternatively demand may be driven by agricultural uses in some regions of the world (e.g., tropical regions where agricultural land is expanding). Thus, more complex models that account for different kinds of demands for land may be necessary to fully assess the implications of climate change on forestry.

- The economic models have not fully reflected the uncertainty. The ecosystem models suggest that disturbance patterns could change dramatically over time, but there has been little use of this information by economic modelers to date. There are a number of stochastic models of forest management under uncertain disturbance regimes (e.g., Daigneault et al., 2010), but few of these are linked to climate models .

- Ecosystem models are calibrated without reference to models of human behavior. This likely causes them to over-estimate the potential effects of climate change on ecosystems. In many ecosystems, for instance, one would expect humans to adapt to damages, and this adaptation is missing from the ecosystem models. There is substantial room for modelers to conduct integrated economic and ecological analysis that would capture these effects.

References

ABARE – Jaako Poyry. 1999. Global Outlook for Plantations. ABARE Research Report 99.9. Canberra, Australia.

Alig, R., D. Adams, and B. McCarl. 2002. Projecting impacts of global climate change on the U.S. forest and agriculture sectors and carbon budgets. *Forest Ecology and Management,* 169:3-14.

Bachelet, D., R. P. Neilson, T. Hickler, R. J. Drapek, J. M. Lenihan, M. T. Sykes, B. Smith, S. Sitch, and K. Thonicke. 2003. Simulating past and future dynamics of natural ecosystems in the United States. Global Biogeochemistry Cycles 17(2):14.1-14.21.

Bachelet, D., R.P. Neilson, J.M. Lenihan, R.J. Drapek. 2004. Regional differences in the carbon source-sink potential of natural vegetation in the U.S.A. Ecological Management 33(Supplement 1):S23-S43.

Cubbage, Frederick, Sadharga Koesbanda, Patricio MacDonagh, Gustavo Balmelli, Virginia Morales Olmos, Rafael Rubilar, Rafael de la Torre, Vitor Hoeflich, Mauro Murraro, Heynz Kotze, Ronalds Gonzalez, Omar Carrerro, Gregory Frey, James Turner, Roger Lord, Jin Huang, Charles MacIntyre, Kathleen McGinley, Robert Abt, and Richard Phillips. 2010. Global timber investments, wood costs, regulation, and risk. Biomass and Bioenergy. In press. Doi:10.1016/j.biombe.2010.05.008.

Daigneault, A., B. Sohngen, and R. Sedjo. 2008. " Exchange Rates and the Competitiveness of the United States Timber Sector in a Global Economy." Forest Policy and Economics. 10(3): 108-116.

Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007: Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 211-272.

Irland, L.; D. Adams, R. Alig, C.J. Betz, C. Chen, M. Hutchins, B. A. McCarl, K. Skog, and Brent L. Sohngen. 2001. “Assessing Socioeconomic Impacts of Climate Change on U.S. Forest, Wood-Product Markets, and Forest Recreation.” *Bioscience*. 51(9): 753- 764.

Joyce, L.A., J.R. Mills, L.S. Heath, A.D. McGuire, R.W. Haynes, and R.A. Birdsey. 1995. Forest sector impacts from changes in forest productivity under climate change. *Journal of Biogeography*, 22: 703-713.

Joyce, L., J. Aber, S. McNulty, V. Dale, A. Hansen, L. Irland, R. Neilson, K. Skog. 2001. Potential Consequences of Climate Variability and Change for the Forests of the United States. Chapter 17 in Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. National Assessment Synthesis Team, US Global Change Research Program. (http://www.usgcrp.gov/usgcrp/Library/nationalassessment/)

Karjalainen, T., Pussinen, A., Liski, J., Nabuurs, G.J., Eggers, T., Lapvetelainen, T., Kaipainen, T. 2003. Scenario analysis of the impacts of forest management and climate change on the European forest sector carbon budget. Forest Policy and Economics 5: 141-155.

Lelyakin, A.L., A.O. Kokorin, I.M Nazarov. 1997. Vulnerability of Russian Forests to Climate Changes, Model Estimation of CO_2 Fluxes. Climatic Change. 36: 123-133.

Nabuurs, G.J., Päivinen, R., Schanz, H. 2001. Sustainable management regimes for Europe's forests -- a projection with EFISCEN until 2050. Forest Policy and Economics 3: 155-173.

Nabuurs, G.J., Pussinen, A., Karjalainen, T., Erhard, M., Kramer, K. 2002. Stemwood volume increment changes in European forests due to climate change-a simulation study with the EFISCEN model. Global Change Biology 8: 304-316.

Perez-Garcia, J., L.A. Joyce, A.D. McGuire, and C.S. Binkley. 1997. “Economic impact of climatic change on the global forest sector” In *Economics of Carbon Sequestration in Forestry*, eds. R.A. Sedjo; R.N. Sampson; and J. Wisniewski. Lewis Publishers, Boca Raton.

Perez-Garcia, J., L.A. Joyce, A.D. McGuire, and X. Xiao. 2002. "Impacts of Climate Change on the Global Forest Sector." Climatic Change. **54:** 439–461,

Seppala, R., A. Buck, P. Katila. 2009. "Adaptation of Forests and People to Climate Change – A Global Assessment Report. IUFRO World Series Volume 22. Helsinki, Finland, 224 p.

Sohngen, B. and R. Mendelsohn. 1998. “Valuing the Market Impact of Large Scale Ecological Change: The Effect of Climate Change on US Timber." *American Economic Review,* 88(4): 689 - 710.

Sohngen, B. and R. Mendelsohn. 1999. “The US Timber Market Impacts of Climate Change.” Chapter 5 in *The Market Impacts of Climate Change on the US Economy*. Edited by R. Mendelsohn and J. Neumann. Cambridge, U.K.: Cambridge University Press.

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

Sohngen, B. and R. Sedjo. 2005. “Impacts of Climate Change on Forest Product Markets: Implications for North American Producers.” *Forestry Chronicle* 81(5): 669-674

Sohngen, B. 2010. Outsourcing Timber: The Role of Emerging Region Plantations on Southern US Production. Working Paper. AED Economics. Ohio State University.

VEMAP Members (J.M. Melillo, J. Borchers, J. Chaney, H. Fisher, S. Fox, A. Haxeltine, A. Janetos, D.W. Kicklighter, T.G.F. Kittel, A.D. McGuire, R. McKeown, R. Neilson, R. Nemani, D.S. Ojima, T. Painter, Y. Pan, W.J. Parton, L. Pierce, L. Pitelka, C. Prentice, B. Rizzo, N.A. Rosenbloom, S. Running, D.S. Schimel, S. Sitch, T. Smith, and I. Woodward). 1995. Vegetation/ecosystem modeling and analysis project: comparing biogeography and biogeochemistry models in a continental-scale study of terrestrial ecosystem responses to climate change and CO2 doubling. Global Biogeochemical Cycles 9:407-437.