The Role of Forests in Carbon Cycles, Sequestration, and Storage

Issue 3: The Economics of Carbon Sequestration in Forests

M. Obersteiner[1], P. Benitez[2], I. McCallum[1], M. Lexer[3], S. Nilsson[1], B. Schlamadinger[4], B. Sohngen[5], Y. Yamagata[6]

[1]International Institute for Applied Systems Analysis (IIASA), A-2361 Laxenburg, Austria, e-mail: oberstei@iiasa.ac.at
[2]Department of Economics, University of Victoria, PO Box 1700 STN CSC, Victoria BC V8W 2Y2, Canada
[3]University for Natural Resources and Applied Life Sciences, A-1190 Vienna, Austria
[4]Joanneum Research, Institute of Energy Research, Elisabethstrasse 5, A-8010 Graz, Austria
[5]The Ohio State University, 2120 Fyffe Road, Columbus 43210, USA
[6]National Institute for Environmental Studies, Onogawa , Japan

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Technical editing: Johanna Kohl, Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)

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Foreword

Climate change, land use change and the world's forests are inextricably linked. Man-made emissions of the greenhouse gas, carbon dioxide, into the earth's atmosphere continue to escalate. Forests cover more than 4 billion hectares of the Earth's land surface area and contain huge reservoirs of carbon in their vegetation and soils. Understanding the role of forests in carbon cycles and predicting whether they will be carbon sinks or sources in the future are important to ongoing international dialogue on the subject of climate change.

IUFRO is a non-profit, non-governmental international network of forest scientists whose objectives are to promote international cooperation in forestry and forest products research. Recognizing the duality of importance of forests in global carbon cycling and the uncertainty which exists around it, IUFRO in 2001 established a Task Force on the Role of Forests in Carbon Cycles, Sequestration and Storage. Its mandate is to report on the issues with a view towards improved decision making.

IUFRO is pleased to publish the Task Force e-NOTE series and provide a suite of timely, readily accessible, concise, and informative state of science summaries. This, the third issue brings very timely focus onto economic aspects of the long-term storage of carbon in forests. The multinational team of authors believes that this storage potential represents "…a critical intervention point by which humans can modify the dynamics of the carbon cycle."

Editors:

Dr. Kevin E. Percy
Task Force Coordinator
Natural Resources Canada
Canadian Forest Service - Atlantic Forestry Centre
Fredericton, Canada kpercy@nrcan.gc.ca

Dr. Robert Jandl
Deputy Task Force Coordinator
Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)
Vienna, Austria robert.jandl@bfw.gv.at

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1.1 Executive summary

Human intervention in forest ecosystems has been occurring for thousands of years at various levels, and has impacted the global carbon cycle. However, only over the last two centuries have anthropogenic changes in carbon fluxes become comparable in magnitude to the major natural fluxes in the global carbon cycle, and only in the last years of the 20th century have humans widely recognized the threat of adverse consequences, and begun to respond collectively. Long-term storage of carbon on land provides a critical intervention point by which humans can modify the dynamics of the carbon cycle. Methods include reducing land disturbance, reforestation, afforestation, altered forest management practices, altered use patterns and consumption, and fossil-fuel substitution. IUFRO is active in addressing the need for improved forest management and its economic implications with respect to improving the global carbon cycle. In particular, we are interested in identifying points of intervention using forests, economic assessment of management options in geographic space, and questions related to implementation.

1.2 IUFRO and Forest Carbon

IUFRO's vision is that of promoting "science-based sustainable management of the world's forest resources for economic, environmental, and social benefits." IUFRO believes that public policy decisions supported by sound science produces decisions that have public support and yield benefits to society.

Forests play a major role in the natural global carbon cycle by capturing carbon (C) from the atmosphere through photosynthesis, converting it to forest biomass, and releasing it into the atmosphere through plant respiration and decomposition. At local, regional, and global levels, the exchange of C between forests and the atmosphere is influenced by, among other things, anthropogenic and natural disturbances. This forest–atmosphere interaction supports the view that controlling land use, and land-use change practices involving forests, helps prevent the increase in atmospheric greenhouse gases and, additionally, that some forest management activities may effectively reduce the rate of CO_2 accumulation in the atmosphere.

The United Nations, through its Framework Convention on Climate Change and the Kyoto Protocol, is working to achieve international agreement on incorporating forestry activities in the international response to this major environmental challenge. According to the Intergovernmental Panel for Climate Change[1], approximately 136 GtC have been emitted as a result of land-use change, predominately from forest ecosystems, and approximately 115 GtC has been absorbed by terrestrial ecosystems between 1850 and 1998. Land Use, Land-Use Change and Forestry (LULUCF) activities can provide a relatively cost-effective way of combatting climate change, either by increasing the removals by sinks of greenhouse gases from the atmosphere, or by reducing emissions. There are drawbacks, however, as it may be difficult to calculate greenhouse C stock changes in certain pools such as soil. In addition, greenhouse gases may be unintentionally re-released if a sink is damaged or destroyed through a forest fire or disease, for example.

Ultimately, it will be forest managers who will be responsible for putting forestry-related components of international agreements on climate change into effect on the ground. These managers will require a sound scientific basis to be successful, so IUFRO, in partnership with a number of international science networks such as: the Intergovernmental Panel for Climate Change[1]; and the Global Carbon Project[2] of the International Global Biosphere Program[3]; the International Human Dimensions Program[4]; and the World Climate Research Program[5]; is mobilizing to improve the understanding of the forests' carbon cycle patterns under anthropogenic change.

1.3 Forest Management as an Option for Climate Mitigation

In policy discussions, "mitigation" refers to efforts to regulate and ultimately reduce emissions of greenhouse gases or to remove C from the atmosphere, with the objective of avoiding significant anthropogenic interference with the carbon–climate system. Mitigation options include changing energy-use patterns (through increased energy efficiency, switching to less carbon-intensive fuels, and reducing consumption), changing industrial processes that produce GHG emissions, and efforts to remove C from the atmosphere. Purposefully induced long-term storage of carbon on land provides a critical intervention point by which humans can modify the dynamics of the carbon cycle and, to some extent, influence the current upward trend of atmospheric CO_2 concentration. This includes:

- Reduction of carbon emissions from land disturbance (e.g., deforestation avoidance, fire and pest management) and the increased carbon sink capacity through reforestation and afforestation.
- Increased sequestration rate of carbon in the forest by altered forest management practices and increased sequestration in the entire life cycle of forest products through altered use patterns and consumption.
- Substituting fossil fuels with forest biomass and possible engineered disposal of the captured CO_2 in geological and oceanic repositories.

In addition to the effects on greenhouse-gas mitigation, large-scale forest-related carbon sequestration activities will carry either ancillary benefits or collateral damage to the environment, economy, and sociocultural values, which in the end may determine the viability of a mitigation measure. Thus, economic analysis of carbon benefits must always be carried out in an environment of polyproduction (e.g., optimizing for timber and carbon values) given a number of environmental and socioeconomic controls. One important example would be monitoring the area expansion of forest plantations to ensure local, regional, and global food security and biodiversity.

1.4 Economic Analysis of Carbon Sequestration

Global assessments of the potential of forest sinks for carbon mitigation started in the early 1990s. Initially, global afforestation potentials for carbon sequestration or biomass fuels were estimated. Cost estimations of mitigation measures on forest lands appeared somewhat later. Economic studies use case study information or extended timber supply models to evaluate the interaction of timber markets and carbon markets. Large differences in the assessment of costs and potential of carbon sequestration reflect differences in the assumptions of forest distribution, composition, and productivity, types of forest management producing carbon value, cost assumptions, discount rates, the interaction with sectors other than the forest sector, and finally whether a dynamic or a static model is assumed. An identified problem is that of market leakage, meaning that, e.g., the introduction of forest conservation in one area might put greater pressure on other regions to harvest wood. Despite many uncertainties it has been estimated that within the cost range of 10 to 150 US$ per ton of carbon, it may be possible to increase global sequestration by more than 2 Gt of carbon per year for several decades.[6] Given the complexity of the analysis and the variation in geographic scale, a consistent and globally comprehensive picture of the full economic potential of all mitigation options on forest lands (incl. potential forest land) is still lacking. In an effort to better understand these complexities, initial work is attempting to estimate the pure economic costs of carbon sequestration spatially over the globe (Figure 1).[7]

Figure 2 represents the cumulative carbon sequestration in 20 years under a carbon price of $50/tC. Based on this graph, Africa, Asia, and South America appear obvious choices for carbon sequestration. When risk is included in the analysis, the relationships are maintained, but the cumulative sequestration of most regions is diminished significantly. Only Australia increased, owing to a risk-adjusted discount rate of 3.6%. The reduction of the carbon supply in Europe is

Figure 2:
Comparison of carbon supply per continent from afforestation, for a 20-year period and a carbon price of $50/tC.

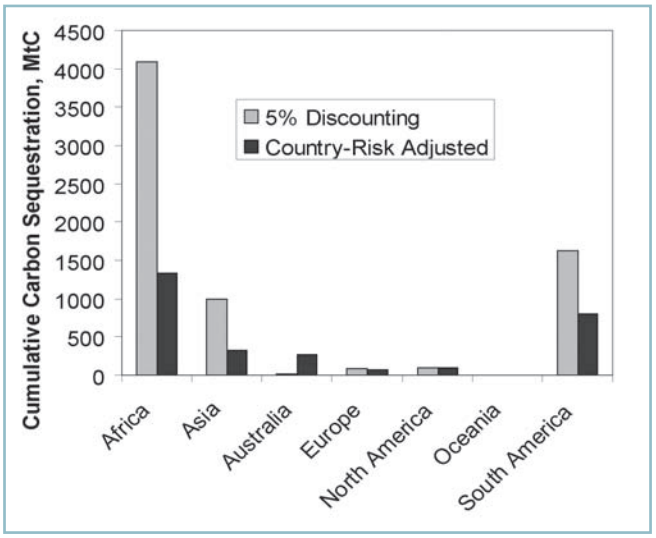
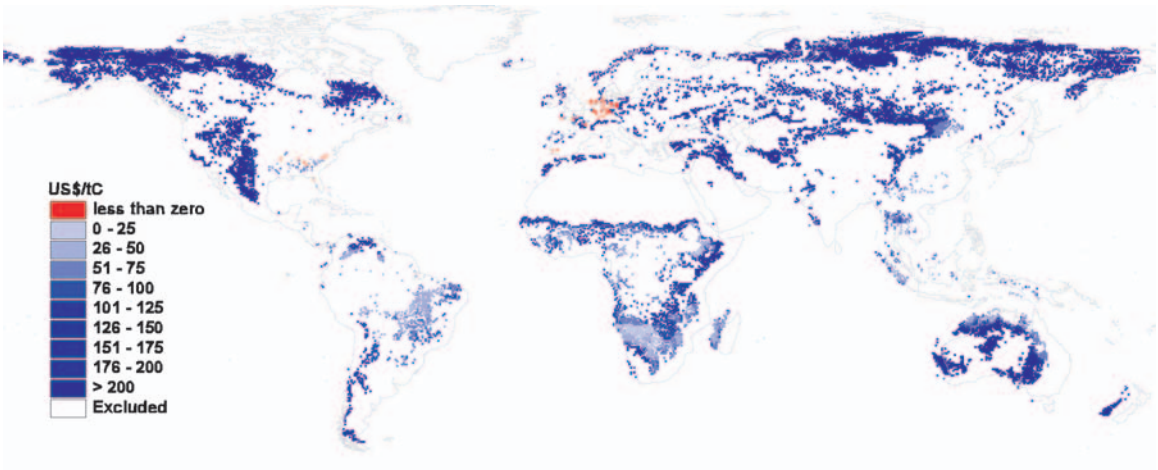


Figure 1:
Global cost of carbon in US$/tC up to a maximum of 1000 US$/tC to trigger carbon sequestration from afforestation, based on the IGBP land-cover data set.



caused by risks associated with countries like Russia, Romania, Belarus, and Ukraine, and the reduction in the carbon supply in North America is caused by risks associated with Mexico.

There are innumerable uncertainties in the assessment of carbon sequestration with respect to parameter choice and input data. Sensitivity analysis has shown that important factors are land price, timber price, and the rate of carbon uptake. In Table 1, a summary of the sensitivity analysis is provided with respect to these factors in three selected points of the 20-year cost curve, using the IGBP land-cover data set and a uniform discount rate of 5%.

Table 1:
Sensitivity analysis of the global carbon supply curve from afforestation

	Cumulative carbon sequestration, 20-year period	
	Carbon price: US$50/tC	Carbon price: US$200/tC
Land price		
50% lower for each grid	7759 (+ 870)	9372 (+ 130)
Main scenario	**6889**	**9242**
50% higher for each grid	6358 (- 531)	9067 (- 175)
Carbon uptake		
25% lower for each grid	4466 (- 2423)	6686 (- 2556)
Main scenario	**6889**	**9242**
25% higher for each grid	9723 (+ 2834)	11779 (+ 2537)

There are three main points to stress from the sensitivity analysis, (i) carbon uptake is the most sensitive parameter, but increasing research efforts on this aspect are reducing current uncertainty levels, (ii) land prices have a lower impact on the supply curve, but it is difficult to have accurate estimates because ultimately, land prices depend on particular preferences, attitudes of landowners, and land market policies, and (iii) carbon prices have a strong influence on the sensitivity, where the higher the carbon price is, the lower the sensitivity and more robust the sequestration results are.

Pathways of local, regional, and global development of the procurement of carbon values from forests are sequences of interrelated changes in social, economic, and political systems, and are usually defined by market interactions. They vary over space and time in ways that are likely to have different net consequences for carbon stocks changes, which in turn may constrain or in other ways feed back into development processes in the socioeconomic sphere, as well as in ecological terms. Issues such as transactions costs, defining property rights, managing risks, institutions, policy instruments for collecting and distributing revenues, and carbon accounting (inventory) methods are crucial for correctly assessing various policy scenarios. Therefore, future research efforts will have to take on these challenges and be dynamic, geographically explicit, and capable of emulating policy variables of a variety of sectors. In addition, the interaction between forest models and economic models has to be improved.

1.5 Issues of implementation

Forests are mentioned in the literature both as a cause and a means to mitigate climate change. A cause through carbon emissions from ecosystem degradation and destruction; a means by sink enhancement and fossil-fuel substitution. The objectives of the United Nations Framework Convention on Climate Change (UNFCCC) mention that climate change should not lead to dangerous interference with the climate system, in the sense that ecosystems can naturally adapt. Thus, the potential occurrence of climate-induced ecosystem breakdown can be viewed as a primary reason to start mitigating climate change now. As a means to mitigate risks from climate change, forest management, and forest biomass use can change the global carbon cycle significantly, even in the face of climate change.

The Kyoto Protocol is currently the international agreement that regulates GHG emission reduction and sink enhancement for those countries that have ratified it. However, it would be beneficial to translate this into national policies that lead to real activities "on the ground." Currently, the fact that a change in land use or land management is undertaken in a country does not mean that a landowner or a company will be eligible to receive financial credits or debits. This will depend on whether and how the national government actually provides incentives or disincentives for changes in forest management, afforestation/reforestation, and reducing deforestation with the goal to improve the GHG balance in compliance with sustainable forest management principles. A particular challenge is to gain experience with forest sink projects within the so-called Clean Development Mechanism (CDM) of the Kyoto Protocol, allowing for financial transfers to developing countries – however, the forest project allowed in the CDM are afforestation and reforestation projects.

According to the World Bank Report, *State and Trends of the Carbon Market*[8], the emerging carbon market encompasses both project-based emission reduction transactions and trade of GHG allowances. Volume exchanged on the carbon market more than doubled over 2002, with the vast majority of volume exchanged through project-based transactions. Buyers comprise governments, public–private partnerships, and increasingly private companies, especially from Japan. The decline of U.S. buyers is seen as directly related to the lack of a federal requirement to constrain GHG emissions. In 2003, nine out of ten tonnes of emission reductions originated from projects located in transition economies or developing countries. Latin America is the leading region in volume terms, followed by Asia and transition economies. China is likely to become a major player in the coming years. Africa and the poorest countries in Asia have thus far been bypassed. Prices differ depending on the segment of the market and on the structure of the transaction, with prices on average below 10 US$/tC. In the early years of the market, LULUCF projects dominated, however trans-

actions are now more evenly distributed. Biomass now accounts for 15% of the market, whereas LULUCF is now 7% of the total volume.

For the successful implementation of carbon sink enhancement projects in developing countries, there is a need to consider relevant issues such as (i) host country attractiveness for investment, reliability of its institutions, and associated political risk, (ii) identification of least-cost sites for carbon sequestration within regions and countries, (iii) short- and long-term potential for carbon sequestration and the choice of crediting method within CDM rules, i.e., decide for temporary crediting (tCER)- or long-term crediting (lCER), (iv) risk for unpredicted releases of sequestered carbon and potential insurability for tree plantations, (v) the development of local markets for land and timber, and (vi) landowners' preferences for forestry compared with agriculture and potential gain/losses of diversifying their farm portfolio. These issues are being clarified by the current implementation of projects and by ongoing forest economics research in developing countries. In this respect, it is all the more important that international institutions (e.g., WorldBank with its BioCarbonFund, http://www.biocarbonfund.org) and governments (in their national procurement programs for CO_2 credits) invest in land-use projects to allow a "learning by doing" experience in this area.

1.6 Glossary

Forest: A minimum area of land of 0.05–1.0 ha with tree crown cover (or equivalent stocking level) of more than 10–30% with trees with the potential to reach a minimum height of 2–5 m at maturity *in situ*. A forest may consist either of closed forest formations, where trees of various storeys and undergrowth cover a high pro portion of the ground open forest. Young natural stands and all plantations that have yet to reach a crown density of 10–30% or tree height of 2–5 m are included under forest, as are areas normally forming part of the forest area that are temporarily unstocked as a result of human intervention, such as harvesting or natural causes, but that are expected to revert to forest.

Forest Management: is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic, and social functions of the forest in a sustainable manner.

Carbon (C): a chemical element that forms large numbers of organic compounds, allowing living organisms to evolve.

CO_2: Carbon dioxide is a greenhouse gas that contributes to global warming.

Reforestation: Direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources on land that was forested but has been converted to non-forested land.

Afforestation: The direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources.

Carbon Sequestration: A method of keeping carbon emissions from reaching the atmosphere by capturing, isolating, and diverting them to secure storage, and/or removing CO_2 from the atmosphere by various means and storing it.

Kyoto Protocol: The protocol commits 38 industrialized countries to cut their emissions of greenhouse gases between 2008 to 2012 to levels that are 5.2% below 1990 levels.

GHG: Greenhouse gases are gaseous components of the atmosphere that contribute to the greenhouse effect.

CDM: Clean Development Mechanism, one of three „Flexible Mechanisms" of the Kyoto Protocol designed to enable the Annex I countries to achieve their quantified emission reduction targets at lower costs.

tCER: temporary Certified Emission Reductions, expiring at the end of the commitment period after the one during which it was issued.

lCER: long-term Certified Emissions Reductions, expiring at the end of a project's crediting period.

LULUCF: Land use, land-use change and forestry. LULUCF activities can combat climate change by increasing removals by sinks of greenhouse gases from the atmosphere (e.g., by planting trees or managing forests), or by reducing emissions (e.g., by curbing deforestation).

1.7 Further Reading

International Governmental Panel for Climate Change. Available at: www.ipcc.ch

Global Carbon Project. Available at: www.gcp.org

International Geosphere Biosphere Program. Available at: www.igbp.kva.se

International Human Dimensions Program. Available at: www.ihdp.uni-bonn.de

World Climate Research Program. Available at: www.wmo.ch/web/wcrp/wcrp-home.html

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