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 introduce the first of eight Task Force e-NOTES which together will provide a suite of timely, readily accessible, concise, and informative state of science summaries. to be issued quarterly. This first TF e-NOTE is intended to provide you, the reader, with a primer on the issues with a view towards improved decision making.

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Dr. Kevin E. Percy
Canadian Forest Service
Task Force Coordinator
1.1 Executive summary

Forests play a significant role in the global carbon cycle, having absorbed approximately one third of recent anthropogenic emissions of carbon dioxide (CO₂) to the atmosphere. However, our activities in the forest have also been a source of carbon emitted to the atmosphere, with deforestation (primarily in the tropics) contributing about one fifth of the annual anthropogenic emissions. Of great concern is the uncertainty over whether forests will be sinks for carbon in the future. In addition, as the world mobilizes to address the issue of climate change, some are proposing to use forest management to increase sequestration of carbon in the biosphere in the short to medium term. This attention on forests and forestry has increased the demand for detailed knowledge of forest functioning and accurate information about the state of the world’s forests. IUFRO is active in addressing the need for better understanding and predictive capacity.

1.2 IUFRO and the changing climate

IUFRO’s Vision is that of promoting “science-based sustainable management of the world’s forest resources for economic, environmental and social benefits.”¹ IUFRO believes that public policy decisions supported by sound science produce better decisions, thus engendering greater public support and more benefits to the society.

Forests play a major role in the natural global carbon cycle by capturing carbon (C) from the atmosphere through photosynthesis, converting that photosynthetic energy to forest biomass, and emitting C back into the atmosphere during plant respiration and decomposition. Globally, these exchanges of C between forests and the atmosphere are influenced by human-caused and natural disturbances.² This forest atmosphere interaction leads to the view that controlling land use change practices involving forests might prevent to some degree the increase in atmospheric greenhouse gases and, additionally, that some forest management activities might effectively reduce the rate of CO₂ 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. 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 is mobilizing to help them meet the challenge.

1.3 Forests: a global resource

In 2000, approximately 30% (3,869 Mha) of the earth’s land area was covered by forest. Almost half of forested lands are in the tropics, a third are in the boreal region, and approximately 10% are in each of the sub-tropical and temperate forest regions.

The proportion of the world’s terrestrial surface that is forested has been changing as a result of anthropogenic activities. For instance, during the decade 1990 to 2000, the forested area within the tropics decreased by 14.2 Mha per year, primarily because of deforestation. Coincidentally, the forested area increased by 1.7 Mha per year in non-tropical forest, mainly from natural expansion.³
1.4 Forests and the global carbon cycle

Forested ecosystems function through interaction among the C, nutrient and hydrological cycles. In turn, these cycles vary as a result of natural environmental shifts that operate on a scale of centuries to millenia. In historical times, human influences have imposed another set of factors in the C balance of forests through deforestation and forest management. More recently, this is occurring due to human modification of atmospheric chemistry and climate change.

The net terrestrial flow of C is the difference between uptake (sinks) and sources. During the 1990s, the terrestrial biosphere (of which forests are a major part) was absorbing C at a rate of approximately 1.4 Gt per year. Forest trees and soils have been estimated to contain 1,146 Gt of C. Approximately 37% of this C is held in low-latitude forests; 14% in mid-latitude forests; and, the remaining 49% at high-latitudes. Carbon density (mass of C per unit forest area) is greatest in high-latitude forests owing to large stocks of soil carbon (Table 1). Carbon density is lowest in mid-latitude forests.

Table 1. Estimated area-weighted carbon densities

<table>
<thead>
<tr>
<th>Latitudinal belt</th>
<th>Carbon densities (10^6 g per hectare)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Vegetation</td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>83</td>
</tr>
<tr>
<td>Canada</td>
<td>28</td>
</tr>
<tr>
<td>Alaska</td>
<td>39</td>
</tr>
<tr>
<td>Mid</td>
<td></td>
</tr>
<tr>
<td>Continental U.S.A.</td>
<td>62</td>
</tr>
<tr>
<td>Europe</td>
<td>32</td>
</tr>
<tr>
<td>China</td>
<td>114</td>
</tr>
<tr>
<td>Australia</td>
<td>45</td>
</tr>
<tr>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>132-174</td>
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<tr>
<td>Africa</td>
<td>99</td>
</tr>
<tr>
<td>Americas</td>
<td>130</td>
</tr>
</tbody>
</table>

The net terrestrial flow of C is the difference between uptake (sinks) and sources. During the 1990s, the terrestrial biosphere (of which forests are a major part) was absorbing C at a rate of approximately 1.4 Gt per year. Forest trees and soils have been estimated to contain 1,146 Gt of C. Approximately 37% of this C is held in low-latitude forests; 14% in mid-latitude forests; and, the remaining 49% at high-latitudes. Carbon density (mass of C per unit forest area) is greatest in high-latitude forests owing to large stocks of soil carbon (Table 1). Carbon density is lowest in mid-latitude forests.

Terrestrial ecosystems are performing as a sink at present because they are aggrading outside of the tropics, and because global environmental changes have benefited photosynthesis more than respiration/decomposition. However, there is no certainty that forests will continue to be sinks for carbon in the future. Moreover, the component of ecosystems where C tends to accumulate differs among forest types, meaning that changes in sink activity of each forest type may differ.

Changes that make the climate more arid are reducing growth, or rendering land unsuitable for forests in some regions of the globe. Severity and extent of moisture stress will increase as climate change continues. However, some areas that were inhospitable for forests in the past are becoming suitable because of climate change. At present, it is not possible to estimate the net effects of these changes in forest area on C sequestration in the biosphere. However, there is substantial concern that permafrost regions are becoming suitable for forests and will be sources of C as the previously frozen peat decomposes.

The present atmospheric CO2 concentration of about 370 ppm is substantially above the pre-industrial level of about 280 ppm. The current rate of increase (0.4% per year) is unprecedented in the past 20,000 years. The year-to-year variability of the annual growth of atmospheric CO2 concentrations is high. Of importance to forestry is the observation that this variability in short-term growth is caused by the effect of climate on C pools having short lifetimes (foliage, plant litter, soil microbes) through variations in photosynthesis, respiration, nutrient cycling and common fire.

In the absence of human intervention, the CO2 balance of forests (uptake versus emission) is in dynamic equilibrium with long-term environmental changes and cycles. Harvesting in excess of growth reduces landscape-level C. Conversion of forests for agriculture results in a rapid net loss of C to the atmosphere. On the other hand, when agricultural land reverts back to forest, C pools can be increased. Retention time of C in forests varies from days for fast decomposing tissues to centuries or millennia for the slower C pools. Retention times vary by forest type and climatic zone and are affected by natural and non-natural disturbances.

There may be unforeseen effects of changing climate on forests. For example, recent evidence suggests that increased atmospheric CO2 concentrations may make trees more susceptible to defoliating insects and that plants receiving additional nitrogen from atmospheric deposition do not harden off normally in the autumn and are more susceptible to frost damage.
These indirect effects of changing climate will reduce productivity, and consequently C sequestration. Moreover, increased levels of the pervasive air pollutant ground-level ozone (main component of smog), reduces forest productivity, and offsets gains from rising atmospheric CO₂ concentrations. Climate change is also predicted to increase the levels of natural forest disturbance by insects and fire, and there is some evidence that this is happening. Forest stand composition may change as the climate acts in a less predictable manner, thus resulting in conversion of forests from C sinks to C sources.

1.5 A role for forest management

Commercial forestry activities may have potential for increasing the amount of C sequestered because long-lived forest products are effective for storing C, and harvesting often converts a stand having little or no current net growth to an actively growing stand. However, these benefits must be evaluated against total ecosystem C. Loss of slash, tops, branches, needles, etc. after harvesting is usually substantial during the recovery of photosynthetic capacity. Silvicultural practices, such as fertilization and tree improvement, that increase stand growth might also increase C sequestration. Moreover, protecting forests from fire, insect, and disease damage, sustains C pools that otherwise would have returned to the atmosphere by acts of nature and, therefore, helps in the effort to limit greenhouse gases entering the atmosphere.

1.6 Future prospects

Large uncertainties exist in our ability to project future forest distribution, composition, and productivity. Through state-of-knowledge reporting such as the 2001 book on CO₂ and forest ecosystems, IUFRO is enhancing awareness within the forestry community and is engaging in providing a balanced view on C sequestration and storage. Scientists of IUFRO member organizations are active at the science-policy interface, reporting through the IPCC, and leading large multinational research projects such as CARBO-Europe, FluxnetCanada, AmeriFlux and FACE.

The theme ‘carbon sequestration’ reaches into central paradigms of forestry such as sustainability and multiple-use. It is not exclusive to this Task Force, and is a key theme of several IUFRO Working Parties within a number of IUFRO Technical Divisions. In this series of Task Force e-NOTES, we embark upon a presentation of selected aspects of carbon sequestration from different points of view. Each of the seven succeeding publications will be based on thorough discussion amongst Task Force members and invited experts. Effective global communication, of course, requires the use of a widely accepted terminology, for which IUFRO (http://iufro.boku.ac.at/iufro/) provides the continuously evolving on-line terminology service SilvaVoc.

1.7 Glossary

decomposition: degradation of organic matter by biological and non-biological processes
FACE: Free-Air Carbon Dioxide Enrichment; open-air CO₂ exposure experiments in North America and Europe
forest: land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0.5 hectares (ha)
Gt: Gigatonnes of carbon (1 Gt = 1,000,000,000 tonnes)
IPCC: Intergovernmental Panel on Climate Change
http://www.ipcc.ch/
M: one million (2 Mha = two million hectares)
photosynthesis: process by which green plants use solar light energy and CO₂ to produce carbohydrates and oxygen.
pool: a reservoir that can accumulate or release carbon
sequestration: removal and storage; carbon dioxide taken from the atmosphere into plants by photosynthesis
sink: a process or mechanism which removes carbon from the atmosphere
source: opposite of a sink

1.8 Further reading


Acknowledgements
The authors thank Task Force members for their contributions. We are grateful to those who provided external reviews of the manuscript, especially to Dr Pierre Bernier, Natural Resource Canada, Canadian Forest Service - Laurentian Forestry Centre.

Further publications in this series

Issue 2:
Influences of Natural/Non-Natural Disturbances on Forest Carbon Sequestration and Storage

Issue 3:
Increasing CO₂, Forest Ecosystem Productivity and Mitigation Capacities

Issue 4:
Increasing CO₂, Forest Composition, Structure and Adaptive Ability

Issue 5:
Operational Strategies to Enhance Adaptation and Mitigation

Issue 6:
Product Strategies to Enhance Mitigation

Issue 7:
Approaches to Forest Carbon Accounting

Issue 8:
A Summary Report

All Newsletters will be made available free of charge at http://iufro.boku.ac.at/taskforce/hptfcs.htm “Newsletters”