SECTION 5

# A Case Study of the Effects of $CO_2$-Induced Climatic Warming on Forest Growth and the Forest Sector: A. Productivity Reactions of Northern Boreal Forests

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## 5.1. Introduction

The purpose of this section is to evaluate the effects of changes in climate under the GISS 2 × $CO_2$ scenario (considered in Section 3) on the productivity of boreal forests. Some of the results reported here will be used as inputs to a further set of experiments concerned with the effect of productivity changes on forestry as an economic activity (*see* Section 6). Together Sections 5 and 6 provide a case study (at a hemispheric scale) of the advantages and limitations of linking biophysical and economic models in attempts to assess the effects of climatic change.

## 5.2. Temperature and the Productivity of Boreal Forests

Cool climate – particularly in spring, summer and autumn – restricts the productivity of boreal forests. Low winter temperatures may not be so crucial, however, because plants are adapted to tolerate low temperatures in their dormant stage. Low productivity occurs partly because of a short growing season due to spring and autumn frosts which force plants to adapt by remaining dormant over a large part of the year. In addition, low growing season temperatures tend to restrict the rate of biological processes and in this way also to decrease productivity. It appears that the productivity of boreal ecosystems is rather closely



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correlated with the amount of heat accumulated during the year, as obtained by subtracting the plants' threshold temperature from the mean temperature of the day and summing up over the year. The value obtained is termed the annual effective temperature sum (ETS) measured in degree-day units.

Two essentially different factors, the magnitude of the warming and the potential of ecosystems to react to it, determine how ecosystems will respond to a possible climatic warming. Under the GISS 2 × $CO_2$ climatic scenario the largest warming would take place in continental regions such as North America and continental Siberia. The GISS 2 × $CO_2$ climatic scenario represents future averaged equilibrium climatic conditions, based on simulations by the Goddard Institute for Space Studies (GISS) general circulation model (GCM) for a doubling of the present concentrations of atmospheric carbon dioxide. (For details, *see* Section 3.) Smaller increases in temperature are estimated in maritime regions. Also, the potential of ecosystems to react to the warming can be assumed to vary in time and space. Within the boreal zone maritime ecosystems may conceivably be potentially more responsive (Kauppi and Posch, 1985). Continental ecosystems were estimated to be potentially less responsive. In this way, it appears that the two factors – climatic warming and ecological response – tend to have regional distributions with opposite effects. However, in our earlier analysis, we did not examine which of the two factors would dominate. This study focuses on the possible long-term increase in the productivity of boreal forests and combines the estimated increase in temperature together with the potential of forests to react to this increase.

Before proceeding with this, however, some important caveats are in order:

(1) Increased atmospheric $CO_2$ concentrations can themselves cause enhanced photosynthetic activity (and hence net productivity) and also increase the water utilization efficiency of plants (Kramer, 1981; Kauppi, 1987).
(2) Changes in other climatic variables – such as precipitation, insolation and windspeed – are also likely to accompany $CO_2$-induced temperature changes.
(3) Several other factors are important to tree growth, for example, the incidence and activity of pests and diseases, the rates of nutrient cycling and other processes in the soil and ground litter, and the susceptibility of trees to frost damage.

These factors, while important, are *not* considered in this study.

## 5.3. Data and Study Procedure

In line with experiments conducted in individual case study regions, this analysis is based on the GISS GCM-generated results for estimating temperature conditions for 1 × $CO_2$ and 2 × $CO_2$ environments (*see* Section 3). In order to generate a scenario for a climatic warming the 2 × $CO_2$ results were compared with the 1 × $CO_2$ results and to gridded observed data (source: Schutz and Gates –