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A Process-Based Boreal Ecosystem Productivity Simulator Using Remote Sensing Inputs

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This paper describes a boreal ecosystems productivity simulator (BEPS) recently developed at the Canada Centre for Remote Sensing to assist in natural resources management and to estimate the carbon budget over Canadian landmass (10^6–10^7 km^2). BEPS uses principles of FOREST biogeochemical cycles (FOREST-BGC) (Running and Coughlan, 1988) for quantifying the biophysical processes governing ecosystems productivity, but the original model is modified to better represent canopy radiation processes. A numerical scheme is developed to integrate different data types: remote sensing data at 1-km resolution in lambert conformal conic projection, daily meteorological data in Gaussian or longitude-latitude gridded systems, and soil data grouped in polygons. The processed remote sensing data required in the model are leaf area index (LAI) and land-cover type. The daily meteorological data include air temperature, incoming shortwave radiation, precipitation, and humidity. The soil-data input is the available water-holding capacity. The major outputs of BEPS include spatial fields of net primary productivity (NPP) and evapotranspiration. The NPP calculated by BEPS has been tested against biomass data obtained in Quebec, Canada. A time series of LAI over the growing season of 1993 in Quebec was derived by using 10-day composite normalized difference vegetation index images acquired by the advanced very high resolution radiometer at 1-km resolution (resampled). Soil polygon data were mosaicked, georeferenced, and rasterized in a geographic information system (ARC/INFO). With the use of the process-based model incorporating all major environmental variables affecting plant growth and development, detailed spatial distributions of NPP (annual and four seasons) in Quebec are shown in this paper. The accuracy of NPP calculation is estimated to be 60% for single pixels and 75% for 3×3 pixel areas (9 km^2). The modeled NPP ranges from 0.6 kg C/m^2/year at the southern border to 0.01 kg C/m^2/year at the northern limit of the province. The total annual NPP in Quebec is estimated to be 0.24 Gt C in 1993, which is about 0.3–0.4% of the global NPP. ©Elsevier Science Inc., 1997

INTRODUCTION

Net primary productivity (NPP) is defined as the difference between accumulative photosynthesis and accumulative autotrophic respiration by green plants per unit time and space (Leith and Whittaker, 1975). NPP provides highly synthesized information useful for natural-resources management to achieve sustainable development and is an important component in the global atmospheric CO_2 budget affecting climate.

Three types of models are generally used to estimate terrestrial NPP. As described by Ruimy et al. (1994). they are: (1) statistical models (Leith, 1975), (2) parameteric models (Law and Waring, 1994; Potter et al., 1993; Prince et al., 1995; Ruimy et al., 1994; Runyon et al., 1994) and (3) process models (Bonan, 1995; Foley, 1994; Melillo et al., 1993; Running et al., 1989). The first type links NPP with meteorological parameters or evapotranspiration or both through regression analysis; the second type uses the efficiency concept to derive NPP from incident solar radiation and its absorption coefficiency by plant canopies; and the third type simulates biological processes affecting NPP, such as photosynthesis, respiration, and transpiration.

Process models are useful tools for revealing the mechanisms of biomass production and plant-environment interaction and for investigating the responses of ecosystems to climate change. They should be more reliable than the other types of models because of their foundation on our understanding of ecosystems. However, models of this type are often sophisticated and re-

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