Public Service Commission of Wisconsin
& The Statewide Energy Efficiency and Renewables Administration

Environmental and Economic Research and Development Program

Executive Summary

October 2010

Managing Wisconsin's Forests for Fiber Production and Carbon Sequestration: A Modeling Approach

Prepared by:

Dr. Stith T. Gower, Forest Ecosystem Ecology Program
Department of Forest and Wildlife Ecology, University of Wisconsin – Madison

This report in whole is the property of the State of Wisconsin, Public Service Commission of Wisconsin, and was funded through the FOCUS ON ENERGY program.

focus on energy[sm]
The power is within you.

Managing Wisconsin's Forests for Fiber Production and Carbon Sequestration: A Modeling Approach

Executive Summary

Ecosystem process models are tools that can be used to examine the long-term effects of different management scenarios on ecosystem dynamics. This issue is particularly important to devising forest management practices and policy to sequester C and still produce wood fiber for biofuel feedstock. The big advantage of ecosystem process models is they provide insight into questions that experimental studies would require decades to centuries to answer.

We used the ecosystem process model Biome-BGC to simulate the effects of harvest and residue removal management scenarios on soil carbon (C), available soil nitrogen (N), net primary production (NPP), and net ecosystem production (NEP) in jack pine (*Pinus banksiana* Lamb.) and sugar maple (*Acer saccharum* Marsh) ecosystems in northern Wisconsin, U.S.A. To assess harvest effects, we simulated short (50-year) and long (100-year) harvest intervals, high (clear-cut) and low (selective) harvest intensities, and three levels of residue retention (15, 25, 35 %) over a 500-year period. Model logic and processes of Biome-BGC and its predecessor, FOREST-BGC, are well described (Running & Coughlan 1988, Running & Gower 1991, Kimball *et al.* 1997, White *et al.* 2000, Thornton *et al.* 2002). We used a modified version of Biome-BGC (version 4.1.2) developed by (Bond-Lamberty *et al.* 2005, Bond-Lamberty *et al.* 2007a, Bond-Lamberty *et al.* 2007b). Biome-BGC simulates multiple, competing vegetation types (Bond-Lamberty *et al.* 2005), as well as disturbance (Bond-Lamberty *et al.* 2007b).

A concerted effort was made to validate the model output of Biome-BGC to determine if the model was providing accurate simulations of vegetation and soil C cycling processes. The model simulation of NPP, soil C accumulation, and NEP agreed reasonably well with biometric and eddy-covariance measurements of these two ecosystems. Simulated NPP for the sugar maple and jack pine stands differed by < 10% from measured NPP for the same two species. Simulated NEP for the base scenario sugar maple stand of 3 tC $ha^{-1}yr^{-1}$ compared favorably to measured annual NEP of 3.8 tC $ha^{-1}yr^{-1}$ for a 70-76 year-old sugar maple-dominated northern hardwood forest (Desai *et al.* 2005). Average NEP for an old growth northern hardwood forest was -0.01 tC $ha^{-1}yr^{-1}$ (Ankur Desai, personal communication), which compares well to modeled NEP of 0.04 tC $ha^{-1}yr^{-1}$ for the sugar maple at an old growth state.

Simulations included clear-cut and selective harvests at 50- and 100-year harvest intervals with varying residue left after harvest from 15-35%. Results of this study indicate that for a given harvest type (clear-cut or selective) and harvest interval, as residue removal increased, mineral soil C losses increased relative to the base scenario. In the sugar maple ecosystem, mineral soil C content increased 0.04 tC ha^{-1} yr^{-1} for the 500-year no harvest management simulation. The largest soil C loss of -0.04 tC ha^{-1} yr^{-1} occurred for 50-year clear-cut scenario with 15% residue retention and represents a 200% decrease from the base scenario. The decline in mineral soil C content is likely due to the reduced amount of C entering the soil pool through decomposition. In general, the more intensive harvest scenarios increased overall net ecosystem production, even though the mineral soil carbon content declined. All the simulated jack pine and sugar maple harvest scenarios decreased mineral soil C and available N content relative to the no-harvest case. Simulations for both the sugar maple and jack pine stands revealed that maximizing carbon storage (i.e. content) in vegetation decreased annual net

ecosystem carbon sequestration rate. These results highlight the complexity of managing forests for carbon sequestration and maintaining long-term soil productivity.

One issue that could not be resolved in this project was which climate data should be used to complete the simulations. There are several climate data sources available, and each has strengths and weaknesses. For example, the NCAR NCEP re-analysis data has a longer record than DayMet. In addition, the documentation to download and acquire DayMet data is out-dated and many links were non-functional. However, some scientists feel the DayMet climate data is of higher quality than NCAR NCEP data. We compared the two climate data sets and observed rather disturbing differences. Moreover, the differences in the climate data result in equally unsettling differences in model results. It is difficult to know which data set is more accurate, but we ended up using the DayMet data. The large differences in the two common climate data sets highlights the need for a collaborative effort among climatologist to evaluate the different climate data and develop one consistent data set.