THE POTENTIAL FOR WIDESPREAD, THRESHOLD DIEBACK OF FORESTS IN NORTH AMERICA UNDER RAPID GLOBAL WARMING

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ABSTRACT

The MC1 Dynamic General Vegetation Model (DGVM) was used to assess the impacts of global warming on North American ecosystems, north of Mexico, under 6 future climate scenarios (3 General Circulation Models X 2 emission scenarios). The simulations were begun in 1900 using observed climate and CO_2 until 2000, then transferring to the future scenarios to 2100. Carbon sequestration over the continent occurred in the late 20th century and for a short period into the 21st century, being fostered largely by increased precipitation, enhanced water-use efficiency and mild temperature increases. However, these 'greening' processes were overtaken by the exponential effects of increasing temperature on evaporative demand and respiration, producing a subsequent decline. Simulation experiments suggested that fire suppression could significantly mitigate the carbon losses, yet many ecosystems were still forced to a lower carrying capacity.

DISCUSSION

An assessment of North American carbon balance and ecosystem dynamics, including changing vegetation distribution and fire disturbance, in 'natural' ecosystems is underway. The VINCERA project (Vulnerability and Impacts of North American forests to Climate: Ecosystem Responses and Adaptation) is an intercomparison among three dynamic general vegetation models (DGVMs) running under 6 new future climate scenarios. The scenarios were produced by three general circulation models (GCMs), each using two different future trace gas emissions scenarios, SRES A2 and B2. The GCM scenarios are from the Canadian Climate Centre (CGCM2), the Hadley Centre (HADCM3) and Australia (CSIRO-MK2). The three DGVMs are MC1, IBIS and SDGVM. All of the scenarios are near the warmer end of the Intergovernmental Panel on Climate Change's projected future temperature range.

We present here only the results from MC1 [*Daly et al*., 2000]. With the exception of the Tundra, which is invaded by the Boreal Forest, all major forested ecosystems in North America exhibit carbon sequestration until the late 20th or early 21st century, followed by a drought induced decline and loss of carbon to levels below those at 1900 in the absence of fire suppression (Fig. 1). By the end of the 21st century in the absence of fire suppression, the entire continent will have lost from 10 to 30 Pg of carbon, depending on the scenario. However, fire suppression can significantly mitigate carbon losses and ecosystem declines, producing a net change in carbon from a loss of about 5 Pg to a gain of about 8 Pg under the different scenarios (Fig. 2). Most of the suppression benefits are obtained in the Western U.S. forests. However, suppression also mitigates carbon losses and conversions to savanna or grassland in the eastern U.S., but forest decline still occurs in the east under all scenarios.

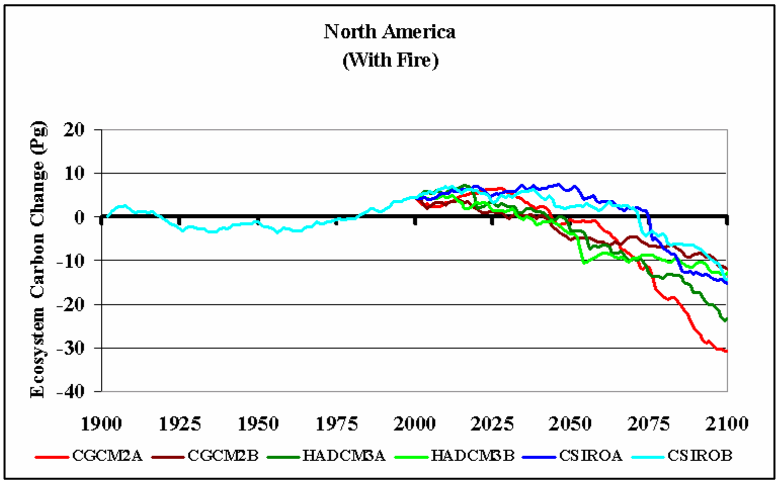

Fig. 1. Net gain or loss of carbon from North American Ecosystems under climate change, without fire suppression.

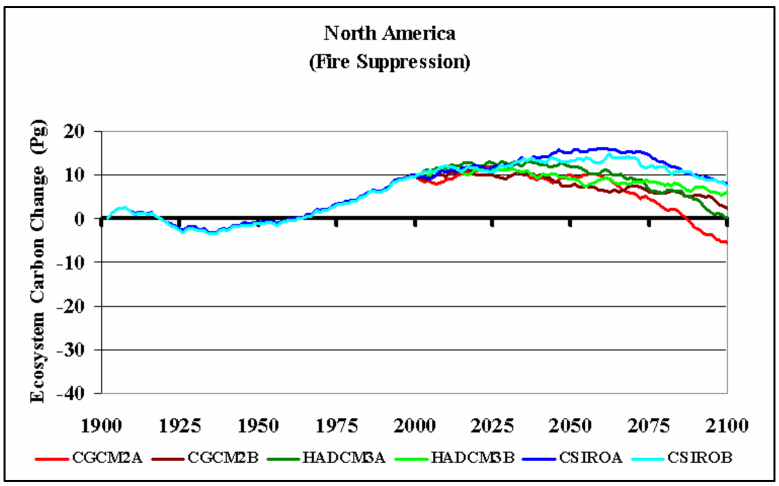

Fig. 2. Net gain or loss of carbon from North American Ecosystems under climate change, with fire suppression.

The MC1 simulations produce a significant dieback in eastern U.S. forests under all scenarios as well as excursions of the central grasslands into the boreal forest zone. Dieback is triggered under two mechanisms. Reduced regional precipitation patterns, variable among the scenarios, are one mechanism for dieback. However, a more insidious and more pervasive effect is due to the exponential influence of rising temperatures on evapotranspiration (ET). Even with the benefits of enhanced water use efficiency from elevated CO_2 and slight increases in precipitation, dramatic increases in temperature can produce widespread, very rapid forest dieback, followed by infestations and fires. The eastern U.S. appears to be particularly vulnerable to this sequence of processes, as does the central boreal forest. The reason for the widespread sensitivity of these forests is the relative flatness of the climate gradients. If one locale is near a transition from forest to savanna, then so too are large neighboring locales.

Under some scenarios, dieback is driven by both increasing temperatures and decreasing precipitation in some regions, notably the Southeastern U.S. and the Northwestern U.S. Following a period of gradual carbon sequestration, the enhanced ET appears to overtake the 'greening' processes producing a rapid dieback. The dieback occurs over North America within a few decades from now, initiating an extended period of rapid losses of ecosystem carbon.

REFERENCE

Daly, C., D. Bachelet, J.M. Lenihan, W. Parton, R.P. Neilson, and D. Ojima (2000), Dynamic simulation of tree-grass interactions for global change studies, *Ecol. Applic. 10*: 449-469.