Forest Ecology and Management 355 (2015) 4–14

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Review and synthesis

Carbon implications of current and future effects of drought, fire and management on Pacific Northwest forests ☆

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ARTICLE INFO

Article history:
Received 9 September 2014
Received in revised form 18 November 2014
Accepted 23 November 2014
Available online 10 December 2014

Keywords:
Forest carbon
Drought effects
Tree mortality
Climate mitigation
Carbon management
Pacific Northwest

ABSTRACT

Climate change has already begun to impact the structure and function of forest ecosystems in the Pacific Northwest by altering the frequency, intensity, and duration of droughts and heat stress, with implications for widespread environmental and socio-economic change. A major realization is that accumulated physiological stress can ultimately lead to tree mortality and changes in species distributions, particularly in areas away from maritime influences. To ameliorate the effects of drought, insect outbreaks, and reduce the risk of crown fires, various strategies are being tested. To make some of these strategies economical, biomass is proposed as an alternative energy source. At the same time that an increase in harvesting is being considered, there is a desire to increase carbon sequestration by forests to offset, at least in part, greenhouse gas emissions. Assessments are needed to determine current and future impacts of climate change, and to evaluate management options while considering carbon storage benefits and sustainability of ecosystem structure and function. Here we provide an overview of research results from the Pacific Northwest region where forests dominate the landscape and contain among the highest biomass on earth. In this review, we present findings that challenge common assumptions, and suggest a way to predict outcomes of changes in climate and land management in the future. The approach includes the use of observation-driven land system models that integrate the extent that forests are vulnerable to climate change, management practices, and economic considerations. It also requires increased emphasis on in situ and remotely sensed observations and experiments to initialize and test the model, and to track trends in forest condition.

Contents

☆ This article is part of a special issue entitled "Carbon, water and nutrient cycling in managed forests".

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http://dx.doi.org/10.1016/j.foreco.2014.11.023
0378-1127/

1. Introduction

Over centuries, human activities have altered forests profoundly, changing their distribution, structure and productivity across landscapes and regions. Now, climate change attributed to rising greenhouse gas emissions is beginning to impact forests as the frequency and severity of droughts and extreme heat events increase (Joyce et al., 2014; Allen et al., 2010). An increase in disturbance affects the carbon balance of forests. More frequent and extensive disturbances reduce the ability of forests to sequester carbon and partially offset greenhouse gas emissions. The complexities of multiple interacting factors have prompted efforts to predict where forests are likely to be vulnerable to natural disturbances, and the carbon consequences of actions that land management might take in response.

The Pacific Northwest (PNW) domain of this synthesis includes British Columbia, Washington, Oregon, and Northern California (Fig. 1). Climate in the PNW is strongly influenced by the Pacific Ocean and mountain ranges, and two large-scale oscillations, the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). When both oscillations are in a warm phase, the possibility of a warmer and drier winter increases (Dalton et al., 2013). There is a strong eco-climatic gradient from the Coastal Range temperate rainforests (~2500 mm precipitation) inland to the Klamath Mountains and Sierra Nevada (1500 mm), East Cascades (~500 mm), and the Columbia Plateau and Northern Basin (250 mm; Fig. 1). Warming has led to ~20% loss of winter snowpack since 1950 (Mote, 2006), and spring snowmelt has occurred 0–30 days earlier depending on location (Stewart et al., 2005). Although the annual precipitation has not changed significantly, winters are becoming drier while the springs are generally wetter (Abatzoglou et al., 2014). The region is expected to experience progressively hotter and longer summers with a 10% reduction in summer precipitation (Mote and Salathé, 2010; Mote et al., 2014). Because Pacific Northwest summers are already dry, a 10% reduction in precipitation, particularly in the semi-arid part of the region, could further stress forests and increase the area burned. Such projections on the region's valuable forests are of great concern.

Carbon cycle research in Pacific Northwest US has focused on understanding how forests respond to climate and subsequent disturbances from the individual tree, upward through ecosystem, landscapes and regions. Some results challenge conventional thinking, and need to be highlighted as land managers and policy

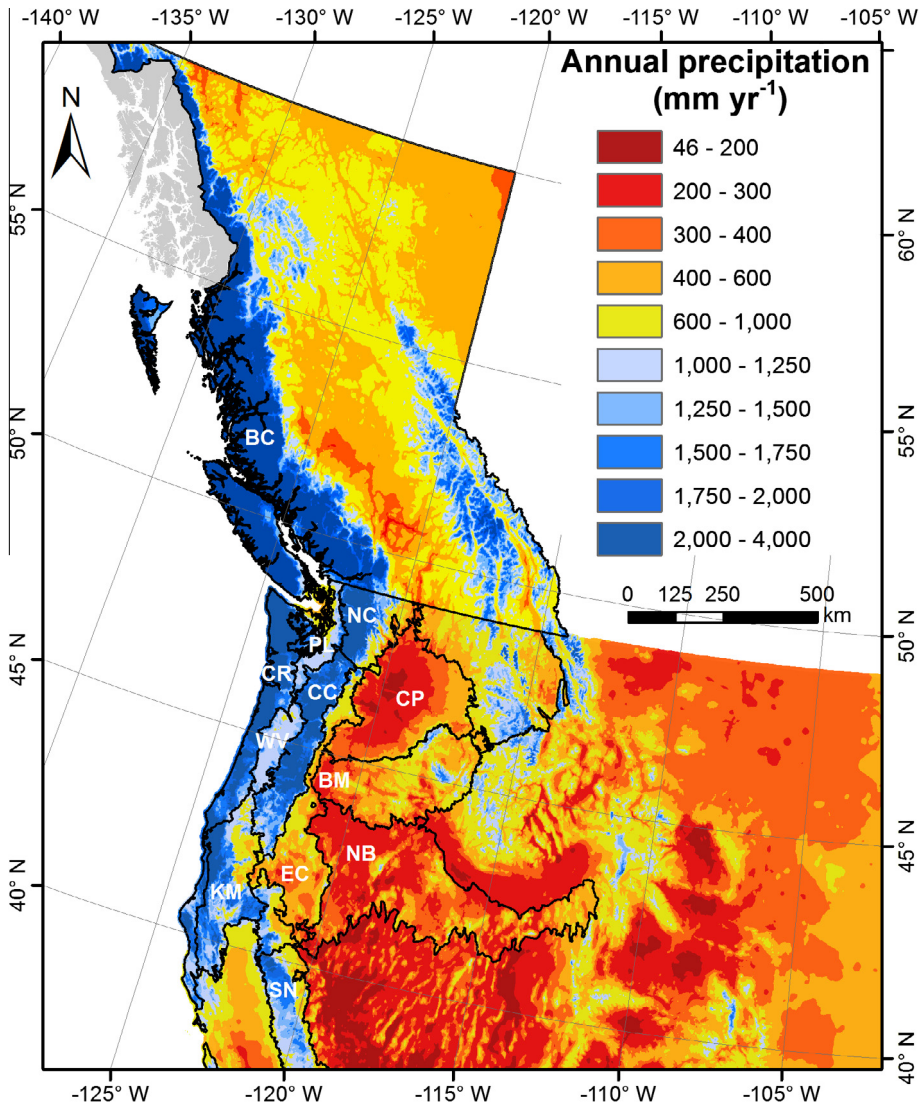

Fig. 1. Thirty year mean annual precipitation (1961–1990) in the Pacific Northwestern US. Note the strong gradient from the coast inland. Data are courtesy of Oregon Climate Service, map by Logan Berner.