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Carbon balance on federal forest lands of Western Oregon and Washington: The impact of the Northwest Forest Plan

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ABSTRACT

The management of federal forest lands in the Pacific Northwest (PNW) region changed in early 1990s when the Northwest Forest Plan (NWFP) was adopted with the primary goal to protect old-growth forest and associated species. A major decline in timber harvest followed, extending an earlier downward trend. The historic and projected future change in carbon (C) stores and balance on federally managed forest lands in Western Oregon (OR) and Western Washington (WA) was examined using the LANDCARB 3.0 simulation model. The projections include C stores on-site, in harvested wood products and disposal and reflect a set of contrasting visions of future forest management in the region formulated as five alternative management scenarios that extend to year 2100. A significant and long-lasting net increase in total C stores on federal forest lands relative to early 1990s level was projected for both OR and WA under all examined management scenarios except the *Industry Scenario* which envisioned a return to historic high levels of timber harvest. In comparison with the *Industry Scenario*, the low levels of timber harvest under the NWFP between 1993 and 2010 were estimated to increase total C stores by 86.0 TgC (5.1 TgC year^{-1} or 2.16 MgC ha^{-1} year^{-1}) in OR; in WA the respective values were 45.2 TgC (2.66 TgC year^{-1} or 1.33 Mg Cha^{-1} year^{-1}). The projected annual rate of C accumulation, reached a maximum between 2005 and 2020 approaching 4 TgC year^{-1} in OR and 2.3 TgC year^{-1} in WA, then gradually declined towards the end of projection period in 2100. Although not the original intent, the NWFP has led to a considerable increase in C stores on federal forest lands within the first decade of plan implementation and this trend can be expected to continue for several decades into the future if the limits on timber harvest set under the NWFP are maintained. The primary goal of the NWFP to protect and restore old-growth forest may take several decades to achieve in WA whereas in OR the area protected from clearcut harvest may be insufficient to meet this goal before the end of projection period in 2100.

1. Introduction

Forests are a critical part of the global biological carbon (C) cycle and their management may contribute to stabilizing the concentration of the greenhouse gas C dioxide in the atmosphere (Pacala and Socolow, 2004). The potential of forest ecosystems to store C is well established (e.g., Post et al., 1990; Nabuurs et al., 2007; Keith et al., 2009), but the degree to which this potential is being met under different management systems is uncertain. The conversion of older forests to younger forests has generally been shown to release C to the atmosphere (Cooper, 1983; Harmon et al., 1990; Dewar, 1991; Harmon and Marks, 2002; Trofymow et al., 2008) and management decisions regarding remaining older forest stands is an important factor in determining how the C balance of forest landscapes changes over time. This is especially important in the Pacific Northwest (PNW) where forests have some of the highest biological potential to store C (Harmon et al., 1990; Smithwick et al., 2002; Birdsey et al., 2007). The PNW is also the region where substantial remnants of productive, high-biomass old-growth forests have survived (DellaSala, 2010) whereas in other temperate forest regions they have been eliminated for centuries. Carbon inventories in the productive high-biomass old-growth forests of the PNW provide a robust measure of the upper limit of C storage (Smithwick et al., 2002) which is rarely available to assess the full potential of C sequestration associated with restoring late-successional forests.

The PNW region has recently experienced major changes in forest management. The adoption of the Northwest Forest Plan (NWFP) in 1994 resulted in a significant decline in timber harvest on federal forest lands extending an earlier downward trend (e.g., Alig et al., 2006). For example, in Oregon (OR) during the peak harvests in the 1970s and 1980s, over five billion board feet (BBF,

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Scribner scale)[2] per year were removed from federal forest lands; in the early 1990s timber removals were about half that amount and in early 2000s the harvest fell below 0.5 BBF (Warren, 2008). This recent period of low timber harvests can be expected to cause significant changes in forest C stores at present and for many decades into the future if the provisions of the NWFP are maintained.

The NWFP assumed that forests in 0.7% of the Plan area would be lost to stand-replacing wildfire per decade, and that 1% of the entire Plan area (or 3% of total late-successional forest area) would be harvested per decade (i.e., a 0.17% year^{-1} combined annual rate of disturbance). Monitoring results, albeit short-term, suggest that during the first 10 years of the Plan estimated gains of older forest far outpaced losses, resulting in a net increase of between 1.25 and 1.5 million acres (500–600 thousand ha) of older forest on federally managed land. This rate of gain was about twice the first decadal gain expected under the Plan (Mouer et al., 2005).

Several regional studies used different methods to examine recent changes in the C balance of PNW forests. Following peak timber harvest of the 1980s, forests of the PNW were losing C (Cohen et al., 1996; Song and Woodcock, 2003) with losses of coarse woody debris representing a significant permanent loss not compensated by regrowth (Harmon et al., 1990). A net uptake of 13.8 TgC year^{-1} (1.68 MgC ha^{-1} year^{-1}) was estimated using Biome-BGC model for forests of western OR in 1995–2000; after accounting for harvest removals and fire emissions the regional net biome production (NBP) was reported at 8.2 TgC year^{-1} (1.00 MgC ha^{-1} year^{-1}, Law et al., 2004). An expanded state-wide assessment by Turner et al. (2007) estimated NBP in 1996–2000 at 6.1 ± 10.2 TgC year^{-1}with climate fluctuations responsible for significant interannual variation. Most of the reported C sink was associated with public forest lands in western OR. Net C uptake in OR forests in 2000–2005 estimated from Biome-BGC simulations (1.10 MgC ha^{-1} year^{-1}) was consistent with the estimate derived from forest inventory data (1.33 ± 0.29 MgC ha^{-1} year^{-1}; Turner et al., 2011). While there is a general consensus that the forests managed under the NWFP have been net sinks of C in recent years and that declining timber harvests contributed to this sink, there is little agreement on expected future changes in the C balance of these forests and the role of management decisions in historic and future C dynamics. Furthermore, it is unclear how long into the future the provisions of the NWFP will be maintained as alternative approaches to the management of federal forest lands are being proposed, including a return to higher timber harvest levels (e.g., BLM, 2008).

Climate change is generally expected to reduce C uptake and increase losses to the atmosphere in PNW forests through decline in forest productivity and increased intensity and frequency of wildfires (e.g., Law et al. 2004; Lenihan et al., 2008; Crookston et al., 2010). Other studies project regional C sinks for decades into the future even with timber harvests exceeding the planned NWFP levels (Smith and Heath, 2004; Alig et al., 2006; Im et al., 2010). The contradictory conclusions regarding the impact of management decisions on C balance of PNW forests (e.g., Mitchell et al., 2012; Trofymow et al., 2008; Perez-Garcia et al., 2005; Harmon and Marks, 2002) have contributed to confusion among stakeholders and decision-makers and stifled the development of effective climate change mitigation measures in the forest sector (Maness, 2009).

The main objective of this study was to analyze the effect on forest sector C stores of varying levels of timber harvest in federally managed forest lands within the NWFP area of OR and Washington (WA). The LANDCARB Model (Mitchell et al., 2012) was used to simulate historic change in C stores on federal forest lands since the onset of wide-spread clear-cut logging in the 1950s up to the present time and to project future change for a set of forest management scenarios representing a broad range of alternatives that are under consideration. The analysis of results focused on assessment of change in forest sector C balance as a result of the NWFP and alternative management scenarios.

2. Methods

2.1. Study area

The study area includes federally managed lands in the NWFP area of western OR (Coast Range, Willamette Valley, and Western Cascades) and western WA (Olympic Peninsula, Western Lowlands and Western Cascades; Fig. 1) where federal forest lands represent 39% and 33% of the total forest area, respectively (Mouer et al., 2005). The total study area is 4.3 million ha or 44% of the entire land area covered by the Plan (9.9 million ha total in OR, WA and Northern California). According to Mouer et al. (2005), at the start of the Plan older forest occupied between 30% and 34% (depending on the definition) of forest-capable public lands managed by the Forest Service, Bureau of Land Management, and National Park Service that were in the range of the northern spotted owl. Forests meeting the most strict definition of old-growth – "Large, multistoried older forest" – occupied about 12% of forest-capable public land. Conservation of these older forests was among the primary goals of the NWFP.

The NWFP record of decision divided federal land into seven land-use allocations; Mouer et al. (2005) combined or further split some allocations. Specifically, three categories of late-successional reserves were grouped together; lands with overlapping late-successional reserve and adaptive management area designations were treated as late-successional reserves (LSRs). Administratively withdrawn and congressionally reserved lands were grouped together (AW/CR). Matrix and adaptive management areas were the land allocations where scheduled timber harvest activities may take place; these were grouped together as well as riparian reserves, which were never mapped separately from Matrix lands at the scale of the entire Northwest Forest Plan. We used these generalized land-use categories and associated area estimates for our study area in western OR and WA (Table 1).

The distribution of stands by age groups within each state and land allocation in the early 1990s (Table 1) was approximated by the proportion of different stand categories reported in Mouer et al. (2005). This report combined "Potentially forested but presently nonstocked" (PF) and "Seedling and sapling" (SS) categories into "very young" forest category (<10 in. diameter at breast height (DBH) and <20 years old); the small-sized trees (10–20 in. DBH) were labeled "young" and assigned stand age 21–60 years old; the old-growth area estimate was based on zone-indexed definition (and assigned age >150 years old) and the balance of area was presumed to be in the mature category (61–150 years old). Note that the range of stand ages included in each of these four age groups varies from about 20 years in the "Very Young" group to >300 years in the "Old-Growth" age group.

2.2. LANDCARB model

The simulation model used for this analysis was LANDCARB 3.0, which builds on earlier modeling work (e.g., Harmon and Marks, 2002) and simulates the accumulation and loss of C over time in a landscape where forest stands are represented by a set of grid cells (Mitchell et al., 2012,

[2] Approximately 24 million m^3. The conversion factor from thousand board feet (MBF, Scribner long-log scale) to cubic meters increased from approximately 4–4.5 in the 1970s to greater than 7 by 1998 (Spelter 2002). In early 2000s 0.5 BBF was approximately 3.6 million m^3.