Oregon Forest Ecosystem Carbon Inventory: 2001-2016

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Acronyms

AB – Assembly Bill

BLM – Bureau of Land Management

C – carbon

CF – cubic feet

CH_4 - methane

CI – confidence interval

CO - carbon monoxide

CO_2e – carbon dioxide equivalent

DBH – diameter at breast height

EPA – Environmental Protection Agency

FF – Forest Land Remaining Forest (IPCC terminology)

FIA – Forest Inventory and Analysis

FIADB – FIA database

FMRL – Forest Management Reference Level

GHG – greenhouse gas

GRM – Growth, Removals and Mortality

HA – hectares

HWP – harvested wood product

ICE – Image-based Change Estimation

IPCC – Intergovernmental Panel on Climate Change

LF – Forest Land Conversions (IPCC terminology)

mm – millimeter

MMT – million metric tons

MT – metric tons

NFS – National Forest System

NGHGI – National Greenhouse Gas Inventory

NMVOC – non-methane volatile organic compounds

N_2O – nitrous oxide

NO_x - nitrogen oxides

NRCS – Natural Resources Conservation Service

NRI – Natural Resources Inventory

ODF – Oregon Department of Forestry

PNW – Pacific Northwest Research Station

RPA – Resources Planning Act

SOC – soil organic carbon

µm – micrometer i.e., one millionth of a meter

UNFCCC – United Nations Framework Convention on Climate Change

USDA – United States Department of Agriculture

USFS – United States Forest Service

USGS – United States Geological Survey

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Appendix organization:

Appendix 1: Forest carbon stocks by forest by forest type and region

Forest carbon stock for forest land remaining forest (FF): by forest type and forest land status
Aboveground live tree pool including foliage:
All of Oregon (Table D1) and ecoregion (Tables D2-D8), 2007-2016
Aboveground dead tree pool:
All of Oregon (Table D9) and ecoregions (Tables D10-D16), 2007-2016
Aboveground live understory vegetation pool:
All of Oregon (Table D17) and ecoregion (Tables D18-D24), 2007-2016
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Belowground live tree pool:
All of Oregon (Table D33) and regions (Tables D34-D40), 2007-2016
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All of Oregon (Table D49) and regions (Tables D50-D56), 2007-2016

Aboveground down dead wood pool:
All Oregon (Table D57) and regions (Tables D58-D64), 2007-2016
Aboveground forest floor pool:
All Oregon (Table D65) and regions (Tables D66-D72), 2007-2016

Appendix 2: 2007-2017 Oregon FIA forest carbon inventory tables

Area
Sampled area:
Sampled area by land status and Owner group for all of Oregon (Table A1) and by ecoregion (Tables A2-A8), 2007-2016
Forest Area for Forest Land Remaining Forest (FF): by owner:
Forest land area by land status and ownership group for all of Oregon (Table A9) and by ecoregion (Tables A10-A16), 2007-2016
Forest Area for Forest Land Remaining Forest (FF): by forest type:
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Net forest carbon flux for forest land remaining forest (FF)
Net carbon flux for all pools by owner:
Annual net change in all forest pools by ownership group for all Oregon (Table B1) and for ecoregions (Tables B2-B8), 2007-2016
Disturbance effects on net forest carbon flux, all forest land:
Annual net change in aboveground carbon pools by disturbance, forest land status, and ownership group, 2001-2006 to 2011-2016 for all Oregon (Table B9.1) and per acre (Table B10); for live trees only on county (Table B9.2) and national forest lands (Table B9.3).
Disturbance effects on net forest carbon flux, timberland:
Annual net change on timberland for aboveground pools by disturbance and owner, 2001-2006 and 2011-2016 – total (Table B11) and per acre (Table B12)
Forest carbon stock for forest land remaining forest (FF): by owner group and forest land status
Aboveground live tree pool including foliage:
All of Oregon (Table C1) and by ecoregion (Tables C2-C8)
All of Oregon by 10-year averages (Tables C9.1)
Aboveground dead tree pool
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Soil-organic carbon pool:
All of Oregon (Table C53) and by ecoregion (Tables C54-C60), 2007-2016
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Aboveground down dead wood pool:
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Chapter 1. Executive summary and key findings

The pursuit of carbon mitigation with forest management policy in Oregon has consistently resulted in the recognition that a reliable forest carbon accounting framework is fundamental to the policy development and monitoring process. This report, based on an extensive field plot monitoring system, supplies the quantitative dimension of that forest carbon accounting framework by providing estimates for the status and trends of carbon in Oregon's forest ecosystems and ownerships since 2001. The Information in this report is based on measurements conducted on 9,483 forested plots in Oregon by the Forest Inventory and Analysis Program (FIA) within the USDA Forest Service. This report includes a brief introduction to the pursuit of forest carbon accounting in Oregon and an overview of the forest carbon cycle (Chapter 2) followed by a description of the methods used to inventory Oregon's forests and estimate forest carbon (Chapter 3). The results of the analysis are presented in Chapter 4 and are based on a subset of the abundant tabular data this analysis provides. Estimates of forest carbon across five forest ownerships and seven ecoregions are first reported in terms of flux, which is the difference between the amount of carbon that enters, and the amount that leaves, one of seven different pools of carbon. Estimates are then reported in terms of the amount of carbon stored in each pool. The results are compared with estimates from other reports and research in Chapter 5 and strategies for improving the inventory and analytical methods are discussed in Chapter 6. In this analysis results of carbon physically present in the forest are given in metric tons (MT) of carbon (C). Results of carbon flux, the amount and rate of gaseous carbon being emitted or sequestered by the forest, are given in metric tons (MT) of carbon dioxide equivalent (CO_2e).

Forest Carbon Flux

One of the most important features of this report is that as of the 2016 reporting period, Oregon's forests have been functioning as a net sink of carbon. According to the estimates made from remeasured FIA plots, Oregon's recent statewide rate of carbon flux from all forest pools across all ownerships and ecoregions is approximately 30.9 ± 7.4 MMT CO_2e per year (Table 4.1). This estimate excludes net CO_2e contributions from other sources such as harvested wood products which will appear in a separate analysis for this reporting period. After accounting for forest land use conversions and non-CO_2 greenhouse gas emissions from wildfire, the 2016 statewide rate of carbon flux on all forest land is approximately 31.6 ± 7.5 MMT CO_2e per year (Table 4.2). The pools of live vegetation (trees, foliage, live roots, and understory vegetation) are accumulating carbon at a net rate of about 37.9 ± 5.8 MMT CO_2e per year (Table 4.3). However, the pools of dead vegetation (standing dead trees, dead roots, and down wood) have been losing CO_2e to the atmosphere and other forest ecosystem pools at a rate of about 7.3 ± 2.1 MMT CO_2e per year.

National forests alone account for approximately 19.1 ± 2.0 MMT CO_2e per year of the total carbon flux (Table 4.3) mostly from growth of live trees. The contribution of those pools on other federal forests is about 9.5 ± 1.4 MMT CO_2e per year. Tree mortality, especially from fire, is highest on productive forests owned by the USDA Forest Service that are withdrawn from harvest at a rate of 0.8 ± 0.4 metric tons of CO_2e annually per acre. Net tree growth on forests owned by private individuals contributes about 3.6 ± 2.3 MMT CO_2e per year. The variation in live tree growth and carbon flux in other pools on forests owned by local and state governments and corporations is too large in this reporting period to determine if the average annual rate of carbon sequestration is statistically different than zero. Nonetheless, on a per acre basis gross tree growth is highest for these two ownerships that contribute the most to the wood products pool (Table 4.4 and Table 4.5).

This report also provides estimates of forest flux from growth, harvest, and mortality of live trees for each ecoregion in Table 4.6. Two ecoregions account for about 58% of the annual net CO_2e sequestration in live trees, the forests of the Western Cascades (9.4 ± 3.0 MMT CO2e/year) and the Oregon Coast Range (8.1 ± 4.3 MMT CO2e/year) (Table 4.6). Although there is a large amount of uncertainty the importance of Coast Range forests to annual carbon flux is reflected in the estimate for gross growth of trees at 30.3 ± 2.4 MMT CO_2/year while the amount harvested from that growth each year is about 17.5 ± 3.8 MMT CO_2. Growth of trees in the Western Cascades ecoregion is also high at about 26.9 ± 1.7 MMT CO_2/year with much less transfer to harvest (8.0 ± 2.5 MMT CO_2e/year) than the Coast Range but experiencing a higher rate of mortality (9.5 ± 1.1 MMT CO_2e/year). The annual net change in live trees is less than 5 MMT CO_2e for the other ecoregions and less than 0.5 MMT CO_2e/year in forests of East Oregon outside of the Blue Mtns.

The carbon accumulation from growth of live trees has been approximately 90.2 ± 2.4 MMT CO_2e/year from all forests in Oregon (Table 4.7a). After accounting for the amount of carbon removed by harvest (-34.8 ± 4.7 MMT CO_2e/year) and mortality from all causes (-25.3 ± 1.7 MMT CO_2e/year) the net accumulation of carbon in live trees is approximately 30.1 ± 5.7 MMT CO_2e per year reflecting the state's high annual tree growth rate across all forest ownerships.

Estimates of carbon flux in live trees for each county from growth, harvest, and mortality can be found in Table 4.7b. Washington county is estimated to have a net loss of carbon (-2.3 ± 2.1 MMT CO_2e/ year) and Douglas County shows a high rate of live tree mortality (-3.5 ± 0.8 MMT CO_2e/year) mostly due to fire and natural causes, but is partially compensated for with a high rate of annual tree growth (12.1 ± 1.4 MMT CO_2e/year). The forests of Lane County lead the state in net carbon flux by sequestering approximately 7.6 ± 2.3 MMT of CO_2e/year.

For carbon flux on National Forests (Table 4.7c) the Deschutes National Forest is currently estimated to have a net loss of carbon based on all pools (-0.2 ± 0.6 MMT CO_2e/year) but this estimate is not statistically different than zero. Other National Forests where net carbon flux is not statistically different from zero include the Fremont, Ochoco, Columbia River Gorge

National Scenic Area, and the Crooked River National Grassland. All other National Forests are accumulating carbon with the highest rate of net flux for all pools on the Willamette with approximately 4.1 ± 0.9 MMT CO_2e/year. The Rogue River-Siskiyou National Forest is experiencing the highest rate of live tree mortality among national forests (-2.8 ± 0.6 MMT CO_2e/year). The causes of tree mortality on National Forests in terms of percent of carbon were fire (23%), disease (20%), insect (18%), and wind (13%). The rate of mortality in terms of percentages of live tree carbon was 0.7% per year for the state and ranged from 1.0% in the East Cascades to 0.4% in the Willamette Valley ecoregions.

Fire was estimated to affect 103 ± 16 thousand acres/year (95% CI), with an additional 16 ± 7 thousand acres/year affected by both fire and tree cutting. The total estimate of emissions from fire is approximately -3.6 ± 1.2 MMT CO_2e/year as CO_2 and -0.2 ± 0.05 MMT CO_2e/year for methane (CH_4) and nitrous oxide (N_2O) (Table 4.8).

Approximately 20 ± 7 thousand acres of forest land were converted to non-forest every year in Oregon while about 24 ± 7 thousand acres of non-forest land were converted to forest every year (Table 4.9). About 53% of the forest loss was conversion to grassland, 88% of which consisted of mechanical removal of juniper and 12% from lack of forest regeneration more than 30 years after a disturbance, primarily fire. Another 34% of the conversion was for powerlines and logging roads. Conversion of non-forest lands to forest is accounted for by regrowth on abandoned logging roads and tree encroachment on grasslands. However, the net change of 4.5 ± 9.3 thousand acres/year is not statistically significant. Consequently, the net gain of 0.9 ± 1.1 MMT CO_2e/year from forest land conversions was also not significant with most of the gains and losses occurring in the live tree pool (Table 4.10).

Forest Carbon Storage

In Section 4.2 of this report you will find estimates for the amount of forest area in each ecoregion, such as Table 4.11, and each forest type across productivity levels of each ownership, such as table 4.12. The heart of the forest carbon numbers for each pool across ownerships is in Table 4.13a where according to estimates made from the FIA plot measurements over the most recent 10-year reporting cycle (2007-2016) there are 3.2 ± 0.03 billion metric tons of carbon stocks (C) on forest land including forest floor and forest soils across all ownerships in Oregon. Approximately 70% of this C is found on public forest land with the National Forests containing over half of all C (52%). Just under half of all stored C is found belowground in forest soils (49%), and about a third is found aboveground in the live tree pool (32%). The remaining stored C is distributed among dead trees (2%), roots (7%), down wood (5%), forest floor (4%) and the understory vegetation pool (1%). Table 4.13a also reports the amount of forest area estimated for each ownership.

For each county Table 4.13b provides estimates of forest C storage for each forest pool and estimates for the amount of forest area. Douglas and Lane County have the largest amount of forest C storage with 380.1 ± 25.9 MMT C and 377.6 ± 25.3 MMT C, respectively. Counties east of the Cascade Mountains tend to have the largest amount of C stored in standing dead and down wood pools relative to other forest pools such as Jefferson County with 32% and Wheeler County with 26%. Similar estimates for each National Forest are found in Table 4.13c.

Forest land carbon stocks by specific pool on both public and private ownerships are reported in Tables 4.14 through Table 4.21 for all of Oregon and each ecoregion of the state. These tables show that two Westside regions account for over half of Oregon's forest C stocks (52%), the Western Cascades with 969.1 MMT C and the Oregon Coast Range with 717.7 MMT C. In the Oregon Coast Range public forests have on average 168.4 MT C/acre while privately managed forests have 111.8 MT of C/acre. The Willamette Valley has the lowest total forest carbon storage with about 106.3 MMT C.

Carbon stock estimates in each pool for the major forest types (Table 4.22 and Table 4.23) show that the Douglas-fir forest type contains about 47% of Oregon's C stocks (1,511.1 ± 42.0 MMT C). The fir/spruce/mountain hemlock type stores over three times less at approximately 435.3 ± 24.8 MMT and the ponderosa pine forest type stores about 419.5 ± 17.9 MMT C. Of the hardwood forest types, the alder/maple forests are currently storing the most total forest carbon at 122.7 ± 15.5 MMT C.

Estimates of forest carbon stocks and flux for each ownership are reported in four pairs of tables for live trees and understory vegetation (Table 4.24 and 4.25), Roots (Table 4.26 and 4.27), standing dead trees and down woody material (Table 4.28 and 4.29), and forest floor and soil carbon (Table 4.30 and 4.31). Carbon storage for each forest pool based on 10 year averages are provided in Table 4.32 and for ownership and land status in Table 4.33 and 4.34.

Chapter 5 provides a comparison of the results in this report are with estimates of forest carbon reported in the National Greenhouse Gas Inventory (USDA OCE Climate Change Program Office 2016), the 2018 forest carbon report from the Oregon Global Warming Commission, and other research that contains comparable forest carbon information (Gray and Whittier 2014, Gray et al. 2014, Law et al. 2018, Campbell et al. 2007). Strategies to improve the inventory are described in Chapter 6 and include increasing the number of plots that are measured each year, improved estimation of non-sampled plots, increased use of remote sensing, better equations for calculating tree biomass, and ideas for improving forest carbon reporting.