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# NACP Biome-BGC Modeled Ecosystem Carbon Balance, Pacific Northwest, USA, 1986-2010

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Documentation Revision Date: 2016-04-29

Data Set Version: V1

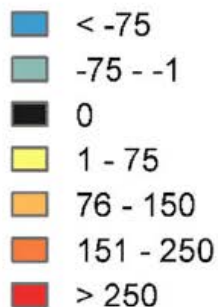
## Summary

This data set provides Biome-BGC modeled estimates of carbon stocks and fluxes in the U.S. Pacific Northwest for the years 1986-2010. Fluxes include net ecosystem production (NEP), and net aboveground wood growth. Stocks include aboveground wood mass. Also present are mapped distributions of associated forest disturbances, distinguished by disturbance type (harvest, fire, pest/pathogen). The data are presented in a mapped form as well as in tabular summaries broken out by ownership and ecoregion. Maps of annual precipitation and temperature data are included for the years 1980-2010.

The model was used in a spatially distributed mode (i.e., run cell-by-cell over a grid) over the four-state Northwest US region including Washington, Oregon, Montana, and Idaho. Landsat data were used to characterize disturbances, and Forest Inventory Analysis (FIA) plot data were used to parameterize the model.

There are 18 data files with this data set. This includes eight files in GeoTIFF (.tif) format in 25-m and 1000-m resolution, and 10 files in comma-separated (.csv) format.

## Net Ecosystem Production Mean 2006-2010 (gC m<sup>-2</sup> yr<sup>-1</sup>)



— State Boundary  
— Ecoregion Boundary

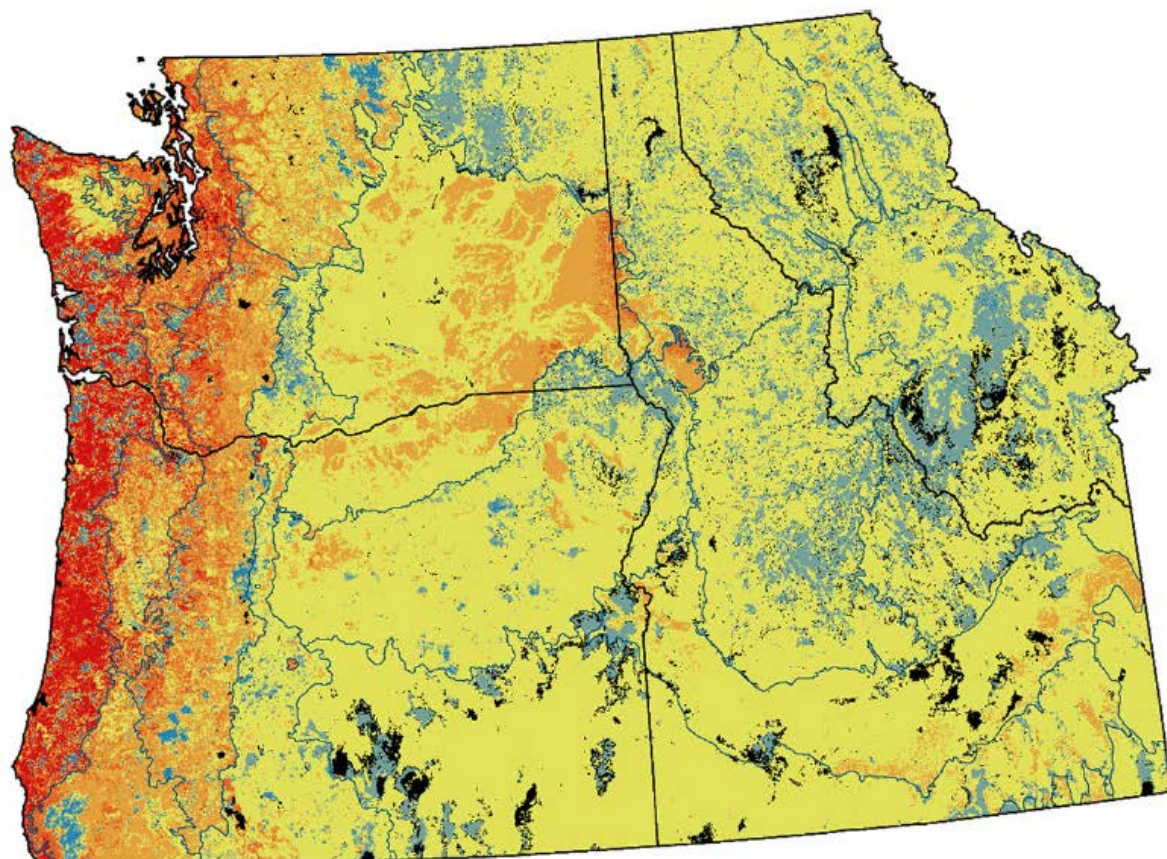
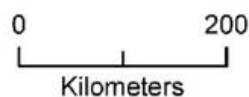


Figure 1. Mean net ecosystem production for 2006-2010 (from Turner et al., 2016).

## Citation

Turner, D.P., W.D. Ritts, R.E. Kennedy, A.N. Gray, and Z. Yang. 2016. NACP Biome-BGC Modeled Ecosystem Carbon Balance, Pacific Northwest, USA, 1986-2010. ORNL DAAC, Oak Ridge, Tennessee, USA. <http://dx.doi.org/10.3334/ORNLDAAC/1317>

**In addition to the data set citation, the following should also be referenced when using these data:**

Turner, D.P., W.D. Ritts, R.E. Kennedy, A. Gray, and Z. Yang, 2016. Regional carbon cycle responses to 25 years of variation in climate and disturbance in the US Pacific Northwest. Reg Environ Change. doi: [10.1007/s10113-016-0956-9](https://doi.org/10.1007/s10113-016-0956-9).

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## 1. Data Set Overview

**Project:** North American Carbon Program (NACP)

This data set provides Biome-BGC modeled estimates of carbon stocks and fluxes in the U.S. Pacific Northwest for the years 1986-2010. Fluxes include net ecosystem production (NEP), and net aboveground wood growth. Stocks include aboveground wood mass. Also present are mapped distributions of associated forest disturbances, distinguished by disturbance type (harvest, fire, pest/pathogen). The data are presented in a mapped form as well as in tabular summaries broken out by ownership and ecoregion. Maps of annual precipitation and temperature data are included for the years 1980-2010.

The model was used in a spatially distributed mode (i.e., run cell-by-cell over a grid) over the four-state Northwest US region including Washington, Oregon, Montana, and Idaho. Landsat data were used to characterize disturbances, and Forest Inventory Analysis (FIA) plot data were used to parameterize the model.

The [North American Carbon Program \(NACP\)](#) is a multidisciplinary research program designed to improve scientific understanding of North America's carbon sources and sinks and of changes in carbon stocks needed to meet societal concerns and to provide tools for decision makers.

## 2. Data Characteristics

**Spatial Coverage:** Pacific Northwest Region, USA

**Spatial Resolution:** GeoTIFFs are provided at 25 m and 1000 m resolution.

**Temporal Coverage:** Carbon data are for the years 1986 - 2010. Temperature and precipitation data are for the years 1980 - 2010.

**Temporal Resolution:** Annual.

**Study Area** (All latitudes and longitudes are given in decimal degrees.)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Pacific Northwest Region, USA (parts of Washington, Oregon, Montana, and Idaho)	-127.2886.90	-109.678	50.88111	39.79639

### Data File Information

**NOTE:** The data files provided by the author were used to produce the figures in [Turner et al. \(2016\)](#) . The files are named according to the figures in that paper. Files named "SFig\_" correspond to the supplementary figures or charts for that paper.

### GeoTIFFs

There are eight GeoTIFF files (\*.tif) described below. There are common spatial properties to all files, and individual properties which are listed with each individual file description.

### Spatial Data Properties (all files)

#### Parameters

Spatial Representation Type: Raster

Number of Bands: 1

Raster Format: GeoTIFF

units=m

Min\_x= -2305000, Max\_X= -1120000

Min\_y= 2200000, Max\_y= 3185000

Coordinates in decimal degrees:

West	East	North	South
-127.288	-109.678	50.88111	39.79639

Projection: North\_America\_Albers\_Equal\_Area\_conic

False\_Easting: 0.0

False\_Northing: 0.0

Central\_Meridian: -96.0

Standard\_Parallel\_1: 29.5

Standard\_Parallel\_2: 45.5

Latitude\_Of\_Origin: 23.0

Linear\_Unit: Meter (1.0)

Geographic Coordinate System: GCS\_North\_American\_1983

Angular\_Unit: Degree (0.0174532925199433)

Prime\_Meridian: Greenwich (0.0)

Datum: D\_North\_American\_1983

Spheroid: GRS\_1980

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314140356

Inverse Flattening: 298.257222101

**File descriptions**

1) **SFig1\_pnw\_epa\_level3\_ecoregions.tif**: A modified version of the EPA Level 3 Ecoregions (Omernick 1987).

**Spatial properties**

Spatial resolution: 1,000 m

Number of columns: 1,185

Number of rows: 985

Fill value: 0

Data type: byte

**Ecoregions in the GeoTIFF:**

Class	Short_description	description
0	nd	nodata
1	CR	Coast Range
2	PL	Puget Lowlands
3	WV	Willamette Valley
4	WC	West Cascades
9	EC	East Cascades
10	CP	Columbia Plateau
11	BM	Blue Mountains
12	SR	Snake River Plain
13	CB	Central Basin and Range
15	NR	Northern Rockies
16	IB	Idaho Batholith
17	MR	Middle Rockies
18	WB	Wyoming Basin
41	CA	Canadian Rockies

77	NC	North Cascades
78	KM	Klamath Mountains
80	NB	Northern Basin and Range

2) **Fig2\_pnw\_LTM\_TBS\_last\_disturbance\_type.tif**: The most recent disturbance type. Disturbance types were extracted from the Monitoring Trends in Burn Severity (MTBS 2015) and Landtrendr (Kennedy et al., 2010) disturbance data sets.

**Spatial properties**

Spatial resolution: 1,000 m

Number of columns: 1,185

Number of rows: 985

Data type: float 32

**Recent disturbance types in the GeoTIFF:**

Class Name	Description
-1: No Disturbance	Duration = 0, Magnitude = 0
1: Low Magnitude Fire	MTBS override
2: Moderate Magnitude Fire	MTBS override
3: High Magnitude Fire	MTBS override
4: Low Magnitude Cut	1 <= LT Duration <= 4, 11 <= LT Magnitude <= 40
5: Moderate Magnitude Cut	1 <= LT Duration <= 4, 41 <= LT Magnitude <= 70
6: High Magnitude Cut	1 <= LT Duration <= 4, 71 <= LT Magnitude <= 100
7: Short Low Magnitude Pathogen	5 <= LT Duration <= 12, 11 <= LT Magnitude <= 50
8: Short High Magnitude Pathogen	5 <= LT Duration <= 12, 50 <= LT Magnitude <= 100
9: Medium Low Magnitude Pathogen	13 <= LT Duration <= 20, 11 <= LT Magnitude <= 50
10: Medium High Magnitude Pathogen	13 <= LT Duration <= 20, 51 <= LT Magnitude <= 100
11: Long Low Magnitude Pathogen	21 <= LT Duration <= 28, 11 <= LT Magnitude <= 50
12: Long High Magnitude Pathogen	21 <= LT Duration <= 28, 51 <= LT Magnitude <= 100

3) Fig3\_pnw\_mean\_NEP\_2006\_2010.tif: Mean Annual NEP from 2006-2010 (kgC/m2/yr) derived by the PNWC Biome-BGC process model.

**Spatial properties**

Spatial resolution: 1,000 m

Number of columns: 1,185

Number of rows: 985

Data type: float 32

4) Fig1\_pnw\_nlcd2011\_landcover.tif: A modified version of the 2011 National Land Cover Dataset (NLCD). These classes were reclassified.

**Spatial properties**

Spatial resolution: 25 m

Number of columns: 47,400

Number of rows: 39,400

Fill value: -128

Data type: byte

**Band-Landcover class**

Class	Description
2	Not Vegetated
4	Cropland
5	Grassland
6	Shrubland
7	Juniper Woodland
8	Conifer Forest
9	Deciduous Forest

**Reclassified Landcover classes**

NLCD Code	PNWC Code
0 – Nodata	0 No data
11 - Open Water	2 Not Vegetated
12 - Perennial Ice/Snow	2 Not Vegetated
21 - Developed Open Space	5 Grass
22 - Developed Low Intensity	2 Not Vegetated

23 - Developed Medium Intensity	2 Not Vegetated
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**5) SFig3\_pnw\_standage\_class.tif:** A modified version of the GNN Standage age (<http://lemma.forestry.oregonstate.edu/data>). The GNN data set was available for Washington and Oregon. Robert Kennedy created a GNNtype standage for Idaho and Western Montana. We also used the MTBS-Landtrend disturbance layer as the basis for the youngest age class.

#### Spatial properties

Spatial resolution: 25 m

Number of columns: 47,400

Number of rows: 39,400

Fill value: 255

#### Stand Age Classes in the GeoTIFF:

Class	Description
0	Standage = 0
45	0 < Standage <= 60
80	60 < Standage <= 100
150	100 < Standage <= 200
250	Standage > 200

**6) SFig2\_pnw\_ownership.tif:** Public/Private ownership data.

#### Spatial properties

Spatial resolution: 25 m

Number of columns: 47,400

Number of rows: 39,400

Fill value: -1

Data type: byte

**7) SFig4\_pnw\_total\_annual\_precip\_1986\_2010.tif:** Mean annual precipitation from 1986 to 2010 derived from Daymet daily meteorological data (Thornton et al, 2014).

#### Spatial properties

Spatial resolution: 1,000 m

Number of columns: 1,185

Number of rows: 985

Data type: float 32

**8) SFig4\_pnw\_mean\_annual\_temperature\_1986\_2010.tif:** Mean annual temperature for 1986-2010 in degrees C derived from Daymet daily meteorological data (Thornton et al, 2014).

**Spatial properties**

Spatial resolution: 1,000 m

Number of columns: 1,185

Number of rows: 985

Data type: float 32

**Comma separated (.csv) files**

There are 10 comma-separated (.csv) data files with this data set. The ecoregions and four states of the PNW in the column headers are referenced by abbreviations provided in the table below.

Table 1. **Pacific Northwest and Ecoregions**

<b>Ecoregion</b>
Pacific Northwest (PNW)
Coast Range (CR)
Puget Lowland (PL)
Willamette Valley (WV)
Klamath Mountains (KM)
North Cascades (NC)
West Cascades (WC)
East Cascades (EC)
Blue Mountains (BM)
Northern Rockies (NR)
Idaho Batholith (IB)
Canadian Rockies (CA)
Middle Rockies (MR)
Oregon (OR)
Western Montana (MT)
Washington (WA)



**Data file descriptions**

1) **Table1\_Ecoregion\_mean\_pct\_disturbance.csv**: Mean percent of forested areas disturbed; provided for the ecoregions CR,PL, WV, KM, NC, WC, EC, BM, NR, IP, CA, and MR by disturbances Harvest, Fire, and Pests/Pathogen.

Column name	Units/format	Description
Ecoregion	text	Ecoregions where XX= CR,PL, WV, KM, NC, WC, EC, BM, NR, IP, CA, and MR
Harvest	percent	Percent of area disturbed from harvesting
Fire	percent	Percent of area disturbed from fires
Pest/Pathogen	percent	Percent of area disturbed from pests or pathogens

2) **Fig4\_Mean\_NEP\_ecoregion.csv**: Mean NEP (g C/m2/yr) for the years 1986-2010, by ecoregion for each year.

Column name	Units	Description
Year	yyyy	Year of data-1986-2010
XX_nep	g C/m2/yr	Mean NEP for each ecoregion for each year, 1986-2010, where XX = CR, PL, EC, WV, KM, WC, BM, NR, IB, CA, and MR.

3) **Fig5\_NEP\_total\_carbon\_public\_private.csv**: Net ecosystem production (NEP), fire emissions, harvest removals, and net ecosystem carbon balance (NECB) for private forested land and public forested land, provided in Tg C/yr.

Column name	Units/format	Description
C_source	text	Sources of carbon= NEP, Harvest, Fire emissions, or NECB
PNW_C_totals	TgC/yr	Carbon totals for the PNW area
PNW_C_Private	Tg C/yr	Carbon totals for privately owned forested land
PNW_C_Public	Tg C/yr	Carbon totals for public forested land

4) **Sfig5\_OR\_CR\_EC\_abg\_woodmass\_FIA\_BGC\_agebin.csv**: Aboveground wood biomass means for the Oregon Coast Range (OR-CR) and Oregon East Cascades (OR-EC) for observed FIA plot data and simulated (optimized Biome-BGC) biomass.

Values not reported, not applicable, or missing are provided as -9999.

Column name	Units/format	Description
ageclass	numeric	Biomass age class (10 yr increments) from 20-160---20,30,40,etc.
OR-CR_FIA_stemmass	kgC/m2	Aboveground wood biomass for the OR-CR ecoregion from FIA data
OR-CR_BGC_stemmass	kgC/m2	Aboveground wood biomass for the OR-CR ecoregion from the Biome-BGC model
OR-EC_FIA_stemmass	kgC/m2	Aboveground wood biomass for the OR-EC ecoregion from FIA data
OR-EC_BGC_stemmass	kgC/m2	Aboveground wood biomass for the OR-EC ecoregion from the Biome-BGC model

5) **SFig6\_prcp\_tavg\_1980\_2010.csv**: Mean annual temperature and annual precipitation over the Northwest region for years 1980-2010.

Column name	Units/format	Description
Year	yyyy	Year of data (1980-2010)
prcp	cm	Precipitation in cm
t	degrees C	Mean annual temperature in degrees C

6) **SFig7\_harvested\_area\_private\_public.csv**: Area of private and public forested land harvested for the years 1986-2010.

Column name	Units/format	Description
Year	yyyy	Year of data (1986-2010)
PNW_private_hvst	km2	Total PNW private forested area harvested
PNW_public_hvst	km2	Total PNW public forested area harvested

7) **SFig8\_harvested\_area\_intensity\_class.csv**: Area harvested by intensity class (1986-2010) over the study domain for the years 1986-2010.

Column name	Units/format	Description
Year	yyyy	Year of data (1986-2010)
Private_lowcut	km2	Private land- low intensity harvested area
Private_modcut	km2	Private land-moderate intensity harvested area
Private_highcut	km2	Private land- high intensity harvested area
Public_lowcut	km2	Public land- low intensity harvested area
Public_modcut	km2	Public land- moderate intensity harvested area
Public_highcut	km2	Public land- high intensity harvested area

8) **SFig9\_burned\_area\_public\_private.csv**: Total burned area of private and public forested land for each year, 1986-2010.

Column name	Units/format	Description
Year	yyyy	Year of data (1986-2010)
Private_burned_area	km2	Total PNW private burned forested area
Public_burned_area	km2	Total PNW public burned forested area

9) **SFig10\_abg\_woodmass\_FIA\_BGC.csv**: Ecoregion mean aboveground wood mass (reported as kg C/m<sup>2</sup>) for Biome-BGC simulations and FIA plot data.

Column name	Units/format	Description
Ecoregion	text	Data for the following ecoregions: CR, PL, WV, KM, NC, WC, EC, BM, NR, IB, CA, and MR
BGC_woodmass_mean	kg C/m <sup>2</sup>	Mean aboveground wood mass produced from the BIOME-BGC simulation
FIA_woodmass_mean	kg C/m <sup>2</sup>	Mean aboveground wood mass from FIA plot data

10) **SFig11\_CFlux\_ecoregion\_private\_public.csv**: Mean C (aboveground wood mass and net aboveground wood growth) by the carbon source (NEP), fires, harvesting, (NECB) and by ecoregions totals, ecoregions public and private lands (three columns for each ecoregion- total, public, and private).

Note: Ecoregions XX = PNW, CR, PL, EC, WV, KM, WC, BM, NR, IB, CA, MR, OR, WA, and MT.

Column name	Carbon source
	Total carbon from private and public forested land by

XX_Total_C_private_public	source: NEP, Harvesting, Fire Emissions, and NECB
XX_Total_C_private	Total carbon from private forested land by source: NEP, Harvesting, Fire Emissions, and NECB
XX_Total_C_public	Total carbon from public forested land by source: NEP, Harvesting, Fire Emissions, and NECB

Sample data entries from *SFig11\_CFlux\_ecoregion\_private\_public.csv*:

Carbon_source	PNW_total_C_private_public	PNW_Total_C_private	PNW_Total_C_public	CR_Total_C	CR_C_public	CR_C_private
NEP	43.56579	58.52343	32.22572	202.7228	234.0523	180.3652
Harvest	19.24919	37.43446	5.464104	103.3653	44.9123	145.0789
Fire Emission	3.204932	0.480929	5.267691	0.07252	0.150493	0.016876
NECB	21.11167	20.60805	21.49393	99.28493	188.9895	35.26944

### 3. Application and Derivation

These data are of value to the modeling community to better understand the terrestrial carbon cycle. To evaluate the possibilities for increased carbon sequestration, there is wide interest in quantifying carbon fluxes at more local and regional scales (Lu et al. 2013). The ecoregions are distinct with respect to climate, soil, and vegetation (USGS 2015).

### 4. Quality Assessment

Uncertainty in the simulated carbon stocks and flux estimates arise from errors in the spatially distributed inputs to the model, as well as from Biome-BGC model structure and parameter uncertainty. Uncertainties have previously been investigated in the distributed meteorological data (e.g., Hasenauer et al., 2003; Oyler et al., 2015), soil depth and texture (Peterman et al., 2014), disturbance mapping (Cohen et al., 2010), and stand age mapping (Ohmann and Gregory 2002). Observations of Biome-BGC parameters were compiled by White et al. (2000), and there is obvious species-level variation within a plant functional type. This issue was addressed by use of ecoregion-level parametrization based on (1) observations (e.g., foliar nitrogen concentration) and (2) parameter optimization (with reference to FIA observations) (Turner et al., 2016).

Efforts at validation of carbon stocks included comparison to aggregated FIA plot data. The comparison (SFig. 10) of ecoregion mean values suggests a positive bias in the simulated tree carbon stocks. The explanation may lie in a difference in the age class distributions in the wall-to-wall simulations versus the sample of FIA plots (Duane et al., 2010).

### 5. Data Acquisition, Materials, and Methods

#### Site description

The four-state (Oregon, Washington, Idaho, and Western Montana) Pacific Northwest regions (PNW) are distinct with respect to climate, soil, and vegetation (USGS 2015). Evergreen needleleaf forests dominate much of the region. The region is undergoing multiple changes in climate and vegetation relevant to the carbon cycle (Law and Waring 2015). A trend of climate warming over recent decades is observed in meteorological station data (e.g., Barnett et al. 2008; Pederson et al. 2010) albeit with controversy about the relative influence of internal climate variability versus anthropogenic factors (Abatzoglou et al. 2014; Johnstone and Mantua, 2014; Mote 2003) and possible artifacts in the observational record (Oyler et al. 2015). The forest disturbance regime in the northwest region is characterized by an increasing incidence of wildfire (Littell et al. 2009; Turner et al. 2015), generally attributed to climate warming. Pest and pathogen outbreaks are likewise increasing (Hicke et al. 2013), again associated with warming (Preisler et al. 2012). The drought in the Western USA from 2000 to 2004 strongly reduced the background carbon sink (Schwalm et al. 2012).

#### BIOME-BGC model simulation

A model run consisted of a spin-up, to bring slow turnover carbon pools (e.g. soil) into near equilibrium with the local climate, followed by one or two disturbance events (identified by year, type, magnitude, and duration). To limit the number of simulations required, only the 10 most frequent combinations of cover type and disturbance history in each 1-km<sup>2</sup> grid cell were run. Area weighted mean values were then reported for carbon stocks and fluxes by year. Over 90% of the original study area was covered with this approach. The Biome-BGC model was applied in a spatially distributed mode (i.e., run cell-by-cell over a grid) over public and private land in the PNW.

#### Methods

The ecoregion boundaries are a modified version from Omernik (1987). To produce the file *SFig1\_pnw\_epa\_level3\_ecoregions.tif*, the data were resampled to 25 m and clipped to the PNW four state study region.

Ownership boundaries were from the Gap Analysis Program (GAP 2014). To produce the file *SFig2\_pnw\_ownership.tif*, the data were resampled to 25 m,

clipped to the PNW four state study region, and reclassified.

The model was adapted to simulate disturbance and recovery associated with forest harvest (Law et al., 2004), wildfire (Meigs et al., 2011), and pests/pathogens (Turner et al., 2015). Mass balance was maintained by transfers among C pools and to the atmosphere at the time of a disturbance.

Landsat data were used to characterize disturbances, and Forest Inventory Analysis (FIA) data were used to parameterize the model. The 2010 land cover over a 25-m grid was from the National Land Cover Database (NLCD 2006) and was based on the Landsat data. To produce the file **Fig1\_pnw\_nlcd2011\_landcover.tif**, the data were resampled to 25 m, clipped to the PNW four state study region, and reclassified.

### Disturbance events

For the forest cover type, the disturbance history of each 25-m grid cell was specified based on Landsat observations. A time series (1985–2011) of Landsat images (one per year) were assembled over all forest areas and the trajectories and inflection points of a spectral vegetation index were evaluated for each 25-m pixel (Kennedy et al., 2010, 2012; Meigs et al., 2015). The disturbance type was classified as harvest, fire, or pest/pathogen. Abrupt disturbances (i.e., a sharp drop in the vegetation index) were classified as fire if they overlapped with the Monitoring Trends in Burn Severity data set (MTBS 2015), and otherwise as harvest. Non-abrupt disturbances were classified as pest/pathogen, and the remote sensing observations indicated a beginning year and a year of maximum impact.

To produce the file **Fig2\_pnw\_LTM\_TBS\_last\_disturbance\_type.tif**, the following processing steps were followed:

- MTBS and Landtreindr data sets were resampled to 25 meters
- Clipped to the PNW study region
- Disturbance was called a fire if MTBS called it a fire
- Landtreindr was used to define the remaining disturbed pixels based upon the classification described above. Basically, short duration disturbances were assumed to be clear cuts. Longer duration disturbances were assumed to be pathogens.

Disturbances prior to 1985 were based on stand age, estimated from Landsat data using Gradient Nearest Neighbor (GNN) analysis (Ohmann and Gregory 2002). GNN-based stand age was not available for Idaho and Montana, so spectral relationships of Landsat data and stand age in eastern Oregon and Washington were used (with reference to the observed age class distributions from FIA data in Idaho and Montana) to estimate stand age in those states. The MTBS-Landtreindr disturbance layer was used to identify stands with age less than 30.

A class (bin) for disturbance magnitude and a class for duration were associated with each disturbance event (Turner et al., 2015), and for reporting purposes, the year of the event was assigned to the year of maximum magnitude.

To produce the file **SFig3\_pnw\_standage\_class.tif**, the following processing steps were followed as described above:

- Data were resampled to 25 m,
- Clipped to the PNW study region,
- Lemma GNN Stand age for Washington and Oregon were combined with an in-house stand age layer for Idaho and Western Montana. The MTBS-Landtreindr disturbance layer was used to identify stands with age less than 30, and
- Stand age was reclassified.

### Meteorological data

The 25-year time series of daily meteorological fields at 1-km resolution was from Daymet daily meteorological data for North America (Thornton et al, 2014). These data were developed by interpolation of meteorological station data using digital elevation maps and general meteorological principles (Thornton et al., 1997).

## 6. Data Access

This data is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

[NACP Biome-BGC Modeled Ecosystem Carbon Balance, Pacific Northwest, USA, 1986-2010](#)

Contact for Data Center Access Information:

- E-mail: [uso@daac.ornl.gov](mailto:uso@daac.ornl.gov)
- Telephone: +1 (865) 241-3952

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