LAND-BASED NET CARBON INVENTORY

Submitted to the
OREGON LEGISLATURE

by the
OREGON DEPARTMENT OF ENERGY and
OREGON CLIMATE ACTION COMMISSION

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ACKNOWLEDGEMENTS

[To be added in final report.]

EXECUTIVE SUMMARY

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CLIMATE ACTION IN OREGON

To address the climate crisis, society must quickly take two actions to meet national and global climate goals. First, we must rapidly reduce emissions and make a clean energy transition. Second, we must also rapidly increase efforts to remove carbon already in the atmosphere. Taking these actions is necessary to stop global temperatures from rising beyond livable thresholds.

Oregon began a concerted effort to reduce emissions in 2007 by setting sector-based state emissions reductions goals through HB 3543, and the Oregon Department of Energy (ODOE) began taking actions to reduce emissions the same year. The Oregon Climate Action Commission (OCAC) is charged with tracking the state's progress to achieve these goals. Many agencies contribute to the climate studies, analyses, and modeling that the OCAC considers and uses to make recommendations to the legislature. ODOE contributes to the state's climate studies, analyses, and modeling by assessing our progress in meeting our emission reduction goals through the many programs and regulations that we have already adopted (see the TIGHGER project), and by modeling pathways and developing recommendations to help us achieve a least-cost clean energy transition (see the Oregon Energy Strategy). The Department of Environmental Quality maintains and updates the state's sector-based greenhouse gas (GHG) emissions inventory and the consumption-based GHG emissions inventory to track trends in emissions, and manages the Climate Protection Program (CPP), Clean Fuels Program, and the Advanced Clean Cars and Trucks programs. The Oregon Public Utility Commission (OPUC) ensures that regulated utilities comply with the clean electricity bill (HB 2021) and the CPP. These are some of the many ways that Oregon's state agencies have worked to reduce emissions.

In recent years, climate specialists and technologists have turned their attention toward actions to remove carbon already in the atmosphere. Oregon has followed suit. The Department of Geology and Mineral Industries is researching the potential to store carbon directly captured from the air in Oregon's geologic formations. In 2023, recognizing the multiple benefits that nature offers toward increasing climate resiliency across the climate action spectrum (adaptation and mitigation), the Oregon legislature passed HB 3409, a broad-based package of laws on climate and natural climate solutions. It defined natural and working lands (N&WL) and natural climate solutions (NCS), and established a policy to use NCS as a tool to combat climate change. It directed the OCAC, ODOE, and seven land managing agencies[i] to track outcome-based progress for NCS project implementation on natural and working lands and establish an accounting system fundamental to tracking greenhouse gases[ii] in Oregon's landscape. This land-based inventory that accounts for greenhouse gas emissions and carbon removals across Oregon's lands over time is the subject of this report.

OVERVIEW AND PURPOSE

This Land-based Net Carbon Inventory (Inventory) provides a statewide snapshot of what has happened, and is happening, in Oregon's landscape in terms of GHG emissions and removals and identifying carbon stocks.[iii] ODOE is responsible for improving the Inventory over time and updating it at regular intervals.

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[i] Department of Agriculture, Department of Forestry, Department of Fish and Wildlife, Department of Land Conservation and Development, Parks and Recreation Department, Department of State Lands, and Watershed Enhancement Board.

[ii] https://ghginstitute.org/2025/01/17/the-differences-between-allocational-and-consequential-greenhouse-gas-accounting-summarized/

[iii] A carbon stock is the amount of carbon in a particular carbon pool or store. A carbon pool or store is a system that has the capacity to remove or emit greenhouse gases.

HB 3409 also requires that the state holistically approach nature-based mitigation efforts by prioritizing and investing in nature-based action that achieves three aims. NCS must enhance or protect carbon sequestration and storage, maintain or increase ecosystem function, and maintain or increase community wellness.[iv] The law prioritizes the use of existing programs and removing barriers to implementation for landowners and land stewards. Another accounting system, to be established, will track selected actions via explicit metrics that measure the actions' net carbon contributions, as well as contributions toward ecosystem function and community wellness.

Oregon's first Inventory represents a critical step in tracking greenhouse gas emissions and removals associated with the land sector. In addition, it begins to identify landscape-scale questions that will need to be answered to help us understand how nature-based actions can be deployed and upscaled to effectively draw down atmospheric carbon. In the future, these nature-based mitigation actions may be supplemented by technological advances, like direct air capture, but nature-based actions will always play an important role because natural systems underpin the health and well-being of society in addition to their role balancing atmospheric carbon levels.

Summary

This project developed Oregon's first land-based net carbon inventory and establishes a program to improve and maintain the inventory through time.

[To be added in final report]

Why Create a Land-based Net Carbon Inventory?

Oregon's lands emit carbon to, and sequester carbon from, the atmosphere. They have a carbon balance, or a net carbon flux, calculated from the amounts of greenhouse gases they emit and the carbon they sequester. Land sequesters and stores carbon dioxide in vegetation and soil (e.g. a forest or wetland). Land also produces GHG emissions through natural processes (e.g., methane produced by decaying plants in wetlands) or anthropogenic processes (e.g., methane or nitrous oxide produced by human-caused wildfires). To understand Oregon's overall contribution to global greenhouse gas emissions, it is necessary to establish an inventory to estimate carbon sinks or stores[v], and sources of land-based emissions. Identifying sources and sinks will enable Oregon to take action to reduce or avoid land-based emissions, and to accelerate the pace and scale of actions that protect stores and increase natural sequestration.

Oregon's first inventory establishes a historical baseline for carbon in specific pools[vi] and establishes rates of emissions and sequestration in Oregon's ecosystems. It provides the state, decision-makers, and the public a better understanding of the effects of the past 35 years of changes to Oregon's land on its GHG emissions and removals.

Over time, updates to the Inventory will provide additional trend information on emissions and removals from the land. The Inventory is designed to be updated and improved over time as more information and data becomes available, including improvements in alignment of land cover and land use data or region-specific models to estimate emissions and removals from particular activities. Such updates and improvements will likely require institutional arrangements between land managing agencies and ODOE,

[iv] ORS 468A.183

[v] Carbon pool/store is a system that has the capacity to remove or emit carbon.

[vi] Carbon pool/store is a system that has the capacity to remove or emit carbon

as well as support for the team of cross-agency staff that track the data necessary for the Inventory. This need is discussed further in the Institutional Arrangements Section of this report. Figure 1 summarizes the uses for the Inventory.

Figure 1: Uses for the Land-based Net Carbon Inventory

- Establishes long term trends in emissions and removals from land, starting in 1990
- Basis for future projections
- Enables tracking of progress when updated routinely
- Informs policy making
- Demonstrates the role Oregon lands play in greenhouse gas emissions and removals

PROJECT BACKGROUND

This section provides an explanation of the carbon cycle on natural and working lands as well as basic information that is helpful to navigate the methodology and results.

The Carbon Cycle in Natural and Working Lands

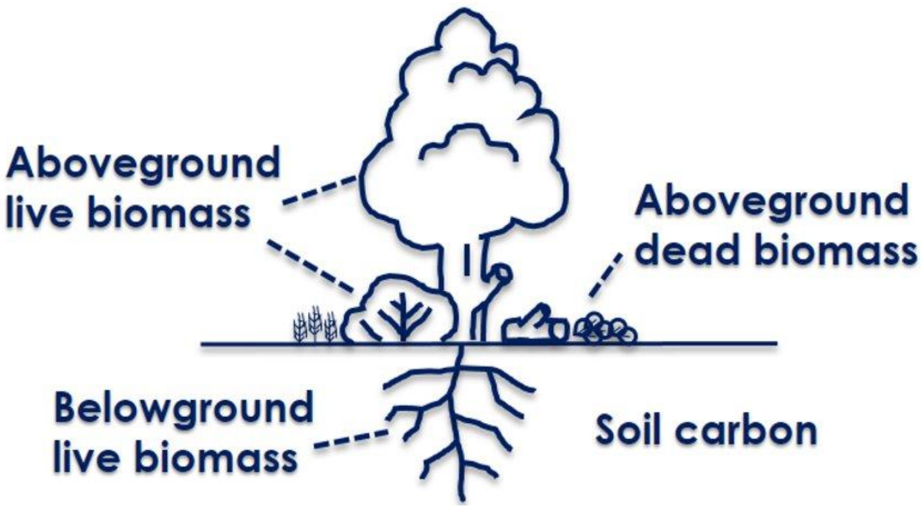
The Inventory estimates emissions and removals between the atmosphere and Oregon's ecosystems. The methods and data used in the inventory estimate greenhouse gases moving into and out of its six principal land categories, shown in Table 1, as recommended in the International Panel on Climate Change (IPCC) guidelines. The definitions for each category are in Appendix A.

Table 1: Six Principal Land Categories of the Land-based Net Carbon Inventory

Land Category	Description
Forest land	• Land with woody vegetation consistent with thresholds used to define forest land
Cropland	• Land used for annual, perennial, and forage crops • Agroforestry • Pasture/Hay
Grassland	• Rangelands • Grasslands
Wetlands	• Land that is covered or saturated by water for all or part of the year • Coastal and inland
Developed land	• Low, medium, and high density developed land
Other land	• Includes bare soil, rock, and ice • Emissions from these lands are assumed minimal and not included in Inventory

Terrestrial ecosystems contain four carbon pools: 1) aboveground biomass (e.g., tree trunks and branches), 2) belowground biomass (e.g., plant roots), 3) dead organic matter (e.g., discarded dead leaves and branches), and 4) soil.

Figure 2: Major Carbon Pools



Carbon can move between pools (e.g., aboveground biomass converts to dead organic matter as leaves and branches fall from trees) and exchange with the atmosphere due to natural processes (e.g., growth of shrubs and trees), land use change (e.g., when forest land is converted to cropland), and disturbance events (e.g., wildfires).

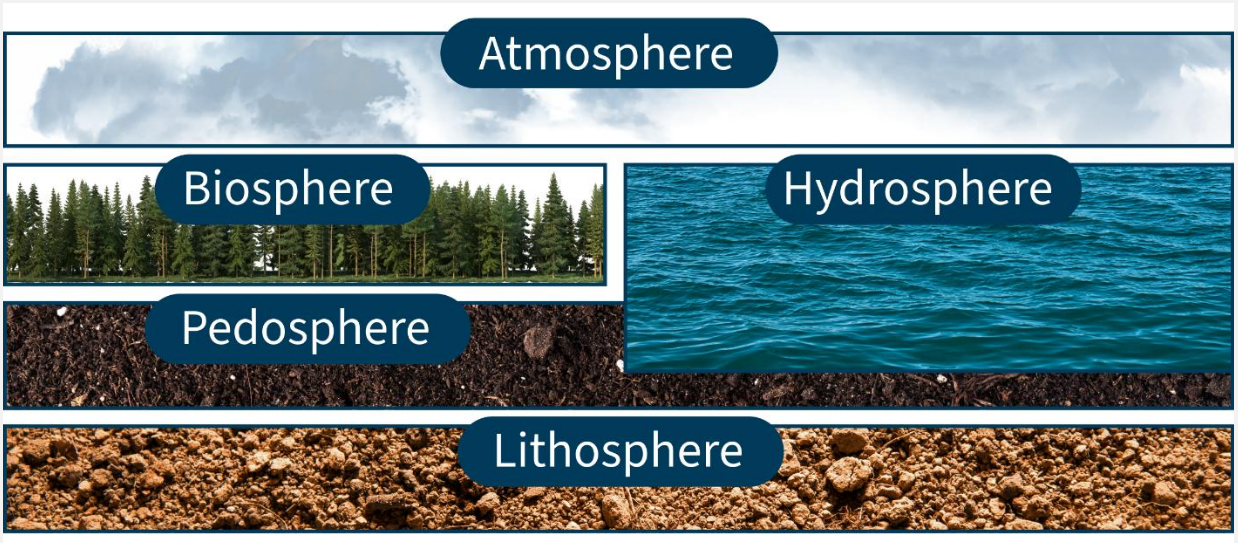
FAST AND SLOW CARBON CYCLES

Earth's carbon cycle involves the exchange of carbon between five main carbon reservoirs: atmosphere, biosphere (e.g., bacteria, plants, insects, animals), hydrosphere (i.e., water bodies), pedosphere (i.e., soils), and lithosphere (e.g., Earth's crust and mantle, including rocks and fossil fuel precursors). The atmosphere contains just over 1 percent of Earth's total carbon, the biosphere just under 1 percent, the pedosphere about 4 percent, the hydrosphere about .04 percent, and the lithosphere the remainder. Carbon is cycled between all reservoirs due to both natural and human-caused processes and occurs on two primary timescales, referred to as the slow and fast carbon cycles.

The slow carbon cycle operates at geologic timescales (hundreds of millions of years) and relates the major movements of carbon occurring between the atmosphere, hydrosphere, pedosphere, and lithosphere. The fast carbon cycle occurs at the timescale of human lives and comprises much smaller though impactful movements of carbon between all five reservoirs. In contrast with the lithosphere's role in the slow carbon cycle that involves substantial uptake of carbon by rocks, the lithosphere's role in the fast carbon cycle is, outside of geoengineering, mostly limited to carbon emissions resulting from the burning of fossil fuels.

The fast carbon cycle is particularly affected by the exchange of carbon between the biosphere and the atmosphere, pedosphere, and hydrosphere. The biosphere removes carbon from the atmosphere chiefly via photosynthesis, which converts CO_2 and sunlight into sugar, which in turn may be converted to cellulose and other molecules necessary for structure and metabolic processes. A portion of this carbon is returned to the atmosphere when plants and animals die and their tissues decompose or combust, among other processes; another portion of this carbon may move into the pedosphere (soils) but be released when it is disturbed through natural or human-caused actions.

The Inventory is concerned with many of the processes that move carbon from the biosphere and pedosphere to the atmosphere.



Land-based Net Carbon Inventory Basics

The Inventory accounts for the balance of GHG emissions and removals, also known as net carbon flux, over time, due to changes in Oregon's land. EPA captures these emissions in the "Land Use, Land Use Change, and Forestry"[vii] section of the National Greenhouse Gas Inventory (NGHGI).

Oregon's Inventory includes emissions and removals of carbon dioxide (CO_2) due to carbon stock changes as well as emissions of methane (CH_4) and nitrous oxide (N_2O)—the latter emissions collectively being referred to as "non-CO_2 emissions." Carbon stock changes and non-CO_2 emissions occurring in land categories remaining the same or converting to new land categories over time are included in this Inventory. Carbon stocks may change within a land category for various reasons, such as carbon stocks increasing in Forest Land due to year-over-year growth of trees. Carbon stocks will also change in land converted to other categories, such as when Grassland converts to Forest Land via the encroachment of juniper trees.

Additionally, the Inventory tracks emissions from drained organic soils occurring on Cropland and Developed Land. Organic soils are soils rich in organic carbon, which accumulate over long periods of time in soils that are flooded or otherwise waterlogged. When these soils are drained, usually due to human activities like diverting a waterway or draining land for agriculture or development, the organic carbon in these soils oxidizes and converts to CO_2, CH_4, and N_2O emissions. When soils remain flooded or waterlogged, a portion of the organic carbon in this system is converted to methane, and the Inventory tracks these emissions. In contrast, mineral soils have relatively lower amounts of organic carbon than

[vii] www.epa.gov/system/files/documents/2024-04/us-ghg-inventory-2024-main-text_04-18-2024.pdf

organic soils. Even so, carbon fluxes occur in mineral soils and are calculated in the Inventory for these soils as well.

The Inventory also tracks emissions related to biomass burning as a separate category (e.g., wildfires and prescribed burns). Carbon dioxide emissions from biomass burning are tracked as changes in carbon stock in Forest Land and Grassland. Non-CO_2 emissions, which occur as a byproduct of combustion of biomass are tracked separately in their own category.

The land area classification is the basis for estimating emissions and removals from land use that remains consistent over time and estimating emissions and removal from land use change. Thus, the principal land categories (see Table 2) are further divided into "land remaining land" for each category (e.g., Forest Land Remaining Forest Land) and "land converted to different land" (e.g., Cropland Converted to Forest Land). This division creates 12 land subcategories. When land undergoes a transition, it is always accounted for in the new land category and stays in this transitional category for 20 years per IPCC guidelines. A complete account of the land base in Oregon ensures that the Inventory does not omit or double-count emissions and removals. See Table 2, which is similar to Table 1, but with the right-hand column showing additional divisions.

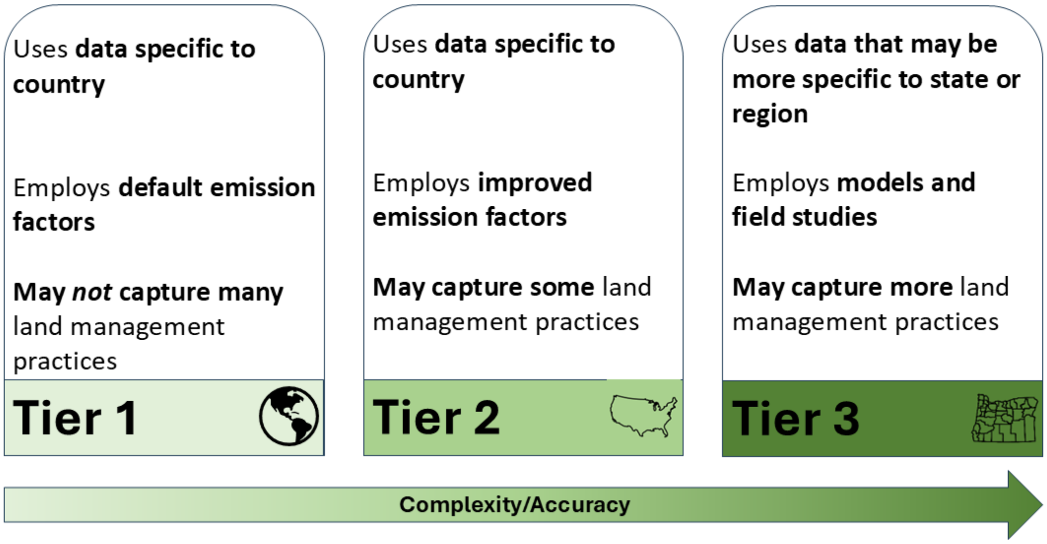
Table 2: Six Principal Inventory Land Categories and the 12 Sub-categories

Land Category	Description	Land Sub-categories
Forest land	• Land with woody vegetation consistent with thresholds used to define forest land	• Forest land remaining forest land • Land converted to forest land
Cropland	• Land used for annual, perennial, and forage crops • Agroforestry • Pasture/Hay	• Cropland remaining cropland • Land converted to cropland
Grassland	• Rangelands • Grasslands	• Grassland remaining grassland • Land converted to grassland
Wetlands	• Land that is covered or saturated by water for all or part of the year • Coastal and inland	• Wetlands remaining wetlands • Land converted to wetlands
Developed land	• Low, medium, and high density developed land	• Developed land remaining developed land • Land converted to developed land
Other land	• Includes bare soil, rock, and ice • Emissions from these lands are assumed minimal and not included in Inventory	• Other land remaining other land • Land converted to other land

Inventory Tiers

IPCC guidelines for inventory methodologies establish a system of Tiers to provide a rough shorthand to indicate the complexity and accuracy of the underlying data and methods used to produce emissions and removals estimates. Tiers range from 1 to 3, with the complexity and accuracy generally increasing with the number of Tier, as shown in Figure 3.

Figure 3: Methodological Tiers of the Inventory, Based on Descriptions from the IPCC



Tier 1 methodologies are the most basic, relying on data collected in the country on activities like land use and land use change, and generic methods that employ generic emission factors provided in IPCC guidance documents that are not specific to any particular country. Emission factors are coefficients applied to land area data to produce an estimate of GHG emissions from a given activity.

Tier 2 methodologies are of intermediate complexity, relying on data collected "in country" combined with emissions factors that are also specific to that country.

Tier 3 methodologies are of high complexity, relying on highly specific data collected in the country, typically at spatial units of even finer spatial resolution (e.g., state, county, or ecoregion). Tier 3 methods may employ routine measurement systems as well as process-based models that are appropriate for the data being used. Process-based models are used to simulate and predict outcomes by incorporating specific information about relationships and processes. Tier 3 methodologies use process-based models to replace the use of emission factors in Tiers 1 and 2. They are more complex and can only be employed when more complex data are available.

Emission factors for an activity in Tier 1 inventory methodologies may have been derived by summarizing the findings of a few studies conducted across the globe, while emission factors for an activity in Tier 2 inventory methodologies may have been derived by summarizing the findings of studies within a particular country. Tier 3 level emissions factors can be derived from routine measurement systems established at fine spatial scales (e.g. monitoring data collected in the field) or from process-based models as described above.

The use of Tier 3 inventory methodologies over lower-tier ones is generally encouraged because they provide estimates of greater certainty than lower tiers. Even estimates produced by Tier 3 methodologies will be inherently uncertain and there is always room—and potential need—for improvement even within Tier 3 methodologies.

See Appendix B for assigned Tier for each land category and subcategory of the Inventory.

How Data is Used in an Inventory

In general, the complexity and accuracy of an inventory will increase with higher-quality data. Quality of data may refer to more than one data characteristic, such as regional specificity (e.g., soil cores from specific ecoregions of Oregon) or the use of collection methods with high accuracy and precision (e.g., LiDAR) or to data at high spatial (e.g., 1-meter) or temporal (e.g., collected every year) resolution.

Many types of data are appropriate to use in an inventory and generally the objective is to use the best available data. Some data may be spatial in form, such as the National Land Cover Database on land cover and include information for the entire state of Oregon. Other data may be tabular, such as crop types and acres planted, and provide information limited to particular land category or limited to some areas within a given land category. Other types of data used in an inventory may be neither spatial nor tabular, such as crop rotation information gathered through interviews with practitioners and university extension offices working closely with practitioners.

Differences in data forms and the specificity of these data may limit the ways that inventory results can be disaggregated and communicated. For example, the results of an inventory cannot be presented on a map if the underlying data are not spatial or do not have a spatial component at the appropriate scale. For example, if data on crop type and acreage are only reported at the scale of the county, usually to protect landowner privacy, the finest scale at which results may be reported without introducing additional sources of error is the county.

Availability of data should not be confused with *quality* of data. For example, data providing estimates of aboveground biomass in the Grassland category may technically be available for the entirety of Oregon's Grassland area, but these estimates may be derived from spatially biased vegetation surveys (e.g., many parts of the state may be only sparsely surveyed while others may be abundantly surveyed) or collected in a single year or in very few years. Thus, while data may be available and appropriate for use, there may be a need for additional data processing, normalization, and validation to reduce uncertainty in these data. Land categories where data allowed the application of higher-Tier inventory methodologies may still benefit from improvements in data and quantification methods.

Oregon's Three Greenhouse Gas Inventories

Oregon now has a suite of inventories to track greenhouse gas (GHG) emissions, removals, and storage (see Table 3). The Department of Environmental Quality (DEQ) maintains two of Oregon's three inventories. The sector-based inventory characterizes and quantifies the anthropogenic (human-caused) GHG emissions resulting from activities occurring in Oregon, for example from the energy and industrial sources, while excluding the land sector, which this Inventory addresses. The consumption-based inventory tracks emissions produced around the world due to Oregonians' consumption of goods and services. ODOE worked closely with DEQ to ensure the newest inventory would be complementary to these other inventories. Appendix C lists the categories and subcategories of the Sector-based GHG Emission Inventory and the Land-based Net Carbon Inventory to demonstrate that no double counting will occur between these two greenhouse gas accounting tools.

Table 3: Oregon Greenhouse Gas Inventories

Sector-based GHG Emissions Inventory	Consumption-based Emissions Inventory	Land-based Net Carbon Inventory
Maintained by DEQ Tracks CO2, CH4, N2O, and F-gases, produced within Oregon by economic sector, such as industrial and transportation sectors, and emissions associated with electricity use in Oregon. Integrates data from DEQ's Greenhouse Gas Reporting Program and the State Inventory Tool produced by the U.S. Environmental Protection Agency's (EPA).	Maintained by DEQ Estimates the global, life-cycle emissions associated with Oregon's consumption of energy, goods, and services, including economic consumption by households, businesses, and government entities. Uses data from EPA's national inventory and other sources.	Maintained by ODOE Tracks the balance of GHG emissions and removals—also known as net carbon flux—from land use, land use change, forestry, some land management practices, and some natural disturbances (e.g., wildfire) on Oregon's natural, working, and developed lands. Also uses EPA-approved methods.

ENGAGEMENT

HB 3409 directed the Commission and ODOE to conduct extensive engagement during the development of the Inventory.

Natural & Working Lands Advisory Committee

A Natural & Working Lands Advisory Committee was convened nine times to advise the Commission on the work, with specific committee positions required by statute that represent natural and working lands experiences and knowledge bases. Table 4 lists the positions required by statute. ODOE has worked to fill the Tribal seat referenced below, but we have not identified someone for this role. This has been a consistent theme across similar bodies, where the legislation includes a requirement for Tribal membership, but there is simply not capacity among Tribes to participate. The approach ODOE and the OCAC are using for engagement with the nine federally recognized Tribes in Oregon, which aims to be respectful of their sovereign status and time, is described below.

Table 4: Natural & Working Lands Advisory Committee Positions Listed in ORS 468A.197

Number of Members*	Position(s) Description	Names and Affiliations
1	Tribal culture, customs, and government	Vacant
1	Local government representative whose primary economic activity is derived from agriculture, forestry, fishing and hunting	Ellen Hammond, Jefferson County SWCD
1	Urban forestry or parks management	Jonathon Soll, Metro
3	Forestry or forest products, including one private forest landowner with less than 5,000 acres of forestland	Ben Hayes, Hyla Woods and Springboard Forestry Betsy Earls, Weyerhaeuser Jason Callahan, Green Diamond

Number of Members*	Position(s) Description	Names and Affiliations
2	Agriculture, including one who owns a small family farming operation	Mike McCarthy, McCarthy Family Farm LLC Jocelyn Bridson, Tillamook Creamery
1	Livestock experience	Aubri Spear, Eocene Environmental Group
1	Blue carbon experience	Jazmin Dagostino, The Pew Charitable Trusts
1	Environmental justice experience	Nikita Vincent, Oregon Agricultural Trust David Mildrexler, Eastern Oregon Legacy Lands, Partnership for Policy Integrity
2	Conservation or environmental management	Megan Kemple, Oregon Climate and Agriculture Network Lauren Link, The Nature Conservancy
2	Landowner technical assistance	Dean Moberg, Tualatin SWCD Andrea Kreiner, Oregon Association of Conservation Districts

**The Commission may appoint additional members as needed to provide additional expertise or represent other interests.*

State Agency Coordination

An inter-agency working group was convened three times during the development process with multiple one-on-one meetings with appropriate agency staff, particularly during the data discovery phase. More than 30 datasets were identified and reviewed for potential use in the methodologies developed to create the Inventory. Appendix D lists the datasets considered by the project team.

The seven land managing agencies listed in the Natural Climate Solutions statute (ORS 468A.183-.199) include:

- Department of Agriculture
- Department of Fish and Wildlife
- Department of Forestry
- Department of Land Conservation and Development
- Parks and Recreation Department
- Department of State Lands
- Oregon Watershed Enhancement Board

The Department of Environmental Quality has also been an important advisor and partner to develop the Inventory.

Tribal Nations

Through HB 3409, the legislature directed OCAC to establish a process for consultation with Tribal Nations in this state to advise the OCAC on the performance of its natural climate solutions duties.

We are currently in a phase of discovery, uncovering past lessons learned by the Commission's efforts in working with Tribes, developing an understanding of Oregon Tribes' history and how that may inform this effort, identifying which Tribes are interested in engagement on this topic once funding is secured, and determining who our Tribal government staff contacts may be.

Starting in September 2024, Director Benner and Commission Chair Macdonald sent a formal letter to the Chairs of the nine federally recognized Tribes to provide an update on NCS work and to extend an offer to participate in the process to advise the Oregon Department of Energy and Oregon Climate Action Commission on NCS workstream deliverables, including a Land-based Net Carbon Inventory, a NCS Workforce and Training Program Needs Study, and the adoption of NCS Goals and Metrics to increase net carbon sequestration and storage on the state's natural and working lands over time. ODOE staff were able to talk to the Coquille Tribe in response to the letter. In response to their feedback — as well as receiving guidance from the Affiliated Tribes of Northwest Indians as they work to coalesce publicly available knowledge on climate resilience plans for each Tribe in Oregon — ODOE staff plan to review all available Tribal climate resilience documents and deepen engagement with Tribes in 2026.

While the work to establish the Inventory occurred rapidly, Inventory improvements and natural climate solutions are ongoing. The OCAC and ODOE have created a separate parallel process based on a longer timeframe to meaningfully engage with Tribal Nations. The approach aims to create meaningful interactions and co-develop next steps and a process useful to the Tribes to advise the Commission on NCS work, including this Inventory. In fall 2024, the OCAC received a Draft Engagement Strategy,[viii] presented by Against the Current Consulting. This strategy is guiding the approach that ODOE and the OCAC are taking to work with the Tribes. ODOE and the OCAC have been conducting outreach to gauge Tribal Nation interest and needed support throughout 2025 and will continue crafting an in-depth process to work together as we hear from Tribes.

Oregon Climate Action Commission Meetings

Finally, the OCAC discussed the Inventory and provided opportunities for public input at three of their meetings in 2025: July, November, and December.

PROJECT APPROACH

Generally, the development of Oregon's first Land-based Net Carbon Inventory occurred in four phases: preparation, development, quantification, and refinement (Figure 4). Preparing to develop a state-level inventory for the first time includes reviewing documents and identifying any regional and state datasets or research that would improve estimates of GHG emissions and removals. Based on the statute largely governing natural climate solutions,[ix] the Inventory must be consistent with methodologies used by the NGHGI to the extent possible. Since the NGHGI was developed to be consistent with IPCC guidelines, this is the basis for Oregon's Inventory as well. A Technical Manual is being developed for the state to support ongoing Inventory maintenance, including a compilation cycle and documentation of priority

[viii] Affiliated Tribes of Northwest Indians Resolution #24-15, "Supporting Tribal Engagement and Climate Action in Oregon: Endorsement of the Oregon Climate Action Commission's Tribal Engagement Strategy in Alignment with Oregon House Bill 3409 Priorities."

[ix] ORS 468A.183-.199 insert sentence here on direction for the inventory

improvements to put in action during future Inventory updates. Inventory methodologies, results, and supporting tables are in the Appendices of this report.

Figure 4: Four Phases of Developing the Inventory

Preparation →	Development →	Quantification →	Refinement
• Review statutory direction • Review major state reports and region-specific research • Interview data producers/stewards	• Determine Inventory period • Organize land classification to categories • Determine methodologies per land category • Assign Tier per category and sub-category	• Calculate land conversion estimates over Inventory period • Calculate emissions and removals per land category	• Quality assurance and quality control procedures • Cross sector checks

Three additional state-generated reports were reviewed to inform Inventory development. The Institute for Natural Resources at Oregon State University developed *The Foundational Elements to Advance the Oregon Global Warming Commission's Natural and Working Lands Proposal (2023)*, which provided recommendations for datasets and further considerations for Inventory development. The white paper *Incorporating Coastal Blue Carbon Data and Approaches in Oregon's First Generation Natural and Working Lands Proposal (2021)* was also reviewed and subsequent follow up occurred with the regional researchers and the Oregon Coastal Management Program within the Department of Land Conservation Development. Lastly, the *Oregon Forest Ecosystem Carbon Report (2019)*, produced by the Department of Forestry, was reviewed and multiple meetings occurred with ODF to align as much as possible with their ongoing forest ecosystem carbon accounting program.

Agencies, researchers, and data stewards offered regional and state datasets via engagement meetings, interviews, and emails, which were reviewed and evaluated for their applicability. Appendix D lists state-level data offered and reviewed.

After potential datasets were identified and evaluated, the methodology for the Inventory was developed and included:

1) Determining the Inventory period
2) Classifying land into principal land categories
3) Determining methodologies per sub-category
4) Assigning a methodological Tier

The Inventory period establishes the timespan over which results are reported. The inventory is compiled to develop annual estimates for all years between 1990-2024, using periodically available data sources and interpolation and extrapolation methods. For this report, data in tables are presented for a selection of years during that time span to communicate long and near-term trends and a manageable amount of information. Specifically, the years reported in tables are 1990, 2006, 2012, and each year during 2016-2024.

The Inventory begins with the year 1990, which aligns with the NGHGI. The following years were chosen to align with other available land cover data. The interval period the analysis uses for land cover analysis is five years, which was determined based on dataset publication rates as well as data interpretation considerations.

Multiple sources of data related to land use, ecological conditions, and other relevant characteristics were selected and joined spatially.

Methodological approaches (i.e., the steps, calculations, and data sources used to quantify emissions and removals) were developed for each land category and sub-category included in the inventory. Methodological Tiers for each sub-category included in the inventory were selected based on availability of calculation methods and data. Preliminary methodologies were shared with stakeholders for input and consultation. Next, emissions and removals across all land categories and sub-categories were quantified. A summary of the overall methodology employed for the Inventory is discussed in the next section with detailed information in Appendix E.

During quantification, spatial and tabular (non-spatial) datasets were integrated to generate relevant data for each analysis year, and equations consistent with IPCC guidelines were used to calculate annual carbon stock changes and non-CO_2 emissions. In cases where data gaps occurred (e.g., data not available for the entire time series), surrogate data and default IPCC parameters were used following the decision trees and good-practice principles outlined in the 2006 IPCC Guidelines.

Lastly, once the initial time series of estimates were produced, a refinement process took place. This process included internal quality assurance/quality control (QA/QC) checks, cross-comparisons with independent state and federal estimates, where available, and alignment checks to ensure consistency over time and across land categories. Feedback from technical experts and state agency stakeholders was incorporated, often leading to adjustments to certain parameters, reclassification of specific land areas, and the resolution of methodological inconsistencies identified during review. Recalculations were performed to maintain a coherent and methodologically consistent time series.

This iterative refinement step ensures that the final inventory reflects the best available data and methods and provides a transparent and traceable account of Oregon's net emissions and removals from 1990 through 2024.

METHODOLOGY SUMMARY

The Inventory follows internationally recognized standards for greenhouse gas (GHG) inventories established by the IPCC and followed by the U.S. EPA in the NGHGI. IPCC Guidelines contain the latest scientifically robust and internationally accepted methods for estimating national GHG inventories. In their entirety, the IPCC Guidelines outline the preeminent methods for estimating seven GHGs[x] across all sectors of the economy: energy (including transport), industrial sources, agriculture, land use, land use change and forestry (LULUCF), and waste.

[x] Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride (SF_6), and Nitrogen Trifluoride (NF_3)

These specific volumes of the IPCC guidelines are the basis for the Inventory methodology:

- 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry, and Other Land Use
- 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use

The methodology selected to prepare the Inventory is described in detail in Appendix E and is organized by land category.

The methodology is based on the IPCC LULUCF sector guidelines. Where possible, it applies definitions and methods that are consistent with the NGHGI to enable comparisons across states and use of national estimates to fill in gaps in the state-level inventory where needed. The specific volumes of the IPCC guidelines, which are the basis for the Inventory methodology are at left.

The following section summarizes the approaches used to:

- Consistently represent land in Oregon
- Estimate all relevant GHG emissions and removal for each land category
- Prioritize future inventory improvements using key category analysis

Consistent Land Representation

In a LULUCF GHG inventory, land area classification is the basis for estimating emissions and removals from land use remaining constant over time as well as land use change. The approach requires defining and characterizing all the land in Oregon consistently over time to ensure that emissions and removals associated with different land uses and land conversions are accurately estimated and to avoid double counting or omissions.

Land in Oregon is divided into six main land categories (see Table 1 and Appendix A). The National Land Cover Database (NLCD), published annually by the U.S. Geological Survey, is used to classify land in Oregon into these categories, which are aligned with IPCC land category definitions. NLCD provides wall-to-wall coverage of area over the inventory time series, starting in 1990 to present, and is used in the NGHGI to classify and track land over time. Other land cover datasets were considered, namely the LANDFIRE existing vegetation layer. LANDFIRE was not used due to a misalignment of vegetation classes with inventory methods, limited historical data, and irregular publication of new data.

According to the 2006 IPCC guidelines, anthropogenic GHG emissions and removals are those occurring on managed land.[xi] This is a simplification designed to overcome the challenge of distinguishing between natural and human-caused emissions from land. The simplification has been analyzed and deemed to enhance comparability while being reasonably accurate and tractable. [xii] Therefore, while the 2019 IPCC Refinement provides guidance for how to factor out "natural emissions and removals" occurring on land, whether defined as managed or not, the NGHGI continues to estimate all emissions and removals on managed land regardless of whether the driver was natural or anthropogenic. In addition, the NGHGI

[xi] Which is "land where human interventions and practices have been applied to perform production, ecological or social functions (IPCC 2006)."
[xii] (Ogle 2018). https://pubmed.ncbi.nlm.nih.gov/29845384/

uses a method to discern managed from unmanaged land, classifying only 5 percent of U.S. lands as unmanaged. For this Inventory, all land in Oregon is defined as being managed land and all emissions and removals from land in Oregon are included in the Inventory. Future inventories may explore using criteria to distinguish land into managed and unmanaged categories.

Spatially explicit NLCD land cover maps for the years 1990, 1996, 2001, 2006, 2011, 2016, 2021 were used to identify the extent of land in each category at each point in time by pixel (NLCD resolution is 30 x 30-meter pixels or about the size of four tennis courts). Over these intervals, the amount of land remaining in each land category and the amount of land that transitioned between categories was identified and interpolated to annual estimates of land area. This subcategorization of land to reflect land use dynamics enables the Inventory to consider the unique impact of land use change on carbon dynamics.

In general, when we think of land conversion, we may naturally think of a change from, for example, agricultural use to developed land use, which may be permanent or relatively permanent. In the Inventory, a different type of conversion is considered as well. For this latter type of conversion, temporal factors are applied to account for changes in the land's carbon dynamics. Likewise, soil organic carbon takes time to reach a new equilibrium after land use changes. As a result, land that transitions to a different land category is assumed to be in a transitional state for 20 years after conversion to address this temporal nature of carbon dynamics, consistent with the IPCC guidelines. The NLCD maps were analyzed to identify land in a transitional state; specifically, when a pixel of converted land was identified (e.g., a pixel identified as cropland in 1990 changed to grassland in 1996), it was moved into a land transition category and kept there for either (a) 20 years, at which point it was redefined as land in the post-transition category (e.g, "grassland remaining grassland"), or (b) if the pixel of land was identified to change to another category before the end of 20 years it was moved to a different transitional land category, (e.g., if the pixel that was cropland converted to grassland in 1996 becomes developed land before 2016, it is moved to the category of "grassland converted to developed land").

NLCD data layers were spatially joined with the following datasets:

- Oregon ecoregions (based on EPA Level 3 ecoregion designation)
- US Department of Agriculture Soil Survey Geographic Database (SSURGO) Map Units to stratify based on soil taxonomy
- US Forest Service Forest Inventory Analysis Forest Group Type Map
- National Oceanic and Atmospheric Administration Coastal Change Analysis Program
- PMEP Geographic Tidal extent boundary

Following the IPCC guidelines, emissions and removals for land transitions are accounted for in the post-transition land category. For example, when cropland converts to grassland, it is accounted for in the grassland category. Recall Inventory methods and results are organized within each land category by two groups: (a) land remaining in that category and (b) land converted to that category. The latter group is made up of the land areas that are within the 20-year transition period.

Land areas are fundamental inputs to estimating CO_2 emissions and removals and must be further stratified to match the scale of the other parameters used in the calculation methods. For example, when equations or variables in an equation are specific to an ecoregion or soil type, the area of land in each subcategory needs to be further divided into ecoregion or by soil type and calculations performed at that level. Therefore, NLCD data layers were spatially joined[xiii] with the datasets in the callout box above to enable the data to be disaggregated as needed for each specific land category analysis. Further information on the datasets and details on specific land area stratifications employed for each land category are provided in Appendix E.

Estimates of GHG Emissions and Removals

The Inventory covers emissions and removals of carbon dioxide (CO_2) due to carbon stock changes, as well as non-CO_2 emissions of methane (CH_4) and nitrous oxide (N_2O). While the goal of a GHG inventory is to account completely for all relevant emissions and removals for subcategories in each category of land, in practice, the ability to quantify emissions and removals is constrained by the availability of data and calculation methods. Following extensive review of available data and methods for Oregon, Tier levels that could be used for estimation were determined. Every applicable category is addressed in the Inventory, and a range of Tier levels is employed to provide a comprehensive assessment of emissions and removals for Oregon's land base. See *Inventory Tiers Section* for an explanation of the IPCC guidelines' 3-level methodology hierarchy.

The 12 different land categories, in addition to non-CO_2 emissions from wildfires and biomass burning that occur across multiple land categories and are estimated separately from the land categories, create 49 different sub-categories of emissions and removals by land and gas that are covered in the inventory, each with unique quantification approaches. See Appendix B for each category and Tier assignment.

The specific data and calculation methods used for each land category and gas are described in detail in Appendix E. Below is summary information about the methods, including the primary data sources used, and conceptual explanations of how emissions and removals are calculated.

Primary Data Sources

The NLCD, soil, and ecoregion data analysis described above, and several other data sources were used to estimate emissions and removals (Table 5). State and federal experts were also consulted on key assumptions. See Appendix D for the complete list of state-level data considered for use in the Inventory.

Table 5: Primary data sources or organizations that provided data used in addition to IPCC information and NLCD to estimate emissions and removals by land category

Category	Source(s)
Forest land	• Oregon Department of Forestry (ODF) FERNS database • USFS Forest Inventory and Analysis (FIA)
Grassland	• Rangeland Analysis Platform
Cropland	• USDA Census and Survey • USGS Fertilizer data* • USDA Crop Progress
Wetland	• Coastal Change Analysis Program • Pacific Marine and Estuarine Fish Habitat Partnership • The Nature Conservancy • Pacific Northwest Blue Carbon Working Group

[xiii] Spatially joined means to merge data from multiple different sources based on their geographic locations.

	• Scientific literature (see Appendix E)
Developed land	• USGS NLCD Tree Cover
Biomass burning	• ODF historic burn perimeters • US Department of Interior (US DOI), Monitoring Trends in Burn Severity (MTBS) database • NASA MODIS imaging • National Interagency Fire Center (NIFC) • ODF Smoke Management Program

*While fertilizer data is used as part of soil carbon estimates, please see Appendix C for descriptions of where fertilizer emissions are accounted for in state inventories.

Estimating CO_2 Emissions and Removals from Land

To estimate CO_2 emissions and removals, land area values are multiplied by parameters associated with characteristics of the land (generically referred to as "emission factors" or more specifically as "carbon densities") to estimate the amount of carbon stored in carbon pools. The calculation is performed separately by carbon pool (see Figure 2) and summed; the change in total carbon stored over time is calculated (also called carbon flux).

When carbon stocks are quantified in terms of the mass of carbon (C), the result is converted to CO_2 emissions or removals by applying the molecular weight ratio 44/12, which is the molecular weight of CO_2 (44 g/mol) divided by the molecular weight of carbon (12 g/mol). This ratio (44/12) accounts for the additional mass contributed by the oxygen atoms, ensuring that reported emissions reflect the total molecular mass of carbon dioxide rather than just the carbon content.

HOW TO READ CARBON FLUX VALUES

Carbon flux indicates either emissions or removals of CO_2, as follows:

Negative values = net **removals** (i.e., from atmosphere) or carbon sequestered.

Positive values = net **emissions** (i.e., to atmosphere) or greenhouse gases emitted.

Estimating non-CO_2 Emissions associated with the Land

The approach for estimating non-CO_2 emissions differs because the emissions are not derived from carbon pool dynamics. To calculate non-CO_2 emissions, for example, N_2O from biomass burning data, such as fuel load in tonnes of biomass, is multiplied by an appropriate emission factor describing tonnes of N_2O emissions per tonne of biomass burned — as indicated by the following equation[xiv]:

$$\textbf{Emissions} = \textbf{AD} \times \textbf{EF}$$

Emissions = Tonnes of emissions

AD = Activity data relating to the emissions source

EF = Emission factor for a specific gas and source category (Tonnes of emissions per unit of AD)

Calculations are conducted for each land category, emission or removal category, and gas. Consistent with the NGHGI, emissions are converted to units of carbon dioxide equivalent (CO2e) based on the 100-

[xiv] 2006 IPCC Guidelines, Vol. 4, Ch. 2, Equation 2.6

year global warming potential (GWP) of each gas as defined in the IPCC Fifth Assessment Report (AR5) published in 2014 and shown at right.

100-yr Global Warming Potentials from the IPCC Fifth Assessment Report (2014)

Methane (CH_4) = 28

Nitrous Oxide (N_2O) = 265

When nitrous oxide (N_2O) emissions are estimated and expressed in terms of nitrous oxide–nitrogen (N_2O–N), which represents only the nitrogen component of the N_2O molecule, the result is converted to the full N_2O molecule. To convert from N_2O–N to N_2O, a molecular weight ratio is applied: the molecular weight of N_2O (44 g/mol) divided by the molecular weight of the nitrogen atoms it contains (28 g/mol). This ratio (44/28) accounts for the additional mass contributed by the oxygen atoms, ensuring that reported emissions reflect the total molecular mass of nitrous oxide rather than just its nitrogen fraction (Equation: 1 N_2O = 44/28 x N_2O–N)

Key Category Analysis

The ability to accurately quantify emissions and removals will change over time because of changes in availability of data and advancement of science and calculation methods. Therefore, the IPCC developed an approach called key category analysis (KCA) to evaluate the contribution of different gases to overall emissions and removals to inform prioritizing inventory improvements. Key category analysis is conducted when the Inventory estimates are complete to identify categories that have the largest GHG contributions, the highest rate of change indicating a growing emission source, and other qualitative characteristics. Additional information on the KCA approach will be in a forthcoming Technical Manual.

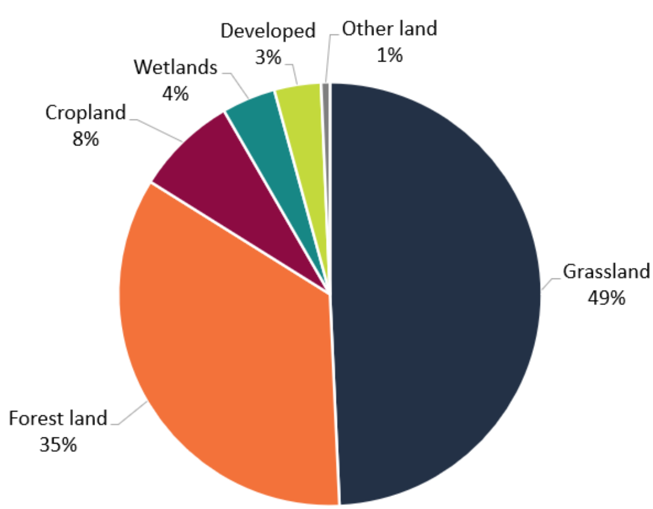
SUMMARY FINDINGS

Below, results from the first-generation Inventory are presented. For detailed results, see Appendix F.

Land Cover Change

The vast majority of Oregon is grassland and forests (49 percent and 35 percent respectively) (Figure 5). Cropland makes up 8 percent of the land base, wetlands 4 percent, and developed 3 percent. A small portion is considered other land/barren (1 percent).

Figure 5: Composition of Land Categories in Oregon in 2021



The composition of land in Oregon has been fairly consistent over the last 35 years. However, some changes have occurred, such as loss of wetlands and forest land and increase in developed areas. These trends and their impact on GHG emissions are discussed further below.

Carbon Stocks

The amount of carbon stored in carbon pools ("carbon stocks") varies by vegetation types, climate zones, and ecological conditions. For example, a relatively large amount of carbon is stored in above- and below-ground biomass in forests, particularly in Oak groups, Hemlock/Sitka Spruce, and Douglas Fir forests (Table 6), when compared to carbon stored in mineral soils abundant in cropland and grassland (Table 7). By far, the largest carbon stocks are in wetland soils, with the highest values seen in wetland scrub/shrub systems (Table 8).

These tables illustrate the relative amounts of carbon stored in various ecoregions, land categories, and carbon pools in Oregon by normalizing average carbon stocks per unit of area to enable comparisons. The Inventory is constructed using more specific values along with land areas and other information to estimate net carbon flux in land in Oregon. These data are provided to illustrate the relative amounts of carbon stored and indicate potential opportunities to protect and preserve carbon by maintaining and enhancing carbon stocks.

Table 6: Average carbon stocks in forest biomass (above and below ground) by forest type group as classified by the USFS Forest Inventory Analysis (tonnes C per acre)

Forest type group	tC/ac
Oak / hickory group	82
Hemlock / Sitka spruce group	77
Douglas-fir group	71
Tanoak / laurel group	57
Fir / spruce / mountain hemlock group	50
Alder / maple group	43
Western larch group	35
Elm / ash / cottonwood group	34
Other hardwoods group	25
Ponderosa pine group	25
Western oak group	24
Lodgepole pine group	18
Aspen / birch group	13
Western white pine group	7
Woodland hardwoods group	7
Other western softwoods group	6
Nonstocked	3
Pinyon / juniper group	2

Source: U.S. Forest Service FIA EVALIDator database

Table 7: Average carbon stocks in mineral soil at 30 cm depth (tonnes C per acre)

IPCC mineral soil categories	USDA taxonomic order	Ecoregion: Blue Mountains, Eastern Cascades Slopes and Foothills, Northern Basin and Range IPCC Climate zone: Cool Temperate, Dry	Ecoregion: Columbia Plateau IPCC Climate zone: Warm Temperate, Dry	Ecoregion: Coast Range, Klamath Mountains, West Cascades, Willamette Valley IPCC Climate zone: Warm Temperate, Moist
High-activity clay	Alfisols, Mollisols, Vertisols	17	15	21
Low-activity clay	Aridisols, Inceptisols, Ultisols	18	10	16
Sandy	Entisols	10	6	12
Volcanic	Andisols	50	50	50
Spodic Soils	Spodisols	35	35	43
Wetland	n/a	39	39	39

Source: USDA Methods of Entity-Scale Inventory 2024 for all but wetland; wetland derived from Uhran et al. 2022

Table 8: Average carbon stocks in wetland soils at 1 meter depth (tonnes C per acre)

Wetland Type	tC/ac
Estuarine Scrub-Shrub Wetland	215
Palustrine Scrub/Shrub Wetland	215
Estuarine Forested Wetland	155
Palustrine Forested Wetland	155
Woody Wetland-Tidal	155
Estuarine Emergent Wetland	116
Palustrine Emergent Wetland	116
Herbaceous Wetland-Tidal	116

Source: PNWBCC (Schile-Beers et al. 2025)

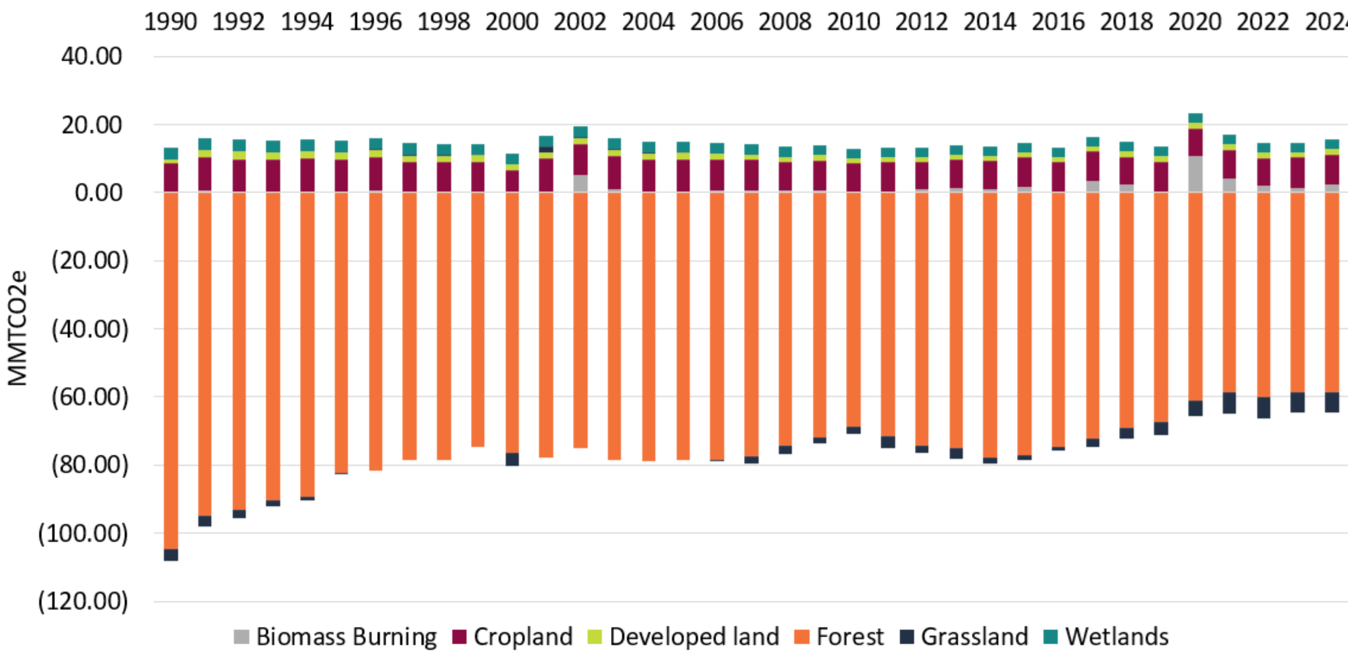
GHG Emissions and Removals from Land Use and Land Use Change

Note to Readers: Carbon removals are reported as a negative value and denoted in parentheses () or below the '0' on the y-axis of charts. Greenhouse gas emissions are reported as positive value and are illustrated above the '0' on the y-axis.

In Oregon, more CO_2 is removed from the atmosphere and stored in biological carbon pools than the amount of CO_2, CH_4, and N_2O emitted overall when accounting for land-based emissions and removals of GHGs. This is true year over year from 1990-2024 (Figure 6) with net removals decreasing over time from 94.82 $MMTCO_2e$ in 1990 to 48.71 $MMTCO_2e$ in 2024.

The net CO_2 removal is primarily due to CO_2 sequestered and stored in forest biomass and the amount of CO_2 remaining stored as carbon in durable harvested wood products produced from Oregon forests.

Figure 6: GHG Emissions and Removals in Oregon from 1990 - 2024 by Category (MMTCO2e)



Multiple sources and sinks cause GHG emissions and removals to occur in Oregon. Figure 7 shows the contribution of each GHG category to land sector emissions and removals in 2024. In 2024, drained organic soil was the largest source of GHG emissions. All land categories in Oregon contain organic soils called histosols. Histosol soils are characterized by having a high content of organic matter, which accumulates over time due to a variety of factors, including soil saturation. Drainage for the purposes of managing histosol soils leads to CO_2, CH_4, and N_2O emissions. Histosol soils occurring on cropland and developed land are assumed to be drained, resulting in GHG emissions.

Wetland soils both emit and remove GHGs. Emissions and removals in wetlands are influenced by geographical location, salinity, and other factors, with tidally connected wetlands generally having lower magnitude emissions and removals than inland wetlands.

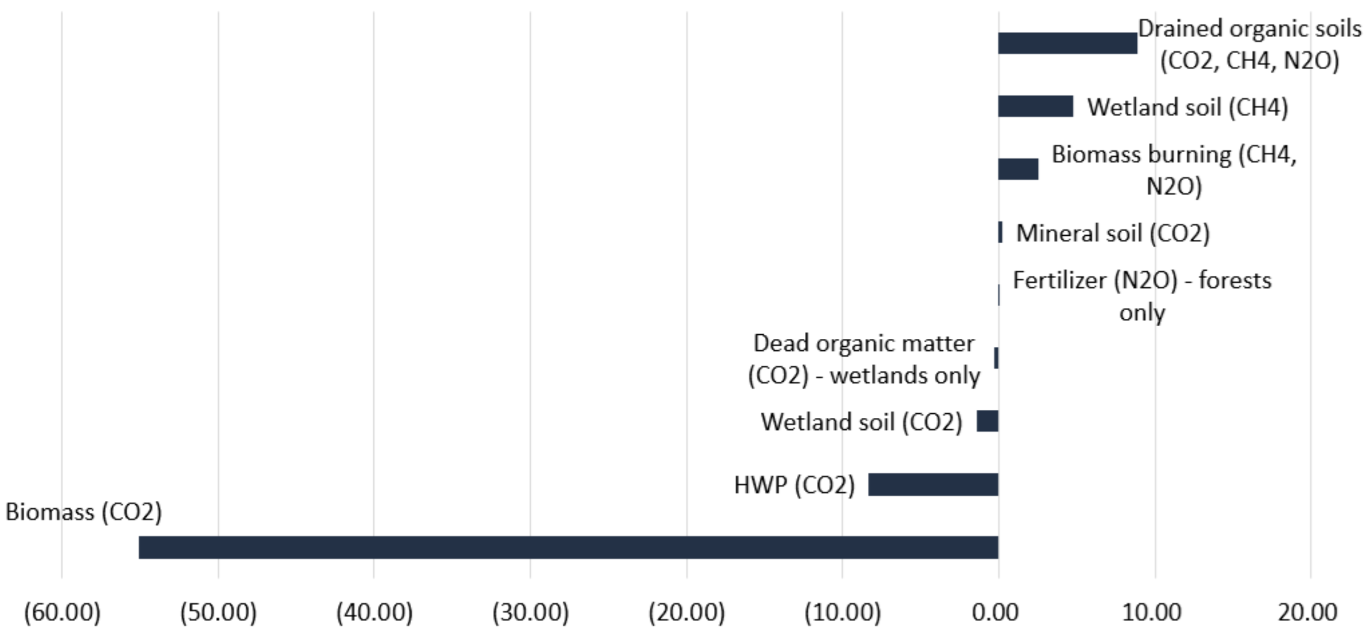
The biomass burning category includes wildfires and prescribed burning CH_4, and N_2O emissions from incomplete combustion. Carbon dioxide emissions from biomass loss due to burning are accounted for in the biomass CO_2 calculations. Biomass burning emissions combined were the third largest source of emissions in 2024 (Figure 7).

CO_2 emissions and removals in mineral soils are influenced by management and climate conditions. Over time, mineral soils have been both a net sink and a net source of CO_2 emissions; in 2024, mineral soils were a net source in Oregon (Figure 7). Mineral soils are common and consist of inorganic matter derived from rocks and minerals. Mineral soils contain organic matter, but much less so than organic soils. Management practices such as cover crops, tillage intensity, and grazing practices impact CO_2 emissions and removals from mineral soils on cropland and grassland. Mineral soils remain relatively stable on developed land and forest land. Therefore, most of the trend in CO_2 emissions and removals on mineral soils is from cropland and grassland.

Carbon dioxide is both emitted and sequestered in biomass from carbon dynamics occurring in forests, grasslands, croplands, wetlands, and developed land. Overall, there is more carbon stored than emitted in biomass across all land categories, making biomass CO_2 the largest category in magnitude and a large driver of net removals of CO_2 (Figure 7).

Not shown in Figure 7 are the low emissions of N_2O occurring in fish hatcheries.

Figure 7: Emissions and Removals by GHG Category in 2024 (MMTCO2e)



At the land category level, forest remaining forest land contributes the most to the overall trend of net removals in Oregon, followed by grassland remaining grassland (Table 9). Cropland remaining cropland contributes the most to land sector emissions, followed by wildfires and wetlands remaining wetlands. Developed land remaining developed land is a relatively small source of emissions (Table 9). Land conversion categories are relatively small compared to the land remaining categories. Within land categories there are various other emissions and removal categories that influence overall land category emissions as can be seen in Table 10 and 11, which provide all emissions and removals included in the inventory.

Table 9: Total GHG Emissions and Removals in Oregon by land category, wildfires, and prescribed burns (MMTCO2e)

Land Category	1990	2006	2016	2017	2018	2019	2020	2021	2022	2023	2024
Forest remaining forest	(104.50)	(78.14)	(74.31)	(71.78)	(68.75)	(66.92)	(60.50)	(58.08)	(59.73)	(58.22)	(58.21)
Land converted to Forest	0.00	(0.23)	(0.40)	(0.40)	(0.40)	(0.41)	(0.41)	(0.42)	(0.42)	(0.42)	(0.42)
Grassland remaining grassland	(3.60)	0.47	(0.58)	(1.96)	(2.75)	(3.69)	(4.53)	(6.15)	(5.75)	(5.70)	(5.55)
Land converted to Grassland	0.09	(0.59)	(0.34)	(0.37)	(0.32)	(0.28)	(0.23)	(0.20)	(0.23)	(0.25)	(0.23)
Cropland remaining cropland	7.67	8.14	7.16	7.24	6.43	6.78	6.18	6.63	6.26	6.85	6.60
Land converted to Cropland	0.77	1.00	1.45	1.43	1.83	1.85	1.87	1.80	1.65	2.08	2.08
Wetlands remaining wetlands - coastal	0.93	0.74	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.44
Land converted to Wetland - coastal	0.0007	0.0015	0.0014	0.0019	0.0024	0.0029	0.0033	0.0038	0.0038	0.0038	0.0038
Wetlands remaining wetlands - inland	2.51	2.39	2.31	2.32	2.33	2.33	2.34	2.34	2.34	2.34	2.34
Land converted to Wetland - inland	0.00	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Wetlands remaining wetlands – aqua-culture	0.0017	0.0015	0.0015	0.0014	0.0015	0.0014	0.0015	0.0014	0.0015	0.0015	0.0015

Developed land remaining developed land	0.99	0.56	0.57	0.61	0.64	0.68	0.71	0.75	0.75	0.75	0.75
Land converted to Developed land	0.00	1.25	0.93	0.93	0.92	0.92	0.91	0.91	0.91	0.91	0.91
Wildfires	0.17	0.51	0.23	3.28	2.08	0.32	10.74	4.04	1.99	1.20	2.39
Prescribed burns	0.14	0.14	0.15	0.13	0.16	0.15	0.11	0.14	0.11	0.14	0.13
Total	(94.82)	(63.73)	(62.34)	(58.10)	(57.36)	(57.79)	(42.31)	(47.75)	(51.62)	(49.83)	(48.71)

Land Category Highlights

Below are highlights for each land category. More details can be found in Appendix F.

Forest land

- Oregon's forests remained a net carbon sink in 2024, removing 58.62 MMTCO2e.
- In 2024, Douglas fir forests were responsible for the majority of carbon sequestered in forests remaining forests (86 percent), followed by Fir/Spruce/Mountain hemlock (10 percent) and Hemlock/Sitka spruce forests (2 percent).
- Oregon’s forest carbon removal has declined from 104.5 MMTCO2e in 1990 to 58.62 MMTCO2e in 2024 (44 percent decline) because of declining accumulation of carbon, with the largest percent decline occurring in the harvested wood products carbon pool (66 percent decline).

Grassland

- Emissions and removals in grasslands fluctuate over the time series. Starting in 2006, grasslands overall remove carbon from the atmosphere.
- In 2024, aboveground biomass in grassland remaining grassland, sequestered 3.9 MMTCO2e and removals from mineral soils were 1.6 MMTCO2e.
- Mineral soils in grasslands consistently remove carbon from the atmosphere over the time series, increasing the net removal by 32 percent between 1990 and 2024.
- Systematic information on management and targeted remote sensing imagery will enable future improvements to the inventory for grasslands.

Cropland

- In 2024, drained organic soils were the largest emissions source for cropland remaining cropland at 5.89 MMTCO2e.
- These emissions were partially countered by carbon sequestration in mineral soils on all cropland types and in biomass of orchards and vineyards (including ,for example, hazelnuts, Christmas trees, and pears), which together totaled 0.71 MMTCO2e.
- In 2024, the highest emissions from mineral soils in cropland occurred in row crops (such as alfalfa, barley, hay, oats, sugar beets, and wheat) in Linn County.
- Conversely, in 2024, the highest carbon sequestration in mineral soils in cropland occurred in Umatilla County where winter wheat is the dominant crop.
- Conversion of forest land to cropland, with the second largest number of acres converted, resulted in significant loss of biomass from the removal of trees. By far the largest number of acres converted to cropland comes from grassland; however, the impact on carbon sequestration from this type of conversion is relatively small compared to forest land conversion to grassland.

Wetland

- In tidal wetlands, total emissions have declined substantially since 1990, from 0.93 MMTCO2e to approximately 0.44 MMTCO2e in 2024 and have remained relatively stable over the past decade. This reduction corresponds with a marked decrease in Wetland to Open Water conversions, suggesting that large-scale historical habitat loss has slowed and that restoration and protection efforts may be stabilizing carbon dynamics along the coast.
- Among tidal wetland categories, Wetland to Open Water transitions continue to generate the largest carbon dioxide emissions, primarily due to the loss of biomass, dead organic matter, and soil carbon stocks.
- Non-tidal wetlands are the largest contributors to total wetland emissions in Oregon, with annual emissions around 2.3 MMTCO2e and little change since 1990. This stability reflects minimal variation in wetland extent (<1 percent) and relatively consistent carbon fluxes from vegetation and soils.
- N2O emissions from aquaculture are minimal, contributing less than 0.1 percent of total wetland emissions.

Developed land

- The amount of developed land increased in Oregon from 1.86M acres in 1990 to a total of 2.25M acres in 2021. This is the sum of Developed Land remaining Developed Land (1.95M acres) and land that was converted to Developed Land, 0.3M acres, from other land categories. Over the time series, forest lands, grassland, and croplands were converted to Developed Land in roughly equal amounts and were primary contributors to development of land. Conversion of forest land appears to have slowed down, while conversion of grasslands and cropland continues at a similar rate from 2000 onward.

- Urban trees in Oregon are estimated to have an annual net sequestration of 1.33 MMTCO2e in 1990, which increased to 1.74 MMTCO2e in 2024. Dominant factors affecting carbon flux trends for urban trees are the amount of developed land area and urban tree cover. The open space and low intensity developed lands contribute the most in terms of area as well as percentage tree cover.
- The conversion of forest land to developed land contributes the most to CO2 emissions with a total of 1.32 MMTCO2e emitted. Emissions gradually decrease, and starting in 2007, remain steady at approximately 0.7 MMTCO2e due to decreased areas of conversion.
- Drainage of organic soils is common when wetland areas have been developed. Emissions from drained organic soils in developed land remaining developed land were relatively steady at about 2.31 MMTCO2e from 1990 to 2006 and increased slightly to 2.49 MMTCO2e by 2024.
- Emissions from drained organic soils on land converted to developed land increased between 1990 and 2011, peaking at 0.46 MMTCO2e in 2011. Between 2011 and 2024, emissions decreased gradually to 0.36 MMTCO2e.

Biomass burning

- Wildfires and prescribed burning occurring in Oregon result in emissions of CO_2, CH_4 and N_2O. CO_2 emissions are accounted for as changes in biomass carbon stocks in the forest land and grassland categories.
- While the total area of wildfires and distribution of wildfires across land categories varies year to year, overall wildfires have increased significantly in area and corresponding emissions between 1990 and 2024. In 1990, burn area was approximately 85,000 acres resulting in emissions of 0.17 MMTCO2e while in 2024, the area burned was 1.3M acres resulting in emissions of 2.39 MMTCO2e.
- While large areas of grassland have burned, for example in years 2006, 2012, 2024, emissions are primarily driven by wildfires occurring on forest land due to the high amount of above ground biomass in forest ecosystems.
- Emissions from prescribed burns are relatively small compared to wildfires and remain steady at approximately 0.14 MMTCO2e over the time series, with pile and landing burns contributing the most due to high amounts of fuel. Other types of prescribed burns included in the analysis are broadcast, understory, right of way, and rangeland fuel management burns.

Summary Tables for All GHG Emissions and Removals in the Inventory

Table 10: GHG Emissions and Removals by Land Remaining Land Categories and Subcategories (MMTCO2e)

Land Category	1990	2006	2016	2017	2018	2019	2020	2021	2022	2023	2024
Forest remaining forest	**(104.50)**	**(78.14)**	**(74.31)**	**(71.78)**	**(68.75)**	**(66.92)**	**(60.50)**	**(58.08)**	**(59.73)**	**(58.22)**	**(58.21)**
Biomass (CO2)	(79.87)	(68.34)	(65.44)	(62.34)	(59.23)	(56.13)	(53.03)	(49.93)	(49.93)	(49.93)	(49.93)
Fertilizer (N2O)	0.03	0.03	0.05	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.04
HWP (CO2)	(24.67)	(9.84)	(8.92)	(9.49)	(9.55)	(10.82)	(7.48)	(8.17)	(9.82)	(8.31)	(8.31)

Grassland remaining grassland	**(3.60)**	**0.47**	**(0.58)**	**(1.96)**	**(2.75)**	**(3.69)**	**(4.53)**	**(6.15)**	**(5.75)**	**(5.70)**	**(5.55)**
Biomass (CO2)	(2.35)	0.89	0.72	(0.20)	(1.13)	(2.05)	(2.98)	(3.91)	(3.91)	(3.91)	(3.91)
Mineral soil (CO2)	(1.24)	(0.42)	(1.30)	(1.76)	(1.62)	(1.64)	(1.55)	(2.24)	(1.84)	(1.80)	(1.64)
Cropland remaining cropland	**7.67**	**8.14**	**7.16**	**7.24**	**6.43**	**6.78**	**6.18**	**6.63**	**6.26**	**6.85**	**6.60**
Biomass (CO2)	0.00	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Mineral soil (CO2)	1.28	1.99	1.18	1.27	0.47	0.84	0.26	0.72	0.37	0.97	0.74
Drained organic soils (CO2, CH4, N2O)	6.39	6.16	6.01	6.00	5.98	5.97	5.95	5.94	5.92	5.91	5.89
Wetlands remaining wetlands - coastal	**0.93**	**0.74**	**0.43**	**0.43**	**0.43**	**0.43**	**0.44**	**0.44**	**0.44**	**0.44**	**0.44**
Biomass (CO2)	0.02	0.00	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Dead organic matter (CO2) - wetlands only	0.00	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Wetland soil (CH4)	0.35	0.33	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Wetland soil (CO2)	0.56	0.40	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14
Wetlands remaining wetlands - inland	**2.51**	**2.39**	**2.31**	**2.32**	**2.33**	**2.33**	**2.34**	**2.34**	**2.34**	**2.34**	**2.34**
Biomass (CO2)	(0.10)	(0.10)	(0.14)	(0.13)	(0.13)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Dead organic matter (CO2) - wetlands only	(0.23)	(0.26)	(0.27)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Wetland soil (CH4)	4.26	4.19	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22
Wetland soil (CO2)	(1.42)	(1.44)	(1.49)	(1.49)	(1.49)	(1.49)	(1.49)	(1.49)	(1.49)	(1.49)	(1.49)
Wetlands remaining wetlands - aquaculture	**0.0017**	**0.0015**	**0.0015**	**0.0014**	**0.0015**	**0.0014**	**0.0015**	**0.0014**	**0.0015**	**0.0015**	**0.0015**
Developed land remaining developed land	**0.99**	**0.56**	**0.57**	**0.61**	**0.64**	**0.68**	**0.71**	**0.75**	**0.75**	**0.75**	**0.75**

Biomass (CO2)	(1.33)	(1.74)	(1.85)	(1.82)	(1.80)	(1.78)	(1.76)	(1.74)	(1.74)	(1.74)	(1.74)
Drained organic soils (CO2, CH4, N2O)	2.31	2.29	2.42	2.43	2.45	2.46	2.48	2.49	2.49	2.49	2.49
Wildfires	**0.17**	**0.51**	**0.23**	**3.28**	**2.08**	**0.32**	**10.74**	**4.04**	**1.99**	**1.20**	**2.39**
Prescribed burns	**0.14**	**0.14**	**0.15**	**0.13**	**0.16**	**0.15**	**0.11**	**0.14**	**0.11**	**0.14**	**0.13**
Total	**(95.69)**	**(65.19)**	**(64.01)**	**(59.73)**	**(59.42)**	**(59.91)**	**(44.50)**	**(49.89)**	**(53.59)**	**(52.21)**	**(51.11)**

Table 11: GHG Emissions and Removals by Land Converted to Land Categories and Subcategories (MMTCO2e)

Land Category	1990	2006	2016	2017	2018	2019	2020	2021	2022	2023	2024
Land converted to Forest	**0.00**	**(0.23)**	**(0.40)**	**(0.40)**	**(0.40)**	**(0.41)**	**(0.41)**	**(0.42)**	**(0.42)**	**(0.42)**	**(0.42)**
Biomass (CO2)	0.00	(0.24)	(0.43)	(0.43)	(0.44)	(0.44)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
Mineral soil (CO2)	0.00	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Land converted to Grassland	**0.09**	**(0.59)**	**(0.34)**	**(0.37)**	**(0.32)**	**(0.28)**	**(0.23)**	**(0.20)**	**(0.23)**	**(0.25)**	**(0.23)**
Biomass (CO2)	0.00	(0.87)	(0.39)	(0.34)	(0.28)	(0.23)	(0.17)	(0.12)	(0.12)	(0.12)	(0.12)
Mineral soil (CO2)	0.09	0.28	0.05	(0.03)	(0.04)	(0.05)	(0.06)	(0.08)	(0.11)	(0.13)	(0.11)
Land converted to Cropland	**0.77**	**1.00**	**1.45**	**1.43**	**1.83**	**1.85**	**1.87**	**1.80**	**1.65**	**2.08**	**2.08**
Biomass (CO2)	0.00	0.48	0.55	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Drained organic soils (CO2, CH4, N2O)	0.00	0.02	0.06	0.07	0.08	0.09	0.10	0.11	0.09	0.10	0.10
Mineral soil (CO2)	0.77	0.49	0.84	0.73	1.13	1.14	1.15	1.07	0.93	1.36	1.36
Land converted to Wetland - coastal	**0.001**	**0.002**	**0.001**	**0.002**	**0.002**	**0.003**	**0.003**	**0.004**	**0.004**	**0.004**	**0.004**
Biomass (CO2)	(0.004)	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Dead organic matter (CO2) - wetlands only	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wetland soil (CH4)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Wetland soil (CO2)	0.003	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005
Land converted to Wetland - inland	**0.002**	**0.026**	**0.034**	**0.037**	**0.039**	**0.042**	**0.044**	**0.047**	**0.047**	**0.047**	**0.047**
Biomass (CO2)	(0.038)	(0.073)	(0.060)	(0.065)	(0.069)	(0.074)	(0.078)	(0.082)	(0.082)	(0.082)	(0.082)
Dead organic matter (CO2) - wetlands only	(0.005)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Wetland soil (CH4)	0.069	0.171	0.162	0.174	0.186	0.197	0.209	0.221	0.221	0.221	0.221
Wetland soil (CO2)	(0.024)	(0.061)	(0.058)	(0.063)	(0.067)	(0.072)	(0.077)	(0.081)	(0.081)	(0.081)	(0.081)

Land converted to Developed land	**0.00**	**1.25**	**0.93**	**0.93**	**0.92**	**0.92**	**0.91**	**0.91**	**0.91**	**0.91**	**0.91**
Biomass (CO_2)	0.00	0.99	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Drained organic soils (CO_2, CH_4, N_2O)	0.00	0.38	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36	0.36
Mineral soil (CO_2)	0.00	(0.12)	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
Grand Total	**0.86**	**1.45**	**1.68**	**1.63**	**2.07**	**2.12**	**2.18**	**2.14**	**1.96**	**2.38**	**2.39**

ROADMAP FOR INVENTORY IMPROVEMENT

A GHG Inventory Improvement Plan (IIP) is essential for strengthening the accuracy, transparency, and credibility of the inventory over time. It provides a structured roadmap for identifying priority data gaps, methodological limitations, and capacity needs, and outlines the steps necessary to address them in a systematic and resource-efficient way. By documenting planned enhancements—such as refining emission factors, improving activity data, integrating new science, or strengthening Quality Assurance/Quality Control procedures—the plan ensures continuous alignment with foundational GHG accounting principles and evolving circumstances. Ultimately, an IIP helps build confidence in reported emissions and removals, supports more robust policy and mitigation planning, and demonstrates commitment to high-quality reporting.

The IIP is intended to be a living document that evolves over time as new data, methods, and state priorities emerge. It is regularly updated as part of the inventory cycle to reflect progress made, reassess outstanding needs, and incorporate newly identified improvements. This iterative approach ensures that the plan remains relevant, forward-looking, and aligned with the latest scientific guidance and inventory best practices. By revisiting and revising the plan routinely, the state can maintain a clear and adaptive roadmap for strengthening the inventory, supporting continuous improvement, and ensuring that reporting keeps pace with changes in policy, technology, and data availability. The detailed IIP for the current inventory cycle will be provided in the final Technical Manual provided to ODOE in January.

More than 30 state-level data sets were identified and reviewed for their applicability to inventory development. Seven state-level datasets in total — collectively provided by ODF, ODFW, and West Coast PMEP — related to wildfires and prescribed burns, fertilizer use in forests, timber harvests, and coastal wetland boundaries were used to prepare the Inventory. These datasets were key in providing locally relevant information to improve the accuracy of results for Oregon instead of relying on national averages and other global data. Further development of locally relevant data sets by, for example, committing to routine updates, including additional characteristics to help align data with calculation methods, and publishing data in a readily available and usable format, would enable their use in future inventories. Appendix D provides a summary of all the state-level data sets reviewed, including notes on the current limitations and needed improvements. Below, we discuss some general improvements for state datasets and highlight 17 areas for improvement.

1) **Land classification:** NLCD dataset is used for land classification as the only regularly updated, wall-to-wall land cover data available for Oregon. Because it captures land cover based on remote sensing imagery data rather than land use information reflective of management and function, it is likely misclassifying land in Oregon. Several specific instances should be addressed in particular: transitions between forest land and grasslands and wetland classification (e.g., when forest land is

harvested, it could be classified as grassland for a number of years until the forest canopy matures and is visibly detected by remote sensing).

2) **Forest land:** Further analysis to identify the best available forest mask GIS layer to use for this Inventory is an important future improvement. This information will ensure that forest remains in the forest land category and is not captured as “in transition” to grassland after harvest, which skews emissions and removals estimates.

3) **Forest land:** The Oregon Department of Forest uses FIA plots and statistical methods to estimate carbon emissions from the forest. Emissions/removals estimated in this inventory using NLCD and FIA plots differ due to the difference in the total area of the forest land in Oregon. State level forest maps developed every 5 years in-line with IPCC land classes will help improve accuracy of GHG emission from forest land category.

4) **Forest land:** Data on growth rates of different forest type groups for new forests are lacking, a study to collect this data will help build state level carbon parameters for land converted to forest from other land use types.

5) **Forest land:** Development of methodology to estimate standard errors and confidence intervals for emissions estimates will be useful to identify future improvements and compare estimates from this Inventory with others.

6) **Grassland:** There is currently no systematic data on management and grazing activities occurring in Oregon **rangelands.** Such data are needed for estimating soil C fluxes. In this Inventory, assumptions informed by expert judgement were utilized to model soil carbon. Developing a systematic data collection process for capturing utilization of grasslands will improve the accuracy of emission/removal estimates for rangelands.

7) **Grassland:** Distinguishing between natural and working grasslands is difficult to do using the NLCD and could reveal important information about carbon fluxes. The following are possible ways to better differentiate between grassland systems in the future: 1) identify and apply high resolution satellite imagery that can distinguish natural prairie from other grasslands and confer with local experts to ground verify classification of satellite imagery; and/or 2) use USDA census data for the amount of hay harvested per county as a proxy for managed grasslands.

8) **Grassland:** Related, additional research to inform calculation methods for natural grasslands, once they can be distinguished, would increase the accuracy of emissions/removal estimates.

9) **Grassland:** The carbon stored in the oaks within oak savannah habitat in Oregon is currently not calculated in the Inventory. Oak specialists could embark on research that measures carbon densities and growth rates of trees in oak savannah habitat.

10) **Cropland:** As research on the carbon dynamics for mineral soils under different cropping systems continues to be published, COMET-Farm, the model used to calculate emission and removals on cropland in the Inventory, will be updated to include those crops. When future Inventories are conducted, new crops can be added to the Modeled Crops section of the Inventory.

11) **Cropland:** Additional data collection on management practices to be used as input into the COMET-Farm tool, such as planting of cover crops, use of enhanced efficiency fertilizers, and use of reduced tillage, can improve the accuracy of COMET-Farm estimates.

12) **Wetlands:** Improving wetland emissions estimates in future inventories will require higher-resolution spatial data, refined biogeochemical inputs, and a more consistent mapping framework. Several forthcoming datasets—including the Wetland Intrinsic Potential tool, The Nature Conservancy's restored lands maps, and a statewide salinity map—will help clarify wetland extent, drained organic soils, restoration benefits, and methane dynamics, while also addressing current gaps such as inland wetland variability and omitted coastal habitats like eelgrass, mudflats, and kelp forests.

13) **Wetlands:** Longer-term improvements may involve transitioning to a Tier 3, spatially explicit modeling framework that captures hydrologic, geomorphic, and biogeochemical processes, reduces uncertainty, and enables more precise representation of Oregon's diverse wetland types; however, significant new monitoring and emissions data, particularly for inland wetlands, are needed to support such an approach.

14) **Wetlands:** Finally, because Oregon's wetland inventory currently relies on national land-cover products released on multi-year cycles, interim updates will require extending existing datasets or extrapolating recent trends, while long-term accuracy depends on building a state-led, spatially explicit mapping system that integrates regional tools, habitat classifications, and satellite imagery.

15) **Developed land:** Current estimates of carbon sequestration use NGHGI methodology, which utilizes state level parameters. Updating and/or disaggregating the parameters by other relevant attributes that better capture urban tree characteristics across Oregon would improve estimates.

16) **Developed land:** Building on the ODF's TreePlotter Inventory, the state could further develop its urban tree inventory to be used for analysis and development of necessary emission parameters.

17) **Developed land:** Refinement of activity data and emission factors for drained organic soils is also recommended to improve the accuracy of the estimates. Currently it is assumed that drained organic soils behave like drained organic soils on croplands.

ADDITIONAL CONSIDERATIONS

As improvements continue, the Inventory will increasingly become a cross-agency land-based GHG tool that is built on the programs, data, and staff time of all the land managing agencies and the academic and land-focused partners the state works with to monitor and steward Oregon's land. In this regard, roles, responsibilities, and arrangements between agencies are important, not only for Inventory improvement, but to understand what kind of resources each agency may need to manage or create critical datasets and track land management activities to a greater extent than has traditionally occurred. This section discusses the typical roles and responsibilities that will help maintain and improve the Inventory, how data may flow between agencies, and what kind of review process the state may want to consider for each Inventory update.

Institutional Arrangements

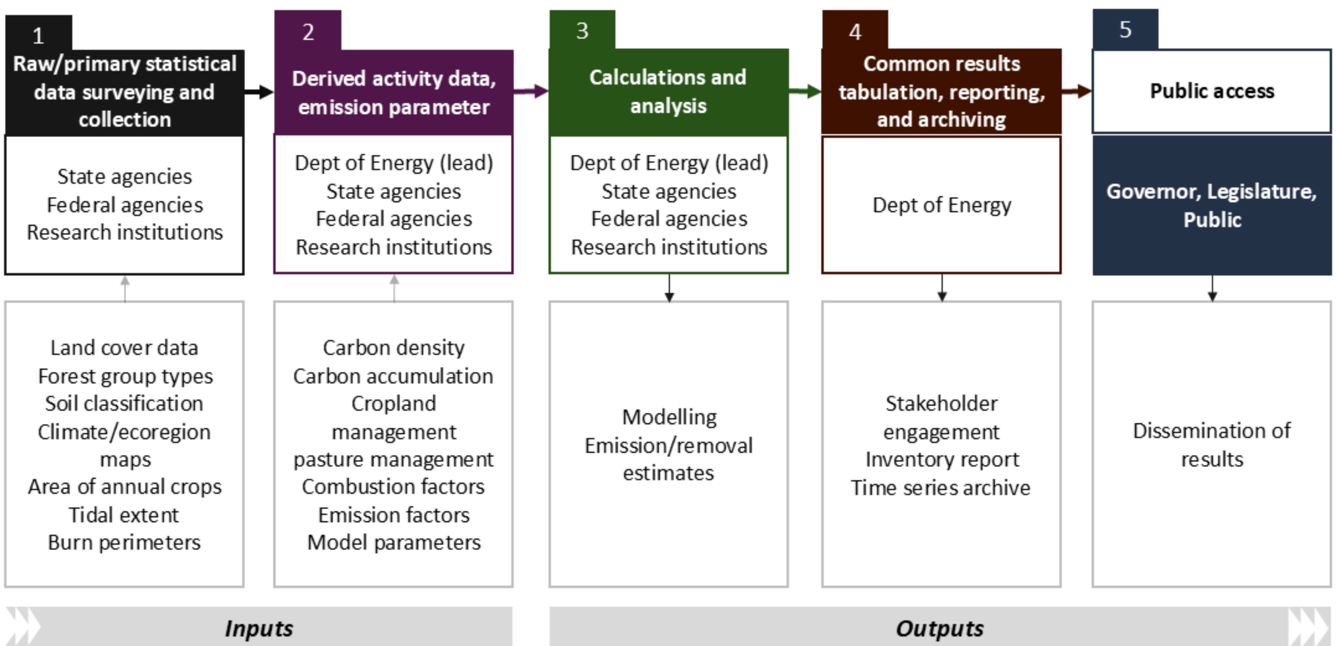
ODOE is responsible for maintaining and improving the Inventory and fills the roles of inventory coordinator, technical lead, archival coordinator, and QA/QC coordinator. However, there are also inventory supporting roles, which are critical to Inventory compilation and improvement. These include:

- Data Collection: Gathering, organizing, and documenting activity data and emission factors from relevant agencies and sources for use in the inventory.

- Model Development: Designing or adapting calculation tools and models to estimate emissions and removals consistently with IPCC methods.
- Research/Analysis: Investigating data gaps, evaluates methodologies, and performs calculations or scenario analyses to improve estimates.
- Technical Review: Independently checking data, methods, and results for accuracy, consistency, and adherence to guidelines before inclusion in the inventory.
- Expert Judgement: Providing informed assumptions or parameter values where data are lacking, drawing on subject-matter expertise and best available science.

Other roles may be identified in the future and added (e.g., staff who track capacity building efforts or staff who may use inventory information for mitigation tracking). As the inventory compilation process evolves, the roles and responsibilities may also change, with representatives from other agencies taking on various inventory support roles and/or technical category lead roles. Defining roles and responsibilities is essential because they dictate how data is collected, shared, and managed for inventory preparation. Current roles will be described in more detail in the Inventory Technical Manual to be submitted to ODOE in January 2026. The general flow of data to compile the Inventory is described in Figure 8.

Figure 8: General Flow of Data for Inventory Compilation



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WHAT WE HAVE LEARNED

Oregon's first Land-based Net Carbon Inventory provides a foundation for understanding how lands contribute to our overall in-state land-based emissions and carbon removals.

Landscapes naturally have both carbon emissions and sequestration processes, which are reflected in the Inventory. The Inventory is designed to help us track how the actions we take on the land affect land use and cover change and therefore, the natural cycling of carbon and other GHGs at the state-wide scale. Taken in aggregate, most land categories in Oregon are net emitters. Forests, the forest product pool, and grasslands are the only net sinks. However, it is important to keep in mind that a given area can be a net emitter one year and a net sink in future years. For example, there may be emissions from disturbances or management practices, but the land area still has the capacity to accumulate additional carbon over time. That is to say, even with ongoing emissions, the overall stocks of carbon in biomass and soil can increase if gains in carbon outweigh the losses.

The Inventory also helps identify what changes in land use and management mean in terms of GHG emissions and removals, and raises new landscape level questions about the causes of changes over the time-period, many of which will need further evaluation and perspective.

ODOE will continue to interpret the information with our partner agencies and run more analyses to illuminate patterns in the near future. The scope of this work included establishing the Inventory, while studying the drivers behind the numbers will come in future analyses that ODOE and our partner agencies undertake.

The agency offers the following information to help future interpretations.

Overall

Two important findings affect multiple land categories. First, land use in Oregon has stayed relatively consistent over the last 35 years, which is a testament to Oregon's land use system.[xv] Even so, Oregon has experienced change throughout the last three decades[xvi] in both land use and management practices, which the Inventory results reflect. Continued protection of Oregon's landmark land use laws will be an important carbon reduction strategy into the future.

Second, and not a surprise to most Oregonians, acres affected by wildfire across many land categories has increased significantly over the inventory period – this too has affected above ground carbon stocks and when fires are severe enough, soil carbon as well.[xvii][xviii] This is another important reason to continue, if not strengthen, efforts to take actions to reduce the scope and scale of catastrophic wildfire.

It is also important not to overlook landscape carbon stocks. Protecting natural carbon stocks is critical. If they are not protected, they become emissions. For example, old growth and mature forests in the Pacific Northwest have the largest carbon densities in the U.S. [xix] As a result, protecting carbon stocks in

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[xvii] Sydney Maya Katz, Daniel Gavin, Lucas C. R. Silva. Mapping Soil Organic Carbon in Wildfire-Affected Areas of the McKenzie River Basin, Oregon, USA. *ESS Open Archive* . June 16, 2023.

[xvii] Sydney Maya Katz, Daniel Gavin, Lucas C. R. Silva. Mapping Soil Organic Carbon in Wildfire-Affected Areas of the McKenzie River Basin, Oregon, USA. *ESS Open Archive* . June 16, 2023.

[xviii] McCool, K.D., S.M. Holub, S. Gao, B.A. Morrissette, J.E. Blunn, A.C. Gallo, and J.A. Hatten. Quantifying impacts of forest fire on soil carbon in young, intensively managed tree farm in the western Oregon Cascades. Soil Sci. Soc. Am. J. 2023;87:1458–1473. https://doi.org/10.1002/saj2.20582

[xix] https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-021-00179-2/tables/1

remaining mature and old growth forests and managing mature forests to become old growth forests are important management strategies on some lands. Similarly, while wetlands may naturally emit methane and are reported as a source of emissions in the results, the carbon stocks that wetlands contain are large, and degradation or destruction of wetlands results in significant emissions not easily recaptured.

Forest

The Inventory demonstrates the importance of Oregon's forests and harvested wood products to the overall contribution our natural and working lands can make to addressing climate change. Global research has established that forests are significant sinks and the same is true in Oregon.[xx] [xxi] As described above, forests in the Pacific Northwest, and in particular in the western portion of Oregon, Washington, and Northern California, have the highest carbon stores and fluxes in the nation. The Inventory highlights the need to protect existing stores and manage our working forests in ways that increase net sequestration, especially where that helps us achieve other state, environmental, and industry goals.

On lands managed to produce forest products, increasing net sequestration in forests ultimately results in more fiber per acre, important to Oregon's economy and communities. However, due to the long-term nature and complexity of changing harvest rotations in these forests while meeting multiple goals, increasing sequestration will require careful consideration and support.

The decline in the contribution of Oregon's forests over the inventory period raises significant concerns and questions. This result could reflect a combination of overestimation of carbon stocks in the early part of the Inventory period, a loss of forest acres, increases in wildfire scale and severity, other climate-related impacts to forest carbon, and changes in management of forests in Oregon. Given the significance of the change, evaluating the causes of this decline is a high priority. The Department of Forestry is nearly finished with a new assessment of forest carbon and ODOE will work closely with ODF to understand trends and future inventory improvements.

Grasslands

Grasslands in Oregon are generally a sink, with some variation year to year. Grasslands vary significantly depending on soils, topography, precipitation, and disturbance history. Grasslands, as classified by NLCD, includes three vegetation types: Grasslands/Herbaceous, Shrub-Steppe, and Shrub-Scrub types. NLCD does not do a good job of distinguishing different "grassland" types in Oregon – and some grasslands in Oregon are likely misclassified as Pasture/Hay, which is in the Cropland land category.

Perennial bunchgrass dominated grasslands store significantly more carbon than non-native annual grass dominated grasslands that establish after significant disturbances.[xxii] In this analysis, the difference in carbon stores in perennial and annual grass dominated grasslands could not be distinguished. In addition, data was not available for grazing intensity. Better mapping and research are critical for this land category, which covers such a large portion of Oregon, to approach the type of understanding we'd like at the landscape scale.

[xx] Griscom, et al., 2017. Natural Climate Solutions. PNAS https://www.pnas.org/doi/10.1073/pnas.1710465114
[xxi] Graves, et al., 2020 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0230424
[xxii] Maxwell, T.M., Quicke, H.E., Price, S.J. *et al.* Annual grass invasions and wildfire deplete ecosystem carbon storage by >50% to resistant base levels. *Commun Earth Environ* **5**, 669 (2024). https://doi.org/10.1038/s43247-024-01795-9

Wildfires in grassland and rangelands in Oregon are on the rise, similar to forests. While the carbon consequences of wildfires in grasslands are much smaller than in forests due to the lower stores of above-ground carbon, the ecological impacts of wildfires can be significant; when severe, wildfires can cause type conversions from perennial grasslands and shrub steppe types to annual grasslands, especially at lower elevations. Prescribed fires in grasslands, like prescribed fires in forests, are important to maintaining resilient and diverse grasslands.

Cropland

Cropland is currently a source of emissions, due largely to emissions from drained organic soils. This aligns with what we know about how Oregon was settled. Much land, not just lands currently used for agriculture, was drained to create productive soil conditions or land suitable for development. Of note, perennial crops are a small and growing sink due to increasing area of orchards and vineyards in Oregon. The accumulation of carbon as they grow is small, therefore they do not make a substantial contribution toward emissions from Oregon's croplands. There are several opportunities for deploying changes in crop practices, such as those the Natural Resource Conservation Service offers through technical assistance that promotes soil health. In addition, given the importance of drained organic soils to our cropland net emissions, returning unproductive cropland to wetland is also an area for consideration, especially as we consider the additional benefits of restoration like improving resilience to drought and habitat for beneficial insects.

Wetlands

Overall, the Wetlands category is reported as a source, although small relative to other land categories. However, as with the other categories, the story is more complex. In coastal wetlands, for example, restored and tidally connected tidal wetlands are a sink.[xxiii] Forested tidal wetlands, while small in overall acreage on the landscape, are on par with Oregon's mature forests in terms of sequestration and storage potential. Conversely, historic coastal wetlands, often behind dikes and disconnected from tidal flow, are a net source of emissions.

As sea level rises and saltwater intrusion creates less productive agricultural land, there is an opportunity to reconnect tidelands, bolstering salmon populations and marine nature-based industries and adapting communities to rising seas, while increasing natural carbon sequestration and storage.

Non-tidal or inland freshwater wetlands are a larger source. We note that the science around the carbon dynamics of inland wetlands is somewhat nascent. New research[xxiv] is occurring in the Pacific Northwest that will hopefully help us better understand the dynamics in this land type.

Of note, we know that net emissions are driven by methane emissions, which is a more potent GHG than CO2. However, wetlands still sequester and store carbon, even while emitting methane. They sequester and store large quantities of soil carbon in a relatively small spatial extent on the landscape compared to other land cover types. Their protection, even with natural methane emissions, is critical to avoid losing carbon stocks.

[xxiii] Janousek, C. N., Krause, J. R., Drexler, J.Z., Buffington, K. J., Poppe, K. L., Peck,E., et al. (2025). Blue carbon stocks along the Pacific coast of North America are mainly driven by local rather than regional factors. Global Biogeochemical Cycles,39, e2024GB008239. https://doi.org/10.1029/2024GB008239

[xxiv] Halabisky, M., Miller, D., Stewart, A. J., Yahnke, A., Lorigan, D., Brasel, T., and Moskal, L. M.: The Wetland Intrinsic Potential tool: mapping wetland intrinsic potential through machine learning of multi-scale remote sensing proxies of wetland indicators, Hydrol. Earth Syst. Sci., 27, 3687–3699, https://doi.org/10.5194/hess-27-3687-2023, 2023.

Lastly, drained wetlands typically have soil emissions three to five times higher in CO_2e because of higher CO_2 and N_2O emissions. Restoring wetlands continues to be to the benefit of Oregon, not just for carbon removal and storage services, but for water quality, drought resilience, flood hazard mitigation, and more.

Developed Land

Developed land is a net source as well, with urban trees acting as a sink and urban drained organic soils, or historic wetlands in these areas, a source of emissions.

Restoring historic wetlands and avoiding further degradation to current wetlands in developed and developing areas is important. As we look to floodplain and wetland restoration as natural ways to protect communities from increasing flood risks, we will gain both nature-based adaptation and mitigation benefits.

Similarly, urban tree canopy offers both nature-based adaptation and mitigation benefits. Increasing tree canopy in urban areas has a host of other societal benefits. In addition, tree canopy reduces energy demand for heating and cooling. As such, this is promising area for meeting nature-based resilience, equity, adaptation, and mitigation goals.

CONCLUSION

Oregon's first Land-based Net Carbon Inventory has provided a first look at emissions and removals on the landscape. The OCAC will consider this information to establish carbon sequestration and storage goals in 2026. In addition, the Inventory has generated a new set of landscape scale questions to answer. Both outcomes provide valuable information and will support land managing agencies, decision makers, private landowners and others when considering actions, new investments, and policy recommendations.

ODOE, the OCAC, and the Interagency Working Group agencies are embarking on work to identify natural climate solutions and select metrics that will help track specific actions that, if implemented at a significant scale, will be reflected in future inventories.

We also recognize that, as stewards of all lands and waters since time immemorial, Tribes are invaluable partners in protecting and advocating for natural climate solutions to safeguard waterways, first foods, medicines, and combat climate change, which disproportionately affects Tribal communities. As we continue to coordinate with Tribes, we hope to build relationships that produce an outcome that is helpful for everyone, and would like to learn how to integrate Indigenous Knowledge with carbon accounting efforts.

The Inventory tracks just one metric of land cover and land use over time; the resilience benefits of natural climate solutions are plentiful. Many land management actions that reduce land-based emissions or actively sequester carbon simultaneously provide communities adaptation benefits like temperature refuge, lower flood risk, cooler water, increased biodiversity, healthy soil, and mental wellbeing. The nature-based actions we take to mitigate climate change also help us adapt. We must do both – quickly.

APPENDICES

Follow the links to access the appendices:

Appendix A – Land Category Definitions for the Land-based Net Carbon Inventory with Oregon-specific Ecosystem or Working Lands Information

Appendix B – Land-based Net Carbon Inventory Categories and Methodological Tiers

Appendix C – Table Comparing Emissions Sources in the Sector-Based Greenhouse Gas Emissions Inventory and the Land-based Net Carbon Inventory

Appendix D – State-specific Datasets Reviewed for Inventory

Appendix E – Detailed Inventory Methods

Appendix F – Detailed Results

FOR MORE INFORMATION

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