Final Report

Foundational Elements to Advance the Oregon Global Warming Commission's Natural and Working Lands Proposal

26 September 2023

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A report submitted to the Oregon Global Warming Commission by the
Institute for Natural Resources at Oregon State University

26 September 2023

The Institute for Natural Resources (INR)

The Institute for Natural Resources (ORS 352.808) works to deliver management-relevant information that informs discussions and decisions about the long-term stewardship of Oregon's natural resources, and works to advance centralized, science-based natural resource information for Oregon and the Pacific Northwest. INR is an Oregon public universities institute located at Oregon State University and Portland State University.

INSTITUTE FOR
NATURAL RESOURCES

OREGON STATE UNIVERSITY (headquarters)
234 Strand Hall
Corvallis, Oregon 97331
http://inr.oregonstate.edu

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For more information about this report, please contact the Institute for Natural Resources, lisa.gaines@oregonstate.edu or jimmy.kagan@oregonstate.edu.

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Abbreviations and Acronyms

AR4—IPCC's Fourth Assessment Report
CARB—California Air Resources Board
CE—Carbon equivalent
CH_4—Methane
CO_2—Carbon dioxide
CO_2e—Carbon dioxide equivalent
CRP—Conservation Reserve Program
CSAF—Climate-smart agriculture and forestry
CSU—Colorado State University
DLCD—Department of Land and Conservation Development
GHG—Greenhouse gases
GWP—Global Warming Potential
HCFC—Hydrochlorofluorocarbon
HFC—Hydrofluorocarbon
INR—Institute for Natural Resources
IPCC—Intergovernmental Panel on Climate Change
MMT—Million Metric Tons
MRV—Measurement, Reporting, and Verification
NASA—National Atmospheric and Space Administration
N_2O—Nitrous oxide
NRCS—Natural Resources Conservation Service
NWL—Natural and Working Lands
O_3—Ozone
OAHP—Oregon Agricultural Heritage Program
OGWC—Oregon Global Warming Commission
OSU—Oregon State University
OWEB—Oregon Watershed Enhancement Board
Pg—Petagram
PFC—Perfluorocarbon
RFI—Request for Information
SARE—Sustainable Agriculture Research and Education
SER—Society for Ecological Restoration
SF_6—Sulfur hexafluoride
Tg—Teragram
TNC—The Nature Conservancy
TOG—Total Organic Gases
UGB—Urban Growth Boundary
UNFCC—United Nations Framework Convention on Climate Change
USCA—U.S. Climate Alliance
USEPA—United States Environmental Protection Agency
WRI—World Resources Institute

Executive Summary

The U.S. Climate Alliance (USCA) and Natural Resources Conservation Service (NRCS) contracted with the Institute for Natural Resources (INR) at Oregon State University to provide a suite of products in support of the Oregon Global Warming Commission (Commission) 2021 Natural and Working Lands Proposal. The OGWC Proposal set a goal for sequestering at least an additional 5 MMTCO$_2$e annually in Oregon's natural and working land (NWL) sectors by 2030, and at least 9.5 MMTCO$_2$e annually by 2050 relative to 2010 and 2019 baselines. These goals are in addition to Oregon's sector-based emission reduction goals established by the Oregon Legislature and updated in Oregon Governor Kate Brown's Executive Order 20-04.

INR was asked to establish and facilitate an NWL Advisory Committee, develop a methodology to inventory net carbon capture in Oregon's natural and working lands, develop climate-smart management practices and help establish activity-based baselines for them, define the scope of work for a workforce and training needs analysis, identify community impact metrics, and produce a final report.

Advisory committee. A total of 26 individuals representing Oregon's geography and a diversity of Oregon's land sectors were selected to participate on the Advisory Committee. The group participated in a total of 11 meetings held monthly from October 2022 through August 2023. The committee was tasked with providing current knowledge, critical thinking, analysis, and perspectives to inform implementation of the OGWC Proposal by participating in meetings, reviewing and commenting on draft products, and working collaboratively to understand issues and perspectives that represent the diversity of interests in Oregon. Advisory Committee members played an instrumental role in adding significant value to the products produced in this report.

Methodology to inventory net carbon capture. The inventory is intended to establish a spatially explicit baseline for carbon stocks, emissions, and sequestration on natural and working lands; allow the state to track changes in carbon stocks and emissions through time; and track the impact of management interventions and disturbances on emissions through time (e.g., attribute changes in emissions to various causes). A list of terms and definitions was developed using the California GHG inventory glossary as an initial reference. Following the terms and definitions, two methodologies were developed to create a science-based, comparable, transparent, and consistent process for reporting GHG sources and sinks within Oregon's NWL. Two methodologies are proposed—a basic methodology that relies on available data, but integrates the data in a detailed fashion, and a more sophisticated version that requires new and detailed mapping. The basic methodology accounts for emissions within the land use categories of blue carbon, rangelands, forests and woodlands, cultivated farmlands, and urban and suburban areas. The more complex methodology would create aboveground carbon stock inventory and fluxes in a two-step process that includes combining predictor data and training data to produce a map of vegetation and carbon stocks, and correlating carbon stock values with likely land uses and predicted climate gas fluxes to generate estimates of CO_2 equivalent value. It would be costlier to implement the more complex inventory because of the time and effort to compile and assess/validate the data, aggregate and collect the predictor data, and use the predictor and training data to create a model.

Climate-smart management practices. Oregon defined seven NWL sectors. Five technical teams, one for each of five of Oregon's project defined NWL sectors (blue carbon, rangelands, forestlands, agricultural lands, and urban and suburban lands) were formed to develop practices and metrics that could contribute to reductions of GHG emissions and enhance carbon sequestration and storage. The additional two sectors—freshwater areas (wetlands, streams, and freshwater bodies) and non-vegetated areas (barrens, glaciers, lava flows, and pavement outside of urban areas)—were not addressed in this project because of capacity issues and insufficient need, respectively. The draft practices and metrics were reviewed by the Advisory Committee and 31 scientists, experts, and other professionals, and summaries of their reviews were shared with the leaders of the technical teams. The technical teams then produced a final document of recommended, not recommended, and emerging practices. Advisory Committee members interested in further discussion on agricultural practices formed a subcommittee and developed a suite of recommended practices they deemed climate-smart and well-supported by NRCS. Upon a final review by INR, 31 practices[1] (Table 1) are recommended based on their demonstrated ability to reduce GHG emissions and sequester and store carbon.

Both the Advisory Committee and technical teams recommended the Commission consider other factors when evaluating practices and metrics, namely soil health, co-benefits, tradeoffs, the viability of Oregon's farmers and ranchers, climate change stressors, statewide impacts of policy implementation, durability, risk of reversals, leakage, and indirect GHG emissions. The recommended practices are intentionally not prioritized, either within land sectors, or across land sectors, recognizing that a robust suite of carbon sequestration and storage practices, accompanied with GHG emission practices, will best allow Oregon to achieve OGWC Proposal goals. However, further analysis is required to determine which strategies have the greatest potential to achieve those goals based on their ability to sequester and store carbon and reduce GHG emissions, required investments, community impacts, co-benefits, and tradeoffs.

Several practices were recognized as having "crossover" characteristics, i.e., practices and concepts shared across two or more NWL sectors. For example, enhancing soil health, protecting natural and working lands from conversion, and restoring riparian habitats are important concepts that span each of the five land sectors. Table Ex-1 lists the practices recommended by the technical teams and the additional agricultural practices recommended by the project Advisory Committee (indicated by asterisks).

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[1] Any proposed practices that were policy or consumer choice-related were not considered a practice implemented by land managers associated with that specific sector, regardless of the origin of those recommended practices, were not included in the list of recommendations. Note: Practices with asterisks were practices recommended by the Advisory Committee.

Table Ex-1. Recommended practices to reduce GHG emissions and sequester carbon in five of Oregon's natural and working lands sectors.

NWL Land Sector	Recommended Practices
Blue Carbon Ecosystems	Tidal wetland conservation
	Tidal wetland restoration
	Seagrass conservation
Rangelands	Prevent conversion to invasive annual plant dominated systems
	Restore deep rooted perennial grasses to areas impacted by invasive species
	Restore functioning riparian areas
	Prevent conversion of grasslands, shrublands, and savannas to juniper woodlands
	Prevent conversion to urban and/or row crop land use
Forestlands	Prevent conversion of forest to non-forest land uses
	Afforestation/Reforestation
	Improved forest management
	Increase the proportion of carbon stored within long-lived harvested wood products
	Reduce wildfire risks
Agricultural Lands	Anaerobic digestion of manure and beneficial use of methane or flaring and appropriate land application of digestate
	Improve irrigation strategies and efficiencies
	Improve nitrogen management
	Reduce enteric emissions from ruminant production systems via approved enzyme feed additives
	Reduce food loss and waste
	Support on-farm renewable energy and energy efficiency
	Protect agricultural lands from urban or industrialized conversion*
	Increase woody plant coverage*
	Encourage no-till and residue till management*
	Implement edge-of-field herbaceous (non-woody) conservation practices*
	Utilize cover crops and crop rotations*
	Improve nutrient management and reduce nitrogen application*
	Prescribed grazing*
	Pasture-based management*
	Alternative manure management*
Urban & Suburban Lands	Maintain and expand forest vegetation cover
	Improve fertilizer use in urban and suburban lands to reduce excess nitrogen releases

*Agricultural practices proposed by the Advisory Committee.

The initial project proposal required INR to develop activity-based baselines for each of the recommended practices. Because 2023 Oregon legislation that goes into effect in January 2024 also requires specific state agencies to develop identify data and create these baselines, they were not developed. It was determined that the best approach was for INR to provide staff support to the individual agency staff when they are ready to begin work on refining the individual practices or identifying the base data to needed to create the baselines.

Scope of work for workforce and training needs analysis. Increasing the pace and scale of workforce development and training as well as technical assistance across numerous Oregon NWL sectors is identified as a key need in the OGWC Proposal. New and expanded land sector workforce programs are needed that create pathways that ensure family-wage employment for all people living and working in communities with current and potential land sector employment. A Request for Information (RFI) was developed to seek qualified entities to provide methodology and estimated costs to conduct a Workforce Development and Training Needs Assessment and Gap Analysis of NWL Sectors in Oregon to evaluate current technical assistance capacity and projected future technical assistance capacity needs associated with implementing the strategies outlined in the OGWC Proposal for achieving NWL sequestration and storage outcomes. The objectives of the assessment and gap analysis were to conduct a comprehensive assessment and gap analysis that defines workforce needs associated with achieving OGWC Proposal NWL goals, including conducting an inventory of existing resources, analyzing gaps, and developing an implementation plan for action, with metrics to assess implementation success.

Community impact metrics. The Commission's NWL Proposal recommended that Oregon establish community impact metrics to inform and evaluate the co-benefits and impacts of NWL strategies, emphasizing the metrics should include effects on jobs, local economies, public health, and access to programs. INR staff conducted a literature review, defining the core elements and criteria to consider when developing a community impact metrics framework, numerous tradeoffs that can be considered (e.g., ecological, environmental, economic, societal, and political) as well as specific examples of metrics and indicators. The Advisory Committee reviewed the literature review and proposed a suite of metrics for NWL that would likely be foundational to all Oregon communities. These included ecological, public health, community support and connection, access to programs, social justice and equity, and socioeconomic indicators.

1. Introduction and Project Background

In August 2021, the Oregon Global Warming Commission (Commission or OGWC), adopted the Natural and Working Lands Proposal (OGWC Proposal). The OGWC Proposal set a net goal for sequestration and storage in natural and working lands[2] (NWL)—sequester an additional 5 $MMTCO_2e$ annually by 2030 and at least 9.5 $MMTCO_2e$ annually by 2050 relative to 2010 and 2019 baselines. The OGWC Proposal included recommendations for methods to track progress as well as identified key strategies and programs needed to achieve the goal. This goal is separate from, and in addition to, Oregon's sector-based emissions reductions goals described in the Oregon Governor's Executive Order 20-04 signed in 2020.

1.1 Project Goals and Objectives

To help set the foundation for implementation of the, the Institute for Natural Resources (INR) at Oregon State University (OSU) applied for and secured funding on behalf of the Commission from the U.S. Climate Alliance[3] and the Oregon Natural Resources Conservation Service[4] to (Appendix A):

- **Create and facilitate** meetings of an NWL Advisory Committee;
- **Develop a methodology for establishing an inventory of net sequestration** based on the best available field-based and remote sensing data on carbon sequestration, using methods consistent with methods used to assess greenhouse gas (GHG) fluxes, and

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[2] Natural and Working Lands is defined as:
(a) Lands:
(A) Actively used by an agricultural owner or operator for an agricultural operation, including but not limited to active engagement in farming or ranching;
(B) Producing forest products;
(C) Consisting of forests, woodlands, grasslands, sagebrush steppes, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas or the submerged and submersible lands within Oregon's territorial sea and marine habitats associated with those lands;
(D) Used for recreational purposes, including, but not limited to, parks, trails, greenbelts and other similar open space lands; or
(E) Consisting of trees, other vegetation and soils in urban and near-urban areas, including, but not limited to, urban watersheds, street trees, park trees, residential trees and riparian habitats; and
(b) Lands and waters described in paragraph (a) of this subsection that are:
(A) Held in trust by the United States for the benefit of any of the nine federally recognized Indian tribes in this state;
(B) Held in trust by the United States for the benefit of individual members of any of the nine federally recognized Indian tribes in this state;
(C) Within the boundaries of the reservation of any of the nine federally recognized Indian tribes in this state; or
(D) Otherwise owned or controlled by any of the nine federally recognized Indian tribes in this state.

[3] https://usclimatealliance.org/

[4] https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/oregon

informed by inventory work in other states as well as the World Resources Institute (WRI) 2020 guide for state NWL;

- **Develop activity-based metrics** (aka climate-smart management practices) and establish an activity-based baseline to help Oregon evaluate progress toward proposed outcome-based goals for increased net sequestration storage as well as help communities, technical assistance providers, and land managers anticipate opportunities to adopt new practices;
- **Define the scope of work for a workforce and training needs analysis** to evaluate current technical assistance capacity, projected future technical assistance capacity needs, and predict the jobs and economic benefits associated with implementing the strategies outlined in the OGWC Proposal;
- **Identify community impact metrics** designed to evaluate the benefits and burdens associated with different strategies, practices, and programs, including effects on jobs, local economies, public health, and access to programs; and,
- **Draft a final report** detailing the process and products from the project.

1.2 Process and Approach

1.2.1 Process

INR established a process for the project that included the creation of a Project Management Team that consisted of the INR Director, an INR Technical Team, and a facilitator (Figure 1). The INR Technical Team, led by the project Principal Investigator, created a suite of ad hoc, land-sector based technical work groups whose role was to gather, compile, and share scientific and technical expertise to inform several of the project deliverables. An Agency Advisory and Coordinating Committee comprised primarily of state agency representatives was formed in early summer 2023 to discuss the project's products that might inform future programmatic approaches to achieve the OGWC Proposal goal. An Advisory Committee, comprised of individuals with experience, expertise, and interests in Oregon's NWL sectors, climate science, technical assistance, and other areas was formed to provide current knowledge, critical thinking, and perspectives to inform implementation of the OGWC Proposal and project deliverables. The intersection of these teams and entities is illustrated in Figure 1.

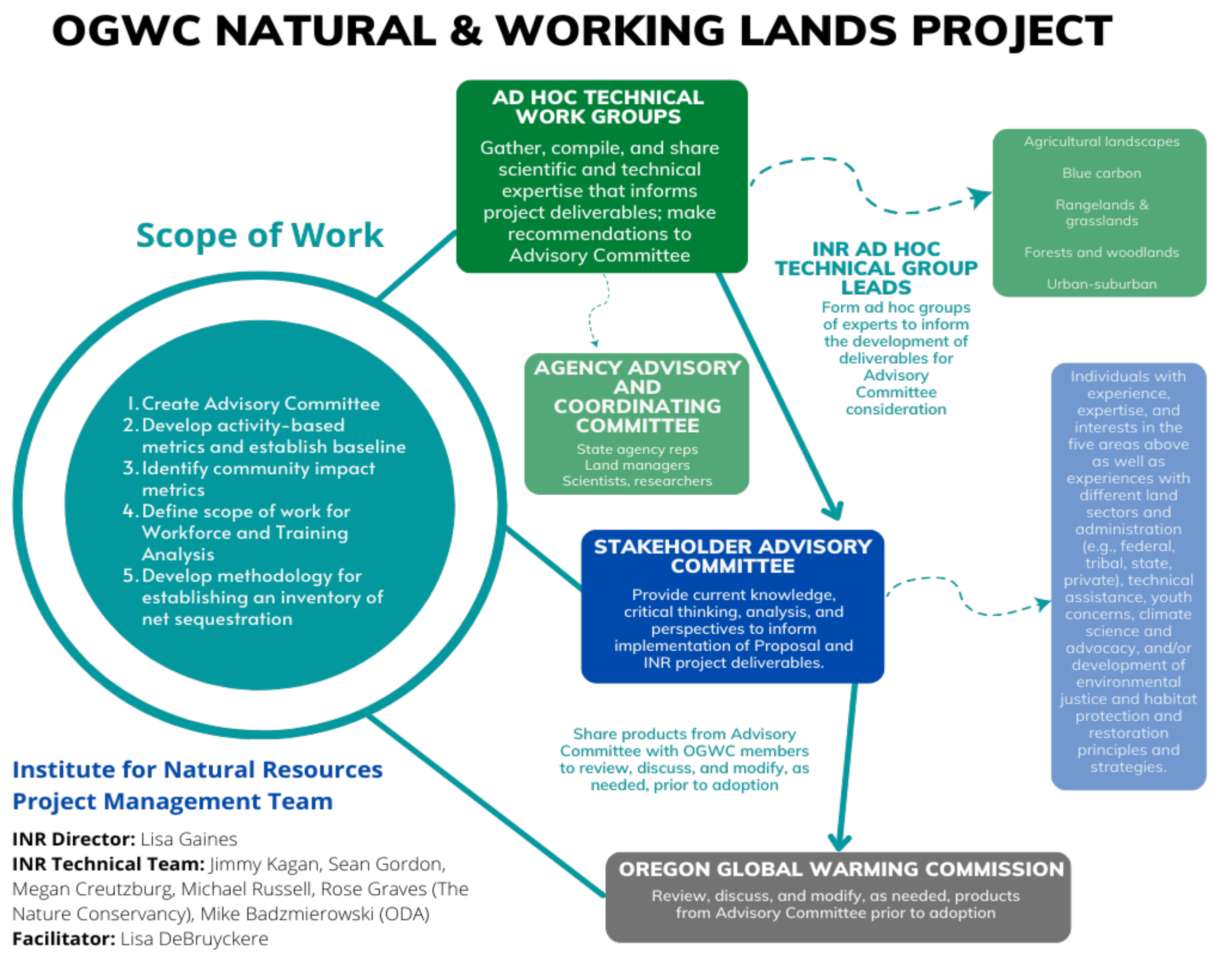
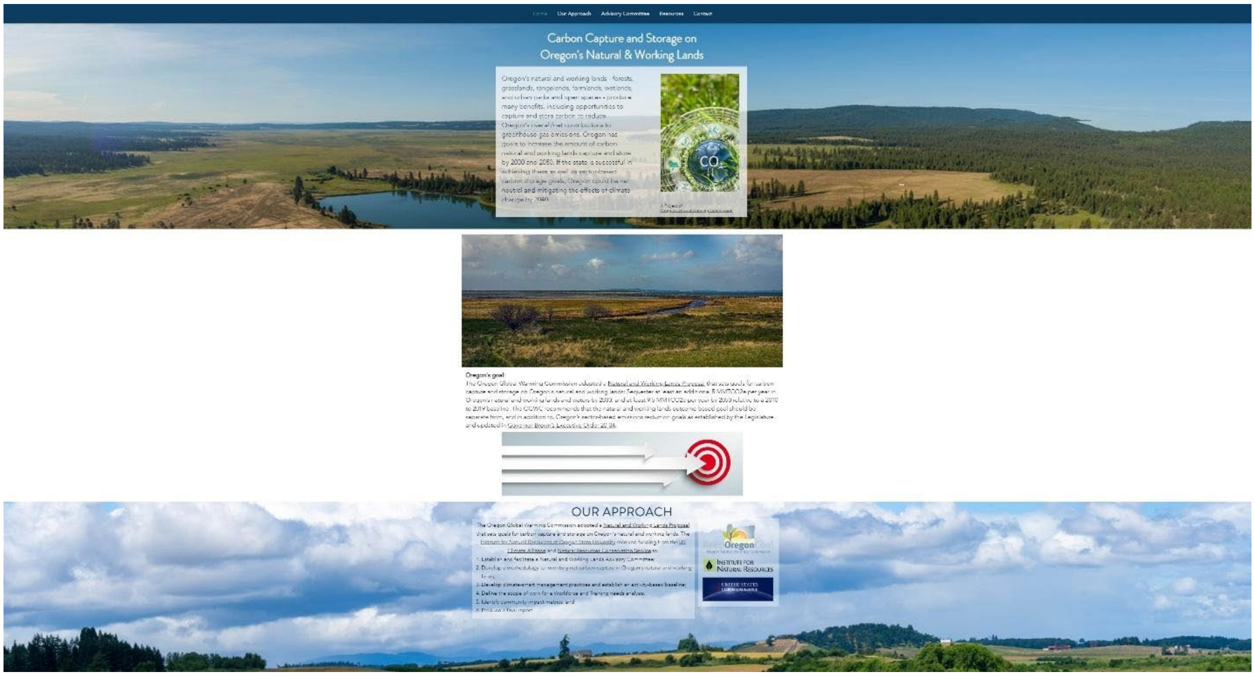


Figure 1. Process used to implement the NWL project.

INR led the development of a Roles and Expectations document (Appendix B) that described the specific expectations and roles of Advisory Committee members, ad hoc technical groups, the Agency Advisory and Coordinating Committee, Facilitator, Commission representative, INR technical leads, and INR Director.

INR created a website, https://www.ogwcnaturalandworkinglands.org (Figure 2) to share information about the project purpose, the approach and process, Advisory Committee member and meeting information, resources and publications relating to the OGWC Proposal and project, and project process. The NWL project website has recently been relocated to INR's Oregon State University website, https://inr.oregonstate.edu/convening-science-advisory-projects/natural-working-lands. The original website was active only during the lifespan of the project, and the new one will remain operational until the Commission replaces it.



Carbon Capture and Storage on Oregon's Natural & Working Lands

Oregon's natural and working lands - forests, grasslands, rangelands, farmlands, wetlands, and urban parks and open spaces - produce many benefits, including opportunities to capture and store carbon to reduce Oregon's overall/net contributions to greenhouse gas emissions. Oregon has goals to increase the amount of carbon natural and working lands capture and store by 2030 and 2050. If the state is successful in achieving these as well as sector-based carbon storage goals, Oregon could be net neutral and mitigating the effects of climate change by 2040.

Oregon's goal:
The Oregon Global Warming Commission adopted a Natural and Working Lands Proposal that sets goals for carbon capture and storage on Oregon's natural and working lands: Sequester at least an additional 5 MMTCO2e per year in Oregon's natural and working lands and waters by 2030, and at least 9.5 MMTCO2e per year by 2050 relative to a 2010 to 2019 baseline. The OGWC recommends that the natural and working lands outcome based goal should be separate from, and in addition to, Oregon's sector-based emissions reduction goals as established by the Legislature and updated in Governor Brown's Executive Order 20-04.

OUR APPROACH

The Oregon Global Warming Commission adopted a Natural and Working Lands Proposal that sets goals for carbon capture and storage on Oregon's natural and working lands. The Institute for Natural Resources at Oregon State University received funding from the US Climate Alliance and Natural Resources Conservation Service to:

1. Establish and facilitate a Natural and Working Lands Advisory Committee;
2. Develop a methodology to inventory net carbon capture in Oregon's natural and working lands;
3. Develop climate-smart management practices and establish an activity-based baseline;
4. Define the scope of work for a Workforce and Training needs analysis;
5. Identify community impact metrics; and
6. Produce a final report.

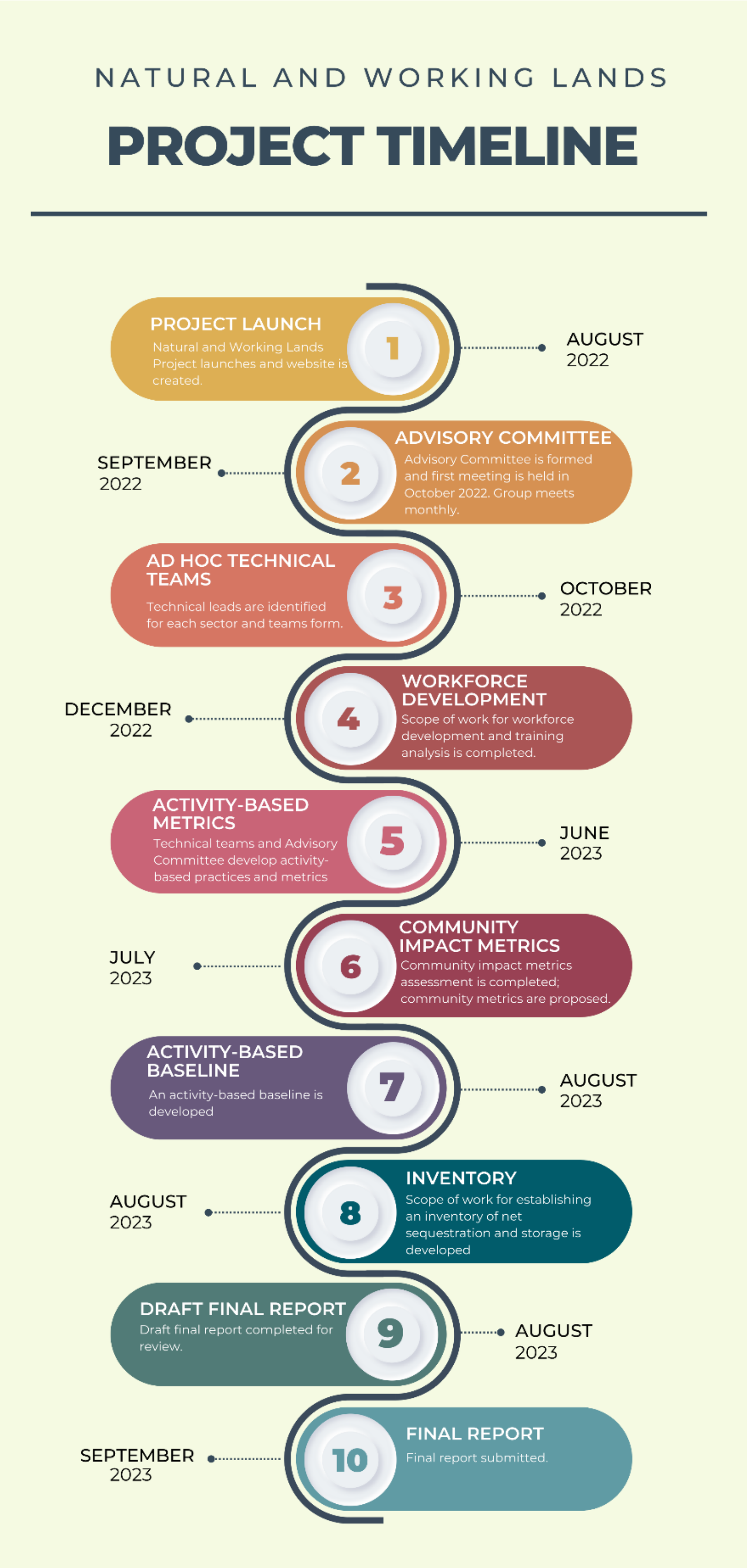
Figure 2. Natural and working lands project website (original).

1.2.2 Approach

Oregon NWL are aggregated into sectors, such as forests, agricultural lands, rangelands, urban and suburban areas, and wet areas. Wet areas include rivers, lakes, freshwater and intertidal and tidal wetlands; intertidal and tidal wetlands were combined and designated as “blue carbon” areas for this project. Agricultural lands and rangelands were classified as separate land sectors for this project because they represent distinct communities and land management activities and extensive areas in Oregon and are separated by the Intergovernmental Panel on Climate Change (IPCC). Grazing lands that are irrigated or fertilized were classified as “agricultural” lands. Freshwater wetlands and freshwater streams, rivers, and lakes were not addressed in this project, although may be incorporated into future efforts.

The first four of five deliverables for the project were developed simultaneously followed by the last deliverable—the methodology for establishing an inventory of net sequestration. Each of the five deliverables and their associated processes are described in detail in the Outcomes section of this report.

The project launched in August 2022 and was completed in September 2023 (Figure 3).



NATURAL AND WORKING LANDS

PROJECT TIMELINE

1. **PROJECT LAUNCH** – Natural and Working Lands Project launches and website is created. – AUGUST 2022
2. **ADVISORY COMMITTEE** – Advisory Committee is formed and first meeting is held in October 2022. Group meets monthly. – SEPTEMBER 2022
3. **AD HOC TECHNICAL TEAMS** – Technical leads are identified for each sector and teams form. – OCTOBER 2022
4. **WORKFORCE DEVELOPMENT** – Scope of work for workforce development and training analysis is completed. – DECEMBER 2022
5. **ACTIVITY-BASED METRICS** – Technical teams and Advisory Committee develop activity-based practices and metrics – JUNE 2023
6. **COMMUNITY IMPACT METRICS** – Community impact metrics assessment is completed; community metrics are proposed. – JULY 2023
7. **ACTIVITY-BASED BASELINE** – An activity-based baseline is developed – AUGUST 2023
8. **INVENTORY** – Scope of work for establishing an inventory of net sequestration and storage is developed – AUGUST 2023
9. **DRAFT FINAL REPORT** – Draft final report completed for review. – AUGUST 2023
10. **FINAL REPORT** – Final report submitted. – SEPTEMBER 2023

Figure 3. Natural and working lands project timeline.

2. Project Outcomes

2.1 Facilitate NWL Advisory Committee Meetings

In July 2022, the Commission announced their interest in forming the Advisory Committee for the project, emphasizing the goal of convening 20–25 people based on geography within Oregon, sector-based and NWL types (i.e., blue carbon, forests, agricultural lands, urban and suburban lands, and rangelands), knowledge of state and federal NWL investment programs, knowledge of sector interests and needs, and demonstrated track record of working collaboratively across interests to find novel solutions while creating triple bottom-line outcomes to NWL issues and opportunities. The goal was to ensure the committee was comprised of representatives from Tribes and local governments as well as forestry, agriculture, environmental justice, and conservation interests, private landowners, technical service providers, and others interested in NWL. Applicants applied to be considered for selection to the Advisory Committee by providing information about their background and expertise in August 2022.

Commission members reviewed the applications and announced a second call for applicants in September 2022 to fill any identified gaps in the first round of applicants, in particular, representation from eastern Oregon land sectors as well as Tribal representation. During the second round of solicitation, direct outreach was conducted to specific individuals to encourage applications.

The Commission announced Advisory Committee member selections in September 2022. A total of 27 individuals were selected (Appendix C). In March 2023, one committee member with a nexus to Tribal governments (consultant to several Tribes) resigned from the committee, noting the challenges of attempting to speak for/represent numerous tribes, and proposing the state engage with Tribes at a government-to-government level.

The Advisory Committee met monthly virtually beginning in October 2022 and through the conclusion of the project in August 2023 for a total of 11 meetings (Table 1). Each meeting was recorded, and the recording, list of attendees, chat box discussion, and any presentations and documents were posted on the website. During the development and review of activity-based practices and metrics, two subcommittees were formed (Agriculture and Forestry) to spend additional time between meetings discussing recommendations for practices and activity-based metrics to achieve OGWC Proposal goals. In addition, there were numerous one-on-one meetings held with individual Advisory Committee members on an as needed or requested basis.

Table 1. Advisory Committee meeting dates and meeting focus.

Dates	Meeting Focus
17 Oct 2022	Kickoff meeting – project deliverables and timelines, roles and responsibilities
3 Nov 2022	Share draft workforce development and training assessment and gap analysis scope of work; technical approach to developing activity-based metrics and inventory
1 Dec 2022	Discuss proposed final version of draft workforce development and training assessment and gap analysis scope of work; presentation by technical leads on developing activity-based metrics and inventory
12 Jan 2023	Review and discuss NWL inventory definitions; background and objectives for GHG inventory, review draft list of practices and metrics
3 Feb 2023	Achieve informed consent on definitions; review timeline for development of practices and metrics; formation of Agriculture and Forestry Subcommittees
2 Mar 2023	Discuss practices and metrics recommendations
6 Apr 2023	Review process to develop practices and metrics; by land sector, identify practices and metrics Advisory Committee members support and do not support as well as those Advisory Committee members want added
4 May 2023	Share and discuss concepts from Agriculture and Forestry Subcommittees; introduce draft community impact metrics framework
1 Jun 2023	Review input from Advisory Committee members on proposed community metrics; review timeline for project and deliverables; discussion of Agriculture and Forestry Subcommittee practices and metrics recommendations
6 Jul 2023	Review the final practices and metrics document produced by the technical teams, review the practices and metrics produced by the Agriculture Subcommittee (Advisory Committee), determine next steps the Forestry Subcommittee (Advisory Committee) seeks to take relative to the development of practices and metrics, and review and finalize recommendations on community metrics.
3 Aug 2023	Finalize community metrics and subcommittee documents/input; review final report

2.1.1 Advisory Committee Role and Informed Consent Process

The role of the Advisory Committee was to provide current knowledge, critical thinking, analysis, and perspectives to inform the implementation of the Commission's NWL Proposal and INR project deliverables. Specifically, their role was to actively participate in committee and subcommittee meetings, review and provide substantive input on draft products developed by INR and other technical experts, and work collaboratively with other advisory committee members to understand issues and perspectives that represent the diversity of interests in Oregon. The role of the Advisory Committee was not to approve or support any documents produced by the technical teams nor INR.

An informed consent process was used with the Advisory Committee to advance topics and recommendations included in this report. The Systematic Development of Informed Consent, or "informed consent" for short (Figure 4), is a term that is commonly used in the medical industry; however, the concept was developed and modified in the 1980s by Hans and Anna Marie Bleiker as a process to engage the public in a productive and meaningful way. The basic premise of the concept is that if people are truly engaged and heard in a process and given the opportunity to be part of something meaningful, they may not fully agree with every element of a project/concept moving forward, but they will support the project/concept/deliverable because they have been part of that meaningful process, and their perspectives have been heard and represented. Critical to the success of this process is respecting the values and perspectives of everyone involved, despite varying levels of expertise and experience. As such, when compiling information and recommendations from meetings and discussions, project facilitators summarized comments in a compiled format versus attributing comments to any specific individuals.

Figure 4. The core elements of informed consent.

2.2 Land Sector Practices and Activity-based Metrics

The first step in developing land sector practices, activity-based metrics, and a baseline of these activities for Oregon's NWL was to develop a technical approach (Appendix D), that sought to answer the following three questions:

- What are the recommended activities to capture and store more carbon and reduce GHGs in Oregon's NWL sector? Which should be included in this effort?

- What method should be used to develop a baseline for these activities and track implementation through time? How much has happened in the past? How much would occur following “business as usual?
- How do we best measure or estimate the amount of carbon that is captured and stored by implementing the activities?

Processes (Appendix D) were created to provide input to the Commission from technical teams and an advisory committee:

- **Technical teams**. Technical teams, comprised of ad hoc land sector representatives, proposed draft science-based practices and metrics that have the potential to meet Commission net carbon sequestration and GHG reduction goals using climate-smart practices on Oregon’s NWL. The April 2023 draft was reviewed by Advisory Committee members and external reviewers; the technical teams then considered the submitted comments and recommendations and finalized the technical team practices and metrics.
- **Advisory committee**. Using an informed consent approach, the Advisory Committee – representative of numerous demographic and industry groups in Oregon – reviewed the practices proposed by the technical leads, while forming subcommittees to specifically focus on forestry and agricultural land practices and metrics. Advisory Committee members were not asked to support or not support what was produced by the technical teams. Instead, they were asked to review and provide comments on the practices and metrics produced by the technical teams and if they chose, submit practices and metrics they believed should be represented by one or more land sectors. That compilation of information was intended to provide the Commission with a comprehensive suite of perspectives relative to practices and metrics Oregon could use to sequester carbon and reduce GHG emissions on NWL.

External reviewers were also invited into the process and asked to objectively review and comment on the initial, April 2023 draft list of proposed practices and metrics. Specifically, INR sought feedback based on the following questions:

- Are there practices and/or metrics that you believe should be included in a particular sector that are currently not included, and if so, why? Do you have one or more scientific references in support of inclusion?
- Are there practices proposed in the document that you do not believe should be included in a particular sector, and if so, why? Do you have one or more scientific references that support excluding the practice?
- Are there metrics proposed in the document that you do not support including for a particular practice, and if so, why? Do you have suggested alternatives, or additional metrics you would like to see included for a particular practice?

A compilation of the input received from external reviewers, including the input that was incorporated into the final technical document, can be found in Appendix E.

2.2.1 Categorizing Practices

The goal was to document all recommended activity-based/climate-smart practice ideas and possible resources (report, articles) that support the ideas, and categorize those practices as recommended, emerging, or not recommended.

- **Recommended practices** were defined as practices most likely to be effective in reducing GHG. These practices have strong evidence, including scientific peer-reviewed publications and sufficient data, to determine directionality as a sink of GHG emissions. These datasets combined with current management practices will help the State develop a baseline based on CO_2 equivalents.
- **Emerging practices** were defined as practices not currently recommended despite the appearance of promise in the reduction potential of GHG emissions because of a need for more data to determine a given practice's effectiveness reducing emissions or because they are prohibited from use due to current laws or regulations.
- **Not recommended practices** are practices not recommended because current data suggests the reduction potential of GHG emissions from implementing a given practice over time is of low confidence. Included in this list are practices that would require full life cycle assessments for every implementation to determine their net GHG balance.

The next section of this report documents the practices and metrics submitted by the technical teams, and practices and metrics submitted by the Advisory Committee Agriculture Subcommittee. Table 2 is a summary of the practices recommended by the technical teams and the Advisory Committee.

2.2.2 Considerations Proposed to the Commission

The practices listed through this section – whether recommended, emerging, or not recommended – are nuanced and require considerations. Both the Advisory Committee and the Technical Team documented factors that the Commission should consider.

Considerations Proposed by the Advisory Committee

Soil health. Soil is a vital living unit and agricultural practices that enhance and increase soil health allow it to perform its natural functions of holding carbon, retaining moisture, and nourishing plant roots to provide nutrient rich food. Practices using principles of good soil health mimic what occurs in nature and allow for the growing of crops without depleting the soil of its living structure and releasing carbon into the atmosphere with every crop cycle. The principles of soil health are: (1) minimize soil disturbance; (2) cover the soil at all times; (3) keep living roots in the soil; (4) increase crop diversity; and, (5) graze when possible.

The size and complexity of this transition is considerable and will take time and support from multiple sources, but the benefits of creating healthy drought-resilient soil along with enhanced farm ecology are immense and critical at this time. The use of these soil health practices will yield greater results economically and environmentally when they are used together to increase the overall ecological health of the farm.

Co-benefits. There are numerous co-benefits associated with NWL practices. Prescribed grazing sequesters carbon in perennial biomass and soils while enhancing or maintaining desired species for forage, improving water quality, increasing stocking rates and livestock vigor, and building soil health. When soil is healthy, plants are naturally more resilient to pests and disease and therefore require fewer inputs of fertilizer and pesticides, thus requiring fewer applications across the field with the tractor (passes). Making fewer passes reduces soil compaction, diesel usage, and the typically high upstream GHG footprints from chemical manufacturing and distribution.

Tradeoffs. Although many practices have co-benefits, it is important to recognize and identify the potential tradeoffs associated with each practice. Although a practice may successfully contribute to desired climate-related activities, implementing the practice may affect the ability of the landowner/land manager to achieve the goals on their lands. Therefore, all practices should remain voluntary so that landowners/land managers can assess the tradeoffs associated with each practice and minimize detrimental effects to their business.

Viability of Oregon's farmers and ranchers. Incentive programs have the potential to create land use change. The State of Oregon has protected and values farmland for many reasons. If programs or incentives are created that take land out of production, policy makers should carefully consider how this affects all segments of agriculture, including the viability of Oregon's farmers and ranchers.

Climate change stressors. The U.S. Department of Agriculture predicts a suite of climate change stressors will create challenges to agricultural management practices. These challenges include increased temperatures across seasons and more frequent extreme heat, decreased snowpack and summer streamflow, increased extreme precipitation, lengthened growing seasons, increased plant moisture stress (i.e., drought conditions), and increased risk of pests and disease.

Statewide impacts of policy implementation. The list of practices in this document are practices an individual landowner or manager could implement, but individual producers would likely not have the information or ability to determine statewide impacts of policy implementation, which is the responsibility of Oregon's legislature with input from the Commission.

Geography matters. Geography matters when dealing with NWL practices, with the exception of natural areas, which are not highly developed compared to most of Oregon's NWL. Oregon is incredibly diverse geographically, and as a result, NWL respond differently – to fire, climate change stressors, and the many activities that affect carbon sequestration. Thus, practices suitable in some parts of the state may not be recommended in other parts of the state, and the carbon benefits will vary as well.

Considerations Proposed by the Technical Teams

Meeting criteria. The technical leads agreed that the following four criteria must be met for practices to succeed as climate mitigation tools,[5]:

- Lead to enhancements to carbon uptake and/or reductions of non-CO_2 GHGs that are additional to what would have occurred in a baseline or counterfactual scenario, and that integrate across all ecosystem sources and sinks.
- Lead to net cooling such that biophysical effects on water and energy cycling do not overwhelm the gains in carbon uptake or emissions reductions.
- Achieve durable carbon storage by accounting for social and environmental risks to the permanence of ecosystem carbon storage and avoided GHG emissions.
- Account for leakage so that gains in one area are not canceled out by shifting activities to another area.

Durability. Durability refers to the period of time over which avoided emissions that result from a practice/intervention persist without failure (i.e., that the net GHG reduction remains out of the atmosphere for a given duration). It is important to recognize that ecosystem carbon storage is temporary in nature and is subject to "reversal" due to ecological risk factors or program governance features (e.g., whether a practice was implemented based on a given contract length or put into an easement). There are recommended practices outside NWL, such as nitrogen fertilization that avoid potential durability issues. For example, a reduction in 5% total nitrogen applied with maintained crop yields, results in a permanent reduction of N_2O emissions and associated supply chain emissions.

Risk of reversal. Reversals can occur with carbon sequestration in biomass and soils, wherein the reductions of atmospheric GHGs associated with changing land management are reversed. The adoption of alternative management practices on NWL can increase carbon storage and sequestration, e.g., riparian reforestation wherein CO_2 is removed from the atmosphere through primary production (plant growth) and sequestered in biomass or soils. However, that CO_2 can be returned to the atmosphere if the landowner reverts to previous practices or a disturbance causes a decline in the biomass or soil carbon stocks.[6] Risk of reversal is influenced by at least three factors: (1) the severity, duration, and frequency of natural disturbances, including fire, pests and pathogens, and severe weather; (2) the response of biota and soils to increasing atmospheric CO_2 concentrations and climate change; and (3) landowner behavior.[7] For activities that reduce CH_4 and N_2O emissions, there is no risk for reversal because avoided emissions are considered permanent. However, if land management reverts to prior practices CH_4 and N_2O emissions will resume and, in

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[5] Novick, K., et al. 2022. The science needed for robust, scalable, and credible nature-based climate solutions in the United States. Full Report. https://doi.org/10.5967/n7r9-7j83

[6] Mackey, B. et al. 2013. Untangling the confusion around land carbon science and climate change mitigation policy. *Nat. Clim. Change* 3: 552–557. http://dx.doi.org/10.1038/nclimate1804

[7] Galik, C.S., and R.B. Jackson. 2009. Risks to forest carbon offset project in a changing climate. *Forest Ecology and Management* 257(11): 2209–2216. https://doi.org/10.1016/j.foreco.2009.03.017

the case of conversion of lands, can lead to emissions equal to or greater than what was avoided during the period of reduced emissions.[8]

Leakage. Leakage refers to ensuring that a practice does increase emissions outside the practice boundaries. This is especially prevalent if practices reduce yields. If market demands are not altered for a given commodity that had a reduction in yield, the practice may result in land use change elsewhere to close the yield gap. Altered market demands may alleviate leakage issues.

Global warming potentials of greenhouse gases and emissions metric approaches. Global Warming Potential (GWP) is a way to provide a common unit of measure to compare the heat absorbed by different gases. The GWP is a measure of how much energy (i.e., heat) the emissions of a given mass of a GHG will absorb over a given time compared to the same mass of CO_2. Larger GWPs indicate a higher potential for warming the Earth compared to CO_2 during that time period. Carbon dioxide is always a GWP of one, regardless of the time period used as it is the reference gas. A period of 100 years has been chosen by many international collaborative efforts (e.g., Paris Agreement), countries, and states to determine GWP. The GWP-100 may not always effectively illustrate climate impacts from sectors that have short-lived GHGs in the atmosphere. This is particularly relevant for CH_4. In the latest IPCC report (AR6) Chapter 7, Table 7.15, the IPCC has slightly revised its estimates on the lifetime of GHGs in the atmosphere and their GWPs.[9] Methane has a lifetime of 11.8 ± 1.8 years and, with the updated radiative efficiency, has a GWP-100 (global warming potential over 100 years) of 27.0 ± 11 CO_2e (non-fossil derived). However, when viewed from the point of 20 years, the GWP-20 of non-fossil CH_4 is 79.7 ± 25.8 CO_2e. Using appropriate metrics, especially for short-lived gases like CH_4, is crucial. Addressing CH_4 emissions can have immediate impacts on preventing immediate warming. Conversely, unmitigated CH_4 emissions can result in significant and immediate global temperature increases. Despite CH_4 having a short lifespan, the rapid increase in global temperature could result in triggering irreversible tipping points of various Earth systems.[10, 11] The IPCC AR6 notes that short- and long-lived GHG emissions should be treated separately compared to approaches that aggregate emissions of GHGs using standard GWP emissions metrics. However, most countries and states have and will be using GWP-100 for GHG accounting, including parties signed on to the Paris Agreement.

This can be reported annually, or for an alternative reporting window as determined by the State. Each activity will have different tracking and estimation methods for determining the increased

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[8] McDaniel, M.D., et al. 2019. The effect of land-use change on soil CH_4 and N_2O Fluxes: A global meta-analysis. *Ecosystems* 22: 1424–1443. https://doi.org/10.1007/s10021-019-00347-z

[9] Forster, P., and T. Storelvmo. 2021. Chapter 7: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity (PDF). IPCC AR6 WG1 2021

[10] Armstrong McKay, D.I., et al. 2022. Exceeding 1.5 C global warming could trigger multiple climate tipping points. *Science* 377(6611): eabn7950. https://doi.org/10.1126/science.abn7950

[11] Ivanovich, C.C., et al. 2023. Future warming from global food consumption. *Nature Climate Change* 13: 297–302. https://doi.org/10.1038/s41558-023-01605-8

carbon storage and/or avoided GHG emissions attributed to that activity. To aggregate the climate mitigation impact across GHGs, all GHG emissions and sequestration will be converted to CO_2e.

Technical background on soil carbon pools. Soils are the largest reserve of terrestrial carbon. The total soil carbon pool includes both soil organic carbon and soil inorganic carbon. Soil organic matter is the primary pool researchers and organizations have assessed for climate change impacts. Soil organic matter is primarily composed of carbon (50–60%),[12] but also includes macro- and micronutrients. A total of 12,000 years of cultivated agriculture has reduced global soil carbon by ~116 Pg (Pg = Petagram = 1 billion metric tons). Increasing soil organic matter generally improves soil health and ecosystem functionality. An increase in soil organic matter stock does not necessarily equate to a reduction in net GHG emissions. It is necessary to quantify changes in GHG emissions to determine if a change in practice is a net GHG sink.

Environmental constraints may limit the feasibility of increasing soil carbon stocks across all land sectors. There needs to be sufficient water, nitrogen, and phosphorus to increase soil organic matter (carbon). Van Groenigen et al. (2017) use the "4 per 1000" initiative that aims at a yearly 0.4% increase in global agricultural soil organic carbon stocks as an example to show that a soil organic carbon sequestration rate of 1200 Tg (Tg = teragram = 1 million metric tons) of carbon per year would require approximately 100 Tg of nitrogen per year.[13] Spohn (2020) made a similar argument for phosphorus requirements to achieve desired soil organic carbon sequestration rates.[14] Beyond nutrient demands, a given soil's potential to increase soil organic matter is based on its properties (e.g., clay and silt content, mineralogy, and current carbon stock) and climatic factors (precipitation and temperature). Soil carbon saturation is the point at which the amount of carbon in the soil reaches its maximum capacity. Additional carbon beyond this saturation point will be released into the atmosphere in GHGs rather than being stored in the soil. Soils furthest from their mineralogical capacity are more effective at accruing carbon.[15] Lastly, there is the potential vulnerability of soil organic carbon stocks to continued warming, which could result in stock losses.[16]

Soil inorganic carbon has received little attention in carbon accounting despite its important role in the carbon cycle. Carbon is stored in groundwater as bicarbonate, often supplied by downward flux from the soil, however, because groundwater is outside the scope of our inventory, it will not be included. Soil inorganic carbon is especially prevalent in areas east of the Cascade Mountains in Oregon and some low precipitation areas in southern Oregon. Nitrogen fertilization and deposition and irrigation (in some instances) have caused and are continuing to cause decreasing inorganic

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[12] Pribyl, D.W. 2010. A critical review of the conventional SOC to SOM conversion factor. *Geoderma* 156(3–4): 75–83. https://doi.org/10.1016/j.geoderma.2010.02.003

[13] Van Groenigen, J.W., et al. 2017. Sequestering Soil Organic Carbon: A Nitrogen Dilemma. *Environmental Science & Technology* 51(9): 4738–4739. https://doi.org/10.1021/acs.est.7b01427

[14] Spohn, M. 2020. Increasing the organic carbon stocks in mineral soils sequesters large amounts of phosphorus. *Glob. Change Biol.* 26: 4169–4177. https://doi.org/10.1111/gcb.15154

[15] Georgiou, K., et al. 2022. Global stocks and capacity of mineral-associated soil organic carbon. *Nature Communications* 13(1): 3797. https://doi.org/10.1038/s41467-022-31540-9

[16] Ibid.

carbon stocks in many arid regions of the State due to pH levels decreasing (i.e., soil acidification).[17,18] Sullivan et al. (2013) discuss the need to lime soils in Oregon areas that used to be alkaline soils before cultivation.[19] This potential pathway of carbon loss (and possible gains) needs to be accounted for in all sectors that have accumulated carbonates.

Important indirect greenhouse gas emissions. Several gas species are recognized as important indirect or precursor GHGs. Nitrogen oxides (NOx) (e.g., nitric oxide and nitrogen dioxide), carbon monoxide, and non-methane biologic volatile organic compounds are chemically active gases that increase the abundance of tropospheric ozone (i.e., surface-level up to 15km ozone that acts as a strong GHG) with increasing emissions or altering the lifetime of CH_4.[20] Methane also increases ozone abundance, but both are direct GHGs. These indirect GHG species can form from wildfires and soil processes in NWL. These indirect GHG species have implications on ecosystem health but are outside the scope of this project.

Ammonia is another precursor to GHG with dominant sources being livestock and crop production (i.e., manure and fertilizer management). Though NOx and CH_3 emissions are linked to lowering surface temperatures, the production of these gases represents nitrogen loss and a reduction in nitrogen use efficiency in agricultural production. This leads to needing more fertilizer while reducing air and water quality.

2.2.3 Summary of NWL Practices and Metrics

In April 2023, the technical teams submitted an initial, draft list of proposed practices and metrics to be reviewed by the Advisory Committee and external reviewers. The Advisory Committee and external reviewers reviewed the technical document and proposed recommendations to those practices. For the external review, project facilitators reached out to 65 scientists, researchers, and other experts, some of whom were recommended by Advisory Committee members, to obtain their perspectives on the first draft of the technical teams' practices and metrics document.

The final version of the technical teams' practices and metrics document can be found in Appendix E-1 and the practices proposed by the Advisory Committee is located in Appendix E-2. Appendix E-3 summarizes the key comments received and characterizes by the external reviewer by land sector and denotes which practices were incorporated into the technical teams final list of practices and metrics.

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[17] Zamanian, K., et al. 2018. Nitrogen fertilization raises CO_2 efflux from inorganic carbon: A global assessment. *Global Change Biology* 24(7): 2810–2817. https://doi.org/10.1111/gcb.14148

[18] Raza, S. et al. 2020. Dramatic loss of inorganic carbon by nitrogen-induced soil acidification in Chinese croplands. *Global Change Biology* 26(6): 3738–3751. https://doi.org/10.1111/gcb.15101

[19] Sullivan, D.M., et al. 2013. Eastern Oregon Liming Guide. EM9060

[20] Ehhalt, D. 2001. Atmospheric Chemistry and Greenhouse Gases. *Chapter 4 of the IPCC Third Assessment Report Climate Change*. https://www.osti.gov/biblio/901482

Technical Team Proposed Practices and Metrics

Key points heard from focus group-type discussions and one-one-one interviews as well as written comments received from external reviewers were compiled and shared with the technical team leads for consideration in the final version of their document (Appendix E-1).

Advisory Committee Proposed Practices and Metrics

In addition to, and based on, the Advisory Committee's overall review of the initial April 2023 draft list of proposed practices and metrics, they formed two subcommittees to specifically discuss the draft forestry and agricultural land sectors practices and metrics proposed by the technical teams.

Agriculture Subcommittee

Because of the significant difference in what the technical team initially proposed for agricultural practices (focus on GHG emissions) and what the Advisory Committee deemed appropriate for agricultural practices based on the OGWC Proposal (GHG emissions and carbon sequestration and storage), the Agricultural Subcommittee created its own version of practices and metrics for consideration by the entire Advisory Committee and the Commission. Advisory Committee Agricultural Subcommittee members expressed concern that in the final version of the technical teams' document:

- One of the recommended practices – reforestation – is not an agricultural practice.
- Soil health was seemingly overlooked.
- Practices strongly supported by the Natural Resources Conservation Service as climate-smart strategies that sequester and store carbon were not included.
- The agriculture practices focused on practices that reduce GHG emissions versus the broader task defined in the OGWC Proposal, which was to include practices that both reduce GHG emissions and sequester and store carbon.
- Practices that promote dietary shifts or selection of one commodity versus another are outside the scope of the project.

Details of the Advisory Committee's recommended practices is found in Appendix E-2.

Forestry Subcommittee

A group of Advisory Committee members formed a Forestry Subcommittee to explore in greater scope and content a potential suite of forest practices and metrics. Numerous concepts drafted by this subcommittee aligned with the practices proposed by the forestry technical team.

- The technical team proposed, "Prevent conversion of forest to non-forest land uses." The subcommittee expressed a similar concept, "Protect forest lands from conversion, especially conversion that reduces their carbon sequestration and GHG potential."

- The technical team proposed, “Afforestation/Reforestation.” Similarly, the subcommittee proposed “Implement afforestation and reforestation where ecologically appropriate (and to enhance forest resilience and health).”
- The technical team proposed, “Improved forest management,” which included “Increase the stocking of trees on understocked areas and/or maintain stocks at a high level.” Although the subcommittee did not propose “Improved forest management,” it did recommend, “Optimize replanting and supplemental planting (reforestation) within its recommended practice, “Restore ecologically appropriate fire regimes on forest land.”
- The technical team proposed, “Increase the proportion of carbon stored within long-lived harvested wood products.” The subcommittee proposed “Incentivize the manufacture and use of long-lived wood products to replace less-sustainable alternatives.” Because incentives are policy choices, the subcommittee recommendation, as stated, is not included as a recommended practice by INR, however, the substance of the recommendation, “manufacturing and using long-lived wood products” remains valid.
- The technical team proposed, “Reduce wildfire risk,” whereas the subcommittee proposed, “Restore ecologically appropriate fire regimes on forest land.” The subcommittee included “Optimize replanting and supplemental planting (reforestation) as part of their recommendation to restore ecologically appropriate fire regimes on forest land.
- The technical teams described “Optimize the use of discarded forest biomass (slash)” as an emerging practice; the subcommittee considered the use of discarded biomass and biochar as an emerging practice.

Forestry Subcommittee members described co-benefits associated with practices suggested by the technical teams. For example, protecting forest lands from conversion, particularly those that have low fire vulnerability and have both high present-day soil carbon stocks and aboveground carbon stocks, provides terrestrial vertebrate habitat for threatened and endangered species as well as a buffer against climate change stressors.

Differences of opinion among subcommittee members in describing the details associated with practices and metrics resulted in the committee ultimately not submitting its own set of recommended practices and metrics. Some of these differences can be attributed to:

- The sheer complexity of Oregon forest landownership and how lands are managed differently within these ownerships;
- The desire to meet the demand for wood products and actively manage forests while recognizing healthy forest stands play a critical role in sequestering and storing carbon;
- Lack of information about which practices best contribute to achieving OGWC Proposal goals across the diversity of Oregon’s forest landscape; and

- The legacy debates that highlight the key differences of opinion between how industrial forests are managed and desired ecological outcomes.

The following are examples of some key differences discussed among members:

- The contribution of past and present forest management to the current state of wildfires in Oregon was attributed to different factors, with scientific references to support both viewpoints.
- Appropriate forest management practices post-fire were debated, again with references to support both viewpoints.
- Forest management practices on private industrial forest lands were debated.

In summary, differences of opinion were focused less on the proposed practices and metrics and more on the narrative accompanying the proposed practices. See Appendix E-4 for the references cited by the Forestry Subcommittee members during their discussions about the practices.

Summary of NWL Practices

Figure 5 represents the list of 31 NWL practices in five Oregon land sectors that are recommended practices Oregon land managers can implement to reduce GHG emissions and sequester and store carbon. The practices listed in Figure 5 are the recommended practices listed in Table 2 minus any practices that select one commodity over another, represent a consumer choice, are not specific to a particular land sector (e.g., recommending a forestry practice in an agricultural sector), or are duplicative/overlapping recommendations made by both the agricultural technical team and Advisory Committee.

Table 2. List of all practices recommended and identified as emerging practices by the technical teams for each of the NWL sectors, and agricultural lands practices recommended by the Advisory Committee (indicated by asterisks).

Land Sector	Practice	Recommended[21]	Emerging[22]
Blue Carbon Ecosystems	Tidal wetland conservation	X	
	Tidal wetland restoration	X	
	Seagrass conservation	X	
	Seagrass restoration		X
	Kelp and seaweed protection and restoration		X
	Enhance tidal wetland resilience to sea level rise		X
Rangelands	Prevent conversion to invasive annual plant dominated systems	X	
	Restore deep rooted perennial grasses to areas impacted by invasive species	X	
	Restore functioning riparian areas	X	
	Prevent conversion of grasslands, shrublands, and savannas to juniper woodlands	X	
	Prevent conversion to urban and/or row crop land use	X	
	Biochar		X
	Supplementations to reduce enteric methane for rangeland livestock		X
	Management practices to store carbon in soil inorganic pools		X
Forestlands	Prevent conversion of forest to non-forest land uses	X	
	Afforestation/Reforestation	X	
	Improved forest management	X	
	Increase the proportion of carbon stored within long-lived harvested wood products	X	
	Reduce wildfire risks	X	
	Increasing soil storage of carbon through mulching, chipping of slash		X
	Increase utilization of discarded forest biomass (slash material)		X
Agricultural Lands	Increase riparian areas beyond the edge of field - reforestation	X	
	Anaerobic digestion of manure and beneficial use of methane or flaring and appropriate land	X	

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[21] **Recommended Practices:** Practices most likely effective in reducing GHG. These practices have strong evidence, including scientific peer-reviewed publications and sufficient data, to determine directionality as a sink of GHG emissions. These datasets combined with current management practices will help the State develop a baseline based on CO_2 equivalents.

[22] **Emerging Practices:** Practices not recommended despite the appearance of promise in the reduction potential of GHG emissions because of a need for more data to determine a given practice effectiveness reducing emissions or because they are prohibited from use due to current laws or regulations.

Table 2. List of all practices recommended and identified as emerging practices by the technical teams for each of the NWL sectors, and agricultural lands practices recommended by the Advisory Committee (indicated by asterisks).			
Land Sector	**Practice**	**Recommended**[21]	**Emerging**[22]
	application of digestate		
	Improve irrigation strategies and efficiencies	X	
	Improve nitrogen management	X	
	Reduce production of high GHG emitting commodities such as ruminant animals and replace with low GHG emitting food crops where possible	X	
	Reduce enteric emissions from ruminant production systems via approved enzyme feed additives	X	
	Reduce food loss and waste	X	
	Support on-farm renewable energy and energy efficiency	X	
	Protect agricultural lands from urban or industrialized conversion*	X	
	Increase woody plant coverage*	X	
	Encourage no-till and residue till management*	X	
	Implement edge-of-field herbaceous (non-woody) conservation practices*	X	
	Utilize cover crops and crop rotations*	X	
	Improve nutrient management and reduce nitrogen application*	X	
	Shift energy sourcing and irrigation techniques to reduce emissions*	X	
	Prescribed grazing*	X	
	Pasture-based management*	X	
	Reduce enteric emissions from ruminant production systems via approved enzyme feed additives*	X	
	Anaerobic digestion of manure*	X	
	Alternative manure management*	X	
Urban and Suburban Lands	Maintain and expand forest vegetation cover	X	
	Improve fertilizer use in urban and suburban lands to reduce excess nitrogen releases	X	

Blue Carbon

- Tidal wetland conservation
- Tidal wetland restoration
- Seagrass conservation

Rangelands

- Prevent conversion to invasive annual plant dominated systems
- Restore deep rooted perennial grasses to areas impacted by invasive species
- Restore functioning riparian areas
- Prevent conversion of grasslands, shrublands, and savannas to juniper woodlands
- Prevent conversion to urban and/or row crop land use

Forest Lands

- Prevent conversion of forest to non-forest land uses
- Afforestation/Reforestation
- Improved Forest Management
- Increase the proportion of carbon stored within long-lived harvested wood products
- Reduce wildfire risks

Agricultural Lands

- Anaerobic digestion of manure and beneficial use of methane or flaring and appropriate land application of digestate
- Improve irrigation strategies and efficiencies
- Improve nitrogen management
- Reduce enteric emissions from ruminant production systems via approved enzyme feed additives
- Reduce food loss and waste
- Protect agricultural lands from urban or industrialized conversion*
- Increase woody plant coverage*
- Encourage no-till and residue till management*
- Implement edge-of-field herbaceous (non-woody) conservation practices*
- Utilize cover crops and crop rotations*
- Improve nutrient management and reduce nitrogen application*
- Prescribed grazing*
- Pasture-based management*
- Alternative manure management

Urban & Suburban Lands

- Maintain and expand forest vegetation cover
- Improve fertilizer use in urban and suburban lands to reduce excess nitrogen releases

Figure 5. List of only the recommended practices to reduce GHG emissions and sequester carbon in five of Oregon's NWL sectors. This list of practices does not include those that were initially recommended by either technical teams or the Advisory Committee that recommend selecting one commodity over another, represent a consumer choice, are not specific to a particular land sector (e.g., recommending a forestry practice in an agricultural sector), or are duplicative/overlapping recommendations. Practices recommended by the technical teams do not have asterisks. Practices only recommended by the Advisory Committee are indicated by asterisks.

2.2.4 Other Considerations

Oregon's Land Use Planning Program

Oregon regulates uses on lands for which it has jurisdiction[23] through its statewide land use planning program,[24] which is guided by 19 overarching goals.[25] The majority of the lands where Oregon's agricultural activities take place are zoned and protected for that purpose under Goal 3.[26] Additional agricultural lands,[27] forest lands, and natural areas are zoned and protected for those purposes under Goals 4, 5, 6, and 15–19.[28] Although the land use program has been successful at protecting these lands, over the years some of the protections have been gradually weakened,[29] conflicts continue to be permitted, and NWL continue to be converted to other uses.[30]

None of the practices for increasing carbon sequestration and reducing GHG emissions listed in the following sections would be possible without a land base on which to implement them. Recognizing that fact, the OGWC Proposal included the following recommendation:[31]

> "Enhance and maintain Oregon's statewide land use planning program goals and commit to a no-net annual loss of NWL and waters."

In addition to protecting lands for their intended uses under current zoning, there are provisions in the land use system for converting farmland into forest land and converting forest land into farmland, for wetland restoration on resource lands, and for other practices that can maintain or enhance carbon sequestration potential with no net loss of NWL. Those elements of the program should be maintained and strengthened where needed. Provisions in the current program that allow

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[23] This includes publicly owned land managed by the state and local governments, and privately-owned land. Oregon does not have land use planning authority over land that is held or managed by the federal government, including public land managed by agencies such as the U.S. Forest Service and the Bureau of Land Management, land included on military installations, and reservation land held in trust on behalf of the federally recognized Tribes within the boundaries of the state.

[24] This program was established in 1973 with the passage of Senate Bill 100. The statewide program is a framework, guided by 19 Goals and related statures and administrative rules. The program is implemented locally by County and City governments, each of which has its own set of plans and ordinances that are consistent with the statewide framework.

[25] For a description of the program and the goals, and links to each of the goals, see https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

[26] See Goal 3, Agricultural Lands. Lands zoned for agriculture include rangelands.

[27] Some agriculture and a significant amount of grazing takes place on forest-zoned land.

[28] See Goal 4: Forest Lands; Goal 5, Natural Resources, Scenic and Historic Areas, and Open Spaces; Goal 6, Air, Water, and Land Resources Quality; Goal 15, Willamette River Greenway; Goal 16, Estuarine Resources; Goal 17, Coastal Shorelands; Goal 18, Beaches and Dunes; and Goal 19, Ocean Resources.

[29] For example, when "Exclusive Farm Use" zoning was created, there were five uses (in addition to growing crops) allowed on farmland. Today there are over 60, many of which are not related in any way to agriculture, and which often cause conflicts with neighboring agricultural operations. For a comprehensive look at these uses and the impacts they have on agriculture, see *Death by 1000 Cuts: The Erosion of Oregon's Exclusive Farm Use Zone*.

[30] For a comprehensive discussion of how Oregon's farm and forest lands are converted to other uses, see DLCD, *Farm Forest Report 2020-2021*.

[31] See OGWC, *Natural and Working Lands Proposal*, Recommendation 3A, p. 14.

the conversion of NWL to non-resource-related rural uses[32] should be limited or eliminated where they increase emissions, decrease sequestration potential, or create conflicts for the resource use of neighboring lands.

Oregon's land use system also recognizes that it is occasionally necessary to expand urban growth boundaries (UGBs)[33] to accommodate future housing, employment, municipal, open-space, or transportation uses. The expansion of UGBs is governed by the statewide Land Use Planning Goal 14 and associated statutes and administrative rules.[34] The process requires that the city demonstrate a need for additional land that cannot be accommodated inside the current boundary. Natural and working lands should be converted to urban or other non-resource uses only when real need is demonstrated, and with careful consideration of the tradeoffs being made.

Co-Benefits by Sector

Co-benefits, in the context of NWL and as noted in Section 2.2.2 of this report (the Advisory Committee proposed considerations), refer to the additional positive outcomes and advantages that accrue alongside (and sometimes as a result of) efforts to address climate challenges. Investments in sustainable practices and management within sectors, such as agriculture, forestry, urban areas, rangelands, and blue carbon ecosystems not only contribute to climate change mitigation and adaptation but also unlock a multitude of interconnected benefits. These co-benefits extend beyond carbon sequestration and encompass various environmental, social, and economic gains. By considering these co-benefits when developing climate strategies in the NWL sector, state and federal programs can be leveraged to create a holistic and robust approach to address climate challenges while simultaneously fostering resilient ecosystems and communities.

An important component of the decision-making process relative to NWL is an intentional recognition that practices that sequester carbon may entail trade-offs. For instance, if longer timber harvest rotations are employed, revenue will be delayed. If a parcel of land is used for estuarine habitat, development or other uses are no longer viable. Trade-offs for the very same action may differ greatly when considered at different scales. For example, if a parcel of private forest land is restored to a wetland/riparian area with a buffer, the landowner may experience decreased revenue whereas the community may experience increased water security (quantity and quality) as well as protection from wildfire. Meanwhile, the entire state may experience decreased wildfire cost, progress toward climate goals, and increased public access and recreational fisheries opportunities.

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[32] Such uses include rural residential, commercial, and industrial uses outside of cities. There are currently more acres zoned for these uses outside of cities in Oregon than inside. See https://www.oregonlegislature.gov/lpro/publications/agriculturalandforestlands.pdf Many acres of land zoned for rural residential purposes remain undeveloped.

[33] Every city in Oregon has a UGB—a line around the city inside of which most residential, employment, shopping, school, and other urban uses and development are located. The majority of Oregonians live inside UGBs. UGBs protect surrounding working lands from conversion to inefficient and expensive sprawl. Most, but not all of the land outside of the UGBs is zoned for resource use—primarily farming, ranching, and forest.

[34] See Goal 14, Urbanization.

Considering trade-offs is a complicated endeavor; making individuals and communities whole if negatively impacted creates durable long-lasting outcomes.

Trade-offs considered as part of collaborative planning processes are often underfunded or poorly executed. To be successful, it is critical to identify planning resources and create capacity to achieve climate-related NWL goals. The opportunity to co-create solutions that include policy change, program establishment, and land management changes can minimize or nullify negative consequences while achieving NWL goals. Tools developed in other geographies, such as California's Sacramento Delta region, a complex system with competing interests around agriculture, water supply and wildlife habitat, could be applied in Oregon to facilitate transparent discussions of trade-offs.[35]

Agriculture

There are numerous co-benefits, beyond carbon sequestration, associated with many of the practices described in this document. Prescribed grazing sequesters carbon in perennial biomass and soils while enhancing or maintaining desired species for forage, improving water quality, increasing stocking rates and livestock vigor, and building soil health. Soil health practices can provide many benefits for farms and ranches, including: resilience to drought and other extreme weather events; economic resilience; improved water and nutrient-holding capacity, reduced erosion, enhanced plant health; improved water quality, and increased biodiversity and pollinator habitat. Soil health practices can require fewer inputs of fertilizer and pesticides, thus requiring fewer applications across the field with the tractor (passes). Making fewer passes reduces soil compaction, and fuel usage. Reduced fertilizer use can also lower the typically high upstream greenhouse gas (GHG) footprints from its manufacturing and distribution. A few co-benefits are highlighted below.

Blue Carbon

Blue carbon ecosystems, including seagrasses, emergent wetlands, and tidal forested wetlands, and potentially marine habitats, such as kelp, offer numerous co-benefits that extend beyond their critical role in climate change mitigation. Coastal habitats play a significant part in preserving the health of Oregon's aquatic resources and supporting resilient ecosystems. As natural filters, they improve water quality by trapping sediments[36] and removing pollutants, creating a nurturing environment for marine biodiversity and promoting human health. They also regulate temperature,[37] balance pH,[38]

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[35] https://www.sfei.org/projects/landscape-scenario-planning-tool

[36] Brophy, L.S. 2009. Effectiveness Monitoring at Tidal Wetland Restoration and Reference Sites in the Siuslaw River Estuary: A Tidal Swamp Focus. Green Point Consulting.

[37] Hodgson, C., and A. Spooner. 2016. The K'ómoks and Squamish Estuaries: A Blue Carbon Pilot Project; Final Report to North American Partnership for Environmental Community Action (NAPECA). 2016, Comox Valley Project Watershed Society.

[38] Khangaonkar, T., et al. 2021. Projections of algae, eelgrass, and zooplankton ecological interactions in the inner Salish Sea – for future climate, and altered oceanic states. *Ecological Modelling* 441: 109420. https://doi.org/10.1016/j.ecolmodel.2020.109420

cycle nutrients,[39, 40, 41] and serve as salinity buffers.[42, 43, 44] Blue carbon ecosystems are essential for coastal economies. The bounty of fish populations within these habitats contributes to the sustenance of fishing communities and food security. By supporting the life stages of Oregon's nearshore finfish,[45, 46, 47, 48, 49] and shellfish,[50, 51] marshlands, tidal forested wetlands, and eelgrass meadows play a critical role in driving the success of Oregon's nearshore commercial fisheries. Eelgrass meadows are designated as Essential Fish Habitat by the National Oceanic and Atmospheric Administration (NOAA), further supporting the inherent relationship between thriving wetlands and thriving fisheries. Additional co-benefits are briefly described below.

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[39] Ibid.

[40] Hejnowicz, A.P., et al. 2015. Harnessing the climate mitigation, conservation, and poverty alleviation potential of seagrasses: prospects for developing blue carbon initiatives and payment for ecosystem service programmes. *Frontiers in Marine Science* 2: 32. https://doi.org/10.3389/fmars.2015.00032

[41] Janousek, C., et al. 2019. Ecohydrological impacts of sea-level rise on flood protection and blue carbon sequestration in Pacific Northwest tidal wetlands. Oregon State University, Pacific Northwest National Laboratories; University of Oregon, Institute for Applied Ecology.

[42] Brophy, L.S. 2009. Effectiveness Monitoring at Tidal Wetland Restoration and Reference Sites in the Siuslaw River Estuary: A Tidal Swamp Focus. Green Point Consulting.

[43] David, A.T., et al. 2015. Wetland loss, juvenile salmon foraging performance, and density dependence in Pacific Northwest estuaries. *Estuaries and Coasts* 39(3): 767–780. https://doi.org/10.1007/s12237-015-0041-5

[44] Brophy, L.S., and S. van de Wetering. 2012. Ni-les'tun Tidal Wetland Restoration Effectiveness Monitoring: Baseline: 2010–2011. Corvallis, Oregon: Green Point Consulting, the Institute for Applied Ecology, and the Confederated Tribes of Siletz Indians.

[45] Brophy, L.S., and K. So. 2005. Tidal Wetland Prioritization for the Umpqua River Estuary. Green Point Consulting.

[46] Swedeen, P., et al. 2008. An ecological economics approach to understanding Oregon's coastal economy and environment. Audubon Society of Portland, Portland, Oregon, USA.

[47] Brophy, L.S., and M.J. Ewald. 2017. Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation into the future. MidCoast Watersheds Council.

[48] David, A.T., et al. 2015. Wetland loss, juvenile salmon foraging performance, and density dependence in Pacific Northwest estuaries. *Estuaries and Coasts* 39(3): 767–780. https://doi.org/10.1007/s12237-015-0041-5

[49] Hering, D.K., et al. 2010. Tidal movements and residency of subyearling Chinook salmon (*Oncorhynchus tshawytscha*) in an Oregon salt marsh channel. *Canadian Journal of Fisheries and Aquatic Sciences* 67(3). https://doi.org/10.1139/F10-003

[50] Brophy, L.S., and K. So. 2005. Tidal Wetland Prioritization for the Umpqua River Estuary. Green Point Consulting.

[51] Lellis-Dibble, K. A., K. E. McGlynn, and T. E. Bigford. 2008. Estuarine Fish and Shellfish Species in U.S. Commercial and Recreational Fisheries: Economic Value as an Incentive to Protect and Restore Estuarine Habitat. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-90, 94pp.

- **Coastal shoreline protection.** Beyond safeguarding coastal resources and associated economies, blue carbon ecosystems act as vital safety buffers, providing natural coastal shoreline protection against storms,[52, 53] erosion,[54, 55, 56] and flooding.[5758, 59, 60, 61]
- **Biodiversity support.** Blue carbon ecosystems provide vital wildlife habitat and ecological support, serving as nurseries and refuge areas for various marine species, while also promoting biodiversity and fostering resilient coastal ecosystems. This includes endangered Coho salmon, black brant, Stellar sea lions, elk, Dungeness crab, bay clams, English sole, brown rockfish, and migrating tundra swans.[62, 63, 64] Several of these species rely on estuarine ecosystems for survival, such as the sensitive black brant that relies almost entirely on eelgrass as a food source.[65]
- **Tourism and recreation.** Blue carbon habitats attract tourists, providing economic opportunities for coastal regions while enriching local cultures through recreational and aesthetic values, ecotourism experiences, and traditional practices closely intertwined

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[52] Swedeen, P., et al. 2008. An ecological economics approach to understanding Oregon's coastal economy and environment. Audubon Society of Portland, Portland, Oregon, USA.

[53] Chastain, S.G., K. Kohfeld, and M.G. Pellatt 2018. Carbon stocks and accumulation rates in salt marshes of the Pacific Coast of Canada. *Biogeoscience*s *Discuss.* 1-45pp. https://doi.org/10.5194/bg-2018-166

[54] Hodgson, C., and A. Spooner. 2016. The K'ómoks and Squamish Estuaries: A Blue Carbon Pilot Project; Final Report to North American Partnership for Environmental Community Action (NAPECA). 2016, Comox Valley Project Watershed Society.

[55] Chastain, S.G., K. Kohfeld, and M.G. Pellatt 2018. Carbon Stocks and Accumulation Rates in Salt Marshes of the Pacific Coast of Canada. *Biogeoscience*s *Discuss.* 1–45pp. https://doi.org/10.5194/bg-2018-166

[56] Crooks, S., et al. 2014. Coastal Blue Carbon Opportunity Assessment for the Snohomish Estuary: The Climate Benefits of Estuary Restoration. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries. February 2014. http://dx.doi.org/10.13140/RG.2.1.1371.6568

[57] Swedeen, P., et al. 2008. An ecological economics approach to understanding Oregon's coastal economy and environment. Audubon Society of Portland, Portland, Oregon, USA.

[58] Hodgson, C., and A. Spooner. 2016. The K'ómoks and Squamish Estuaries: A Blue Carbon Pilot Project; Final Report to North American Partnership for Environmental Community Action (NAPECA). 2016, Comox Valley Project Watershed Society.

[59] Janousek, C., et al. 2019. Ecohydrological impacts of sea-level rise on flood protection and blue carbon sequestration in Pacific Northwest tidal wetlands. Oregon State University, Pacific Northwest National Laboratories; University of Oregon, Institute for Applied Ecology

[60] Chastain, S.G., K. Kohfeld, and M.G. Pellatt 2018. Carbon Stocks and Accumulation Rates in Salt Marshes of the Pacific Coast of Canada. *Biogeoscience*s *Discuss.* 1–45pp. https://doi.org/10.5194/bg-2018-166

[61] Crooks, S., et al. 2014. Coastal Blue Carbon Opportunity Assessment for the Snohomish Estuary: The Climate Benefits of Estuary Restoration. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries. February 2014. http://dx.doi.org/10.13140/RG.2.1.1371.6568

[62] Brophy, L.S., and M.J. Ewald. 2017. Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation into the future. MidCoast Watersheds Council.

[63] Brophy, L.S., and S. van de Wetering. 2012. Ni-les'tun Tidal Wetland Restoration Effectiveness Monitoring: Baseline: 2010-2011. Corvallis, Oregon: Green Point Consulting, the Institute for Applied Ecology, and the Confederated Tribes of Siletz Indians.

[64] Brophy, L.S., and K. So. 2005. Tidal Wetland Prioritization for the Umpqua River Estuary. Green Point Consulting.

[65] Moore, J.E., et al. 2004. Staging of Pacific flyway brant in relation to eelgrass abundance and site isolation, with special consideration of Humboldt Bay, California. *Biological Conservation* 115(3): 475–486. https://doi.org/10.1016/S0006-3207(03)00164-2

with the coastal environment. For example, in 2019, visitors to Tillamook County alone spent $240 million.[66]

- **Cultural services.** These habitats have long provided identity, cultural practice, and food provisioning for Tribal Nations and support the coastal way of life for coastal residents.

Forests

There are numerous co-benefits associated with forest practices. For example, protecting forest lands from conversion, particularly those that have low fire vulnerability and have both high present-day soil carbon stocks and aboveground carbon stocks, provides terrestrial vertebrate habitat for threatened and endangered species as well as a buffer against climate change stressors.[67] Some practices with clear ecological benefits may even release carbon in the short term and the guidance provided here is not intended override the importance of managing for resilient, climate adaptive forests.

- **Biodiversity preservation.** Healthy forests support a wide array of flora and fauna, contributing to biodiversity conservation and the protection of endangered species.
- **Air and water quality improvement.** Trees filter pollutants from the air and help purify water sources, benefiting both human health and the environment.
- **Recreation and tourism.** Well-managed forests provide recreational opportunities and attract tourists, generating economic benefits for nearby communities.

Rangelands

Sustainable grazing practices have significant co-benefits that reduce the vulnerability of rangelands to climate change stressors and enhance rangeland ecosystem function. Sustainable grazing practices support diverse plant communities, the development of healthy plant roots, plants that maintain cover, and soil forming processes. These co-benefits improve soil physical, chemical, and biological properties, leading to enhanced forage production, enhanced profitability for ranchers, and rehabilitation of degraded lands.

- **Erosion control.** Proper grazing management helps prevent soil erosion, maintaining the integrity of rangeland ecosystems.
- **Biodiversity support.** Healthy rangelands provide critical habitats for various plant and animal species, including many native and migratory species.
- **Livestock resilience.** Sustainable rangeland management can improve livestock health and productivity, benefiting ranchers and their communities.

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[66] Dean Runyan Associates. 2019. Oregon Travel Impacts, 1992–2018. Prepared for the Oregon Tourism Commission.

[67] Buotte, P.C., et al. 2019. Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States. *Ecological Applications* 30(2): e02039. https://doi.org/10.1002/eap.2039

Urban and Suburban Areas

Actions that reduce GHG emissions and sequester and store carbon in urban and suburban areas benefit the environment and public health and contribute to equity. These co-benefits include cleaner air, expanded green space, and noise reduction.[68] Safe and active transportation networks, accessible public open spaces that create opportunities for engagement with the outdoors and social interaction, accessible public transportation, low-carbon healthy food availability, sanitation, and clean air and water are examples of co-benefits of climate resilient practices and strategies in urban and suburban areas.[69]

- **Urban heat island mitigation.** Urban green spaces and tree canopy coverage can lower temperatures, mitigating the urban heat island effect and reducing energy consumption for cooling.
- **Improved air quality.** Trees and green infrastructure in urban areas filter pollutants and enhance air quality, leading to better respiratory health for residents.
- **Flood prevention.** Green infrastructure, such as rain gardens and bioswales, can manage stormwater runoff and reduce the risk of flooding during heavy rainfall events.
- **Community well-being.** Access to nature in urban environments positively impacts mental health, physical activity, and overall well-being of residents.

2.3 Community Impact Metrics

The Commission's NWL Proposal recommended that Oregon establish community impact metrics:

> "Community impact metrics should be developed to inform and evaluate the co-benefits and impacts of NWL strategies. Environmental justice considerations should be prioritized throughout carbon sequestration programs, in line with recommendations from Oregon's Environmental Justice Task Force, the Racial Justice Council and Oregon's Interagency Workgroup on Climate Impacts to Impacted Communities. The community impact metrics and goals should be designed to evaluate the benefits and burdens associated with different strategies, practices, and programs. These metrics should include effects on jobs, local economies, public health, and access to programs, among other factors."

To prepare for the development of community impact metrics, INR staff conducted a literature review, defining the core elements and criteria to consider when developing a community impact metrics framework, numerous tradeoffs that can be considered (e.g., ecological, environmental,

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[68] Johnson, L., et al. 2022. Environmental, health, and equity co-benefits in urban climate action plans: A descriptive analysis for 27 C40 member cities. *Front. Sustain. Cities* 4: 869203 https://doi.org/10/3389/frsc.2022.869203

[69] De Nazelle, et al. 2021. Urban climate policy and action through a health lens – An untapped opportunity. *International Journal of Environmental Research and Public Health* 28: 12516. https://doi.org/10.3390/ijerph182312516

economic, societal, and political) as well as specific examples of metrics and indicators (Appendix G). Figure 6 illustrates the core elements of a framework as well as examples of place-based community impact socioeconomic metrics.

The Advisory Committee reviewed the literature review and proposed a suite of metrics for NWL that would likely be foundational to all Oregon communities (i.e., would be considered relevant by state agencies, local governments and others as they implement programs and practices to reduce GHG emissions and enhance carbon sequestration for NWL across a diversity of Oregon communities). Figure 7 illustrates the subset of community metrics proposed by the Advisory Committee.

Natural resource state agency representatives will be reviewing these metrics, comparing them to metrics that are currently using, and considering which of these metrics, if any, would align with work each agency is doing, or planning to do.

Examples of Place-based Community Impact Socioeconomic Metrics

The Framework

Impact metrics measure the benefits and burdens on communities associated with strategies for carbon sequestration in natural and working lands and waters (Senate Bill 1534). Impact measurement is a process of collecting and analyzing data to assess the effect of a program, intervention, or policy on a particular population.[1] Community impact metrics measure the benefits and burdens associated with different strategies, practices, and programs that may inform and evaluate the co-benefits and impacts of GHG emissions reductions and increased carbon storage strategies on natural and working lands.[2] Science-based targets should incorporate consistent and continual reporting processes, transparency in data sources and calculation methodologies, and interoperability with evolving standards and regulations.[3]

Criteria to consider when developing social and cultural metrics[4]:

- Incorporate impacts based on discussions with stakeholders and the recognition of both individual and community-level effects.
- Incorporate proxy and constructed metrics to help overcome measurement difficulties and provide information about context-specific impacts
- Seek to meaningfully engage the diverse potentially affected interests
- Develop measures that are readily understood, concise, and operational to facilitate implementation in decisions.
- Adopt a values-focused approach that allows for personal experience and facilitates analysis of alternatives.
- Document value trade-offs and key risk tolerances.
- Adopt best practices regarding risk and impact communication to highlight impact assessments.
- Incorporate stakeholder perceptions into assessments and inventories.

[1]https://www.sopact.com/

[2]https://www.oregon.gov/lcd/Commission/Documents/2021-11_Item-10_OGWC_Attachment-A_Natural-and-Working-Lands-Carbon-Sequestration-and-Storage-Proposal-OGWC.pdf

[3]https://tideline.com/wp-content/uploads/2022/10/Tideline_Truth-in-Climate-Impact-FINAL-Oct-2022.pdf
[4] Bessette and Gregory (2020)

Economic Stability

Employment
- Reductions in land sector unemployment/ increased employment
- Equitable access to green job opportunities
- Improved access to land-sector based education and training
- Investments in workforce development and local skilled jobs
- Short- and long-term sufficiency wage land sector jobs created and representative of the diversity of local communities
- Capacity of land sector workforce and number of workers
- Contribution of natural and working lands to the state's economy and employment
- # of individuals receiving land sector-based job training

Income
- Increases in medium household income
- Increased local income in communities within and adjacent to natural and working lands

Business Growth
- % change in business establishments
- $ invested in projects that enhance carbon storage and reduce GHG emissions
- Tax incentives available to landowners to support GHG emission reductions and support carbon storage
- Increase in tourism levels

Poverty and low-income
- % of children under 18 years of age in poverty
- No increase in low-income households in communities\

Energy
- Lower consumer energy bills

Neighborhood/ Physical Environment

Housing
- Increases in home ownership across racial and ethnic groups
- Population spending more than 30% of income on housing
- # subsidized housing units per 1,000
- % vacant housing units
- Worker access to housing in the community in which they work
- # of new green roofs

Transportation
- Access to all ages and abilities bicycle network
- % of community members with access to high-frequency public transportation choices within 1/2 mile

Parks
- Equitable distribution and access to parks and open spaces (including walkability)
- Green corridors and connections as well as buffers that provide access to nature and protection and relief from climate hazards
- Proximity to green spaces and green infrastructure within developed lands
- # of citizens benefitting from and using green corridors
- Increase in scenic values

Food

Food security
- % of population that is food insecure
- # of people whose calorie intake falls below FAO-defined specified values

Food quality
- Equitable access to healthy options (fresh food)

Education

Literacy
- % of 3rd graders reading at grade level

Training
- Access to technological and other training for farmers
- Access to vocational training

High School Education
- % CCSD high schools

Higher Education
- Population aged 25 and older with a bachelor's degree or higher

Health

Medical bills
- % of population 18-64 years of age with health insurance
- # of primary care physicians per 100,000

Life expectancy/quality
- Increases in life expectancy of residents
- Fewer air quality-related health problems and impacts

Workers
- Protection of workers to climate hazards

Hospital Visits
- # of asthma emergency department visits by children

Sustainability

Water
- # gallons per capita per day
- Enhanced water quality
- Volume of water reused
- # of violations of Safe Water Drinking Act
- Flood risk reduction

Recycling
- % of municipal waste recycled
- Reduction in total waste disposed

Air quality
- % of good air quality days annually
- Fewer days of unhealthy air quality
- Air pollution that does not exceed NAAQS and standards
- Reduced haze and improved visibility

Incentives
- Annual investment in weatherization, electric heat pump, and community solar incentive/subsidy programs
- Support for farmers to implement climate-resilient agricultural practices
- Amount of consumer incentives that reward people for taking steps to reduce their use of fossil fuels

Fossil Fuel Alternatives
- % of land sector-based businesses that supply all or a portion of their electrical needs with solar, or alternative climate-friendly energy sources
- # of electric vehicle charging stations

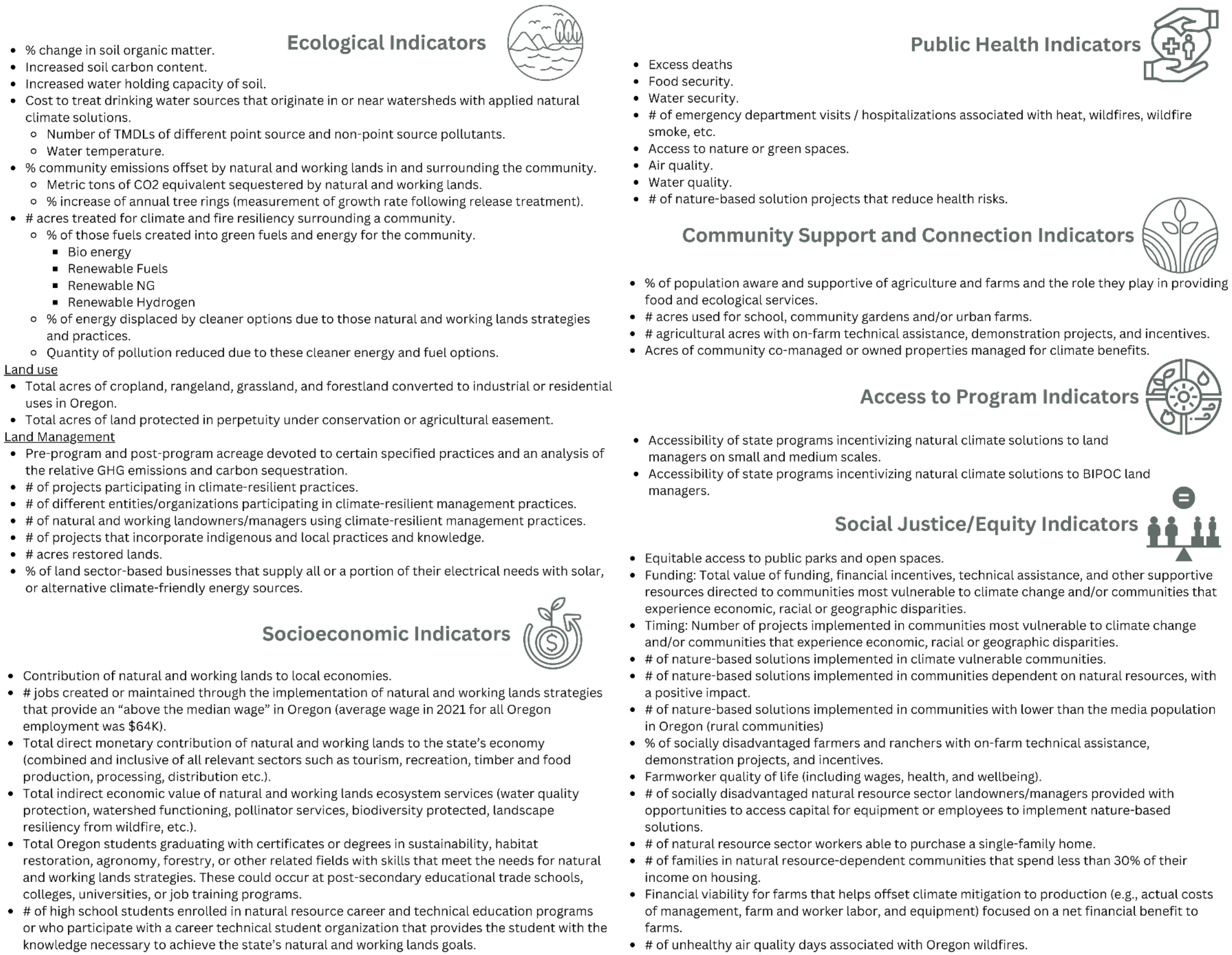
Temperature
- Relative decrease in local temperatures during summer period

Management, ownership, and capacity

Public engagement
- Capacity and access for broad participation in land sector-based scoping, planning, design, and implementation
- Inclusion of small farmers in program development and design
- Development of shared decision-making frameworks with tribal partners
- Incorporation of traditional ecological knowledge and tribal expertise into management
- Strengthened partnerships with RCDs and SWCDs to identify needs and opportunities of small farms, woodlands, and landowners
- % of private property owners and developers that implement climate change preparation measures (e.g., reducing impervious areas)

Land ownership
- Diverse land ownership and management
- Support for diverse organizations and individuals to own, manage, and steward land

Figure 6. Examples of place-based community impact social metrics.



Ecological Indicators

- % change in soil organic matter.
- Increased soil carbon content.
- Increased water holding capacity of soil.
- Cost to treat drinking water sources that originate in or near watersheds with applied natural climate solutions.
  - Number of TMDLs of different point source and non-point source pollutants.
  - Water temperature.
- % community emissions offset by natural and working lands in and surrounding the community.
  - Metric tons of CO2 equivalent sequestered by natural and working lands.
  - % increase of annual tree rings (measurement of growth rate following release treatment).
- # acres treated for climate and fire resiliency surrounding a community.
  - % of those fuels created into green fuels and energy for the community.
    - Bio energy
    - Renewable Fuels
    - Renewable NG
    - Renewable Hydrogen
  - % of energy displaced by cleaner options due to those natural and working lands strategies and practices.
  - Quantity of pollution reduced due to these cleaner energy and fuel options.

Land use

- Total acres of cropland, rangeland, grassland, and forestland converted to industrial or residential uses in Oregon.
- Total acres of land protected in perpetuity under conservation or agricultural easement.

Land Management

- Pre-program and post-program acreage devoted to certain specified practices and an analysis of the relative GHG emissions and carbon sequestration.
- # of projects participating in climate-resilient practices.
- # of different entities/organizations participating in climate-resilient management practices.
- # of natural and working landowners/managers using climate-resilient management practices.
- # of projects that incorporate indigenous and local practices and knowledge.
- # acres restored lands.
- % of land sector-based businesses that supply all or a portion of their electrical needs with solar, or alternative climate-friendly energy sources.

Socioeconomic Indicators

- Contribution of natural and working lands to local economies.
- # jobs created or maintained through the implementation of natural and working lands strategies that provide an “above the median wage” in Oregon (average wage in 2021 for all Oregon employment was $64K).
- Total direct monetary contribution of natural and working lands to the state’s economy (combined and inclusive of all relevant sectors such as tourism, recreation, timber and food production, processing, distribution etc.).
- Total indirect economic value of natural and working lands ecosystem services (water quality protection, watershed functioning, pollinator services, biodiversity protected, landscape resiliency from wildfire, etc.).
- Total Oregon students graduating with certificates or degrees in sustainability, habitat restoration, agronomy, forestry, or other related fields with skills that meet the needs for natural and working lands strategies. These could occur at post-secondary educational trade schools, colleges, universities, or job training programs.
- # of high school students enrolled in natural resource career and technical education programs or who participate with a career technical student organization that provides the student with the knowledge necessary to achieve the state’s natural and working lands goals.

Public Health Indicators

- Excess deaths
- Food security.
- Water security.
- # of emergency department visits / hospitalizations associated with heat, wildfires, wildfire smoke, etc.
- Access to nature or green spaces.
- Air quality.
- Water quality.
- # of nature-based solution projects that reduce health risks.

Community Support and Connection Indicators

- % of population aware and supportive of agriculture and farms and the role they play in providing food and ecological services.
- # acres used for school, community gardens and/or urban farms.
- # agricultural acres with on-farm technical assistance, demonstration projects, and incentives.
- Acres of community co-managed or owned properties managed for climate benefits.

Access to Program Indicators

- Accessibility of state programs incentivizing natural climate solutions to land managers on small and medium scales.
- Accessibility of state programs incentivizing natural climate solutions to BIPOC land managers.

Social Justice/Equity Indicators

- Equitable access to public parks and open spaces.
- Funding: Total value of funding, financial incentives, technical assistance, and other supportive resources directed to communities most vulnerable to climate change and/or communities that experience economic, racial or geographic disparities.
- Timing: Number of projects implemented in communities most vulnerable to climate change and/or communities that experience economic, racial or geographic disparities.
- # of nature-based solutions implemented in climate vulnerable communities.
- # of nature-based solutions implemented in communities dependent on natural resources, with a positive impact.
- # of nature-based solutions implemented in communities with lower than the media population in Oregon (rural communities)
- % of socially disadvantaged farmers and ranchers with on-farm technical assistance, demonstration projects, and incentives.
- Farmworker quality of life (including wages, health, and wellbeing).
- # of socially disadvantaged natural resource sector landowners/managers provided with opportunities to access capital for equipment or employees to implement nature-based solutions.
- # of natural resource sector workers able to purchase a single-family home.
- # of families in natural resource-dependent communities that spend less than 30% of their income on housing.
- Financial viability for farms that helps offset climate mitigation to production (e.g., actual costs of management, farm and worker labor, and equipment) focused on a net financial benefit to farms.
- # of unhealthy air quality days associated with Oregon wildfires.

Figure 7. Community metrics proposed by the Advisory Committee.

2.4 Workforce, Training, and Economic Benefits Analysis

The Commission's Biennial Report to the Oregon Legislature (2020) documented the potential of NWL to reduce Oregon emissions by an additional 18 percent through climate-smart policies, programs, and practices that capture and store carbon. Avoiding conversion of NWL, restoring habitats, mitigating fire effects, and modifying land management practices can contribute to climate mitigation and/or adaptation, while providing economic, health, and environmental co-benefits, to name a few. Achieving these goals requires a trained, skilled, and diverse workforce throughout Oregon.

The OGWC Proposal highlights the need for increasing the pace and scale of workforce development and training as well as technical assistance across numerous Oregon natural and working land sectors. New and expanded land sector workforce programs are needed that create pathways that ensure family-wage employment for all people living and working in communities with current and potential land sector employment (consider communities of color as well as all historically underserved communities).

To address this need, INR developed a Request for Information (RFI) (Appendix H) to seek qualified entities to provide methodology and estimated costs to conduct a Workforce Development and Training Needs Assessment and Gap Analysis of NWL Sectors in Oregon to evaluate current technical assistance capacity and projected future technical assistance capacity needs associated with implementing the strategies outlined in the OGWC Proposal for achieving NWL sequestration and storage outcomes. The Commission sought to identify recommendations for actions that should be taken by the Legislature, agencies, academic institutions, and others to address gaps in workforce training and development that currently serve as programmatic and participation barriers to implementing climate-smart protection,[2] restoration, and land management policies, programs, and practices. This would inform the development of recommendations to advance workforce development opportunities that maintain, or grow, critical NWL sectors responsible for achieving sequestration and storage goals while incorporating training and technical programs that promote diversity, equity, and inclusion in Oregon's economy while implementing, and acting with urgency, science-based land sector strategies to mitigate the effects of climate change stressors.

The process used to develop the RFI was to conduct a literature review of entities throughout the United States that had previously conducted these types of analysis, can compile information on core elements of those analyses. INR staff then reached out to workforce development staff in the State of Oregon, asked them to review the draft RFI, and either provide written comments or participate in small group discussions about the RFI. Comments and recommendations from workforce development experts were incorporated into the draft RFI.

The objectives of the assessment and gap analysis were to conduct a comprehensive assessment and gap analysis that defines workforce needs associated with achieving OGWC Proposal NWL goals, including conducting an inventory of existing resources, analyzing gaps, and developing an implementation plan for action, with metrics to assess implementation success. Mandatory elements of the assessment and gap analysis included:

- Identifying other states conducting similar studies and minimizing duplicative work.
- Compiling baseline information on Oregon's businesses, industries and workers in the NWL economy by land sector segment and estimating growth trajectories.
- Inventorying existing resources, assessing Oregon's capacity to recruit, prepare, place, and or retrain, retain, and advance workers for jobs that are created, or transformed, by GHG reduction and carbon sequestration goals on NWL.
- Projecting future land sector workforce needs in current and emerging markets; and
- Analyzing workforce and labor market dynamics that may affect Oregon's ability to achieve OGWC Proposal goals.

The objective included the development of a Quality Jobs Framework that includes an implementation roadmap of short- and long-term strategies to bridge workforce development and training gaps and achieve OGWC Proposal goals for Oregon's five land sectors. This would not result in the creation of a new program, or a program that operates parallel to existing programs. Rather, the intent is to streamline and accelerate solutions through partnerships and knowledge share with a new, interconnected system.

The Oregon Department of Energy posted the RFI (Appendix H) in August of 2023 and provided six weeks for responses. The results of the RFI will inform a proposed methodology for conducting the workforce, training, and economic benefits analysis as well as understand potential costs for conducting the work.

2.5 Proposed Methodologies for the Greenhouse Gas (GHG) Inventory on NWL in Oregon

2.5.1 Goal

The goal of a GHG inventory for Oregon's NWL is to estimate the amount of carbon dioxide and other GHGs (CO_2, CH_4, N_2O) that are being removed from and released to the atmosphere from Oregon's NWL in a given inventory period. This includes estimating the amount of carbon stored in carbon pools on Oregon's NWL (e.g., carbon stocks) as well as the amount of carbon being moved from one pool to another for the given inventory period. This document describes two potential methodologies that the Oregon Global Warming Commission can adopt to meet the state's climate action goals. The proposed methodologies have been developed by INR to create an Oregon NWL inventory consistent with IPCC Guidelines for National GHG Inventories. The proposals herein adhere to the concept of "good practice," which has been defined by IPCC as "a set of procedures intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that they are precise so far as practicable."

The IPCC describes three methodological tiers for estimating GHG emissions and removals. Tier 1 represents the minimum set of information needed to complete inventories based on default values from global literature reviews, whereas Tiers 2 and 3 represent marked improvements compared to Tier 1 estimates in terms of certainty and sophistication by using estimates based on national, regional, and localized data sets. Tier 3 IPCC estimates require the inclusion of modeled, local processes that impact emissions and lead to increased precision of GHG estimates.[70] Methodologies in all three tiers are generally estimations, rather than direct measurements, of GHG emissions. The most accurate emissions quantification method that is available and practical should be used for each emissions estimate. For a state NWL GHG Inventory, this may mean using Tier 1 estimates for one sector and using Tier 3 estimates for another, depending on the information available.

2.5.2 Key Definitions

1. "Carbon stock and fluxes" refers to the total assemblage of greenhouse gases (i.e., CO_2, CH_4, N_2O) translated into CO_2 equivalents. Carbon stock refers to the carbon (CO2e) within a particular carbon pool at a specified time, while flux refers to the amount of carbon (CO2e) exchanged between carbon pools over a specified time.

2. "Ecosystem carbon stocks" are the sum of carbon stocks across the following carbon pools in a given ecosystem.
   The IPCC defines the following pools for GHG accounting (IPCC 2006): (1) above-ground (trunks, stems, foliage) and (2) below-ground (roots) live vegetation pools, (3) dead wood, (4) litter, and (5) soil organic matter. NWL inventories also often include harvested wood products

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[70] Eggleston, S., et al. 2006. Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

(HWP) as a separate forest biomass pool, defined as all wood material that leaves a harvest site. HWP stocks and fluxes will be reported at a statewide or regional scale, rather than by pixel as with the other pools.

Appendix I is a comprehensive list of NWL GHG inventory definitions developed for Oregon.

2.5.3 Assumptions based on the Commission and the Proposals that Funded this Project

The methodology developed will be:

- Compatible with national and international methods for tracking changes in GHGs, and if possible, compatible with adjacent state methodologies; and,
- Developed by classifying and mapping Oregon's NWL into seven categories, of which five will be included in the initial inventory.

The data used to create these land category maps should allow for change detection (e.g., transition from one land category to another) and aid in estimation of carbon stocks and fluxes. These Oregon land use/land cover categories include:

1. Forests and Woodlands (*IPCC i*), defined in Oregon as all forests and woodlands with greater than 20% forest cover, at whatever scale the land cover is sampled or mapped.
2. Cultivated Farmlands (*IPPC ii*) includes for example, annual crops, perennials, orchards, nurseries, vineyards, improved planted pastures.
3. Rangelands (*IPPC iii*) are native or introduced shrublands, grasslands, hayed native meadows, and wet meadows including chapparal, savannas and woodlands with tree cover below 20%.
4. Urban and Suburban Areas (IPPC v.) represent settlements and developed areas.
5. Blue Carbon (part of *IPPC iv*) are those wetlands with tidal influence, including salt marsh, estuaries, and intertidal and nearshore marine areas.

These categories may be further segmented into subcategories to facilitate measurement or change detection. A sixth category (the remainder of the *IPCC iv. Wetlands* type), represents lakes, streams, and freshwater wetlands, will be addressed in future work. The last category, *IPCC vi. Other land in Oregon* represents snow, ice and bare rock (unvegetated lava flows, active temporary mines and gravel pits), and would be addressed in the landscapes in which they occur. By convention, changes in carbon stocks associated with a land change to a new category are reported in the new category. For example, the carbon stock change associated with converting cropland to urban land is reported in the Urban and Suburban areas category.

The inventory should:

- Establish a spatially explicit baseline for carbon stocks, emissions, and sequestration on NWL. Each of the proposed methodologies should describe decisions related to spatial resolution, emissions that are part of the baseline, and the current rates of sequestration on different working lands.

- Allow the state to track changes in carbon stocks and emissions through time. Thus, it needs to be temporally explicit and updatable, i.e., it needs to use datasets that are consistently updatable on a regular basis, allow continual improvements as new data becomes available, and quantify GHG changes. Decisions on the frequency of updates and reporting (either year-to-year change vs. two, three, or five-year averages) need to be determined.
- Track the impact of management interventions and disturbances on emissions through time (e.g., attribute changes in emissions to various causes), which will likely vary by land use category.
- When high resolution (< 30meter pixels) data is used, the inventory will provide public reporting of carbon stocks and fluxes only at a county or regional scale, and not at individual pixel levels to assure that information obtained from private landowners is protected.

2.5.4 Basic Methodology Option

Mapping Land Cover

Oregon's NWL Inventory requires accurate mapping of land use and land cover across the state. The Basic Methodology proposes to use existing Landsat (30-m) based data to differentiate coarse scale land use and land cover maps (e.g., NLCD, LANDFIRE EVT). These publicly available datasets describing land cover are used for various applications and differ in some major attributes which could impact their utility for Oregon's NWL inventory. For example, the NLCD contains 16-land cover classes and is produced every 5 years (Homer et al. 2015) while the LANDFIRE EVT dataset includes nearly 600 land cover classes across the United States and is updated on a biennial basis (Nelson et al. 2013).

We propose using the LANDFIRE EVT dataset to develop 'masks' of each of the 5 land cover categories described above. Within these land cover categories, NWL will be further subdivided by climate, soil type, management, and/or ecological regions (i.e., strata) appropriate for the estimation of more granular carbon stock and GHG flux. For example, sage-steppe biomass can vary due to different management factors or biophysical limitations and using only the coarsest land cover class would obscure this variation in carbon density and emissions and lead to increased uncertainty in GHG estimates. During the initial NWL GHG inventory, we recommend the State establish upfront rules delineating the accounting of carbon stocks and fluxes in forested tidal wetlands (i.e., should it be counted within the blue carbon or forest land category) to avoid double counting these ecosystems.

Carbon Stock and GHG Inventory Methods by Land Categories

Forests and Woodlands

In 2019, Oregon reported forest ecosystem carbon stocks and flux based on the USDA Forest Service Forest Inventory and Analysis (FIA) plot data and analysis.[71] In this report, forest carbon stocks and fluxes were reported for the period 2001–2010 and accounted for forest carbon stocks in aboveground live biomass, aboveground dead biomass, belowground biomass, and soil carbon. The Forest Carbon inventory will be updated in 2023 to provide a comparison to the 2001 – 2010 baseline period using remeasurements from 2011–2020. The FIA data and associated reporting provide important calibration for remotely sensed carbon monitoring systems.[72] However, in the current FIA sampling plan, plot data are not updated with sufficient frequency to be the sole data used to evaluate changes in carbon stocks and estimate GHG emissions and removals in forests and woodlands in Oregon.

The Oregon NWL inventory proposes using a combination of regional aboveground biomass maps which are calibrated using FIA field plot data to evaluate changes in forest carbon stocks during reporting periods. These maps provide localized aboveground biomass carbon data (Tier 3) which can be combined with regional forest soil carbon data (Tier 2) and, when combined with Landtrendr disturbance mapping, can be used to provide more rapid estimates of change and causation.[73] Three published datasets use the FIA plots as calibration data and predict forest aboveground biomass in 30-m Landsat pixels. Each of these would meet the goals of Oregon's NWL inventory in terms of data availability, transparency, consistency, and completeness for tracking changes in forests and woodlands. Both LEMMA-GNN and eMapR use Gradient Nearest Neighbor (GNN) imputation of forest vegetation combined with satellite imagery to provide annual maps of aboveground live tree and snag biomass. The LEMMA-GNN data are available from 1990 through 2017, with planned annual updates (LEMMA 2020). eMapR links FIA plot data with Landtrendr disturbance to link those changes to disturbance and growth dynamics and are available for 1990–2017.[74] The PNW Carbon Monitoring System (CMS) combines plot-level forest biomass data with lidar data to predict aboveground biomass, bias-corrected using FIA plot data at the county-level.[75] These data are available annually for 2000–2017, with annual updates planned.

Next steps and potential improvements. A next step in NWL Inventory method development is to evaluate the CMS and GNN based biomass models to determine which will be the best fit with respect to the goals and needs of the Oregon NWL Inventory.

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[71] Christensen, G.A., et al. 2019. Oregon Forest Ecosystem Carbon Inventory: 2001–2016. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; Oregon Department of Forestry. https://www.oregon.gov/odf/forestbenefits/Pages/forestcarbonstudy.aspx

[72] Johnson, K.D., et al. 2014. Integrating forest inventory and analysis data into a LIDAR-based carbon monitoring system. *Carbon Balance and Management* 9. https://doi.org/10.1186/1750-0680-9-3

[73] Kennedy, R.E., et al. 2018. Implementation of the LandTrendr algorithm on Google Earth engine. *Remote Sensing* 10(5): 691. https://doi.org/10.3390/rs10050691

[74] Ibid.

[75] Hudak, A.T., et al. 2020. A carbon monitoring system for mapping regional, annual aboveground biomass across the northwestern USA. *Environmental Research Letters* 15(9). https://doi.org/ 10.1088/1748-9326/ab93f9

Because FIA plot data are critical for training and validating these data, the potential exists to increase the spatial and/or temporal resolution of FIA plot data by densification of the plot network, especially across non-Federal lands, which have more statistical uncertainty in the carbon stocks and fluxes,[76] and/or by decreasing the interval between resampling.

Cultivated Farmlands

Cultivated farmlands have a large impact on the carbon cycle and how they are managed determines the amount and length of time carbon is stored and the amount of carbon stored in and emitted or removed from cultivated farmlands depends on crop type, management practices, and soil and climate variables.[77, 78, 79] For example, annual crops are harvested each year so there is negligible long-term storage of carbon in biomass. However, perennial woody vegetation in orchards, vineyards, and agroforestry systems can store significant carbon in long-lived biomass, the amount depending on species type and cultivar, density, growth rates, and harvesting and pruning practices.

Initial proposed methods: use Cropscape to map crop types, use IPCC Tier 1 carbon and GHG estimates based on crop type. Inventory method will account for aboveground live biomass in woody/orchard/vineyard crops, most likely also using default IPCC Tier 1 carbon and GHG estimates. The estimates may be improved by conducting a thorough literature and data review to develop regionally specific regression equations for the woody/orchard/vineyard crops.

Rangelands

For lands mapped as rangelands, vegetation composition will be estimated by combining estimates from the Rangelands Analysis Platform which provides percent coverage of annual and perennial forbs/grasses as well as percent coverage of shrubs and trees. Biomass densities (Mg ha-1) will be approximated for grasses and herbaceous vegetation using the reported biomass in the Rangeland Analysis Platform. Biomass densities for the shrub and tree component of rangelands will be compiled from reference datasets and published literature and belowground carbon will be estimated using regionally specific allometric equations where possible. Biomass will be translated to CO2e using standard, published equations. In the absence of regionally specific estimates, default IPCC emission factors will be used.

Urban and Suburban Areas

Biomass densities in urban and suburban areas will be based on compilations from literature, urban tree inventories, and default IPCC emission factors will be used for the remaining pools.

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[76] Christensen, G.A., et al. 2019. Oregon Forest Ecosystem Carbon Inventory: 2001–2016. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; Oregon Department of Forestry. https://www.oregon.gov/odf/forestbenefits/Pages/forestcarbonstudy.aspx

[77] Burke, I. C., et al. 1989. Texture, climate, and cultivation effects on soil organic matter content in U.S. grassland soils. *Soil Science Society of America Journal* 53: 800–805. https://doi.org/10.2136/sssaj1989.03615995005300030029x

[78] Houghton, R.A., J.L. Hackler, and K.T. Lawrence. 1999. The U.S. carbon budget: Contributions from land-use change. *Science* 285: 574–578. https://doi.org/10.1126/science.285.5427.574

[79] Conant, R.T., et al. 2017. Grassland management impacts on soil carbon stocks: A new synthesis. *Ecological Applications* 27(2): 662-668. https://doi.org/10.1002/eap.1473

Blue Carbon

Coastal wetlands. The Oregon coastal wetlands GHG inventory closely follows the National Greenhouse Gas Inventory (NGGI) approach for including coastal wetlands.[80] The NGGI quantifies GHG emissions and removals from US coastal wetlands by: (1) defining the coastal, tidally-influenced land base, recognized as land below the elevation of the highest tides and estuarine open water bodies; (2) identifying land cover types within the coastal land area; (3) quantifying annual change in land-cover between 1990 and 2019; (4) assigning carbon (C) stocks, carbon accumulation rates, and methane (CH_4) or Nitrous Oxide (N_2O) emissions, as appropriate, to wetland classes to quantify GHG emissions and removals related to the land-cover change; and (5) summing to the respective subcategories of coastal wetlands that remained coastal wetlands and land that was converted to coastal wetlands to determine total emissions and removals.[81]

The Oregon coastal wetland GHG inventory relies on validated modeling of Oregon's estuary extents using NOAA Coastal Change Analysis Program (C-CAP) and Oregon's Coastal and Marine Ecological Classification Standard (CMECS) mapping[82, 83] and state-specific biomass and soil carbon data (Tier 3); regional tidal forested wetland biomass and DOM stocks (Tier 2); and will be updated with recently published local CH_4 emission factors (Tier 3).

Next steps and potential improvements. C-CAP is a good wall to wall dataset but there are many local-scale, more accurate maps for coastal wetlands in Oregon. For example, refined CMECS maps for Coos Bay are currently in development by the PNW Blue Carbon Technical group. Using these data alongside C-CAP would improve the areal estimates of coastal wetlands. CMECS provides one important validation dataset but having continued support of CMECS mapping would allow for improved change mapping.

Eelgrass beds are an integral blue carbon ecosystem; however, we lack data on the areal extent of eelgrass beds over time in Oregon. Mapping of eelgrass over time could be combined with default IPCC Tier 1 soil carbon accumulation values to assess soil carbon flux. Under IPCC GHG guidance, seagrass biomass carbon stocks are not accounted for unless regionally specific Tier 2 or Tier 3 data are available. Developing regionally specific estimates for eelgrass and other submerged aquatic vegetation could improve the coastal blue carbon portion of Oregon's NWL Inventory.

2.5.5 Advanced Methodology Option

1. The initial Oregon Carbon assessment, inventory and baseline would be created within two to three years and be updated subsequently every two years.

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[80] Beers, L., et al. 2021. Incorporating coastal blue carbon data and approaches in Oregon's first generation natural and working lands proposal. White paper submitted to the Oregon Global Warming Commission. 49pp. https://www.pnwbluecarbon.org/_files/ugd/43d666_1859316df7ef415db84fd5d29f6b1d20.pdf

[81] Crooks, S., et al. 2018. Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory. *Nature Climate Change* 8(12): 1109–1112. https://doi.org/10.1038/s41558-018-0345-0

[82] Lanier, A., et al. 2014. Core CMECS GIS Processing Methods: Oregon Estuary Project of Special Merit.

[83] Lanier, A., et al. 2018. Core CMECS GIS Processing Methods: Oregon Estuary Project of Special Merit Phase II.

2. The carbon stock map/model would be created in 3 to 8 sections across the state to minimize variation across carbon process domains, climate and ecological variation, with the final regional maps then carefully integrated to address boundary variations. Likely regions could be the 8 regions defined in the Oregon Conservation Strategy and Natural Areas Plan, or three regions based on a modification of the 1994 Northwest Forest Plan which is currently being updated, the recently completed Oregon Sage Grouse plan, and the remaining areas of northeast Oregon.
3. The aboveground carbon stock inventory and fluxes would be created in a three-step process.
    a. Step 1. At the appropriate pixel scale the map, identify each of the seven land use type with their represented pixel.
        i. Blue Carbon areas would be spatially distinguished from the remainder of state lands and waters by boundaries identified in Oregon's framework estuary plan map. Blue carbon inventory methods would be applied to these areas. In subsequent inventories, changes that may occur that alter the distribution of blue carbon areas identified through improved data or physical changes from other factors (i.e., sea level rise), will be applied in future biennial updates.
        ii. All non-blue carbon inventories will focus on surface and above ground carbon stocks. Below-ground carbon stocks and fluxes changes will be estimated based on surface vegetation composition and structure until improved techniques allow for modeling these stocks and fluxes independently.
        iii. For the terrestrial, riparian and seasonally wet areas, below ground carbon stocks include mineral carbon, soil carbon as well as below ground biomass (e.g., roots, and other biotic materials), developed from models created with soil plot data which would include plots taken as deep as possible, at least 0.5 meters, or deeper as soils allow. The below ground carbon stock models would also use above ground vegetation data, land use information, and data on geology and soils.
    b. Step 2. Develop a map of existing carbon stocks, derived from a high-resolution state-wide map of vegetation composition, size, and structure. The vegetation map will be made using models which combine ground-based training data (i.e., plot-level species, cover, biomass information) with wall-to-wall predictor data (imagery and spatial data) and to determine the most likely vegetation everywhere without field data. These maps will initially be created at 30-meter resolution using Landsat pixels. All future updates would use an identified higher (10-meter or 20-meter) resolution, based on a combination of NAIP or other aerial Imagery, Sentinel and Landsat satellite imagery, and LiDAR data where available. All future 2 or 3-year updates would use this higher resolution scale to better inform carbon in small and irregularly shaped patches (e.g., riparian areas, forest edges, burned areas, and in developed or agricultural lands).
    c. Step 3. Attribute each pixel with current CO_2 flux rates, by attributing each pixel with the identified land uses (activity data), ancillary information (e.g., soil type) and then ultimately with predicted climate gas fluxes (i.e., emission factors). This step would

require consistency among the datasets. In many cases regionally relevant GHG flux data is in development and may not be able to provide a precise baseline. Where specific regional flux data are missing, default IPCC emission factors could be used and updated when improved data are available.

Data and Data Need Approximations

1. Training data includes state and national field inventories that include vegetation composition and when possible carbon stocks as part of their inventory. The majority of the data originates from two of the three regular federal vegetation inventories:
    a. The U.S. Department of Agriculture Forest Service (USFS) Forest Inventory Assessment (FIA) dataset, including regularly updated tree data on all forested lands in Oregon. For the initial assessment, all data from FIA plot data would be summarized. For the second and future assessments at finer scales, either only the central plot would be used, or if possible the three subplots would also be used as separate training points. FIA is currently researching methods to do this, and hopefully by 2025 these methods will be further developed for use in Oregon.
    b. The U.S. Department of Interior Bureau of Land Management (BLM) Assessment, Inventory, and Monitoring (AIM) plant composition dataset, which includes regular updates on all BLM lands in eastern Oregon. AIM plots will include carbon estimates from the BLM eventually, but currently estimates will be developed in Oregon modeled from either a combination of soils and vegetation data, or attributed from the RAP, described in (c.) below.
    c. Data from the third national inventory, USDA Natural Resources Inventory (NRI), will need to be accessed indirectly through publicly released modeled products, such as the USDA Rangeland Analysis Platform (RAP). The RAP also models vegetation productivity from satellite data and BLM AIM data which can also be used to provide biomass estimates.
    d. No field data would be collected as part of this effort, although state and interagency federal cooperation should help inform the utility of existing inventories as well as potentially allow ongoing monitoring by state land management agencies (primarily Department of Environmental Quality (DEQ), Department of State Lands (DSL), Oregon Department of Forestry (ODF), Oregon Department of Fish and Wildlife (ODFW), and Oregon Parks and Recreation Department (OPRD)) to collect sufficient information that their field monitoring can be used to improve the inventory in areas without any federal ownerships.
2. A portion of the costs for the completion of the assessment derive from the assemblage and assessment of training data to assure that the data is in a format suitable for the assessment model, and that the data used for training accurately reflects vegetation present during the dates of the imagery used. Most of this cost will occur in the first two years, when the baseline and initial high-resolution assessment is developed. For subsequent updates, only

newly collected plots, or areas with known disturbances, will need to be evaluated, substantially reducing the costs of updates. A contractor (the equivalent of 0.5 FTE) will need to complete the initial field-data quality control assessment in the first biennium.

3. A second major portion of the cost relates to the initial aggregation and collection of the predictor data. These would include:
    a. A high resolution (1, 2, or 5 meter) digital elevation model developed from statewide LIDAR (Light Detection and Ranging) imagery, which will be available through Oregon's Department of Geology and Mineral Industries (DOGAMI) and the USDI Geological Survey (USGS) across all of Oregon except the Warm Springs Indian Reservation, by early 2024.
    b. For the initial assessment and baseline, statewide 30-meter Landsat data products, either edge matched within a modeling area, or modeled using stacks, will be developed by OSU (COEAS's) eMapR Lab. For the second assessment (the first at 10 meters), Landsat data will be augmented by Sentinel data at 20 and 10 meters.
    c. The State of Oregon and the USDA work together to update statewide Aerial Imagery every 2 or 3 years as part of the National Agricultural Imagery Program. High resolution vegetation texture information (texture metrics) derived from this dataset can be used to improve the 30-meter resolution initial map if the new imagery is available for use by 2024. It will be important to create the 10-meter pixel data map in 2026.
    d. Integrated regional soil maps statewide at the finest modeled scale possible across whatever regions are being modeled.
    e. Integrated regional geology maps at the finest modeled scale possible across a region.
    f. Integrated regional land use data at the finest scale available.
4. Additional costs will be incurred to combine the predictor and training data and create a model that identifies the composition, size and structure of the vegetation, and that converts this to CO_2e metric tons/pixel. To assist with this, likely land uses (activity data) can help inform biomass values with predicted climate gas fluxes (i.e., emission factors) to generate estimates of current CO_2 equivalent value per pixel. This step would require consistency among the datasets, and, in many cases, regionally relevant GHG flux data is in development and may not be able to provide a precise baseline. Where specific regional flux data are missing, default IPCC emission factors could be used, consistent with IPCC Tier 1 methods. These could be updated when improved data is available.
    a. Depending on the accuracy requirements of the stock reporting, standing dead (trees or otherwise) and dead trees, in particular, may be worth modeling explicitly.
    b. For managed working lands where biomass is regularly removed (i.e., forests, orchards), understanding the ultimate destination of the biomass and the length of persistence would improve the results.

References

IPPC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston, H.S., et al. (eds.) Published: IPPC, Switzerland. https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Buendia, C., et al (eds). Published: IPCC, Switzerland. Volume 4: Agriculture, Forestry and Other Land Use. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Appendices

Appendix A. List of Deliverables Produced by the Project

- The Oregon Global Warming Commission NWL website. The original site, https://www.ogwcnaturalandworkinglands.org, was relocated to https://inr.oregonstate.edu/convening-science-advisory-projects/natural-working-lands in August 2023
- Oregon's NWL GHG inventory definitions
- Creation of an Advisory Committee
- Recommended practices and metrics to sequester and store carbon and reduce GHG emissions on Oregon's NWL
- A community impact metrics framework and recommended community impact metrics
- Proposed basic and advanced methodologies for the GHG inventory on NWL in Oregon
- Scope of work for a workforce training needs analysis
- Final report

Appendix B. Roles and Expectations for Individuals Associated with the NWL Project

Expectations

- Prepare for and attend all scheduled meetings.
- Be timely and responsive with communications.
- Be actively engaged in ensuring the fairness and transparency of the process.
- Actively participate in productive exchanges.
- Work collegially to produce quality deliverables.
- Openly acknowledge any potential conflict of interest.

Roles

Advisory Committee

Role. Provide current knowledge, critical thinking, analysis, and perspectives to inform the implementation of the Oregon Global Warming Commission 's Natural and Working Lands Proposal and the Institute for Natural Resource (INR) project deliverables.

- Actively participate in committee and sub-committee meetings.
- Review draft products developed by the Institute for Natural Resources (INR) and other technical experts on behalf of the Commission.
- Provide substantive input on draft products.
- Work collaboratively with other advisory committee members to understand issues and perspectives that represent the diversity of interests in Oregon.

Ad Hoc Technical Groups

Role. Gather, compile, and share scientific and technical expertise that informs the development of Natural and Working Lands project deliverables. Make recommendations for Advisory Committee consideration**.**

Group themes: agricultural landscapes, blue carbon, working forestlands, rangelands and grasslands, urban-suburban

- Work with/help advise INR Technical Leads produce intermediate and final products, including drafting requested information for the final report, if needed.
- Engage with INR Technical Ad Hoc Group Leads.
- Attend technical meetings.
- Conduct research, information gathering, and documentation of process/results/findings.
- Consider the input and perspectives of the advisory committee that may inform intermediate and final products.

Agency Advisory and Coordinating Committee (State Agencies Staff)

Role. Coordinate with INR and the Commission on the completion of the Natural and Working Lands deliverables.

- Respond to Advisory Committee requests for information.
- Make recommendations on agency activities, roles and responsibilities and opportunities for cross-agency collaboration to accelerate outcomes.
- Participate in ad hoc technical work groups, as requested and where appropriate.

Facilitator

Role. Ensure effective and efficient engagement among Advisory Committee members and within and among ad hoc technical groups, create and manage a website that shares the progress made achieving project milestones in a transparent and engaging way, facilitate a process that produces deliverables according to established milestones.

- Work with the INR Director and Commission representative to design Committee meetings.
- Design processes that will achieve the committee's goals and provide fairness and transparency for the process.
- Use group facilitation competencies to add value to the Advisory Committee’s and technical experts’ work – use time and space intentionally, evoke participation and creativity.
- Facilitate all Advisory Committee meetings and work group meetings.
- Steward the process and ensure impartial content.
- Report directly to the INR Director.
- Maintain confidentiality of information.

Oregon Global Warming Commission Representative

Role. Ensure an advisory committee is created that represents the diversity of land management interests and geographies in Oregon and participate throughout the process to ensure the Oregon Global Warming Commission Natural and Working Lands Proposal needs are met.

- Head the process for establishing an Advisory Committee, including any vacancies.
- Attend Advisory Committee meetings.
- As needed, work with the facilitator, Advisory Committee, INR Director, and INR staff.
- Share products from Advisory Committee with Commission members - review, discuss, and modify, as needed, prior to adoption.

Institute for Natural Resources Technical Leads

- Attend any technical meetings.
- Participate in Advisory Committee meetings when requested by facilitators.
- Conduct research, information gathering, and documentation of process/results/findings under the direction and advisement of the project Principal Investigator

- Work with the facilitator and the project team to help produce intermediate and final products including drafting requested information for the final report, if needed.

Institute for Natural Resources Director

- Attend meetings.
- Oversee project process, communications, and development of products.
- Hire and work with the facilitator.
- Provide guidance to INR staff in their logistical, research, and product delivery tasks.
- Work with the facilitator, the Advisory Committee, and OWGC representative to help resolve any issues that may arise in the implementation of the project.
- Serve as the point of contact, with the facilitator and the OWGC representative, regarding stakeholder interactions and communications.

Appendix C. NWL Advisory Committee Members

First Name	Last Name	Affiliation	Title
Jocelyn	Bridson	Tillamook County Creamery Association	Director of Environment & Community Impact
Mimi	Casteel	Hope Well Wine and Vineyard	Owner, Winegrower and Agricultural Consultant
Gary	Clarida	Retired	Forestry technician, sawyer, and equipment maintenance supervisor
Craig	Cornu	PNW Blue Carbon Working Group	Coordinator
Tyler	Ernst	Oregon Forest Industries Council	Policy Counsel, Manufacturing and Resources
Brian	Glaser	Ernest Glaser Farms	Farm Owner and Operator
Greg	Green	Ducks Unlimited	Director of Conservation Programs - PacNW
Ben	Hayes	Springboard Forestry, LLC/Hyla Woods	Manager/Principle
John	Hillcock	Wallowa County	Commissioner
Greg	Holmes	1000 Friends of Oregon	Working Lands Program Director/Southern Oregon Advocate
Megan	Kemple	Oregon Climate and Agriculture Network	Co-Director, Director of Policy Advocacy
Dylan	Kruse	Sustainable Northwest	Vice President
Debora	Landforce	2 Fox Farm	Partner
Jan	Lee	Oregon Association of Conservation Districts	Executive Director
Karen	Lewotsky	Oregon Environmental Council	Rural Partnerships Lead; Water Program Director
Nicole	Maness	Willamette Partnership	Partner, Resilient Habitat and Working Lands
Mike	McCarthy	McCarthy Family Farm, Owner; Parkdale Valley Land Trust, President; Oregon Farm Bureau State Board	
Dan	Probert	Country Natural Beef	Director
Josh	Robinson	Robinson Nursery	Co-Owner
Elizabeth	Ruther	The Pew Charitable Trusts	Science and Policy Analyst
Amanda	Sullivan-Astor	Associated Oregon Loggers	Forest Policy Manager
Laura	Tabor	The Nature Conservancy	Climate Action Director
Joseph	Vaile	Klamath-Siskiyou Wildlands Center	Climate Program Director
Katie	Voelke	North Coast Land Conservancy	Executive Director
Teryn	Yazdani	Beyond Toxics	Staff Attorney, Climate Policy Manager

Appendix D. Project Approach

Facilitation Goal

Provide the Oregon Global Warming Commission (OGWC) with well-rounded, informed, and science-based information that achieves their goals described in the OGWC Natural & Working Lands Proposal (2021)[84] by creating processes that:

- Allow technical teams comprised of subject matter experts to propose science-based practices and metrics that have the potential to meet OGWC net carbon sequestration and GHG reduction goals using climate-smart practices on Oregon's natural and working lands.
- Use an informed consent approach, engage a advisory committee (AC) representative of numerous demographic and industry groups in Oregon in reviewing the practices proposed by the technical leads, while creating the opportunity for the AC to propose sector-based practices and metrics; and
- Provide an opportunity for external review of the technical teams' proposed practices and metrics by recommended academics, scientists, and sector/industry-based experts.

Technical Approach

The original approach was developed in September-October 2022 and was updated in January 2023

Questions

To achieve the goal of developing activity-based metrics and a baseline of these activities for Oregon's NWL, the technical teams sought to answer these questions:

- What are the recommended activities to capture and store more carbon and reduce GHGs in Oregon's NWL sector? Which should be included in this effort?
- What method should be used to develop a baseline for these activities and track implementation through time? How much is occurring and how much has happened in the past? How much would occur following 'business-as-usual'?
- How do we best measure or estimate the amount of carbon that is captured and stored by implementing the activities?

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[84] https://www.keeporegoncool.org/s/2021-OGWC-Natural-and-Working-Lands-Proposal.pdf

Approach

To achieve the goal of developing a methodology that requires a tiered approach for the range of possible costs for the five land sectors and cross-cutting (i.e., riparian) areas, INR will:

1. Identify technical experts and shared the scope of work for the project.
2. Document all subject matter experts that were contacted, including those that provided feedback and perspectives on the proposed practices and metrics.
3. Host a kick-off meeting of the ad hoc technical experts to orient everyone to the project and its goals. This included ensuring all technical experts understood the elements of the national inventory, its drawbacks and challenges, and where the inventory can be improved and augmented across all land sectors. Requested that technical experts describe activity-based/climate-smart practices to address the three key questions and those questions included below. INR specified sideboards, e.g., thinking about greenhouse gas emissions, co-benefits, consistency with IPCC requirements, the EPA approach, best use of available science, and working lands principles. In addition, technical experts were asked to consider additional general criteria as they proposed practices:
4. Collect all activity-based/climate-smart practice ideas and possible resources (report, journal articles, other publications) that support the ideas and incorporate all ideas as well as the recommended ideas in the report.
    a. Is the practice something that is both practical and usable in Oregon now (compared to experimental practices that are being considered)?
    b. Does the practice either reduce climate gas releases or increase carbon sequestration on Oregon's natural and working lands?
    c. Is the practice considered part of (and measured within) the natural and working lands sector compared to other sectors (such as transportation, building efficiencies, agricultural practices)?
    d. ***NOTE:*** All sequestration benefits (regardless of the sector) should be permanent or semi-permanent. Short-term increases, which can be gained through specific land sector practices, are not the intended goals for this project.
5. Document all recommended activity-based/climate-smart practice ideas and possible resources (report, articles) that support the ideas, and categorize those ideas as "Certain" (currently supported by science), "Uncertain", or "Not effective" (not supported by current research; however, if science advances and new scientific information informs understanding, practices can be added.)

6. Develop metrics for the recommended practices, considering probability of restoration success (considering types of restoration) (e.g., 2 types of restoration, and site characteristics to illustrate differences – moisture gradient, etc.) as well as site characteristics.
7. Work on and refine approach document.
8. Present and discuss the technical approach, practices, and metrics with the Advisory Committee (AC).

Advisory Committee (AC) Approach

1. Provide written materials to the AC in a timely manner.
2. Post AC meeting recordings on https://www.ogwcnaturalandworkinglands.org/.
3. Meet with the AC monthly, including a kick-off meeting to provide background information to the AC about the project, the roles of the AC, INR Project Team, technical leads, and ad hoc technical experts, and share some initial practices and metrics concepts from the technical leads.
4. Based on the desires of the AC, schedule additional AC and AC subcommittee meetings.
    a. Meet in sector-based AC sub-committees to propose, review, and refine a list of AC-proposed, sector-based practices and metrics, and request any supporting science-based articles.
5. Review and refine the AC-proposed, sector-based practices and metrics with the full AC through written and verbal comments.
6. Provide the AC an opportunity to review the practices and metrics proposed by the technical leads. Specifically, we asked the AC to answer the following questions:
    a. Are there practices and/or metrics that you believe should be included in a particular sector that are currently not included, and if so, why? Do you have one or more scientific references in support of inclusion?
    b. Are there practices proposed in the document that you do not believe should be included in a particular sector, and if so, why? Do you have one or more scientific references that support excluding the practice?
    c. Are there metrics proposed in the document that you do not support including for a particular practice, and if so, why? Do you have suggested alternatives, or additional metrics you would like to see included for a particular practice?
7. Document AC feedback.

8. Ask the AC agriculture, forestry, and rangelands members to suggest industry representatives to review and comment on the technical leads' practices and metrics proposed for these areas. (These three, in particular, were recommended because of the level of interest; if interest exists, subcommittees on blue carbon and urban areas could form).
9. The AC review of the technical teams document is occurring concurrent with the review by industry representatives.
10. Share the results of all discussions and perspectives with the Oregon Global Warming Commission in the final report.

Vetting Process

1. Share the practices and metrics recommended by technical leads with North American individuals that have expertise in climate issues for their review of practices and metrics.
2. Share the practices and metrics recommended by technical leads with additional agriculture, forestry, and rangelands industry representatives (in addition to AC members that represent these industries) recommended by AC members.
3. External reviewers were asked to answer similar questions presented to the AC:
    a. Are there practices and/or metrics that you believe should be included in a particular sector that are currently not included, and if so, why? Do you have one or more scientific references in support of inclusion?
    b. Are there practices proposed in the document that you do not believe should be included in a particular sector, and if so, why? Do you have one or more scientific references that support excluding the practice?
    c. Are there metrics proposed in the document that you do not support including for a particular practice, and if so, why? Do you have suggested alternatives, or additional metrics you would like to see included for a particular practice?
4. If needed, INR will convene external reviewers in sector-based groups to view and discuss the document, and AC members that would like to participate in these conversations would be welcomed.
5. Resulting feedback will be included in the report to the Oregon Global Warming Commission.

Appendix E. Activity-based Practices and Metrics

Appendix E-1. Practices and Metrics Proposed by Technical Teams

Oregon Natural & Working Lands Proposed Practices to Increase Carbon Stocks and/or Reduce Greenhouse Gas Emissions

Introduction

Background

The Commission's Natural & Working Lands (NWL) Proposal identified an outcome-based goal of sequestering and storing at least an additional 5 MMTCO$_2$e per year in Oregon's natural and working lands and waters by 2030 and at least 9.5 MMTCO$_2$e per year by 2050 relative to an activity-based, business-as-usual net carbon sequestration baseline.[85] The OGWC Proposal also called for the development of activity-based metrics and a baseline to track progress toward the outcome goal.

Goals and Objectives

The State of Oregon is working to promote practices that increase net carbon sequestration and reduce GHG (carbon dioxide, methane, and nitrous oxide) emissions from NWL. This effort is proceeding across many states and nations. Incentives, payments, and other measures are being instituted and proposed. Accurate measurements of net carbon sequestration and additionality will allow incentives to be as effective as possible and provide insight into how to value or compare different activities to prioritize actions. Although the international community and the United States government have developed international and global metrics, Oregon needs to develop metrics to evaluate effective practices.

The proposed activities and their metrics are separate from the NWL GHG Inventory (NWL Inventory), currently in development. However, having accurate and timely activity data can aid in NWL inventory development and help attribute causes to observed changes in statewide NWL carbon stocks and emissions once the NWL inventory is established, consistent land use/land cover type delineations for the activity-metrics and NWL inventory will be maintained.

Describing Practices by Land Use / Land Cover Type and by Land Sector

Land cover describes what covers the surface of the earth. Land use describes how the land is used. Examples of land cover classes include water, snow, grassland, deciduous or coniferous forest, and bare soil. Land use examples include wildlife management areas, agricultural land, urban, and

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[85] Oregon Global Warming Commission. 2021. Natural & Working Lands Proposal. 30pp.

recreation areas. The land cover present in a location is predicated on the climate, soils, and vegetation present.

Oregon land uses are aggregated into sectors, such as forests, agricultural lands, rangelands, urban and suburban areas, and wet areas. Wet areas include rivers, lakes, freshwater, and intertidal and tidal wetlands, the last two of these combined into "blue carbon" areas for this project. Proposed practices are described separately within these five land sector categories due to the high variability of land management. Agricultural lands and rangelands are classified as separate land sectors for this project because they represent distinct communities and land management activities and extensive areas in Oregon. Grazing lands that are irrigated or fertilized will be classified as "agricultural" land use. Freshwater wetlands and freshwater streams, rivers, and lakes are not addressed in this project, although may be incorporated into future efforts.

National and international GHG reporting guidelines[86] have defined sectors for tracking and reporting to promote comparability across jurisdictions. Oregon's GHG sector-based inventory (1990–2019), compiled by the Oregon Department of Environmental Quality, includes agriculture, industrial, residential and commercial, natural gas, electricity use, and transportation sectors. The Commission has recognized that the natural and working lands sector (often referred to as the land use/land cover change and forestry or LULUCF) needs an inventory of GHG emissions and practices that reduce these emissions and increase net carbon sequestration.

Document Scope

The guidance of this section of the document is for the recommendation of practices that will most likely result in a net GHG reduction. Many practices may provide climate resiliency or wide-ranging environmental benefits, however, if the practice is currently not viewed as resulting in a net GHG reduction, the practice was not listed as a recommended practice. Many of the proposed practices will have socioeconomic and environmental justice and equity issues. There also may be environmental tradeoffs if the only focus is the reduction of GHG emissions. Tradeoffs and impacts should be evaluated in future documents with the appropriate expertise. Likewise, many of the recommended practices have not undergone feasibility assessments but should in the future.

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[86] Land Use, Land-Use Change and Forestry (LULUCF), https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf.

BLUE CARBON

Practices to Increase Net Carbon Sequestration and Storage and/or Reduce Greenhouse Gas Emissions from Oregon's Blue Carbon Ecosystems

Author: Rose Graves (The Nature Conservancy)
Technical Group: Craig Cornu, Laura Brophy, Sylvia Troost, Elizabeth Ruther, Steve Crooks, Lisa Beers, Jena Carter, Meg Reed

The science related to carbon sequestration and GHGs in Oregon's blue carbon ecosystems is rapidly evolving, and the recommendations below are subject to change based on future available data. The recommendations are based on the best available science to date and our current understanding of the Blue Carbon sector in Oregon. We considered the number and relevance of studies available about each practice's effect on net carbon sequestration and storage or GHG emission reductions as well as the consistency of results across the body of evidence and present practices in three primary categories: recommended, emerging, and not currently recommended practices (Table 2). In some cases, practices may not currently be recommended due to a lack of monitoring data or research clearly demonstrating the net carbon sequestration or GHG reduction benefit from that practice, despite theoretical or conceptual studies which suggest climate mitigation potential.

Recommendations were developed through consultation with the Oregon Blue Carbon Technical Team, which consists of researchers and experts based in Oregon and elsewhere in the United States with expertise in coastal ecosystems and the practices that have potential to reduce GHG emissions. Based on initial discussions with the technical team as well as extensive review of peer-reviewed literature and existing protocols related to GHG reductions in coastal ecosystems, we compiled a list of practices along with questions about their utility/applicability in Oregon based on existing data and scientific understanding. We received feedback on the practices through group discussions, one-on-one follow up interviews, and comments on document drafts.

The assessment of blue carbon practices focused solely on the climate mitigation benefit of specific activities and is not meant to provide comprehensive guidance on the management of coastal ecosystems, which provide myriad social and ecological benefits. Some practices with clear ecological benefits are not included in this list because they do not lead to measurable increases in net carbon sequestration or reductions in GHGs and may even release carbon in the short term. As such, the guidance provided here is not intended to override the importance of managing for resilient coastal ecosystems.

Table 3. Strength of evidence criteria for inclusion in recommended, emerging, or not recommended categories.		
	Evidence Base/Documentation	**Consistency of Results**
Recommended Practices	Multiple studies; carbon sequestration and/or GHG reductions estimated using well documented and accepted methods; studies include regionally specific data	Studies are mostly consistent; inconsistencies may be explained
Emerging Practices	Fewer studies; studies are not regionally specific	Some inconsistencies; inconsistency reflecting real uncertainty around climate mitigation outcomes from practice
Not Currently Recommended Practices	Limited studies; estimates are based on extrapolations, emerging or untested/undocumented methods	Inconsistent conclusions across studies

Recommended Practices

Blue Carbon Calculator (in development)

Scientists from Silvestrum Climate Associates along with other members of the Oregon Blue Carbon Technical Group are in the process of developing a regional blue carbon 'calculator' designed for estimating net carbon sequestration dynamics and GHG emission reductions or additions (tCO_2e) for a given tidal wetland-related project. Using the most up-to-date data on emission factors for each blue carbon habitat type in Oregon and relevant land uses, they are building an interactive tool that will generate estimates of carbon stocks and GHG emissions/removals based on project specs (e.g., area, vegetation type). The tool will be applicable to both avoided conversion (e.g., conservation of at-risk ecosystems) and restoration projects. Upon completion, we recommend that the tool be evaluated and, if deemed sufficient, the blue carbon calculator may be a sufficient default tool for the State to calculate the metrics for many of the recommended practices below.

Practices with high confidence as GHG mitigation activities are currently focused on tidal wetlands due to the current knowledge base related to climate mitigation benefits from Oregon's coastal and marine ecosystems.[87] Tidal wetlands are defined as: "Coastal wetlands subject to regular or irregular tidal flooding by saline, brackish or fresh water (e.g., mudflats, seagrass beds, emergent marshes, scrub-shrub, and forested tidal wetlands)." Focusing on the conservation of tidal wetlands at-risk of loss and restoration of previously converted tidal wetlands could provide increased net carbon sequestration and may lead to reduced GHG emissions. The sequestered carbon in sediments and

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[87] Lyle, J.T., et al. 2022. Oregon's Blue Carbon Ecosystems: State of the Science. Available online: *Oregon's Blue Carbon Ecosystems: State of the Science*.

aboveground biomass of tidal wetlands can be released back into the atmosphere if these soils are either drowned or filled in the future, but that process and its timeline is not completely understood.

Tidal Wetland Conservation

Tidal wetlands are defined as coastal wetlands subject to regular or irregular tidal flooding by saline, brackish, or freshwater (e.g., mudflats, seagrass beds, emergent marshes, scrub-shrub, and forested tidal wetlands). Oregon's remaining coastal wetlands can store carbon at rates comparable to Pacific Northwest old-growth forests on a per acre basis,[88] providing a net annual sink of 0.051 million metric tonnes CO_2 equivalent (CO_2e). Current carbon stocks in Oregon's coastal wetlands amount to at least 83.7 million metric tonnes CO_2e, largely driven by substantial soil carbon stocks accumulated over centuries to millennia. Protecting tidal wetlands from loss due to conversion is critical to maintaining the net sequestration potential and avoiding GHG emissions from the loss of current carbon stores these key ecosystems. Tidal wetland conservation practices are those that prevent losses which would otherwise result from either deliberate alteration (e.g., wetland fills), or unintended but anticipated conversion and degradation (e.g., sea level rise (SLR)).[89] Protection of at-risk tidal wetlands may include:

- Acquisition of at-risk tidal wetlands with the goal to conserve the tidal wetland and its functions.
- Establishing permanent conservation easements.
- Updating local estuary management plans and protected area maps using more recent estuary maps to avoid impacts during development applications (e.g., by converting development management units to conservation or natural management units).
- Establishing community-supported management agreements.
- Establishing protective government regulations.
- Consistently implementing current no-net loss wetland regulations.
- Preventing disruption of water and/or sediment supply to tidal wetland areas.

The actual avoided loss of carbon stocks and net sequestration benefit due to tidal wetland conservation will vary across tidal wetland type and specific wetland conditions including past land use, salinity, and accretion rate. Protection of tidal wetlands should only be counted toward GHG mitigation goals if the activities are expected to provide net sequestration beyond business-as-usual (i.e., they provide additional net sequestration of CO_2e). For example, if the tidal wetland is not at-risk of conversion in the near term (e.g., it is protected under a local estuary management plan) then additional administrative protection (e.g., conservation easement) does not provide additional

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[88] Kauffman, J.B., et al. 2020. Total ecosystem carbon stocks at the marine-terrestrial interface: blue carbon of the Pacific Northwest Coast, United States. *Global Change Biology* 26(10): 5679–5692. https://doi.org/10.1111/gcb.15248

[89] Beers, L., et al. 2021. Incorporating coastal blue carbon data and approaches in Oregon's first generation natural and working lands proposal. White paper submitted to the Oregon Global Warming Commission. 49pp. https://www.pnwbluecarbon.org/_files/ugd/43d666_1859316df7ef415db84fd5d29f6b1d20.pdf

climate mitigation. Additionality may be demonstrated from site-level conversion risk assessments, such as current development/conversion permit applications, or broader-scale analyses of baseline trends that identify realistic and credible land-use scenarios that would have occurred in the absence of the tidal wetland protection activity. The scenarios should be feasible for the project area taking into account relevant national, state, and local policies as well as historical land uses, practices and economic trends.

Metric

Metric tonnes of carbon dioxide equivalents (tCO_2e) during each reporting period (e.g., annually, or during a longer reporting window as determined by the State). Annual reporting should include the acres of tidal wetland by wetland type under additional protection. These acreage values can be used along with region-specific biomass and soil carbon removal factors and forthcoming region-specific soil emissions factors[90] can be used to estimate the metric tonnes of carbon dioxide equivalents (tCO_2e) attributable to protected tidal wetland per year, including the avoided loss of above and belowground carbon stocks and continued net sequestration by the tidal wetlands.

Carbon stock and sequestration estimates for existing tidal wetlands should be updated regularly as data become available across a wider range of tidal wetland types and preconditions. Accounting for GHG reductions from avoided conversion of tidal wetlands depends on developing a robust baseline against which to assess additionality. The baseline should represent a scenario under which the tidal wetland protection project does not occur, and GHG reductions due to avoided conversion of tidal wetlands should be calculated against this counterfactual baseline. While both backward-looking and dynamic baselines have been used to assess the net effect of a practice, it is important to note that backward-looking counterfactual baselines are based largely upon assumptions (specifically that the future will mirror the past). Dynamic counterfactual baseline methods, such as statistical matching to establish control plots, are likely to provide more accurate and robust estimates of net effect relative to a baseline.

Tidal Wetland Restoration

Restoration that re-establishes natural structures and processes in degraded or previously converted tidal wetlands can increase carbon storage in both aboveground plant biomass and organic wetland soils. Such restoration should focus on the re-establishment of natural processes, such as full tidal flooding, sediment delivery and retention, and recruitment of native plant propagules. Under certain conditions, tidal wetland restoration also reduces methane, carbon dioxide, and other GHG

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[90] Ibid.

emissions[91, 92, 93] and these decreased GHG emissions have been reported within weeks to months of restoration[94] Tidal wetland restoration can also lead to short-term increases in methane emissions which depend on salinity and may outpace carbon sequestration in the initial years, particularly in lower-salinity marshes[95]. Tidal wetland restoration can enhance the sequestration and accretion rates of tidal wetlands[96] but the accumulation of climate benefit from restoration takes time. The timeline for these fluxes is not completely understood and investing resources to update estimates of net GHG emissions and sequestration over time is recommended.

Metric

Annual reporting should include the acres of tidal wetland restored by wetland type. These acreage amounts can be combined with per acre estimates of annual carbon sequestration and GHG emissions (metric tonnes of carbon dioxide equivalents (tCO_2e)) to determine the total net sequestration attributable to tidal wetland restoration. These can be summed to determine the climate mitigation benefit from tidal wetland restoration during each reporting period (e.g., annually, or during a longer reporting window).

The tCO_2e per acre of tidal wetland restoration will depend on the tidal wetland type and preconditions as well as where the project is along its timeline to full restoration/recovery. Carbon benefits from tidal wetland restoration will accrue over time and are not immediate with tidal wetland restoration projects. The methods for calculating tCO_2e should account for this variation.[97] [98] Estimates should be updated as region-specific biomass, soil carbon, and soil emission factors are refined to account for variability across tidal wetland type and precondition. In addition, we recommend continued monitoring and field research to refine estimates of carbon sequestration over time in restored tidal wetlands.

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[91] Poppe, K.L., and J.M. Rybczyk. 2021. Tidal marsh restoration enhances sediment accretion and carbon accumulation in the Stillaguamish River estuary, Washington. *PLoS ONE* 16(9): e0257244. https://doi.org/10.1371/journal.pone.0257244

[92] Beers, L., et al. 2021. Incorporating coastal blue carbon data and approaches in Oregon's first generation natural and working lands proposal. White paper submitted to the Oregon Global Warming Commission. 49pp. https://www.pnwbluecarbon.org/_files/ugd/43d666_1859316df7ef415db84fd5d29f6b1d20.pdf

[93] Poffenbarger, H. J., et al. 2011. Salinity influence on methane emissions from tidal marshes. *Wetlands* 31(5): 831–842. https://doi.org/10.1007/s13157-011-0197-0

[94] Negandhi, K., et al. 2019. Blue carbon potential of coastal wetland restoration varies with inundation and rainfall. *Sci Rep. Mar* 13:9(1): 4368. https://doi.org/10.1038/s41598-019-40763-8

[95] Poffenbarger, H.J., et al. 2011. Salinity influence on methane emissions from tidal marshes. *Wetlands* 31(5): 831–842. https://doi.org/10.1007/s13157-011-0197-0

[96] Poppe, K.L., and J.M. Rybczyk. 2021. Tidal marsh restoration enhances sediment accretion and carbon accumulation in the Stillaguamish River estuary, Washington. *PLoS ONE* 16(9): e0257244. https://doi.org/10.1371/journal.pone.0257244

[97] Crooks, S., et al. 2018. Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory. *Nature Climate Change* 8(12): 1109–1112. https://doi.org/10.1038/s41558-018-0345-0

[98] Beers, L., et al. 2021. Incorporating coastal blue carbon data and approaches in Oregon's first generation natural and working lands proposal. White paper submitted to the Oregon Global Warming Commission. 49pp. https://www.pnwbluecarbon.org/_files/ugd/43d666_1859316df7ef415db84fd5d29f6b1d20.pdf

Seagrass Conservation

Seagrass meadows, located in intertidal and subtidal areas of Oregon's estuaries, along Oregon's coasts are dominated by *Zostera marina* and *Z. japonica* (native and non-native eelgrasses). Seagrasses accumulate carbon from both allochthonous (transported from other places) and autochthonous (in-situ) sources. This matter then accumulates in sediment conditions that do not allow microbial respiration into CO_2 and methane, which makes eelgrass highly effective in sequestering carbon: they accumulate their own carbon and trap and store carbon from other sources. In Oregon, as much as 75% of carbon stored in eelgrass beds could come from external sources like kelp[99]. In addition to capturing and storing carbon, eelgrass beds may also provide localized amelioration of ocean acidification, another climate threat[100]. Oregon's eelgrass beds are vulnerable to disturbance and loss from human impacts such as poor water quality, dredging, dock building and other direct impacts that may increase with the growth of industries like aquaculture and offshore wind as well as vulnerable to indirect threats such as sea level rise, warming oceans, and increased sedimentation[101,102]. Despite the widespread distribution and occurrence of eelgrass, Oregon eelgrass mapping datasets are inconsistent across the coast.

Tracking the protection of at-risk eelgrass beds will depend on consistent maps of the current extent as well as funding the continued mapping of eelgrass overtime, which could include both field measurements and remote sensing/aerial imagery to track changes in eelgrass over time. For example, ODFW has conducted eelgrass mapping efforts in Oregon estuaries since 2010. Extensive habitat data (including eelgrass species, shoot density, percent cover) is collected as part of these surveys. To date Tillamook Bay, Yaquina Bay, Netarts Bay, Siletz Bay, Alsea Bay, and Coos Bay have been surveyed. Only one estuary (Tillamook Bay) has been re-surveyed to provide information on decadal-scale shifts. The eelgrass data collected during these ODFW surveys are interpolated to produce spatial distribution maps which have been used by Oregon DLCD to update eelgrass maps used by the state for planning purposes and have also been incorporated into other regional eelgrass mapping efforts such as the recent report and data products produced by PMEP.

Protection of at-risk eelgrass beds could include:

- Updating local estuary management plans to include recent maps of eelgrass to avoid impacts during development applications.

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[99] Lyle, J.T., et al. 2022. Oregon's Blue Carbon Ecosystems: State of the Science. Available online: *Oregon's Blue Carbon Ecosystems: State of the Science*.

[100] Ricart A. M., et al. 2021. Coast-wide evidence of low pH amelioration by seagrass ecosystems. *Glob. Change Biol.* 27: 2580–2591. https://doi.org/10.1111/gcb.15594

[101] Thom, R., et al. 2014. Climate-linked mechanisms driving spatial and temporal variation in eelgrass (*Zostera marina* L.) growth and assemblage structure in Pacific Northwest estuaries, U.S.A. *Journal of Coastal Research* 68: 1–11. https://doi.org/10.2112/SI68-001.1

[102] Sherman, K., and L. DeBruyckere. 2018. Eelgrass habitats on the U.S. West Coast: State of knowledge of eelgrass ecosystem services and eelgrass extent. A publication prepared by the Pacific Marine and Estuarine Fish Habitat Partnership for The Nature Conservancy. 67pp. https://www.pacificfishhabitat.org/wp-content/uploads/2017/09/EelGrass_Report_Final_ForPrint_web.pdf

- Strengthening regulatory protections against direct disturbance, for example by improving Oregon's ecosystem function-based aquatic mitigation framework to include carbon storage for coastal wetlands.

Improving water quality to limit loss and degradation of existing eelgrass beds could help to protect this carbon sink but may be more challenging to track with respect to the direct impact on net carbon sequestration or GHG emissions reductions.

Metric

Investing resources into updating historic and current estimates of seagrass habitats is recommended. For activities with demonstrated additionality above the baseline, the metric would be the avoided loss of soil carbon sequestration and storage (tCO_2e per year), calculated by multiplying the total area protected by regional carbon stock and sequestration estimates.[103] Intergovernmental Panel on Climate Change (IPCC) guidance states that seagrass biomass carbon stocks are not accounted for unless regionally specific Tier 2 or Tier 3 data are available. Kauffman et al (2020) estimates the total ecosystem carbon stock within the PNW eelgrass meadows is 217.1 ± 60.3 Mg C/ha, 99% of which is stored in soils (80 ± 7.3 Mg C/ha in top 1 m). These C estimates alongside estimates of current extent could be used to provide a baseline upon which GHG benefits of avoided loss could be measured.

Emerging Practices

Seagrass Restoration

Restoration of seagrass beds through direct planting can lead to increased carbon sequestration and storage in the seagrass vegetation and sediments, although restoration projects should carefully consider site conditions to increase the likelihood of restoration success[104]. Tracking successful restoration methods as well as recording site conditions that fostered successful restoration projects, like water quality, salinity, and water velocity parameters, will be key to incorporating seagrass restoration as a practice in the future. In addition, tracking seagrass restoration activities will need to carefully consider the initiation and duration of carbon sequestration. Lack of empirical, time series data on the effectiveness of restored eelgrass meadows currently limits our ability to adequately account for the net carbon sequestration increase or GHG emission reduction of this activity.

Metric

Annual soil carbon sequestration and storage (tCO_2e per year), calculated by tracking the total areal extent of seagrass through time and summing region-specific soil carbon emission factors per acre of restored/increased seagrass.[105] Intergovernmental Panel on Climate Change (IPCC) guidance

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[103] Beers, L., et al. 2021. Incorporating coastal blue carbon data and approaches in Oregon's first generation natural and working lands proposal. White paper submitted to the Oregon Global Warming Commission. 49pp. https://www.pnwbluecarbon.org/_files/ugd/43d666_1859316df7ef415db84fd5d29f6b1d20.pdf

[104] Thom, R., et al. 2018. Eelgrass (*Zostera marina* L.) restoration in Puget Sound: Development of a site suitability assessment process. *Restor Ecol.* 26(6): 1066–1074. https://doi.org/10.1111%2Frec.12702

[105] Ibid.

states that seagrass biomass carbon stocks are not accounted for unless regionally specific Tier 2 or Tier 3 data are available.

Kelp and Seaweed Protection and Restoration

Kelp and other macroalgae are important primary producers in the nearshore coastal ocean.[106] Kelp forests and macroalgae are unlikely to store much carbon in nearby sediments. However, with the high rates of net primary productivity, kelp and perennial seaweeds are important to the blue carbon cycle, both as biomass standing stock and as vectors of carbon export through detritus pathways. Nearshore seaweed beds produce and export carbon-rich biomass year-round, although the magnitude of export varies depending on season and local conditions.[107, 108] There is strong connectivity between macroalgaes and the deep sea, where carbon is unlikely to return to the atmosphere.[109, 110] Additionally, biomass exported from macroalgae is a major contributor to sediment carbon within eelgrass meadows[111] and studies have shown that kelp may contribute as much as one-third of the organic carbon within sediments in eelgrass meadows.[112] Thus, effective management of blue carbon in seagrass and other tidal wetlands should consider the important connection between carbon sequestration in kelp and macroalgae and the long-term storage of that carbon in other blue carbon sinks (i.e., eelgrass meadows).[113]

Restoration of kelp and nearshore seaweed beds may have a positive climate impact but measuring and tracking the amount of carbon sequestered by a particular kelp forest is not yet possible and there are large uncertainties with respect to how much carbon sequestered in kelp and nearshore seaweeds is transferred into long-term carbon storage pools (e.g., the deep sea or sediment). Given the strong connectivity between kelp/macroalgae and other blue carbon habitats, research to better map and understand the fate of kelp/macroalgae carbon in the PNW is recommended.

Enhance Tidal Wetland Resilience to Sea Level Rise

A range of management actions may be employed to increase the resilience of tidal wetlands to sea level rise (SLR) and other climate change impacts. At high rates of SLR, coastal wetlands will be better able to persist through landward migration than through vertical accretion. However, in

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[106] Filbee-Dexter, K., and T. Wernberg. 2020. Substantial blue carbon in overlooked Australian kelp forests. *Scientific Reports* 10: 12341. https://doi.org/10.1038/s41598-020-69258-7

[107] Ibid.

[108] Watanabe, K., et al. 2020. Macroalgal metabolism and lateral carbon flows can create significant carbon sinks. *Biogensciences* 17: 2425–2440. https://doi.org/10.5194/bg-17-2425-2020

[109] Ortega, A., et al. 2019. Important contribution of macroalgae to oceanic carbon sequestration. *Nat. Geosci.* 12: 748–754. https://doi.org/10.1038/s41561-019-0421-8

[110] Queirós, A.M., et al. 2019. Connected macroalgal-sediment systems: blue carbon and food webs in the deep coastal ocean. *Ecological Monographs* 89(3): e01366. https://doi.org/10.1002/ecm.1366

[111] Röhr, M.E., et al. 2018. Blue carbon storage capacity of temperate eelgrass (*Zostera marina*) meadows. *Global Biogeochemical Cycles* 32(10): 1457–1475. https://doi.org/10.1029/2018GB005941

[112] Prentice, C., et al. 2019. Reduced water motion enhances organic carbon stocks in temperate eelgrass meadows. *Limnology and Oceanography* 64(6): 2389–2404. https://doi.org/10.1002/lno.11191

[113] Smale, D.A., et al. 2018. Appreciating interconnectivity between habitats is key to blue carbon management. *Frontiers in Ecology and the Environment* 16(2): 71–73. https://doi.org/10.1002/fee.1765

Oregon estuaries, opportunities for wetland migration can be constrained by human infrastructure (e.g., levees, roads), incompatible land uses (e.g., agricultural operations),[114, 115, 116] or natural barriers[117]. Deliberate actions (e.g., land acquisition, elimination of barriers) can protect existing, or create needed, coastal wetland migration pathways. Recent updated carbon quantification methodologies include protecting landward migration zones as a climate mitigation practice, with net carbon sequestration benefits accruing over time as existing wetlands are drowned and migrate. Substantial wetland drowning is not expected by 2045,[118, 119] thus actions taken to protect landward migration zones for tidal wetlands will have limited climate mitigation in the immediate term. Due to the likely timeline associated with the net carbon sequestration and emission reductions benefits (i.e., not realized until 2045), we are including this as an emerging rather than immediately recommended practice. However, identifying strategies that allow for eventual landward migration is important in the near term as many of these strategies may take time to execute. We recommend that Oregon invest in refinements to recent mapping of landward migration zones[120] as well as additional characterization of landward migration zones in preparation for eventual SLR. Proactive identification of these areas will allow the protection of these areas to be eventually included as a practice for climate mitigation; protection of these landward migration zones will ensure that valued tidal wetland functions, including net carbon sequestration, wildlife habitat, and other co-benefits, persist into the future.

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[114] Orr, M.K., and L. Sheehan. 2012. Memo to Laura King Moon, BDCP Program Manager. BDCP Tidal Habitat Evolution Assessment.

[115] Heady, W.N., et al. 2018. Conserving California's Coastal Habitats: A Legacy and a Future with Sea Level Rise. The Nature Conservancy, San Francisco, CA; California State Coastal Conservancy, Oakland, CA. 146pp. https://www.scienceforconservation.org/products/coastal-assessment

[116] Thorne, J.H., et al. 2018. Climate change vulnerability assessment of forests in the Southwest US. *Climatic Change* 148: 387–402. https://www.doi.org/10.1007/s10584-017-2010-4

[117] Brophy, L.S., and M.J. Ewald. 2017. Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation in the future. 64pp. link to report

[118] Ibid.

[119] Thorne, J.H., et al. 2018. Climate change vulnerability assessment of forests in the Southwest US. *Climatic Change* 148: 387–402. https://www.doi.org/10.1007/s10584-017-2010-4

[120] Brophy, L.S., and M.J. Ewald. 2017. Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation in the future. 64pp. link to report

RANGELANDS

Practices to Increase Net Carbon Sequestration and Storage in Oregon's Rangelands

Authors: Megan Creutzburg (INR), Michael Russell (INR), Dylan O'Leary (INR), and Jimmy Kagan (INR)
Contributors: Rory O'Connor, Mohamed Abdallah, Benjamin Rau, Cameron Duquette, Toby Maxwell, Maddy Case, Lauren Hallett, Lina Aoyama

Introduction

Rangelands are vegetation communities dominated by grasses and/or shrubs, defined here as terrestrial habitats outside of urban areas with tree canopy cover below 20%. Rangelands cover approximately 24.7 million acres, almost 40% of Oregon's terrestrial land. This category covers a wide range of ecosystems in Oregon, including semi-arid sagebrush steppe in southeastern Oregon, prairies of northeastern Oregon, mesic grasslands and oak savannas of the Rogue and Willamette Valleys, and savannas with tree canopy cover under 20%. Rangelands provide opportunities for sequestering and securing carbon throughout the state, with many practices serving the goal of maintaining and increasing carbon stored in healthy rangeland soils. Managing for rangeland soil health is critical for carbon sequestration efforts because about 90% of the carbon in these ecosystems is stored belowground in organic matter.[121, 122, 123, 124, 125, 126] Overarching themes for managing rangelands to store carbon include:

- **Protecting existing carbon** in intact rangeland and grassland systems and preventing loss is often more effective than trying to restore carbon to degraded systems because of the slow accumulation of carbon over time and difficulty in restoring many degraded systems, especially in more arid rangelands.

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[121] Schuman, G.E., J.E. Herrick, and H.H. Janzen. 2001. The dynamics of soil carbon in rangelands. *In* R.F. Follett, J.M. Kimble & R. Lal, eds. The potential of U.S. grazing lands to sequester carbon and mitigate the greenhouse effect, pp. 267–290. Boca Raton, Florida, USA, CRC Press.

[122] Nagy, R.C., et al. 2020. A synthesis of the effects of cheatgrass invasion on U.S. Great Basin carbon storage. *Journal of Applied Ecology* 58: 327–337. https://doi.org/10.1111/1365-2664.13770

[123] Viglizzo, E.F., et al. 2019. Reassessing the role of grazing lands in carbon-balance estimations: Meta-analysis and review. *Science of the Total Environment* 661:531–542. https://doi.org/10.1016/j.scitotenv.2019.01.130

[124] Dass, P., et al. 2018. Grasslands may be more reliable carbon sinks than forests in California. *Environmental Research Letters* 13: 074027. https://doi.org/10.1088/1748-9326/aacb39

[125] Pendall, E., et al. 2018. Chapter 10: Grasslands. *In* Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 399–427, https://doi.org/10.7930/SOCCR2.2018.Ch10

[126] Booker, K., et al. 2013. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Global Environmental Change* 23: 240–251. https://doi.org/10.1016/j.gloenvcha.2012.10.001

- **Managing for healthy and resilient perennial grasses** is key to sequestering carbon because of the role of large perennial bunchgrass roots in stabilizing soil, resisting invasion and disturbance, and replenishing soil carbon pools.
- **Managing for healthy soils and preventing erosion** will protect existing soil carbon, promote perennial grasses which contribute carbon, and also increase infiltration of water, water holding capacity, nutrient retention, and nutrient availability. Rangeland management practices that support soil organic carbon stabilization increase productivity, facilitate perennial growth with longer growing seasons and deeper roots, which in turn will provide more soil carbon.

Recommended Practices

Recommended practices for securing carbon in Oregon's rangelands are grouped into broad management pathways. More specific potential practices are listed but this list is not prescriptive, as many site-specific factors determine relevant practices.

Prevent conversion to invasive annual plant dominated systems

Many rangelands throughout the state are vulnerable to invasive species, which can fundamentally alter carbon dynamics and fire cycles. Many eastern Oregon rangelands that were historically dominated by shrubs and perennial grasses have experienced invasion by annual grasses,[127, 128] which can lead to a cycle of elevated wildfire risks, further invasion, and long-term plant community conversion.[129, 130, 131, 132] Annual grass invasion is increasingly impacting savanna and woodland systems.[133, 134] Both invasive grasses and forbs impact rangelands ecologically and economically around the state.[135] Annual-dominated communities, which produce less above ground biomass and

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[127] Allred, B.W., et al. 2021. Improving Landsat predictions of rangeland fractional cover with multitask learning and uncertainty. *Methods in Ecology and Evolution* 12(5): 841–849. https://doi.org/10.1111/2041-210X.13564

[128] Smith, J.T., et al. 2021. The elevational ascent and spread of exotic annual grass dominance in the Great Basin, USA. *Diversity and Distributions* 28(1): 83–96. https://doi.org/10.1111/ddi.13440

[129] Miller, R.F., and Eddleman, L.L. 2001. Spatial and temporal changes of sage-grouse habitat in the sagebrush biome: Oregon State University Agricultural Experiment Station Technical Bulletin, no. 151, 39 p. Also available at https://catalog.extension.oregonstate.edu/tb151

[130] Balch, J.K., et al. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009): *Global Change Biology* 19(1): 173–183. https://doi.org/10.1111/gcb.12046

[131] Jones, R., et al. 2014. Effect of repeated burning on plant and soil carbon and nitrogen in cheatgrass (*Bromus tectorum*) dominated ecosystems. *Plant and Soil* 386: 47–64. https://doi.org/10.1007/s11104-014-2242-2

[132] Fusco, E.J., et al. 2019. Invasive grasses increase fire occurrence and frequency across US ecoregions. Proceedings of the National Academy of Sciences of the United States of America 116:23594–23599.

[133] Perchemlides, K.A., et al. 2008. Responses of Chaparral and Oak Woodland Plant Communities to Fuel-Reduction Thinning in Southwestern Oregon. *Rangeland Ecology and Management* 61: 98–109. https://doi.org/10.2111/07-026R1.1

[134] Tortorelli, C.M., M.A. Krawchuk, and B.K. Kerns. 2020. Expanding the invasion footprint: Ventenata dubia and relationships to wildfire, environment, and plant communities in the Blue Mountains of the Inland Northwest, USA. *Applied Vegetation Science* 23(4): 562–574. https://doi.org/10.1111/avsc.12511

[135] The Research Group, LLC. Economic Impact from Selected Noxious Weeds in Oregon. Prepared for Oregon Department of Agriculture Noxious Weed Control Program. December 2014. https://www.oregon.gov/oda/shared/Documents/Publications/Weeds/ORNoxiousWeedEconomicImpact.pdf

are more prone to wildfire, store less carbon than perennial communities,[136, 137, 138, 139] although effects of invasion on carbon dynamics vary with climate and soil patterns.[140] Returning perennial grasses and/or shrub cover that can replenish below-ground carbon should increase carbon storage.

Practices to protect intact rangelands and prevent conversion include:

- Early detection and rapid response for invasive species, including invasive annual grasses and other noxious weeds. Success rates for treating invasive species are highest when intervention is early before species become established.[141]
- Fire prevention – reducing wildfire ignitions and extinguishing fire starts quickly – is one of the most important protection mechanisms for fire-prone rangelands. Fuel breaks, if maintained regularly, can be strategically placed to minimize the size of wildfires, and managing fuels through livestock grazing can also reduce fuel continuity.
- Livestock grazing management is one of the most common management tools used in rangelands and can be compatible with healthy, native rangeland ecosystems. Grazing intensity, timing, and frequency can influence the photosynthetic potential of plants, community composition, rates of decomposition through hoof action, and the biomass and diversity of soil microbes, all of which control carbon turnover in the soil.[142] Excessive grazing can result in the loss of deep-rooted perennial grasses[143] or perennial grasses being restricted to areas under shrubs, making them more vulnerable to mortality during a wildfire.[144, 145] Grazing systems that help maintain perennial grasses can include rotational grazing practices that allow rest for perennial species at key times of year. Light to moderate

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[136] Germino, M.J., et al. 2016. Ecosystem impacts of exotic annual invaders in the genus Bromus. Pages 61–95 *In* Exotic brome-grasses in arid and semiarid ecosystems of the western US: Causes, consequences, and management implications. Springer Series on Environmental Management. https://doi.org/10.1007/978-3-319-24930-8_3

[137] Nagy, R.C., et al. 2021. A synthesis of the effects of cheatgrass invasion on U.S. Great Basin carbon storage. *Journal of Applied Ecology* 58: 327–337. https://doi.org/10.1111/1365-2664.13770

[138] Prater, M.R., et al. 2006. Net carbon exchange and evapotranspiration in postfire and intact sagebrush communities in the Great Basin. *Oecologia* 146: 595–607. https://doi.org/10.1007/s00442-005-0231-0

[139] Rau, B.M., et al. 2011. Transition from sagebrush steppe to annual grass (*Bromus tectorum*): Influence on belowground carbon and nitrogen. *Rangeland Ecology and Management* 64: 139–147. https://doi.org/10.2111/REM-D-10-00063.1

[140] Maxwell, T.M., and M.J. Germino 2022. The effects of cheatgrass invasion on US Great Basin carbon storage depend on interactions between plant community composition, precipitation seasonality, and soil climate regime. *Journal of Applied Ecology* 59(11): 2863–2873. https://doi.org/10.1111/1365-2664.14289

[141] The U.S. Department of the Interior. 2016. Safeguarding America's lands and waters from invasive species: A national framework for early detection and rapid response, Washington D.C., 55p.

[142] Holechek, J.L., et al. 2020. Climate change, rangelands, and sustainability of ranching in the western United States. *Sustainability* 12(12): 4942. https://doi.org/10.3390/su12124942

[143] Strand, E., et al. 2014. Livestock grazing effects on fuel loads for wildland fire in sagebrush dominated ecosystems. *Journal of Rangeland Applications* 1:35–57. https://thejra.nkn.uidaho.edu/index.php/jra/article/view/23

[144] Reisner, M.D., et al. 2015. Stress-gradient hypothesis explains susceptibility to *Bromus tectorum* invasion and community stability in North America's semi-arid *Artemisia tridentata wyomingensis* ecosystems. *Journal of Vegetation Science* 26(6): 1212–1224. https://doi.org/10.1111/jvs.12327

[145] Boyd, C.S., K.W. Davies, and A. Hulet. 2015. Predicting fire-based perennial bunchgrass mortality in big sagebrush plant communities. *International Journal of Wildland Fire* 24(4): 527–533. http://dx.doi.org/10.1071/WF14132

grazing can have the effect of reducing fuels and wildfire intensity, which can increase the resilience to wildfires for perennials.[146]

Metric

Estimates of carbon within intact rangelands that would have been lost to annual grass infestation or wildfire without protection measures using remotely sensed estimates of threat-based ecostates based on annually updated vegetation fractional cover maps, which estimate the extent of intact rangelands by functional group, and can be updated over time. Coarse estimation techniques such as those described in Reeves et al (2020)[147] can relate vegetative cover to carbon estimates, or carbon can be estimated based on regional and community type-based estimates of functional group cover in the literature.

Restore deep-rooted perennial grasses to areas impacted by invasive species

Although prevention and early response to invasive species is most cost-effective, restoration may be achievable in areas already significantly impacted by invasive species. Common practices that may restore invasive-dominated rangelands sites to perennial dominance include application of herbicides, aerial or drill seeding, planting, prescribed fire, and/or grazing prescriptions to favor perennial grasses.[148] When conducting restoration, causal factors of degradation such as accumulation of fuels or excessive usage from humans or livestock should be addressed, and careful management post-treatment or post-fire will improve the likelihood of success.

Restoration activities may occur in many different rangelands across the state:

- **Sagebrush steppe communities:** Millions of acres of sagebrush steppe in Oregon could benefit from restoration actions, but success rates are often low in these environments[149, 150] and further work is needed to develop strategies that are consistently successful. [151, 152] In sites with low resilience, native species are very difficult to establish after a disturbance and

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[146] Davies K. W., et al. 2009. Interaction of historical and nonhistorical disturbances maintains native plant communities. *Ecol Appl.* 19(6): 1536–1545. https://doi:10.1890/09-0111.1

[147] Reeves, M.C., et al. 2020. A novel approach for estimating nonforest carbon stocks in support of forest plan revision. Res. Note RMRS-RN-86. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Research Station, 20pp. https://www.fs.usda.gov/research/treesearch/60860

[148] Simler-Williamson, A.B., and M.J. Germino. 2022. Statistical considerations of nonrandom treatment applications reveal region-wide benefits of widespread post-fire restoration action. *Nat Commun* 13: 3472. https://doi.org/10.1038/s41467-022-31102-z

[149] Knutson, K.C., et al. 2014. Long-term effects of seeding after wildfire on vegetation in Great Basin shrubland ecosystems. *Journal of Applied Ecology* 51(5): 1414–1424. https://doi.org/10.1111/1365-2664.12309

[150] Chambers, J.C., et al. 2014. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of Western North America. *Ecosystems* 17(2): 360–375. https://doi.org/10.1007/s10021-013-9725-5

[151] Davies, K.W., and C.S. Boyd. 2018. Longer-term evaluation of revegetation of medusahead-invaded sagebrush steppe. *Rangeland Ecology and Management* 71(3): 292–297. https://doi.org/10.1016/j.rama.2018.02.001

[152] Pilliod, D. S., et al. 2017. Seventy-five years of vegetation treatments on public rangelands in the great basin of North America. *Rangelands* 39(1): 1–9. https://doi.org/10.1016/j.rala.2016.12.001

non-invasive non-native deep-rooted species such as crested wheatgrass may stabilize sites and increase carbon.[153]

- **NE OR/Columbia Basin Prairies:** Bunchgrass prairies historically dominated much of the Oregon Columbia Basin, along with the high plateaus, canyons and valleys of Wallowa County. In many lower elevation sites, bunchgrasses are replaced by introduced annuals from hot fires or improper management. In most of these sites, however, bunchgrass restoration practices have a higher level of success than in the sage steppe due to their deep soils and access to more traditional grass planting equipment. Higher elevation areas are resistant to most annual grass invasions, but previously farmed areas now fallow and used as rangelands tend to have high cover of either introduced species, such as Kentucky or bulbous bluegrass. These areas can often be restored by planting deep-rooted native perennial grasses, such as Idaho fescue and bluebunch wheatgrass.
- **Chapparal:** These stands of fire adapted open shrublands historically supported significant cover of deep-rooted bunchgrasses, making them significant sources of carbon, especially in southwestern and southcentral Oregon. As with other dry-site rangelands, many of these areas have been invaded by introduced annual grasses and forbs (yellow star-thistle, *Centaurea solstitialis*), replacing the native understory perennial forbs and bunchgrasses. In other areas, fire suppression leads to dense, closed canopy shrublands, significantly reducing cover of the native perennial grasses and forbs. When these areas burn, they usually become invaded by introduced annuals. In some areas, wildfires have maintained open, native perennial dominated shrublands, but significant restoration is needed in others. Unfortunately, there are limited examples of successful chapparal restoration, even after wildfire.
- **West side upland grasslands and savannas:** Other rangelands in western Oregon include upland grasslands in the Rogue and Willamette Valleys, which are used to support livestock on small farms and store carbon when dominated by perennial native or deep-rooted pasture grasses. However, many of these rangelands have become invaded by shallow rooted, short lived perennial grasses and annual weeds. Methods for controlling these species and restoring native bunchgrasses are underway, including restoring some farmlands to native prairie.
- **Dry savannas and woodlands:** Open woodlands and savannas dominated by old-growth Ponderosa pine, Oregon white oak, Jeffrey pine, and occasionally western Juniper are common along the eastern Cascades, Blue Mountain margins, and southwestern Oregon. Historically, this natural community type supported an understory of deep rooted, fire adapted perennial grasses and forbs, with isolated trees able to survive the frequent ground fires that occurred without fire suppression. When fire is restricted, or areas overgrazed, the deep-rooted perennials are replaced by annual grasses, shallow rooted perennials, or dense stands of very young trees. When these areas burn, remaining perennials and sometimes trees are killed, reducing both their productivity and carbon sequestration potential.

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[153] Hooker, T.D., et al. 2008. Distribution of ecosystem C and N within contrasting vegetation types in a semiarid rangeland in the Great Basin, USA. *Biogeochemistry* 90: 291–308. https://doi.org/10.1007/s10533-008-9254-z

Restoring these areas can be achieved by controlling annuals, removing tree seedlings with prescribed fire, and/or planting perennial forbs and grasses. Broadcasting native seeds and planting young bunchgrasses are effective methods, depending on the area and seed availability.

Metric

Estimated change in carbon relative to increasing perennial species cover. Perennial grass cover following restoration activities can be tracked and monitored over time on a project-level basis, and cover and biomass estimates for annual and perennial herbaceous species can be derived from remotely sensed products such as the Rangeland Analysis Platform. Remote sensing-derived products are often less reliable in disturbed landscapes,[154, 155] and these measures of biomass can vary tremendously with precipitation, but may be useful in tracking recovery over medium to long time frames.

Restore functioning riparian areas

Mesic areas such as streams and wet meadows are limited in many of the drier rangelands in the state. In grazed rangelands, cattle and horses tend to congregate near water, which can lead to the destruction of vegetation and soil disturbance if left unchecked.[156] The loss of vegetation reduces annual contributions to litter and soil organic matter pools and can lead to erosion and bank incision. Trampling by cattle and horses can also disturb the soil and break up soil aggregates that can stabilize organic matter in upper soil layers. The soil surface disturbance can lead to increased erosion of organic and mineral soil [157, 158, 159] and channel incision with the concomitant lowered water table. Degraded hydrology can lead to reduced water tables and productivity, and can mean the difference between meadows with intact hydrology being a major carbon sink, and meadows with degraded hydrology becoming a carbon source.[160, 161]

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[154] Applestein, C., and M.J. Germino. 2022. How do accuracy and model agreement vary with versioning, scale, and landscape heterogeneity for satellite-derived vegetation maps in sagebrush steppe? *Ecological Indicators* 139: 108935. https://doi.org/10.1016/j.ecolind.2022.108935

[155] Applestein, C., and M.J. Germino. 2021. Detecting shrub recovery in sagebrush steppe: comparing Landsat-derived maps with field data on historical wildfires. *Fire Ecology* 17: 5. https://fireecology.springeropen.com/articles/10.1186/s42408-021-00091-7

[156] Burdick, J., et al. 2021. Lentic meadows and riparian functions impaired after horse and cattle grazing. *The Journal of Wildlife Management* 85(6):1121–1131. https://doi.org/10.1002/jwmg.22088

[157] Booker, K., et al. 2013. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Global Environmental Change* 23: 240–251. https://doi.org/10.1016/j.gloenvcha.2012.10.001

[158] Boyd, C., and T. Svejcar. 2012. Biomass production and net ecosystem exchange following defoliation in a wet sedge community. *Rangeland Ecology and Management* 65: 394–400. https://doi.org/10.2111/REM-D-11-00159.1

[159] Boyd C. and T. Svejcar. 2004. Regrowth and production of herbaceous riparian vegetation following defoliation. *Journal of Range Management* 54: 448–454. https://doi.org/10.2111/1551-5028(2004)057[0448:RAPOHR]2.0.CO;2

[160] Norton, J.B., et al. 2011. Soil carbon and nitrogen storage in upper montane riparian meadows. *Ecosystems* 14: 1217–1231. https://doi.org/10.1007/s10021-011-9477-z

[161] Reed, C.C., et al. 2021. Montane meadows: A soil carbon sink or source? *Ecosystems* 24(5): 1125–1141. https://doi-org.oregonstate.idm.oclc.org/10.1007/s10021-020-00572-x

There are a number of practices that can reduce erosion, restore hydrologic function, and increase vegetation complexity and productivity.[162, 163] These may include:

- Fencing to keep livestock out of riparian areas, including physical fencing or virtual fencing using GPS collars for more precise and flexible direction of livestock movement. Exclusion of livestock through fencing and infrastructure to supply water outside of riparian areas can protect riparian vegetation and belowground biomass in the riparian exclosures.[164, 165]
- Development of infrastructure to move some water from the riparian area to a livestock trough in a less sensitive area.
- Planting or seeding shrubs and trees to restore degraded riparian communities.
- Low-tech stream restoration, such as beaver dam analogs, where appropriate.[166]
- Repairing down-cut or otherwise degraded watercourses to increase riparian function and raise water table, and/or floodplain restoration in places where streams have been channelized.

Metric

Estimated change in carbon relative to changes in fractional groups and riparian vegetation classes using fractional cover estimates derived from Rangeland Analysis Platform data and plot data. As previously stated, caution should be used as vegetation can vary greatly with precipitation, and these fractional cover estimates are updated on an annual basis.

Prevent conversion of grasslands, shrublands, and savannas to juniper woodlands

In higher elevation and more moist areas of eastern Oregon, conifers – most notably western juniper – have encroached into historic shrub steppe across large areas during the last century. Juniper encroachment can increase the amount of above-ground and near-surface soil carbon over short time frames,[167, 168] but in most places this carbon stored in trees is not stable and at risk of declines over longer time frames due to fire. If left unchecked, juniper encroachment reduces shrub

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[162] Batchelor, J.L., et al. 2015. Restoration of riparian areas following the removal of cattle in the Northwestern Great Basin. *Environmental Management* 55(4): 930–942. https://doi.org/10.1007/s00267-014-0436-2

[163] Matzek, V., et al. 2020. Increases in soil and woody biomass carbon stocks as a result of rangeland riparian restoration. *Carbon Balance and Management* 15:1–15. https://doi.org/10.1186/S13021-020-00150-7/FIGURES/8

[164] Kauffman, J.B., et al. 2004 Livestock exclusion and belowground ecosystem responses in riparian meadows of eastern Oregon. *Ecological Applications* 14(6): 1671–1679. https://doi.org/10.1890/03-5083

[165] Kauffman J.B., et al. 2022. Riparian vegetation composition and diversity shows resilience following cessation of livestock grazing in northeastern Oregon, USA. *PLoS ONE* 17(1): e0250136. https://doi.org/10.1371/journal.pone.0250136

[166] Silverman, N.L., et al. 2019. Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands. *Restoration Ecology* 27:269–278. https://doi:10.1111/rec.12869

[167] Fusco, E.J., et al. 2019. Invasive grasses increase fire occurrence and frequency across US ecoregions. Proceedings of the National Academy of Sciences of the United States of America 116: 23594–23599. https://doi.org/10.1073/pnas.1908253116

[168] Throop, H.L., and K. Lajtha. 2018. Spatial and temporal changes in ecosystem carbon pools following juniper encroachment and removal. *Biogeochemistry* 140: 373–388. https://doi.org/10.1007/s10533-018-0498-y.

and perennial grass cover, [169, 170] and the loss of soil carbon associated with shrub and grass vegetation generally offsets any gain in above-ground carbon from tree biomass.[171, 172] Furthermore, many of the plant communities where trees are encroaching rangelands are in areas with a high risk of wildfire. [173, 174] Woodlands with greater stem density often exhibit greater burn severity [175] and may experience rapid turnover (into CO_2) following wildfires.[176] In combination, these factors increase the likelihood that few perennials persist post-fire and the site will be invaded by annuals.[177] Juniper management may have similar beneficial impacts on carbon storage in savannas and sparse woodlands, which are widespread along the eastern edge of the Cascades and the margins of the Blue Mountains, depending on the site type and tree canopy cover. As with invasive species, early intervention efforts to prevent conversion of rangelands and savannas to woodlands are generally most effective.[178, 179, 180] Note that savanna systems are defined as having <20% tree canopy cover; refer to the forestry section for management of forests and woodlands.

Practices to prevent conversion of existing grasslands, shrublands, and savannas to juniper woodlands include juniper removal through lopping small trees, mechanical removal of trees with heavy machinery, and/or prescribed fire. Prescribed fire must be used with extreme caution, and released carbon into the atmosphere from the burning may offset some of the climate benefit of this

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[169] Morford, S.L., et al. 2022. Herbaceous production lost to tree encroachment in United States rangelands. *Journal of Applied Ecology* 59(12): 2971–2982. https://doi.org/10.1111/1365-2664.14288

[170] Miller, R.F, et al. 2005. Biology, Ecology, and Management of Western Juniper. In: Technical Bulletin 152. Oregon State University Agricultural Experiment Station, p. 77.

[171] Rau, B.M., et al. 2012. Developing a model framework for predicting effects of woody expansion and fire on ecosystem carbon and nitrogen in a pinyon juniper woodland. *Journal of Arid Environments* 76: 97–104. https://doi.org/10.1016/j.jaridenv.2011.06.005

[172] Abdallah, M.A.B., et al. 2020. Ecosystem carbon in relation to woody plant encroachment and control: Juniper systems in Oregon, USA. *Agriculture, Ecosystems and Environment* 290: 106762. https://doi.org/10.1016/j.agee.2019.106762

[173] Gilbertson-Day, J.W., et al. 2018. Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results, v2, *Pyrologix* 90 pp. http://oe.oregonexplorer.info/externalcontent/wildfire/reports/20170428_PNW_Quantitative_Wildfire_Risk_Assessment_Report.pdf.

[174] Schmidt, A., et al. 2022. A quantitative wildfire risk assessment using a modular approach of geostatistical clustering and regionally distinct valuations of assets—A case study in Oregon. *PLoS ONE* 17(3): e0264826. https://doi.org/10.1371/journal.pone.0264826

[175] Strand, E.K., et al. 2013. Influence of wildland fire along a successional gradient in sagebrush steppe and western juniper woodlands. *Rangeland Ecology & Management* 66: 667–679. https://doi.org/10.2111/REM-D-13-00051.1

[176] Neff, J.C., et al. 2009. Soil carbon storage responses to expanding pinyon–juniper populations in southern Utah. *Ecol. Appl.* 19: 1405–1416. https://doi.org/10.1890/08-0784.1

[177] Miller, R.F., and R.J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. *In*: Gallet, K.E.M., Wilson, T.P. (Eds.), Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species, pp. 15e30. Tall Timbers Research Station Miscellaneous Publications No. 11, Tallahassee, FL.

[178] Miller, R.F., et al. 2019. The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States. Gen. Tech. Rep. RMRS-GTR-403. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 284 p.

[179] Oklahoma Cooperative Extension Service. 2021. Reducing woody encroachment in grasslands: a guide for understanding risk and vulnerability. 32pp. https://naldc.nal.usda.gov/download/7548409/pdf

[180] Rau, B.M., et al. 2012. Developing a model framework for predicting effects of woody expansion and fire on ecosystem carbon and nitrogen in a pinyon-juniper woodland. *Journal of Arid Environments* 76: 97–104. https://doi.org/10.1016/j.jaridenv.2011.06.005

practice. Lopping of limbs to increase tree debris contact with soil surface when felling trees can help prevent further soil loss from erosion,[181] and removal of piled juniper slash can help control fuels and reduce risk of fire and release of invasive species.

Metric

Amount of carbon maintained in rangelands that would have been lost due to understory depletion. Remotely sensed estimates of threat-based ecostates based on rangeland vegetation composition estimate the extent of intact rangelands and can be updated over time. Coarse estimation techniques such as those described in Reeves et al (2020) can relate vegetative cover to carbon estimates, or carbon can be estimated based on regional and community type-based estimates of functional group cover in the literature.

Prevent conversion to urban and/or row crop land use

Rangelands, both globally as well as here in Oregon, tend to be slow at carbon sequestration but superior at long-term carbon storage because most of the carbon stored in these ecosystems exists belowground as organic matter.[182, 183, 184, 185] Avoiding conversion of rangelands to other land uses prevents the loss of these long-term carbon stores, thereby increasing future rangeland carbon sequestration potential across large swaths of land. Urban development reduces carbon sequestration potential by reducing or eliminating vegetation growth, thus reducing mechanisms of carbon flux, and by creating impermeable surfaces above the soil, effectively disconnecting atmospheric and terrestrial carbon pools. The intensive management currently practiced for most food commodities produced on agricultural land results in significantly less carbon stored in agricultural soils. Tillage in particular increases carbon loss by exposing organic matter to atmospheric gases and weather, which increases rates of decomposition and subsequent return of carbon to the atmosphere.[186, 187] Conservation easements are common mechanisms for maintaining rangeland uses and often involve direct payments and/or tax incentives to compensate owners for forgone development value.[188, 189] Other options include payments for avoided conversion (e.g.,

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[181] Pierson, F.B., et al. 2013. Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting. *Rangeland Ecology & Management* 66(3): 274–289. https://doi.org/10.2111/REM-D-12-00104.1

[182] Viglizzo, E.F., et al. 2019. Reassessing the role of grazing lands in carbon-balance estimations: meta-analysis and review. *Science of the Total Environment* 661: 531–542. https://doi.org/10.1016/j.scitotenv.2019.01.130

[183] Dass, P, et al. 2018. Grasslands may be more reliable carbon sinks than forests in California. *Environmental Research Letters* 13(7): 1–8. https://doi.org/10.1088/1748-9326/aacb39

[184] Pendall, E., et al. 2018. Chapter 10: Grasslands. *In* Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 399-427, https://doi.org/10.7930/SOCCR2.2018.Ch10

[185] Booker, K., et al. 2013. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Global Environmental Change* 23: 240–251. https://doi.org/10.1016/j.gloenvcha.2012.10.001

[186] Ibid.

[187] Uri, N.D., and H. Bloodworth. 2000. Global climate change and the effect of conservation practices in U.S. agriculture. *Global Environmental Change* 10(3): 197–209. https://doi.org/10.1016/S0959-3780(00)00023-6

[188] Naugle, D.E., et al. 2019. CEAP quantifies conservation outcomes for wildlife and people on western grazing lands. *Rangelands* 41(5): 211–217. https://doi.org/10.1016/j.rala.2019.07.004

[189] Havstad, K.M., et al. 2007. Ecological services to and from rangelands of the United States. *Ecological Economics* 64(2): 261–268. https://doi.org/10.1016/j.ecolecon.2007.08.005

Conservation Reserve Program), and payments for restoration or conversion of marginal cropland back to rangeland (e.g., Conservation Enhancement Activity via the Conservation Stewardship Program).

Metric

Amount of carbon that is preserved in rangelands and not converted to other land use types. Datasets such as the National Land Cover Database provide estimates of the extent of natural vegetation communities and urban or agricultural land uses over time, and can be related to carbon equivalent through region-specific estimates derived from the literature.

Emerging Practices

The following management topics are **emerging,** and more data are required to have confidence in their efficacy to promote carbon sequestration:

- **Biochar or adding carbon** – adding biochar, sugar, or other carbon has been proposed as an amendment to rangeland soils to alter soil biogeochemistry, reduce annual plant invasions, and promote native perennial species.[190, 191, 192] Rates of success and the potential for adverse effects on soil health are not well understood and mediated by many factors, including source materials and preparation conditions.[193] More research is needed to determine the efficacy and ability of this practice to be applied at scale in Oregon's rangelands.
- **Supplementations to reduce enteric methane for rangeland livestock** – enteric emissions of methane from ruminants can be a large source of greenhouse gases. There are a number of methods that have been proposed which could mitigate this issue,[194] but vary in their suitability for implementation and with unknown levels of effectiveness. More data is needed to determine if this practice can appreciably reduce methane emissions from grazed rangelands.
- **Management practices to store carbon in soil inorganic pools** – soil inorganic carbon stocks may be as large as soil organic carbon stocks in semi-arid and arid rangelands,[195] but the dynamic nature of soil inorganic carbon storage and cycling is a topic needing more

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[190] Gao, S., and T.H. DeLuca. 2022. Rangeland application of biochar and rotational grazing interact to influence soil and plant nutrient dynamics. Geoderma 480: 115572. https://doi.org/10.1016/j.geoderma.2021.115572

[191] Phillips, C.L., et al. 2021. Manipulating rangeland soil microclimate with juniper biochar for improved native seedling establishment. *Soil Science Society of America Journal* 85: 847–861. https://doi.org/10.1002/saj2.20207

[192] Ossanna, L.Q., and E.S. Gornish. 2023. Efficacy of labile carbon addition to reduce fast-growing, invasive non-native plants: A review and meta-analysis. *Journal of Applied Ecology* 60(2): 218–228. https://doi.org/10.1111/1365-2664.14324

[193] Zhang, Y., J. Wang, and Y. Feng. 2021. The effects of biochar addition on soil physiochemical properties: A review. *Catena* 202: 105284. https://doi.org/10.1016/j.catena.2021.105284

[194] Thompson, L.R., and J.E. Rowntree. 2020. Invited Review: Methane sources, quantification, and mitigation in grazing beef systems. *Applied Animal Science* 36(4): 556–573. https://doi.org/10.15232/aas.2019-01951

[195] Naorem, A., et al. 2022. Soil inorganic carbon as a potential sink in carbon storage in dryland soils—A review. *Agriculture* 12(8): 1256. https://doi.org/10.3390/agriculture12081256

research.[196, 197, 198, 199] Soil inorganic carbon stocks will likely respond to changes in the aboveground plant community, for example, in response to invasive annual grasses, which can change the hydrologic regime of soil[200] in addition to altering the composition of the soil atmosphere, thereby impacting soil inorganic carbon[201] formation and cycling. Under some conditions, root respiration leads to high concentrations of dissolved carbon dioxide in soil water, which later precipitates as solid carbon containing calcium carbonate upon desiccation of soils during the annual summer drought. Due to the relatively shorter growing season and shallow root system of invasive annuals compared to native perennials, less carbon dioxide is expected to enter the soil, and under a different hydrologic regime, all of which may limit soil inorganic carbon formation and storage as mineral calcium carbonate. More information is needed to determine what, if any, practices can influence soil inorganic carbon.

Practices Currently Not Recommended

The following management pathways were considered but are **currently not recommended** because they were either of low confidence, had the potential to cause harm to the system, or their efficacy to result in a net reduction in greenhouse gas emissions is low:

- **Expansion of conifers or afforestation on rangelands** – Most rangelands naturally lack tree cover, and there is a risk of harm to the system through attempts at afforestation. Although trees store more carbon above-ground as compared to shrubs and grasses, below-ground soil carbon pools are at risk of depletion, resulting in an overall carbon loss as

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[196] Ibid.

[197] Huber, D.P., et al. 2019. Vegetation and precipitation shifts interact to alter organic and inorganic carbon storage in cold desert soils. *Ecosphere* 10(3): p.e02655. https://doi.org/10.1002/ecs2.2655

[198] Lohse, K.A., et al. 2022. Multiscale responses and recovery of soils to wildfire in a sagebrush steppe ecosystem. *Scientific Reports* 12*(*1): 22438. https://doi.org/10.1038/s41598-022-26849-w

[199] Stanbery, C., et al. 2023. Controls on the presence and storage of soil inorganic carbon in a semi-arid watershed. *Catena* 225: p.106980. https://ui.adsabs.harvard.edu/link_gateway/2023Caten.22506980S/doi:10.1016/j.catena.2023.106980

[200] Garbowski, M., et al. 2021. Invasive annual grass interacts with drought to influence plant communities and soil moisture in dryland restoration. *Ecosphere* 12(3): p.e03417. https://doi.org/10.1002/ecs2.3417

[201] Huber, D.P., et al. 2019. Vegetation and precipitation shifts interact to alter organic and inorganic carbon storage in cold desert soils. *Ecosphere* 10(3): p.e02655. https://doi.org/10.1002/ecs2.2655

described above under the section on preventing conversion of rangelands to woodlands.[202, 203, 204, 205, 206, 207]

- **Oak savanna restoration** – Similar to other rangelands experiencing conifer encroachment, oak savanna natural communities have been overtaken by conifer forests throughout much of their historic range due to lack of disturbance, and many efforts to restore historic oak savanna ecosystems are underway. If not maintained through prescribed fire or other management, these habitats will naturally convert to forests and woodlands of Douglas-fir and oak, which sequester significantly more carbon than savannas.
- **Mesic grasslands restoration** – Although no longer abundant, the remaining wet prairies on the west side of the state dominated by perennial bunchgrasses, rushes, sedges, and forbs are being actively restored and conserved due to the presence of at-risk plants and animals restricted to the habitats. Although these are seasonal wetlands, they are only flooded in the winter, and are dry enough throughout most of the growing season that methane emissions are unlikely to exceed carbon sequestered in the soil, plants, and isolated trees.

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[202] Miller, R. et al. 2019. The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States. Gen Tech. Rep. RMRS-GTR-403. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 284 p.

[203] Rau, B.M., et al. 2012. Developing a model framework for predicting effects of woody expansion and fire on ecosystem carbon and nitrogen in a pinyon juniper woodland. *Journal of Arid Environments* 76: 97–104. https://doi.org/10.1016/j.jaridenv.2011.06.005

[204] Abdallah, M.A.B., et al. 2020. Ecosystem carbon in relation to woody plant encroachment and control: Juniper systems in Oregon, USA. Agriculture. *Ecosystems and Environment* 290: 106762. https://doi.org/10.1016/j.agee.2019.106762.

[205] Booker, K., et al. 2013. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Global Environmental Change* 23: 240–251. https://doi.org/10.1016/j.gloenvcha.2012.10.001

[206] Veldman, J.W., et al. 2015. Where Tree Planting and Forest Expansion are Bad for Biodiversity and Ecosystem Services. *BioScience* 65(10): 1011–1018. https://academic.oup.com/bioscience/article/65/10/1011/245863

[207] Baldocchi, D., and J. Penuelas. 2018. The physics and ecology of mining carbon dioxide from the atmosphere by ecosystems. *Global Change Biology* 25(4): 1191–1197. https://onlinelibrary.wiley.com/doi/10.1111/gcb.14559

FOREST LANDS

Practices to Increase Carbon Stocks and/or Reduce Greenhouse Gas Emissions from Oregon's Forest Lands

Authors: Sean Gordon (INR), Rose Graves (The Nature Conservancy)
Reviewers: Charles Maxwell, Danny Norlander, Andrew Yost, Ryan Haugo, Kerry Metlen, Kendall DeLyser

These draft recommendations for practices on forested lands were developed through an iterative process. Initial recommendations were identified through a literature review and consultations with the NWL Carbon project team. This initial practice list was then sent out to external subject matter experts for review. Their suggestions were integrated and incorporated into this draft based on further review by the NWL Carbon project team.

Recommended Practices

Prevent Conversion of Forest to Non-forest Land Uses

Forested lands tend to hold the most carbon of any land use/cover classes, thus maintaining lands in this class is an important contribution to carbon sequestration.[208] Avoiding conversion of forests to other land uses prevents the loss of existing forest carbon stores and future forest carbon sequestration potential. Conservation easements are common mechanisms for maintaining forested land uses and often involve direct payments and/or tax incentives to compensate owners for forgone development value.

The estimated net mitigation potential from increasing the protection of forests through conservation easements, tax incentives, or land use planning is uncertain. Estimating the mitigation potential from any of these activities is sensitive to the assumed baseline and system boundaries. Forest protection activities should only be considered a GHG mitigation practice if they are expected to provide net sequestration beyond business-as-usual and, where possible, incentives aimed at avoided conversion of forest lands for GHG mitigation should include some assessment of conversion risk. For example, if the forest is not threatened by conversion in the near-term (e.g., 15 years) then administrative protection does not provide any additional climate mitigation. Accounting for the GHG reductions due to protection of forests should be calculated against a backward-looking counterfactual or dynamic baseline.

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[208] U.S. Environmental Protection Agency (EPA). 2022. *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018*. US Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per acre of protected forestland, plus any growth and minus any harvest, plus storage in wood products and landfills measured over a certain period (e.g., a time-limited easement or planning horizon).

$$\text{Metric} = [(SLT_a - SLT_b) + (SDT_a - SDT_b)] * L + HWP_a - HWP_b$$

Where: a/b subscripts = actual project as proposed vs. baseline
SLT = standing live trees
SDT = standing dead trees
L = market leakage factor
HWP = hardwood products

Method for tracking

Per acre values would need to be estimated from inventory values for similar forest types and age classes. Values could be discounted by expected rates for leakage and loss due to natural hazards if reasonable to estimate.

Afforestation / Reforestation

Afforestation/reforestation activities will generally increase carbon storage and sequestration capacity of lands not currently forested. Marginal agricultural lands and riparian areas are potential areas of opportunity.[209, 210] Afforestation can be considered detrimental in some ecosystems (e.g., juniper encroachment in sagebrush ecosystems), thus any afforestation/reforestation activities should consider ecological integrity, including consideration of appropriate species composition. Oregon already requires replanting after timber harvests, however, there are other planting opportunities/practices that could enhance carbon storage, such as after wildfire and other natural disturbances. However, replanting / supplemental planting should consider species composition, density, and spatial patterns to promote ecological resilience relative to operational resilience and anticipated future climate impacts and disturbances.[211] With caveats for appropriate species composition and forest structure/spatial patterns that will be resilient to anticipated disturbances, opportunities for increasing carbon stocks and fluxes could include:

- Afforestation/reforestation of non-forested lands
- Planting trees in riparian areas within other land uses/classes
- Increased or more comprehensive replanting after wildfires[212]

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[209] Janowiak, M., et al. 2017. Considering Forest and Grassland Carbon in Land Management. General Technical Report WO-95. Washington, DC: USDA Forest Service. https://www.fs.usda.gov/sites/default/files/fs_media/fs_document/wo-95-consideringforestandgrasslandcarboninlandmanagement-508-92517.pdf

[210] Graves, R.A. et al. 2020. Potential greenhouse gas reductions from Natural Climate Solutions in Oregon, USA. *PLoS ONE* 15(4): 1–30. https://doi.org/10.1371/journal.pone.0230424

[211] North, M.P., et al. 2019. Tamm Review: Reforestation for resilience in dry western U.S. forests. *Forest Ecology and Management* 432: 209–224. https://doi.org/10.1016/j.foreco.2018.09.007

[212] Graves, R.A. et al. 2020. Potential greenhouse gas reductions from Natural Climate Solutions in Oregon, USA. *PLoS ONE* 15(4): 1–30. https://doi.org/10.1371/journal.pone.0230424

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per acre of forestland. These benefits only accumulate over time, so a certain analysis period would need to be chosen.

Method for tracking

Per acre values would need to be estimated from inventoried values for similar forest types and age classes (or using forest growth models). Values could be discounted by expected rates for leakage and loss due to natural hazards if reasonable to estimate. A baseline of bare ground or a natural regeneration estimate could be used.

Improved Forest Management

The California Air Resources Board (CARB) US Forest Protocol[213] and the two main GHG offset market registries in the US (American Carbon Registry[214], Climate Action Reserve[215]) all include protocols related to "Improved Forest Management". These protocols tend to focus on increasing above ground carbon storage in forests. CARB states that eligible management activities may include, but are not limited to:

(1) Increasing the overall age of the forest by increasing rotation ages;
(2) Increasing the forest productivity by thinning diseased and suppressed trees;
(3) Managing competing brush and short-lived forest species;
(4) Increasing the stocking of trees on understocked areas; and/or
(5) Maintaining stocks at a high level.

Practices that extend harvest rotations or reduce harvest intensities (partial cut, variable-retention, uneven-aged management, increased riparian buffers) have the potential to maintain more carbon in particular forest management units, however, if overall GHG reduction is the objective, other carbon pools and contingencies also should be considered. Soils are estimated to store approximately half of the carbon in Oregon's forested ecosystems, but showed little change

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[213] California Air Resources Board (CARB). 2015. *Compliance Offset Protocol: U.S. Forest Projects*. California Environmental Protection Agency, Air Resources Board. https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory_technical.pdf

[214] ACR. 2022. Methodology for the Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emissions Reductions and Removals for Improved Forest Management (IFM) on Non-Federal U.S. Forestlands (Version 2.0). American Carbon Registry. https://americancarbonregistry.org/carbon-accounting/standards-methodologies/improved-forest-management-ifm-methodology-for-non-federal-u-s-forestlands

[215] Climate Action Reserve (CAR). 2019. Forest Protocol (Version 5.0). Climate Action Reserve. https://www.climateactionreserve.org/how/protocols/ncs/forest/

compared to other pools in inventory and modeling studies.[216, 217, 218] The CARB protocol includes belowground biomass and ACR optionally includes dead wood, but other pools are relatively small according to the Oregon Forest Ecosystem Carbon Inventory: dead trees (2%), roots (7%), down wood (5%), forest floor (4%) and understory vegetation (1%).[219] The Oregon inventory estimates the largest loss in forest carbon coming from timber harvests, but harvested wood is converted into forest products that have a range lifespans and decay rates. Protocols have integrated the storage of carbon in harvested wood products (HWP C) using lookup tables based on broad product categories and estimated lifespans.[220] Oregon has recently sponsored an inventory of HWP C and created a tool to more accurately estimate categories and lifespans.[221, 222] Carbon protocols also consider "leakage" as a secondary effect. Leakage in a market sense refers to a harvest reduction in one place (e.g., due to carbon incentives) leading to increased harvesting elsewhere. Leakage rate estimates have ranged widely from <10 to >90%.[223, 224, 225] CARB applies a uniform rate of 20%, while ACR varies by project type/size from 0-30%. A further consideration, not currently covered by the protocols is "substitution," where forest products are substitutable with other resources, such as steel and concrete for buildings or fossil fuels for energy. A few studies have found that the effects of substituting wood for other building materials and fossil fuels are potentially large and

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[216] Christensen, G.A., et al. 2019. Oregon Forest Ecosystem Carbon Inventory: 2001–2016. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; Oregon Department of Forestry. https://www.oregon.gov/odf/forestbenefits/Pages/forestcarbonstudy.aspx

[217] Creutzburg, M.K., et al. 2017. Forest management scenarios in a changing climate: Trade-offs between carbon, timber, and old forest. *Ecological Applications* 27(2): 503–518. https://doi.org/10.1002/eap.1460

[218] Holub, S.M., and J.A. Hatten. 2019. Soil carbon storage in Douglas-Fir forests of western Oregon and Washington before and after modern timber harvesting practices. *Soil Science Society of America Journal* 83(S1): 175–S186. https://doi.org/10.2136/sssaj2018.09.0354

[219] Christensen, G.A., et al. 2019. Oregon Forest Ecosystem Carbon Inventory: 2001–2016. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; Oregon Department of Forestry. https://www.oregon.gov/odf/forestbenefits/Pages/forestcarbonstudy.aspx

[220] Smith, J.E., et al. 2006. *Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States* (General Technical Report (GTR) GTR-NE-343). U.S. Department of Agriculture, Forest Service, Northeastern Research Station. https://doi.org/10.2737/ne-gtr-343

[221] Morgan, T.A., et al. 2020. *Oregon Harvested Wood Products Carbon Inventory 1906 – 2018*. USDA Forest Service, Forest Inventory and Analysis Program; Oregon Department of Forestry. https://www.oregon.gov/odf/Documents/forestbenefits/oregon-harvested-wood-products-carbon-inventory-report-1906-2018.pdf

[222] Groom Analytics. 2022. Harvested Wood Products Carbon Model, v.R. https://groomanalyticsllc.shinyapps.io/HWP-C-vR/

[223] Murray, B.C., B.A. McCarl, and H.-C. Lee. 2004. Estimating leakage from forest carbon sequestration programs. *Land Economics 80*(1): 109–124. https://doi.org/10.2307/3147147

[224] Gan, J., and B.A. McCarl. 2007. Measuring transnational leakage of forest conservation. *Ecological Economics* 64(2): 423–32. https://doi.org/10.1016/j.ecolecon.2007.02.032

[225] Wear, D.N., and B.C. Murray. 2004. Federal timber restrictions, interregional spillovers, and the impact on US softwood markets. *Journal of Environmental Economics and Management* 47(2): 307–30. https://doi.org/10.1016/S0095-0696(03)00081-0

could reduce overall GHG emissions even with more intensive harvesting.[226, 227, 228, 229] It should also be noted that incentives which change harvesting levels can have secondary effects on a variety of other non-GHG related policy concerns, such as ecosystem services, employment, and processing infrastructure.

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per acre of forestland retained over a business-as-usual baseline.

$$\text{Metric} = [(SLT_a - SLT_b) + (SDT_a - SDT_b)] * L + HWP_a - HWP_b$$

Where:
a/b subscripts = actual project as proposed vs. baseline
SLT = standing live trees
SDT = standing dead trees
L = market leakage factor
HWP = hardwood products

Method for tracking

Baselines could be estimated from historic practices by surrounding ecoregion, forest type, and ownership class. Assuming that active management would continue on the land, a certain analysis period (i.e., a set number of years) would need to be chosen. Per acre values over time would need to be estimated using forest growth models to provide a meaningful counterfactual. Values could be discounted by expected rates for leakage and loss due to natural hazards if reasonable to estimate. Storage and release from wood products could also be considered using recently developed models.

Increase the Proportion of Carbon Stored Within Long-lived Harvested Wood Products

A large amount of carbon moves from the forest into the HWP pool annually. Over time, a portion of the carbon is released from the HWP pool back to the atmosphere through natural decay and burning. The rate of emission varies considerably among different HWPs and depends on product end-of-life. For example, if timber is harvested for fuelwood, combustion releases carbon immediately. When discarded HWPs are burned, other greenhouse gases (CH_4, N_2O, CO, and NOx) are emitted. If HWPs are disposed of in solid waste disposal sites, the carbon contained in the wood

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[226] Dugan, A.J., et al. 2018. A systems approach to assess climate change mitigation options in landscapes of the United States forest sector. *Carbon Balance Manage.* Sep 4; 13(1):13. https://doi.org/10.1186/s13021-018-0100-x

[227] Gustavsson, L., et al. 2017. Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels. *Renewable and Sustainable Energy Reviews* 67: 612–624. https://doi.org/10.1016/j.rser.2016.09.056

[228] NCASI. 2020. *Review of Carbon Implications of Proforestation.* https://www.ncasi.org/wp-content/uploads/2020/12/Review_Carbon_Implications_Proforestation_Dec2020.pdf

[229] Smyth, C., et al. 2017. Estimating product and energy substitution benefits in national-scale mitigation analyses for Canada. *GCB Bioenergy* 9: 1071–84. https://doi.org/10.1111/gcbb.12389

may be released many years or decades later.[230] Timber harvested and used as lumber decays more slowly, persisting for the useful life of the building or longer if materials are recovered, reused, or repurposed.[231] In addition to long-term carbon storage, HWPs used for mass timber buildings have reported the potential to reduce emissions by displacing some steel and concrete building materials.[232, 233, 234, 235] Increasing the proportion of harvested carbon stored within long-lived harvested wood products (HWP) may be a tool to mitigate climate change. However, changes in carbon stocks associated with the production and end use of HWPs fall within a broader system, and accounting should consider carbon dynamics both in forests and in end-use HWPs.[236]

Metric

Metric tons of carbon dioxide equivalents (tCO2e) per year retained in wood products compared to the business-as-usual baseline.

Method for tracking

Baselines could be estimated from historic practices by region, and forest type. A certain analysis period would need to be chosen. Storage and release from wood products would be estimated using recently developed models based on reported forest products and usage data.[237, 238]

Reduce Wildfire Risks

Wildfires are a major source of carbon released into the atmosphere from forests. Some wildfire is natural to all forests; however, the natural frequency and intensity vary considerably between forest types. A century of fire exclusion has led to a buildup of forest densities and fuels, including loss of

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[230] U.S. Environmental Protection Agency (EPA). 2022. *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018*. US Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

[231] Johnston, C., and V. Radeloff. 2019. Global mitigation potential of carbon stored in harvested wood products. *Proc. Natl. Acad. Sci.* USA 116: 1426–14531. https://doi.org/10.1073/pnas.1904231116

[232] Gu, H., and R. Bergman. 2018. Life Cycle Assessment and Environmental Building Declaration for the Design Building at the University of Massachusetts; General Technical Report FPL-GTR-255; U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: Madison, WI, USA. pp. 1–73.

[233] Liang, S., et al. 2020. Comparative life-cycle assessment of a mass timber building and concrete alternative. *Wood Fiber Sci.* 52(2): 217–229.

[234] Pierobon, F., et al. 2019. Environmental benefits of using hybrid CLT structure in midrise non-residential construction: An LCA based comparative case study in the U.S. Pacific Northwest. *J. Build. Eng.* 26: 100862. https://doi.org/10.1016/j.jobe.2019.100862

[235] Puettmann, M., et al. 2021. Comparative LCAs of conventional and mass timber buildings in regions with potential for mass timber penetration. *Sustainability* 13: 13987. https://doi.org/10.3390/su132413987

[236] McKinley, D.C., et al. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. *Ecological Applications* 21(6): 1902–24. https://doi.org/10.1890/10-0697.1

[237] Groom Analytics. 2022. Harvested Wood Products Carbon Model, v.R. https://groomanalyticsllc.shinyapps.io/HWP-C-vR/

[238] University of Montana (n.d.). *Logging utilization and biomass*. Bureau of Business and Economic Research. Retrieved February 9, 2023, from https://www.bber.umt.edu/FIR/logUtil.asp

non-forest habitats, which leads to higher fire intensities, mortality, and carbon releases.[239, 240] Fire exclusion has thereby generated a "carbon debt" meaning excess carbon in contemporary forests.[241] Recent studies in California, applicable to the mixed conifer/hardwood forests of Oregon, found that forests resilient to historically frequent fires likely had 25%[242] to 50%[243] of carbon now found in contemporary forests, commensurate with tree density/stocking levels of approximately 25%.[244] A variety of activities can be used to manage density and fuel loads[245, 246] and thus reduce fire intensity/severity and long-term reductions in carbon stocks/fluxes. Activity-based accounting is difficult because the atmospheric benefit of a treatment depends upon the likelihood of the treatment experiencing wildfire, the scale of treatments, and the long-term maintenance of treatments. However, several modeling studies have found that a combination of fuel treatments (mechanical removal and prescribed fire) could provide carbon benefits in fire-prone forests at larger scales (>50,000 ac) over longer time periods (>40 years)[247, 248, 249, 250, 251, 252] This activity could include any of the following specific management practices:

- Thinning to stocking levels more resilient to fire and drought
- Removal of trees killed or damaged by insects and diseases

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[239] Haugo, R.D., et al. 2019. The missing fire: Quantifying human exclusion of wildfire in Pacific Northwest forests, USA. *Ecosphere* 10(4): e02702. https://doi.org/10.1002/ecs2.2702

[240] Hagmann, R.K., et al. 2021. Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. *Ecological Applications* 31(8): e02431. https://doi.org/10.1002/eap.2431

[241] Serra-Diaz, J.M., et al. 2018. Disequilibrium of fire-prone forests sets the stage for a rapid decline in conifer dominance during the 21st century. *Scientific Reports* 8:6749. https://doi.org/10.1038/s41598-018-24642-2

[242] Bernal, A.A., et al. 2022. Biomass stocks in California's fire-prone forests: mismatch in ecology and policy. *Environmental Research Letters* 17: 044047. https://doi.org/10.1088/1748-9326/ac576a

[243] Knight, C.A., et al. 2022. Land management explains major trends in forest structure and composition over the last millennium in California's Klamath Mountains. *Proceedings of the National Academy of Sciences* 119: e2116264119. https://doi.org/10.1073/pnas.2116264119

[244] North, M.P., et al. 2019. Tamm Review: Reforestation for resilience in dry western U.S. forests. *Forest Ecology and Management* 432: 209–224. https://doi.org/10.1016/j.foreco.2018.09.007

[245] Janowiak, M., et al. 2017. Considering Forest and Grassland Carbon in Land Management. General Technical Report WO-95. Washington, DC: USDA Forest Service. https://www.fs.usda.gov/sites/default/files/fs_media/fs_document/wo-95-consideringforestandgrasslandcarboninlandmanagement-508-92517.pdf

[246] McKinley, D.C., et al. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. *Ecological Applications* 21(6): 1902–24. https://doi.org/10.1890/10-0697.1

[247] Hurteau, M.D., et al. 2016. Restoring forest structure and process stabilizes forest carbon in wildfire-prone southwestern ponderosa pine forests. *Ecological Applications* 26: 382–391. http://dx.doi.org/10.1890/15-03371.1/

[248] Krofcheck, D.J., et al. 2019. Optimizing forest management stabilizes carbon under projected climate and wildfires. *J Geophys Res Biogeosci* 124: 3075–3087. https://doi.org/10.1029/2019JG005206

[249] Ibid.

[250] Liang S., et al. 2018. Large-scale restoration increases carbon stability under projected climate and wildfire regimes. *Frontiers in Ecology and the Environment* 16: 207–212. https://doi.org/10.1002/fee.1791

[251] Loehman, R., et al. 2018. Can land management buffer impacts of climate changes and altered fire regimes on ecosystems of the southwestern United States? *Forests* 9: 32pp. https://doi.org/10.3390/f9040192

[252] McCauley, L.A., et al. 2019. Large-scale forest restoration stabilizes carbon under climate change in Southwest United States. *Ecol Appl.* 29. https://doi.org/10.1002/eap.1979

- Mechanical understory removal
- Prescribed fire

Metric

Net ecosystem carbon benefit in metric tons of carbon dioxide equivalents (tCO_2e) per acre of forestland treated over a no action (or business as usual) baseline, as derived from model simulations.

Method for tracking

Baselines and treatment alternatives would need to be simulated over large spatial and temporal scales, including disturbance patterns by region, forest type, and ownership class. Practices would be restricted to and prioritized by forest types and stocking levels at the most risk of high-intensity fire. Storage and release from wood products could also be considered using recently developed models.

Further Research Suggested

Increasing Soil Storage of Carbon Through Mulching, Chipping of Slash

Further research suggested on the efficacy of or the ability to create a baseline for related practices.

Increase Utilization of Discarded Forest Biomass (slash material)

Forest harvesting leaves a significant fraction of discarded biomass onsite (slash material), which is typically disposed of via pile burning or left to decay, releasing much of its carbon either quickly upon burning or over tens of years if left to decay naturally. Developing alternative uses for this material could reduce biogenic carbon emissions due to biomass decomposition from soils and slash left on-site or could offset other emissions sources. For example, converting tree plantation residues to biochar reduces the residues left on site (forest floor and soil) and biochar may have a slower decay rate.

- Divert more of this material to wood products (like oriented strandboard and other pulp products)
- Use this material to generate bioenergy as a substitute for fossil fuel energy[253]
- Use this material to create biochar, either on-site or in dedicated facilities.
- Use this material to create transportation fuels (renewable diesel and aviation fuel).

Further research suggested on lifecycle and substitution effects.

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per acre of forest harvest debris diverted to other uses.

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[253] U.S. Department of Energy. 2011. *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*. U.S. Department of Energy; Oak Ridge National Laboratory. https://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf

Method for tracking

Baselines could be estimated from historic practices by region, forest type, and ownership class. Storage and release from wood products could be considered using recently developed models. Methods to estimate the carbon impacts of biochar and fuels use may require further research.

Not Recommended at this Time

Reduce Biological Risks

- Reduce the risk of forest carbon loss due to pests and pathogens.
- Interception of agents
- Forest health treatments

Not recommended at this time because of insufficient information to link practices to GHG impacts.

AGRICULTURAL LANDS

Practices to Increase Carbon Stocks and/or Reduce Greenhouse Gas Emissions from Oregon's Agricultural Lands

Author: Mike Badzmierowski (Oregon Department of Agriculture)
Experts Consulted: Markus Kleber, Lucas Silva, Kiara Winans, Emily Oldfield, Jonathan Sanderman, Andrew McGuire, Devin Rippner, Stewart Wuest, Serkan Ates, Richard Waite, Ermias Kebreab, Jennifer Moore, Laurel Pfeifer-Meister

The agriculture land use/sector has an important role in reducing GHG emissions while providing food and raw material. Global food consumption alone could add nearly 1°C to warming by 2100.[254] Given that the global temperature has increased approximately 1.2 °C since 1880, this additional increase in global food consumption emissions would consume all of the global GHG budget to limit the temperature increase to 2°C and fail to meet the goal of 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' set by the 2015 Paris Agreement.[255]

There are many strategies to reduce GHG emissions and/or sequester net carbon that do not fall within the context of GHG inventory for the NWL's initial efforts. However, it would be impossible to meaningfully address the emissions related to agriculture without including emissions that are included in other sectors. Oregon's agricultural sector emissions are dominated by enteric fermentation (48%), followed by nitrogen fertilizers (38%), and manure management (13%), not including on-farm energy use.[256] It should be noted these values use global warming potentials on a 100-year timeframe and does not consider a 20-year timeframe for short-lived gases such as methane. The technical team has decided to provide practices in agriculture that would be included in the NWL sector and as well as other sectors. This broader view of agriculture and emissions has allowed the inclusion of an extensive list of potential practices but is not exhaustive.

The following includes practices currently recommended and practices currently not recommended. Practices are listed alphabetically but separated by sector. Future iterations should consider practices to be ranked according to their potential to reduce GHG emissions. All practices are subject to change classification based on future available data. The strategy of this land use was two-fold. The first was to have generalized discussions with Oregon researchers and experts on broad-scale practices and their potential to reduce GHG emissions. This first round of discussions did not

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[254] Armstrong McKay, D.I., et al. 2022. Exceeding 1.5 C global warming could trigger multiple climate tipping points. *Science* 377(6611): eabn7950. https://doi.org/10.1126/science.abn7950

[255] United Nations/Framework Convention on Climate Change. 2015. Adoption of the Paris Agreement, 21st Conference of the Parties, Paris: United Nations.

[256] Allaway, D., et al. 2018. Oregon's Greenhouse Gas Emissions Through 2015: Sector and Consumption-Based Inventories. Oregon Department of Environmental Quality. https://www.oregon.gov/deq/FilterDocs/OregonGHGreport.pdf

include practices outside the N&WL sector. We received guidance from INR that we may include more comprehensive agricultural sector practices. This new guidance led to soliciting a more standardized approach to gaining expert opinion on a wide set of practices both in the N&WL sector and the agriculture sector. Two approaches were taken simultaneously. One approach was through a long interview. Discussions were held with experts to allow for nuance and clarity when discussing practices. Experts had the choice to either use the conversation as testimony and/or provide their recommendations via the second approach: a standardized form. The second approach used a standardized form that allowed experts from Oregon and across the United States to:

- Rate their confidence level that a given practice will be a net reduction in GHG emissions after ensuring the practice is additional.
- Rate the associated risk of reversal (the risk that potential net GHG reductions could be reversed).
- Provide comments on durability or leakage.
- Provide comments on feasibility.

The experts were given the choices, “high,” “low,” “need more data and/or case-by-case basis,” and “abstain” for the previously mentioned tasks one and two.

This is an ongoing process to receive as much feedback from as many sources as possible. Experts were chosen and contacted based on known experts by the technical team, recommendations by experts, and personalized emails to lead authors on natural climate solutions reports and related published documents.

Metric

Metric tonnes of carbon dioxide equivalents (tCO_2e) per unit (i.e., a unit referring to the subject could be acres, livestock, etc.) will be the standard measuring unit for all practices compared to the business-as-usual pathway and/or a suitable dynamic check (control). There should be a breakdown of each gas species (CO_2, CH_4, and N_2O) of their contribution to the whole single-basket GWP of tCO_2e.

Practices currently recommended as “high confidence” for the reduction of GHG emissions

Natural and Working Lands Sector

Increase Riparian Areas Beyond the Edge of Field – Reforestation[257]

Dybala et al. (2019) provide evidence that reforestation of riparian areas most likely reduces GHG emissions due to the increased biomass associated with trees.

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[257] Dybala, K.E., et al. 2019. Carbon sequestration in riparian forests: A global synthesis and meta-analysis. *Global Change Biology* 25(1): 57–67. https://doi.org/10.1111/gcb.14475

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per acre converted from non-forested crops to tree vegetation.

Method for tracking

Number of acres converted and using remote sensing to confirm and determine success over time.

Other Sectors

* † ‡ § Anaerobic Digestion of Manure and Beneficial Use of Methane or Flaring and Appropriate Land Application of Digestate [258, 259]

Anaerobic digestion and capture/beneficial use of methane is the best option from a GHG reduction perspective to reduce emissions from large-scale manure handling operations. This can include covered lagoons and digesters.

Metric

Metric tons of carbon dioxide equivalents (tCO_2e) per digester adjusted for type of digester.

Method for tracking

Number and type of animals serving as feedstock to the digester.

*** Improve Irrigation Strategies and Efficiencies** (Irrigation is directly related to soil GHG emissions and nitrogen fertilizer emissions and efficiency. Irrigation efficiency is a part of this strategy but has the most effects on the energy sector, i.e., improvement in water efficiency implies less mass of water that is pumped and delivered which reduces GHG emissions).[260, 261, 262, 263, 264]

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[258] Aguirre-Villegas, H.A., and R.A. Larson. 2017. Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. *Journal of Cleaner Production* 143: 169–179. https://doi.org/10.1016/j.jclepro.2016.12.133

[259] Battini F., et al. 2014. Mitigating the environmental impacts of milk production via anaerobic digestion of manure: Case study of a dairy farm in the Po Valley. *Science of The Total Environment* 481: 196–208. https://doi.org/10.1016/j.scitotenv.2014.02.038

[260] Andrews, H.M., et al. 2022. Water-conscious management strategies reduce per-yield irrigation and soil emissions of CO_2, N_2O, and NO in high-temperature forage cropping systems. *Agriculture, Ecosystems, & Environment* 332: 107944. https://doi.org/10.1016/j.agee.2022.107944

[261] Gao, J., et al. 2021. Vertical distribution and seasonal variation of soil moisture after drip irrigation affects greenhouse gas emissions and maize production during the growth season. *Science of the Total Environment* 763: 142965. https://doi.org/10.1016/j.scitotenv.2020.142965

[262] Wang, C., et al. 2021. Optimizing tillage method and irrigation schedule for greenhouse gas mitigation, yield improvement, and water conservation in wheat-maize cropping systems. *Agricultural Water Management* 248: 106762. https://doi.org/10.1016/j.agwat.2021.106762

[263] Li, C., et al. 2020. Impact of irrigation and fertilization regimes on greenhouse gas emissions from soil of mulching cultivated maize (*Zea mays* L.) field in the upper reaches of Yellow River, China. *Journal of Cleaner Production* 259: 120873. https://doi.org/10.1016/j.jclepro.2020.120873

[264] Zhang, X., et al. 2020. Mitigation of greenhouse gas emissions through optimized irrigation and nitrogen fertilization in intensively managed wheat-maize production. *Scientific Reports* 10: 5907. https://doi.org/10.1038/s41598-020-62434-9

Soil moisture status is the most important soil parameter for soil gas emissions.[265] Soil moisture status controls microbial activity and potential pathways of nutrient use. Increasing soil moisture status can lead to conditions suitable for N_2O production, with completely anaerobic conditions (often due to soil saturation) resulting in CH_4 production. Additionally, to improve nitrogen use efficiency, many fertilizers require adequate moisture to prevent nitrogen losses such as ammonia. During extended drought or in dry soil conditions, soil can be a sink for GHGs. However, upon rewetting, GHG pulses can occur.[266]

Metric

Metric tons of carbon dioxide equivalents (tCO_2e).

Method for tracking

Gallons of water used by landowner. This could be combined with description of irrigation method change.

† Improve Nitrogen Management (right source, right rate, right time, right place)[49, 267, 268, 269, 270, 271, 272]

Synthetic and organic nitrogen fertilizers are needed for crop productivity. However, overapplication, poor timing, source, and placement can result in nitrogen loss in N_2O, ammonia, and NOx gases, lowering the nitrogen use efficiency. Nitrogen management is important across many land uses. Two-thirds of synthetic fertilizer emissions occur after the nutrients have been applied to the field.[273] Improving nitrogen use efficiency can reduce nitrogen gas emissions and indirectly reduce GHG emissions from nitrogen manufacturing and distribution. Improving efficiency can include using precise application rates based on crop needs, splitting applications to

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[265] Oertel, C., et al. 2016. Greenhouse gas emissions from soils-A review. *Geochemistry* 76(3): 327–352. https://doi.org/10.1016/j.chemer.2016.04.002

[266] Kim, D.G., et al. 2012. Effects of soil rewetting and thawing on soil gas fluxes: a review of current literature and suggestions for future research. *Biogeosciences* 9: 2459–2483. https://doi.org/10.5194/bg-9-2459-2012

[267] Fan, D., et al. 2022. Global evaluation of inhibitor impacts on ammonia and nitrous oxide emissions from agricultural soils: A meta-analysis. *Global Change Biology* 28(17): 5121–5141. https://doi.org/10.1111/gcb.16294

[268] Akiyama, H., et al. 2010. Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N_2O and NO emissions from agricultural soils: meta-analysis. *Global Change Biology* 16(6): 1837–1846. https://doi.org/10.1111/j.1365-2486.2009.02031.x

[269] Shoji, S., et al. 2001. Use of control release fertilizers and nitrification inhibitors to increase nitrogen use efficiency and to conserve air and water quality. *Commun. Soil Sci. Plant Anal.* 32: 1051–1057. https://doi.org/10.1081/CSS-100104103

[270] Sehy, U., et al. 2003. Nitrous oxide fluxes from maize fields: relationship to yield, site-specific fertilization, and soil conditions. *Agric. Ecosyst. Environ.* 99: 97–111. https://doi.org/10.1016/S0167-8809(03)00139-7

[271] Halvorson, A.D. 2010. The effect of enhanced-efficiency fertilizers on nitrous oxide emissions from various cropping systems, *In* International Conference on Enhanced-Efficiency Fertilizers (Miami, FL).

[272] Venterea, R.T., et al. 2012. Challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems. *Front. Ecol. Environ.* 10: 562–570. https://doi.org/10.1890/120062

[273] Gao, Y., and A.C. Serrenho. 2023. Greenhouse gas emissions from nitrogen fertilizers could be reduced by up to one-fifth of current levels by 2050 with combined interventions. *Nature Food* 4: 170–178. https://doi.org/10.1038/s43016-023-00698-w

avoid application of more nutrients the plant can use, using improved fertilizer choices such as slow/controlled release fertilizers and nitrification inhibitors, timing applications when nitrogen is least susceptible to loss, placing the fertilizer precisely where the crop can use it, and avoiding applications for areas not needed.

Metric

Metric tons of carbon dioxide equivalents (tCO_2e).

Method for tracking

Pounds of nitrogen and type applied per landowner. Initial data could start with overall sales of nitrogen purchased in Oregon.

Reduce Production of High GHG Emitting Commodities such as Ruminant Animals and Replace with Low GHG Emitting Food Crops Where Possible

Effectiveness of this practice will depend on potential leakage (see section on "Leakage"). Reduction in production without associated reduction in demand for high GHG emitting foods, including meats (especially ruminants), will not result in net emissions reductions.

The evidence is clear that the quantity of livestock, especially ruminant livestock, is creating a disproportionate amount of GHG emissions on a calorie and protein basis compared to lower emitting food crops. [274, 275, 276, 277] There is strong evidence that a reduction in the production of high GHG emitting commodities and increasing the production of low GHG emitting foods crops can significantly reduce GHG emissions **as long as there is no leakage**. This is **NOT** a practice suggesting eliminating animal production, but a reduction, and replace with low GHG emitting food crops where possible. This practice generally coincides with a shift in diets which has been recommended across many national and international organizations with the latest recommendation by the European Scientific Advisory Board on Climate Change (an independent scientific advisory body established by the European Climate Law of 2021) to the European Union to achieve a sustainable reduction in agricultural emissions.[278]

Metric

Metric tons of carbon dioxide equivalents (tCO_2e). This can be determined based on population of livestock in by type of animal.

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[274] Clune, S., et al. 2017. Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production* 140(2): 766–783. https://doi.org/10.1016/j.jclepro.2016.04.082

[275] Poore, J., and T. Nemecek. 2018. Reducing food's environmental impacts through producers and consumers. *Science* 360(6392): 987–992. https://doi.org/10.1126/science.aaq0216

[276] Boehm, R., et al. 2018. A comprehensive life cycle assessment of greenhouse gas emissions from U.S. household food choices. *Food Policy* 79: 67–76. https://doi.org/10.1016/j.foodpol.2018.05.004

[277] Willett, W., et al. 2019. Food in the Anthropocene: the EAT-Lancet Commission on health diets from sustainable food systems. *The Lancet Commissions* 393(10170): 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

[278] European Scientific Advisory Board on Climate Change. 2023. Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. https://doi.org/10.2800/609405

Method for tracking

Oregon public data on livestock population sizes.

* Reduce Enteric Emissions from Ruminant Production Systems Via Approved Enzyme Feed Additives

This practice's leading candidate, 3-nitrooxyproponal, is currently not approved in the United States, and therefore not currently feasible. However, there is hope that approval could be soon, and upon approval by the United States Food and Drug Administration, this practice should immediately be considered for its potential to reduce GHG emissions, particularly in dairies.[279, 280, 281, 282]

Support on-farm renewable energy and energy efficiency

Electrification of farm equipment and vehicles can reduce on-farm GHG emissions. Installation of more energy-efficient equipment could also lead to a reduction in GHG emissions. Equipment that uses methane from on-site anaerobic digesters could also serve as an option to reduce GHG emissions. Equipment that uses biofuels must consider full life cycle assessments of the source. Current evidence suggests that, **if no land-use change is involved**, first-generation biofuels (e.g., corn, soybean, palm oil, etc. feedstocks) can—on average—have lower GHG emissions than fossil fuels, but the reductions for most feedstocks are insufficient to meet the GHG savings required by the EU Renewable Energy Directive. However, second-generation biofuels (i.e., non-food feedstocks like switchgrass, poplar, municipal solid waste, etc.) have, in general, a greater potential to reduce emissions, **provided there is no land use change**.[283, 284]

Metric

Metric tons of carbon dioxide equivalents (tCO_2e).

Method for tracking

Gallons of fuel purchased by landowner and type of fuel.

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[279] Hristov, A.N., et al. 2015. An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production. *Proceedings of the National Academy of Sciences.* 112(34): 10663–10668. https://doi.org/10.1073/pnas.1504124112

[280] Van Wesemael, D., et al. 2019. Reducing enteric methane emissions from dairy cattle: Two ways to supplement 3-nitrooxypropanol. *Journal of Dairy Science* 102(2): 1780–1787. https://doi.org/10.3168/jds.2018-14534

[281] van Gastelen, S., et al. 2020. 3-Nitrooxypropanol decreases methane emissions and increases hydrogen emissions of early lactation dairy cows, with associated changes in nutrient digestibility and energy metabolism. *Journal of Dairy Science* 103(9): 8074–8093. https://doi.org/10.3168/jds.2019-17936

[282] Melgar, A., et al. 2021. Enteric methane emission, milk production, and composition of dairy cows fed 3-nitrooxypropanol. *Journal of Dairy Science* 104(1): 357–366. https://doi.org/10.3168/jds.2020-18908

[283] Jeswani, H.K., et al. 2020. Environmental sustainability of biofuels: a review. *Proceedings Royal Society A.* 476: 20200351. https://doi.org/10.1098/rspa.2020.0351

[284] Lark, T.J., et al. 2022. Environmental outcomes of the US Renewable Fuel Standard. *Proceedings of the National Academy of Sciences.* 119:9 e2101084119. https://doi.org/10.1073/pnas.2101084119

* Must not result in increasing herd size which may offset gained GHG reductions.

† Must consider potential ammonia emissions that lead to N_2O emissions elsewhere.[285]

‡ Must ensure correct operation and maintenance and no leakage occurs or could make practice a net contributor to GHG emissions

Practices currently not recommended

The following practices are **currently** not recommended. The experts decided the following practices were of "low confidence" or "need more data and/or case-by-case basis" to be a net reduction in GHG emissions after ensuring the practice is additional. Full life cycle assessments are generally needed for the following practices to determine their net GHG balance.

- Biochar
- Biosolids
- Compost
- Composting of manure
- Cover cropping
- Crop rotation
- Daily spread of manure
- Enhanced weathering
- Forbs and various forage species incorporated into grazing systems
- Increase riparian areas beyond the edge of field – grasslands
- Legume incorporation into rotations
- Livestock integration
- Restoration of wetlands/organic soils from agricultural fields

Practices not currently categorized

All practices will continue gathering additional input and subject to classification with improved datasets in future iterations. Additional practices that future iterations need to classify include: closing the yield gap, transitioning to zero expansion of new agricultural land at the expense of natural ecosystems, reducing peat use, solids separation for manure management, manure acidification, improving genetic breeding of ruminant species, livestock reproductive efficiency, improving forage quality, plant bioactive compounds for pasture systems, and feed additives such as seaweed to reduce enteric emissions. The original solicitation for the practice of "shift annual production systems to perennial systems" was too broad and led to many experts saying this practice would need to be evaluated on a case-by-case basis. We have further split this practice into more sub-practices to gain a better perspective from experts. We expect that in future iterations several of

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[285] Lee, S.K., et al. 2017. Using nitrification inhibitors to mitigate agricultural N_2O emission: a double-edged sword? *Global Change Biology* 23: 485–489. https://doi.org/10.1111/gcb.13338

these non-classified practices would be included in our recommendation. More discussions should be had on overall system productivity and reducing GHG emissions per unit of calorie, protein, water use, etc. This approach could benefit both the producer and the state. Issues can arise when considering additionality for efficiency improvement practices. There needs to be sufficient evidence that the improvement would not have occurred otherwise. Careful consideration of such projects is needed as efficiency is generally always trying to be optimized. Overall, improving efficiency in agriculture is a necessary approach to reducing agricultural GHG emissions while recognizing the need to support sustainable healthy diets for a growing human population.

URBAN AND SUBURBAN LANDS

Recommended Practices to Increase Sequestration and Reduce Greenhouse Gas Emissions from Urban and Suburban Lands

Author: Jimmy Kagan (INR)

Maintain and Expand Forest and Vegetation Cover in Urban and Suburban Areas

Maintaining and expanding tree and woody vegetation cover within our communities has enormous benefits beyond carbon, including shading, clean air, clean water, reduced flood damage, and recreational and employment opportunities.[286] Mitigation and adaptation benefits are provided through expansion, enhancement, and preservation of urban riparian habitats. There are four primary practices to accelerate the process and provide additionality to increase sequestration rates including:

1. Expanding these efforts to replace some pavement with patches of soil and planting more street trees, particularly in the more intensely developed areas.
2. Replacing mowed grass areas in some urban and suburban parks, natural areas, and yards with trees, and increasing tree cover in these areas, including using incentives for industrial landowners with large lawns.[287]
3. When existing street trees die or need to be replaced, where possible, use large, fast growing and long-lived trees.
4. Maintaining the health of trees and protecting remaining tree cover in urban areas.
5. Expand existing urban streams, create new stream corridors, and restore poorly vegetated streams, incorporating riparian forest plantings along these streams. Native riparian trees, such as alder (red and white), black cottonwood, Oregon white, California black oak, Oregon ash (although invasive insects such as emerald ash borer may prohibit the use of ash), and large willows (Pacific willow, greenleaf willow and shining willow) all grow quickly and sequester carbon well, while supporting native wildlife.

Metric

- Metric tons of above ground carbon from urban trees/hectare within urban areas.
- Metric tons/ha of above ground carbon from natural vegetation within urban riparian areas.

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[286] From, New England's Climate Imperative: Our Forests as a Natural Climate Solution.

[287] Abbate, S., et al. 2021. Carbon update dynamics associated to the management of unused lands for urban CO_2 planning. *Renewable Energy* 178: 945–959. https://doi.org/10.1016/j.renene.2021.06.124

Method for tracking

Calculating carbon content from urban trees using models that rely on combination of tree height and tree cover estimated from high resolution imagery and LiDAR and available measured tree data along with tree species estimates to calculate carbon stores.

Improve fertilizer use in urban and suburban lands to reduce excess nitrogen releases

While synthetic and organic nitrogen fertilizers often are useful in urban and suburban areas, overapplication, poor timing, source, and placement can result in nitrogen loss in N_2O, ammonia, *and NOx gases, lowering the nitrogen use efficiency. Nitrogen management is important across many land uses. Two-thirds of synthetic fertilizer emissions occur after the nutrients have been applied.*[288] *Improving nitrogen use efficiency can reduce nitrogen gas emissions and indirectly reduce GHG emissions from nitrogen manufacturing and distribution. Improving efficiency can include: using precise application rates based on crop needs, splitting applications to avoid application of more nutrients the plant can use*, using improved fertilizer choices such as slow/controlled release fertilizers and nitrification inhibitors, timing applications when nitrogen is least susceptible to loss, placing the fertilizer precisely where the crop can use it, and avoiding applications for areas not needed. These problems occur on golf courses, playing fields, and in urban and suburban yards. Working with urban households and governments, assuring that only the amount of nitrogen-based fertilizers that can be immediately used be applied can make significant difference in the release of climate causing gases from urban lands. These would include:

1. Providing clear guidance on fertilizer use for urban and suburban households that outlines the dangers of improper use.
2. Work with urban park and golf-course managers to improve the timing and use of nitrogen-based fertilizers to avoid nitrogen runoff or nitrous oxide production.

Metric

Amount of nitrous oxide found in urban streams, rivers and stormwater.

Method for tracking

Oregon's Department of Environmental Quality currently tracks greenhouse gas emissions, along with pollution of all types in Oregon's waterways. Identifying ways to measure reductions in excess fertilizer use would be critical for this practice to be monitored.

Other Considered Activities

These practices are either impractical, unmeasurable or of uncertain outcomes related to carbon storage or GHG releases.

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[288] Gao, Y., and A.C. Serrenho. 2023. Greenhouse gas emissions from nitrogen fertilizers could be reduced by up to one-fifth of current levels by 2050 with combined interventions. *Nature Food* 4: 170–178. https://doi.org/10.1038/s43016-023-00698-w

Promote green roofs and planters on large buildings where solar cells are not practical

Wherever possible in urban areas, increasing vegetated surfaces helps store carbon and improve water quality and slows runoff.

1. Provide incentives to expand green roofs, which both help with water quality issues during storms, and provide some carbon storage.
2. Provide incentives for large planters (and perhaps rain storage devices to sustain them during dry months) on roofs and balconies of large apartment buildings.

Metric

Metric tons of above ground carbon from vegetation on recently paved sites/hectare within urban areas.

Method for tracking

Calculating carbon content from previously paved or built sites trees using models that rely on vegetation cover models, based on cover and type (tree, shrub or herbaceous) estimated from high resolution imagery and LiDAR and planting information where available.

Reason not recommended: Impractical to develop a baseline, and the change is hard to measure.

Expand urban efforts to improve water quality by reducing pavement when possible[289]

Currently, many of Oregon's cities and towns are working to expand tree cover to improve water quality and slow runoff. These practices can assist with the water quality goal while increasing sequestration:

1. Expand the number of green streets and vegetated swales, and plant trees, where possible.
    - Reason not currently recommended: These activities are currently not measurable, and at least initially, may release more climate gases than would be stored by sequestration.

Increase carbon stored in urban and suburban soils[290, 291]

Many urban and suburban soils can support much higher levels of carbon than is currently present. Some practices can increase sequestration and storage in soils, including:

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[289] From, New England's Climate Imperative: Our Forests as a Natural Climate Solution.

[290] Carbon Sequestration in Urban Ecosystems, Rattan Lal & Bruce Augustin, Editors, 2012 (ISBN 978-94-007-2365-8)

[291] Brown, S., et al. 2012. Carbon Sequestration Potential in Urban Soils. *In*: Lal, R., Augustin, B. (eds) Carbon Sequestration in Urban Ecosystems. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-2366-5_9

1. Creating incentives for changing management practices of turfgrass (lawns, park fields, etc.) to increase sequestration and slow releases of GHGs.
2. Replacing decorative lawns in yards or parks with a "prairie" with deep rooted perennial grasses mowed only occasionally.
    - Reason not currently recommended: These activities are currently not measurable. They may have long-term potential, but additional research is needed to create methods for evaluating results, as well as to better determine which practices significantly increase carbon concentrations in urban soils on a long-term basis.

Use carbon sequestration as a benefit in all urban and suburban land management decisions

Considering sequestration and carbon releases is likely to be critical for improved land management outcomes.

1. For all parks, land acquisition, restoration, and urban planning, accounting for carbon storage and releases is likely to significantly increase Oregon's urban and suburban carbon balance.
    - Reason not currently recommended: These activities are currently not measurable. They may have long-term potential, but additional research is needed to create methods for evaluating results, as well as to better determine which practices significantly increase carbon concentrations in urban soils on a long-term basis.

Appendix E-2. Practices and Metrics Proposed by the Advisory Committee's Agriculture Subcommittee

Oregon Natural & Working Lands Proposed Practices to Increase Net Carbon Sequestration and Storage and/or Reduce Greenhouse Gas Emissions from Oregon's Natural Resource Sectors

Oregon's Agricultural Lands

The agricultural practices included in this document are recommended by the Natural and Working Lands (NWL) Advisory Committee as practices Oregon should use and track to sequester and store carbon and reduce GHG emissions. The practices listed here are not intended to represent a complete list of practices. Other practices, which may sequester and store carbon or reduce GHG emissions, are not included here because they may be difficult to track or measure, may not have current adequate science to support inclusion, and/or may have other issues associated with them that prevent them from being recommended at this time. In addition, as more is learned about the deep carbon pool (soil carbon deeper than one meter), there may be a need to modify practices that protect or add to carbon sequestered in this pool.

Considerations for Proposed Practices

The purpose of this section is to create context, including factors the Oregon Global Warming Commission (OGWC) should consider when evaluating practices and metrics, namely soil health, co-benefits, tradeoffs, the viability of Oregon's farmers and ranchers, climate change stressors, and statewide impacts of policy implementation.

Soil Health. Healthy soils are vital to resilient ecosystems, and many agricultural practices that improve soil health enhance its ability to store carbon. The principles of soil health are: 1) Maximize Presence of Living Roots 2) Minimize Disturbance 3) Maximize Soil Cover 4) Maximize Biodiversity (Source: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health). The recommended practices in Sections III, IV, and V below align with these principles. Implementation of multiple soil health practices can yield greater results economically and environmentally when they are used together.

The benefits of maintaining or improving soil health, along with enhanced farm ecology, are significant and critical.

Co-benefits. There are numerous co-benefits, beyond carbon sequestration, associated with many of the practices described in this document. Prescribed grazing sequesters carbon in perennial biomass and soils while enhancing or maintaining desired species for forage, improving water quality, increasing stocking rates and livestock vigor, and building soil health. Soil health practices can provide many benefits for farms and ranches, including resilience to drought and other extreme weather events; economic resilience; improved water and nutrient-holding capacity, reduced erosion, enhanced plant health; improved water quality, and increased biodiversity and pollinator habitat. Soil health practices can require fewer inputs of fertilizer and pesticides, thus requiring fewer applications across the field with the tractor (passes). Making fewer passes reduces soil compaction and fuel usage. Reduced fertilizer use can also lower the typically high upstream greenhouse gas (GHG) footprints from its manufacturing.

Tradeoffs. Although many practices have co-benefits, it is important to recognize and identify the potential tradeoffs associated with each practice. Although a specific practice may successfully contribute to desired climate-related goals, implementing the practice may affect the ability of a landowner or land manager to achieve their own goals for their lands. Therefore, all practices should remain voluntary so that landowners/land managers can assess the tradeoffs associated with each practice and minimize detrimental effects to their business.

Viability of Oregon's Farms and Ranches. The State of Oregon has protected and valued farmland for many reasons. If programs or incentives are created that take land out of production, policy makers should carefully consider how this affects the viability of Oregon's farmers and ranchers.

Climate Change Stressors. The U.S. Department of Agriculture (USDA) predicts a suite of climate change stressors will create challenges to agricultural management practices. These challenges include increased temperatures across seasons, more frequent extreme heat, decreased snowpack and summer streamflow, increased extreme precipitation, lengthened growing seasons, increased plant moisture stress (i.e., drought conditions), and increased risk of pests and disease.[292]

Statewide Impacts of Policy Implementation. The list of practices in this document are practices that an individual landowner or land manager could implement, but individual producers would likely not have the information or ability to determine statewide impacts of policy implementation, which is the responsibility of Oregon's legislature with input from the OGWC.

I. Protect Agricultural Lands from Urban or Industrialized Conversion

Protecting farmland from development ensures the many functions of the soil, such as carbon sequestration and nutrient and water cycling, are maintained. The primary method for protecting farmland from development in Oregon is through the statewide land use planning program. However, there are numerous mechanisms in current law for rezoning land or for allowing incompatible non-farm-related uses on farmland.

One significant approach farmers can use to permanently protecting farmland is through voluntary conservation easements. Easements may also lower the total monetary value of farmland, making it more tax efficient for current and future generations.

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[292] https://www.climatehubs.usda.gov/hubs/northwest/topic/exploring-western-perennial-crop-cultivation-changing-climate

In addition to these benefits, studies show that protecting agricultural lands from urban or industrialized development is good not only for food security and land use planning, but also for GHG reduction. A California study compared emissions from farmlands to developed areas and found that "on average, California's irrigated farmland emits 0.89 tonnes of carbon dioxide equivalent (CO_2e) per acre per year in comparison to an average 51 tonnes of CO_2e per year per acre for California's urban areas. The takeaway message from this study is clear; California's productive irrigated farmland emits GHG on a level that is an order of magnitude less than urban areas."[293] Following this and other research, California has created a Sustainable Agricultural Lands Conservation Program, which invests in the protection of critical agricultural lands at risk of conversion to more GHG-intensive residential uses through conservation easements and developments of Agricultural Conservation Plans.[294]

Making the decision to permanently protect farmland should remain a voluntary choice for landowners, but assistance of land trusts and Oregon's Land Conservation and Development Commission can play a role in making it easier for willing landowners.

Metrics:

- # agricultural acres in permanent easements.
- # acres converted from agriculture to development.
- # non-farm-related uses allowed and permitted on agricultural land.

II. Increase Woody Plant Coverage

Planting woody plant species on farms has the potential to sequester above- and below-ground carbon, similar to that of a forest. This strategy generates other ecosystem services, such as provision of pollinator and bird habitat, water quality protection, reduction of wind, and moderation of temperature impacts on streams. For hedgerow, riparian, and other non-crop plantings, there should be a focus on planting locally adapted native species, or regionally native species that may be adaptable to future climates. There are numerous on-farm practices that include woody plantings that could be included in this section:

- **Hedgerow Planting (CPS 422)** Replacing a strip of cropland with 1 row of woody plants.
- **Riparian Forest Buffer (CPS 391)** Replacing a strip of cropland near watercourses or water bodies with woody plants.
- **Silvopasture (CPS 381)** Establishment and/or management of desired trees and forages on the same land unit as animals graze.
- **Tree/Shrub Establishment (CPS 612)** Establishing woody plants by planting seedlings or cuttings, by direct seeding, and/or through natural regeneration.

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[293] Benefits of Farmland Conservation in California, page 11

[294] Sustainable Agricultural Lands Conservation Program (SALC) (ca.gov)

- **Windbreak/Shelterbelt Establishment and Renovation (CPS 380)** Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.

Metric: # acres with woody plants

III. Encourage No-till and Residue Till Management

- **No-till (CPS 329)**[295] Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year-round.
- **Residue and Tillage Management (CPS 345)** Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.[296]

Metrics:

- # acres in no-tillage.
- # acres in residue and tillage management.

IV. Implement Edge-of-field Herbaceous (non-woody) Conservation Practices[297]

- **Contour Buffer Strips (CPS 332)** narrow strips of permanent, herbaceous vegetative cover on sloping cropland – Convert strips of irrigated cropland to permanent unfertilized grass cover or legume cover.
- **Vegetative Barriers (CPS 601)** Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow areas.

Metric: # acres utilizing these practices.

V. Utilize Cover Crops and Crop Rotations

Implement in-field conservation practices that increase soil coverage and sequester carbon. Examples include:

- **Cover Crop (CPS 340)** Grasses, legumes, and forbs planted for seasonal vegetative cover. Growing additional crops during the fallow season to retain cover year-round.
- **Conservation Crop Rotation (CPS 328)** also called extended crop rotation – extends crop rotation to include additional crops, e.g., grasses, legumes, small grains, for several more

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[295] There are herbicide considerations associated with no-till agriculture that should be considered outside scope of carbon sequestration and storage as well as emission reduction potential. For example, when herbicides are applied, microbial health of soil can be reduced, thus reducing potential to sequ/store C).

[296] https://efotg.sc.egov.usda.gov/api/CPSFile/20421/345_OH_CPS_Residue_and_Tillage_Management%2C_Reduced_Till_2017

[297] Recognition that most food crops are annual production system crops (currently).

growing seasons (CPS 328) growing additional crops during the fallow season to retain cover year-round.

- **Stripcropping (CPS 585)** Growing planned rotations of erosion-resistant and erosion-susceptible crops or fallow in a systematic arrangement of strips across a field so that soil is stabilized.
- **Alley Cropping (CPS 311)** AKA Intercropping – The practice of planting rows of trees, maize, or other plants with a companion crop in between.

Metric: # acres utilizing these practices.

VI. Improve Nutrient Management & Reduce Nitrogen Application

The 4Rs of nutrient stewardship include applying the right nutrient source at the right rate at the right time in the right place to improve nutrient use efficiency by the crop and to reduce nutrient losses to surface and groundwater and to the atmosphere.[298] Although this strategy only addresses one of the 4Rs - (right rate) - it is an NRCS practice and could result in reduced nitrous oxide emissions coming from farms.

- **Nutrient Management (CPS 590)** Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.

Metric: # acres implementing nutrient management plan and/or before/after pounds of fertilizer being applied for participating farms.[299, 300]

VII. Shift Energy Sourcing and Irrigation Techniques to Reduce Emissions

As with other industries, there are opportunities to reduce emissions through shifts in energy sourcing and the energy needed for equipment and irrigation on farmlands. Some activities to directly reduce emissions from farmlands include:

- Switch from diesel to electricity-powered wells.
- Switch from diesel/gasoline farm machinery to electric, renewable diesel or other lower-impact fuels.
- Install more energy-efficient equipment such as fans and cooling systems.
- Reduce total irrigation water used and associated emissions by using technology, such as drip irrigation, or soil moisture monitoring.
- Enhance efficiency of irrigation pumping systems to minimize energy use.
- Employ soil health practices so that fewer inputs are used, thus requiring fewer passes across the field with the tractor. When soil is biologically healthy, plants are naturally more resilient to pests and disease and therefore require fewer inputs of fertilizer and

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[298] Natural Resources Conservation Service. 2019. Nutrient Management – Conservation Practice Standard: https://www.nrcs.usda.gov/sites/default/files/2022-09/Nutrient_Management_590_NHCP_CPS_2017.pdf

[299] A proxy for rate (total nitrogen applied) could be found by collecting total pounds of total nitrogen sold per year based on retailer fertilizer sales. However, this is dataset would be challenging to analyze as cropping patterns change.

[300] Fertilizer: Must consider Source, Timing, Rate, Crop

pesticides, thus requiring fewer applications across the field with the tractor (passes). Making fewer passes reduces soil compaction, diesel usage and the typically high upstream GHG footprints from chemical manufacturing and distribution.

Metric: # farms or systems shifting energy sourcing or irrigation techniques.

VIII. Prescribed Grazing (CPS 528)

NRCS defines prescribed grazing as "managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives."

Prescribed Grazing (CPS 528) Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.

Metric: # acres.

IX. Pasture-based Management

Pasture management is the practice of growing healthy forage grasses and legumes that ensures lasting food sources for livestock while focusing on maintaining and improving the ecological health of the soil.[301] Consideration should be given to evolving and emerging science and knowledge of best practices associated with GHG emissions relating to pasture-based management.

The U.S. Environmental Protection Agency (EPA) estimates there is an estimated 90% relative methane emissions reduction from livestock manure management implementing pasture-based management.[302, 303] In the United States, carbon sequestration strategies reduced GHG emissions by more than 100% in a few grazing systems (Cusack 2021).

Metric: # acres utilizing pasture-based management.

X. Reduce Enteric Emissions from Ruminant Production Systems Via Approved Enzyme Feed Additives

There are a number of feed additives currently being researched that show significant reductions in enteric methane production in ruminant animals. One leading candidate, 3-nitrooxyproponal, is already approved for use in the European Union and is currently being assessed by the United States Food and Drug Administration. Similarly, in 2022 California Department of Food and Agriculture (CDFA) approved use of seaweeds for use as a natural digestive aid that also reduces methane

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[301] https://piercecd.org/605/Pasture-Management

[302] https://www.epa.gov/agstar/practices-reduce-methane-emissions-livestock-manure-management

[303] Methane reductions are estimated based on converting from an uncovered anaerobic lagoon in a dry temperate climate. If converting from other scenarios or practices, relative emission reductions would differ.

emissions for California's dairy industry.[304] Feed additives should be considered for its potential to reduce GHG emissions.[305, 306, 307, 308]

> **Metric:** Metric tonnes of carbon dioxide equivalents (tCO_2e) per unit (i.e., a unit referring to the subject could be acres, livestock, etc.).

XI. Anaerobic Digestion of Manure

Anaerobic digestion (AD) (CPS 366) is a component of a waste management system in which biological treatment breaks down animal manure and other organic materials in the absence of oxygen. Anaerobic digestion of dairy and other animal manure has many environmental and economic benefits. The three main greenhouse gas benefits include:

- Reduction in on-farm manure emissions: AD significantly reduces GHG emissions from farms by capturing methane that would normally go into the atmosphere and converting it to biogas.
- Reduction in on-farm fertilizer emissions: The liquid and solid digestate byproducts can be used for nutrient-rich fertilizer and organic-rich compost, which may further reduce on-farm GHG emissions by replacing traditional fertilizers, which typically have high upstream GHG footprints from manufacturing and nitrous oxide emissions from land application.
- The main by-product of ADs is renewable natural gas. This can directly replace the use of fossil-fuel based natural gas or be converted to renewable electricity, further reducing emissions for gas and electricity users.[309]

The potential for cost-effective carbon reduction is large. According to the EPA, 'The AgSTAR program, a collaborative effort of the EPA and the USDA, estimates that there is potential for anaerobic digester systems on approximately 2,700 additional dairy farms in Oregon, with the potential to reduce 29.9 MMTCO2e each year.'[310] Because of a relatively large upfront investment, typically only larger farms with adequate amounts of manure, food waste or other feedstock can make AD strategies work. However, when public and private funding is combined, digesters are much lower cost than other GHG activities. For the California Climate Investments Program

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[304] Straus Dairy Farm's Carbon-Neutral Goal Draws Near as CDFA Approves | Dairy Business News

[305] Hristov, A.N., et al. 2015. An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production." *Proceedings of the National Academy of Sciences.* 112(34): 10663–10668. https://doi.org/10.1073/pnas.1504124112

[306] Van Wesemael, D., et al. 2019. Reducing enteric methane emissions from dairy cattle: Two ways to supplement 3-nitrooxypropanol. *Journal of Dairy Science* 102(2): 1780–1787. https://doi.org/10.3168/jds.2018-14534

[307] van Gastelen, S., et al. 2020. 3-Nitrooxypropanol decreases methane emissions and increases hydrogen emissions of early lactation dairy cows, with associated changes in nutrient digestibility and energy metabolism. *Journal of Dairy Science* 103(9): 8074–8093. https://doi.org/10.3168/jds.2019-17936

[308] Melgar, A., et al. 2021. Enteric methane emission, milk production, and composition of dairy cows fed 3-nitrooxypropanol. *Journal of Dairy Science* 104(1): 357–366. https://doi.org/10.3168/jds.2020-18908

[309] How Does Anaerobic Digestion Work? | US EPA

[310] Anaerobic Digestion on Dairy Farms | US EPA

(CCIP), dairy digesters are listed as the most cost-effective investments of all strategies implemented through the CCIP, costing only $9 per metric ton of CO_2e emissions.[311]

As listed above, in addition to sourcing manure on farms, anaerobic digesters can also convert food waste to renewable natural gas. The Oregon Department of Environmental Quality's (DEQ) Food Waste Study Report found that anaerobic digestion of food waste provides the highest climate and fertilizer replacement benefit compared to other methods of handling food waste (anaerobic composting, in sink grinding/wastewater treatment and landfilling).[312] Therefore, this on-farm anaerobic digester strategy could be coupled with Oregon's food waste diversion efforts for maximum economic and greenhouse gas benefit.

Metrics:

- Tons CO_2e sequestered through on-farm anaerobic digesters.
- Number of digesters installed per year.

XII. Alternative Manure Management

There are other manure treatment and storage practices that can reduce greenhouse gas emissions such as:

- Solid separation
- Conversion of flush to scrape
- Drying or composting of collected manure
- Manure tank aeration
- Manure tank cover and flare
- Composting Facility (No.) (317) A structure or device to contain and facilitate an aerobic microbial ecosystem for the decomposition of manure, other organic material, or both, into a final product sufficiently stable for storage, onfarm use, and application to land as a soil amendment.
- Waste Separation Facility (No.) (632) A filtration or screening device, settling tank, settling basin, or settling channel used to partition solids and/or nutrients from a waste stream.
- Waste Treatment (No.) (629) Use of mechanical, chemical, or biological technologies to change the characteristics of manure and agricultural waste.
- Waste Recycling (No.) (633) The on-farm agricultural use of nonagricultural waste by-products, or the off-farm nonagricultural use of agricultural waste by-products.

These are "alternative" to business-as-usual practices and to anaerobic digester strategies, and therefore are often referred to as "alternative manure management" strategies. Offering these types of strategies will allow for smaller or remote animal farms to reduce manure-based emissions without investing in anaerobic digesters.

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[311] California Climate Investments 2022 Mid-Year Data Update

[312] FoodWasteStudyReport.pdf (oregon.gov)

Greenhouse gas reductions for these practices have been quantified by California Air Resources Board[313] for the CDFA Alternative Manure Management Program (AAMP) incentive program.[314] The primary GHG benefits of these practices include:

- Reduction in on-farm manure emissions
- Sequestration of carbon in soil: due to compost application (if compost solution followed)

Metric: lbs. manure implementing these different strategies.

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[313] CCI Quantification, Benefits, and Reporting Materials | California Air Resources Board
[314] CDFA - OEFI - AMMP (ca.gov)

Additional References

Climate Mitigation Potential of Regenerative Agriculture is Significant: The latest from leading scientists in 2020. Relevant to crop rotations and cover crop adoption

Natural climate solutions for the United States: a solid 2018 study quantifying soil carbon sequestration and reduced greenhouse gas potential of natural climate solutions, including agricultural solutions, in the US. "Carbon sequestration opportunities in croplands include the use of cover crops and improved cropland nutrient management."

Oregon Forests and Farms Can Fight Climate Change: January 2020 study from The Nature Conservancy and Portland State University. Agriculture solutions include: no-till, cover crops, and nitrogen management

Carbon Sequestration Potential on Agricultural Lands: A 2015 review of current science and available practices. Includes a review of impacts of implementing different practices, including Conventional No-Till and Conservation Tillage; Cover Crops and Crop Rotations; Rotational Grazing and Perennial Cropping Systems

USDA Natural Resource Conservation Service Climate-Smart Mitigation Activities: a 2022 list connecting conservation practices and greenhouse gas mitigation potential. NRCS is continually evaluating and updating their climate-smart mitigation activities to ensure the latest science and quantifiable benefits are reflected.

American Farmland Trust. 2022. Combatting Climate Change on US Cropland: Affirming the technical capacity of cover cropping and no-till to sequester carbon and reduce greenhouse gas emissions. 32pp. link to report

Aryal, J.P., et al. 2014. On-farm economic and environmental impact of zero-tillage wheat: A case of Northwest India. *Experimental Agriculture* 51: 1–16. https://doi.org/10.1017/S001447971400012X

Bergman, K. 2022. Conservation practice impact on carbon sequestration. Center for Rural Affairs. 5pp. link to report

Biffi, S., et. al. 2022. Soil carbon sequestration potential of planting hedgerows in agricultural landscapes. *J. Environ. Manage.* https://doi:10.1016/j.jenvman.2022.114484

Bolinder, M.A., et al. 2020. The effect of crop residues, cover crops, manures and nitrogen fertilization on soil organic carbon changes in agroecosystems: a synthesis of reviews. *Mitig Adapt Strat Glob Change* 25(6): 929–952. https://doi.org/10.1007/s11027-020-09916-3

Corbeels, M., et al. 2016. Evidence of limited carbon sequestration in soils under no-tillage systems in the Cerrado of Brazil. *Scientific Reports* 6: 21450. https://doi.org/10.1038/srep21450

Cusack, D.F., et al. 2021. Reducing climate impacts of beef production: A synthesis of life cycle assessments across management systems and global regions. *Glob. Chang. Biol.* 27(9): 1721–1736. https://doi.org/10.1111/gcb.15509

Davidson, E.A., and I.L. Ackerman. 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. *Biogeochemistry* 20: 161–164. https://doi.org/10/1007/BF00000786

Delonge, M.S., R. Ryals, and W.L. Silver. 2013. A lifecycle model to evaluate carbon sequestration potential and greenhouse gas dynamics of managed grasslands. *Ecosystems* 574 16:962–979. https://doi.org/10.1007/s10021-013-9660-5

De Moraes Sá, J.C., et al. 2001. Organic matter dynamics and carbon sequestration rates for a tillage chronosequence in a Brazilian Oxisol. *Soil Sci. Soc. Am. J.* 65: 1486–1499. http://dx.doi.org/10.2136/sssaj2001.6551486x

Driver, J.G., et al. 2019. Blue Urea: Fertilizer with reduced environmental impact. *Front. Energy Res.* 7. https://doi.org/10/3389/fenrg.2019.00088

Erenstein, O., et al. 2008. On-farm impacts of zero tillage wheat in South Asia's rice–wheat systems. *Field Crops Research* 105: 240–252. https://doi.org/10.1016/j.fcr.2007.10.010

FAO. 2015. Global Forest Resources Assessment 2015, How Are the World's Forests Changing? Food and Agriculture Organization of the United Nations: Rome, Italy, 2015. Link to report

FAO. 2016. Reducing enteric methane for improving food security and livelihoods. 4pp. Link to document

Fargione, J.E., et. al. 2018. Natural climate solutions for the United States. *Science Advances* 4: eaat1869. 14pp. https://doi.org/10.1126/sciadv.aat1869

Farooqui, Z., et al. 2018. Enhancing carbon sequestration using organic amendments and agricultural practices. *In:* Carbon Capture, Utilization and Sequestration, ed. R.K. Agarwal. http://dx.doi.org/10.5772/intechopen.79336

Gomez-Casanovas, N., et al. 2018. Grazing alters net ecosystem C fluxes and the global warming potential of a subtropical pasture. *Ecological Applications* 28(2): 557–572. https://doi.org/10.1002/eap.1670

Hobbs, P.R. 2007. Conservation agriculture: What is it and why is it important for future sustainable food production? *J. Agric. Sci.-Camb.* 145: 127. https://doi.org/10/1017/S0021859607006892

Huber, K. 2018. Decarbonizing U.S. agriculture, forestry, and land use. C2ES Climate Innovation 2050. 5pp. Link

Hunt, J., et al. 2016. Carbon budgets for an irrigated intensively grazed dairy pasture and an unirrigated winter-grazed pasture. *Biogeosciences* 13: 2927–2944. https://doi.org/10.5194/bg-13-2927-2016

Hussain, S., et al. 2021. Carbon sequestration to avoid soil degradation: A review on the role of conservation tillage. *Plants* 10: https://doi.org/10.3390/plants10102001

Jahanzad, E., et al. 2020. Orchard recycling improves climate change adaptation and mitigation potential of almond production systems. *PLoS ONE* 15(3): e0229588 https://doi.org/10.1371/journal.pone.0229588

Kalu, S., et al. Potential of biochar to reduce greenhouse gas emissions and increase nitrogen use efficiency in boreal arable soils in the long-term. *Front. Environ. Sci.* 10: https://doi.org/10.3389/fenvs.2022.914766

Kaplan, M., et al. 2021. Ecosystem Service Valuation Approaches and Carbon Mitigation Considerations for Garden State Agriculture. New Brunswick, NJ: Rutgers, The State University of New Jersey. https://doi:10.7282/t3-2zcv-d592

Ledo, A., et al. 2020. Changes in soil organic carbon under perennial crops. *Global Change Biology* 26(7): 4158–4168. https://doi.org/10.1111/gcb.15120

Lehmann, J., et al. 2021. Biochar in climate change mitigation. *Nat. Geosci.* 14: 883–892. https://doi.org/10.1038/s41561-021-0088852-8

Liang, B.C., et al. 2020. Revisiting no-till's impact on soil organic carbon storage in Canada. *Soil Tillage Res.* 198: 104529. https://doi.org/10.1016/j.still.2019.104529

Ogle, S.M., et al. 2019. Climate and soil characteristics determine where no-till management can store carbon in soils and mitigate greenhouse gas emissions. *Scientific Reports* 9: 11665 https://doi.org/10.1038/s41598-019-47861-7

Paustian, K.E., et al. 2019. Soil C sequestration as a biological negative emission strategy. *Front. Clim.* 1. https://doi.org/10.3389/fclim.2019.00008

Popleau, C., and A. Don. 2015. Carbon sequestration in agricultural soils via cultivation of cover crops – a meta-analysis. *Agric. Ecosyst. Environ.* 200: 33–41. https://doi.org/10.1016/j.agee.2014.10.024

Powlson, D.S., et al. 2014. Limited potential of no-till agriculture for climate change mitigation. *Nat. Clim. Change* 4: 678–683. https://doi.org/10.1038/nclimate2292

Proctor, K.W., G.S. Murthy, and C.W. Higgins. 2021. Agrivoltaics align with green new deal goals while supporting investment in the US' rural economy. *Sustainability* 13(1): https://doi.org/10.3390/su13010137

Roe, S., et al. 2019. Contribution of the land sector to a 1.5 degree C world. *Natura Climate Change* 9: 817–828. https://doi.org/10.1038/s41558-019-0591-9

Roe, S., et al. 2021. Land-based measures to mitigate climate change: potential and feasibility by country. *Glob. Change Biol.* 27(23): 6025–6058. https://doi:10.1111/gcb.15873

Ryals, R., and W. L. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grassland ecosystems. *Ecological Applications* 23: 46–59. https://doi.org/10.1890/12-0620.1

Seitz, D., L.M. Fischer, R. Dechow, M. Wiesmeier, and A. Don. The potential of cover crops to increase soil organic carbon storage in German croplands. *Plant and Soil* https://doi.org/10.1007/s11104-022-05438-w

Six, J., and K. Paustian. 2014. Aggregate-associated soil organic matter as an ecosystem property and a measurement tool. *Soil Biology and Biochemistry* 68: A4–A9. https://doi.org/10.1016/j.soilbio.2013.06.014

Sperow, M. 2019. Marginal cost to increase soil organic carbon using no-till on U.S. cropland. *Mitig. Adapt. Strateg. Glob. Change* 24: 93. http://dx.doi.org/10.1007/s11027-018-9799-7

Sun, J., et al. 2022. Biochar promotes soil aggregate stability and associated organic carbon sequestration and regulates microbial community structures in Mollisols from Northeast China. *EGUsphere* https://doi.org/10.5194/egusphere-2022-1084

Sun, W., et al. 2020. Climate drives global soil carbon sequestration and crop yield changes under conservation agriculture. *Global Change Biology* 26(6): 3325–3335. https://doi.org/10.1111/gcb.15001

S Swan, A., et al. COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning. U.S. Department of Agriculture, Natural Resources Conservation Service and Colorado State University. http://comet-planner.com/

Tautges, N.E., et al. 2019. Deep soil inventories reveal that impacts of cover crops and compost on soil carbon sequestration differ in surface and subsurface soils. *Global Change Biology* 25(11): 3753–3766. https://doi.org/10.1111/gcb.14762

The Nature Conservancy. 2022. Biological Carbon Capture Solutions for Resilient Natural and Working Lands in North Dakota. 30pp.

Via, S. 2022. Increasing Soil Health and Sequestering Carbon in Agricultural Soil: A Natural Climate Solution. Izaak Walton League of America and National Wildlife Federation. https://www.iwla.org/docs/default-source/conservation-docs/agriculture-documents/via-2021-carbon-sequestration-report-final_lowres.pdf?sfvrsn=2bb28e0d_12

Wang, C., et al. 2019. Effects of different organic materials application on aggregate composition and stability of latosol. *Soil Science* 50(6): 7. https://doi.org/10.19336/j.cnki.trtb.2019.06.10

Wilson, D., et al. 2016. Greenhouse gas emission factors associated with rewetting of organic soils. *Miles and Peat* 17(04): 1–28. https://doi:10.19189/MaP.2016.OMB.222

Appendix E-3. External Reviewer Comments

A total of 31 external reviewers participated in focus group-type discussions or one-on-one interviews, and/or submitted written comments to project facilitators. Some external reviewers provided comments on more than one land sector. External reviewers did not necessarily agree with all of the points included in the collated reviews and/or the INR report.

The first shareable draft of activity-based practices and metrics (April 2023) drafted by the technical teams was shared in April and May 2023 with the Advisory Committee and numerous external reviewers, some of whom were recommended by Advisory Committee members, and others who were selected by project facilitators based on their expertise. The facilitators reached out to a total of 61 individuals to provide external reviews and conducted interviews and received written comments from 31 individuals.

This section of the report a) summarizes the key comments received and characterizes them by land sector. Comments denoted by the symbol ► were incorporated into the technical teams final list of practices and metrics; all comments not incorporated into the final version of the technical teams' practices and metrics document are noted as "Other comments." A list of reviewers and reviewer comments that were incorporated into the final practices document submitted (July 2023) by the technical teams is noted at the beginning of each land sector section. Official submissions on organization letterhead are included at the end of this appendix.

A. Blue Carbon Practices and Metrics

Concepts from external reviewers incorporated into practices and metrics

► Tidal Wetland Conservation—"Backward-looking" counterfactual baselines are based largely upon assumptions (specifically that the future will mirror the past). Experts on monitoring, reporting, and verifying net climate benefits from natural climate solutions are moving towards dynamic counterfactual baselines. Methods, such as statistical matching, to establish control plots are likely to provide more accurate estimates of net effect relative to a baseline and will be more robust against future scrutiny (for both tidal wetland and forest ecosystems).

► Tidal Wetland and Seagrass Restoration—Seagrass restoration has a 36% probability of being successful (global meta-analysis), therefore conservation of seagrass should be prioritized over restoration. There's more opportunity to preserve blue carbon through conservation mechanisms versus restoration. More can be achieved through ecosystem-based management, and the cost of restoration is very high.

►Protection and restoration strategies for emergent and shrub-scrub and seagrass are quite different. From national statistics, there are overlapping gaps between emergent shrub-scrub and adjacent forested wetlands, etc. Seagrass is mentioned in tidal wetland conservation, but it isn't called out. Depending on the period in which you're trying to restore the carbon, you're going to run into SLR, and with that is salinity change, which affects the split between carbon and methane, which affects the equation. Habitat migration occurs. In the aggregate you have no net loss, but habitats are in different locations. Seaward, seagrass, shrub-scrub, emergent wetlands – horizontal carbon flow occurs among emergent/shrub-scrub and seagrass because they are inundated and experience erosion. We see an enrichment of carbon at that boundary. These are issues that arise with horizontal carbon flow. Establishing baseline is important for this conservation category because you have to demonstrate these are high quality tonnes.

►**Metric:** Metric tonnes of carbon dioxide equivalents (tCO_2e) per acre of protected tidal wetland per year. When you calculate per year you can aggregate across numerous years to achieve long-term goals. But in situations in which you delay your release from year 1 to year 20 (year 1 is -1 ton, but in year 20, it is +1, so net is zero) – it's the point at which the tonne enters the atmosphere. How you net that out is important.

►State explicitly that long-sequestered carbon can be released back into the atmosphere if soils are either drowned or filled, but that process and its timeline is not completely understood.

►15 years is a short timeline to be working on and does not fully recognize the uncertainties in the calculations of risk of conversion. Allow a longer timeline and/or ensure that estimates of conversion are very conservative.

►Carbon accumulation in blue carbon soil systems remain highly uncertain, as we have not developed robust methodologies to account for lateral transport of carbon (e.g., from soil column into near-coastal areas) or to account for allochthonous vs. autochthonous carbon. Moreover, carbon accumulation in blue carbon soils is highly variable across space and depends on many poorly mapped variables (e.g., hydro-geomorphological characteristics). Accounting for carbon in restored wetland and seagrass systems will be a coarse estimate at best and may not be sufficiently accurate to include in state-level accounting.

►Enhanced Tidal Wetland Resistance to Sea Level Rise—There is a fair amount information on emergent wetlands and how these will change with sea level rise. The breakdown of the structure at the edge of the emergent community – numerous issues affecting pathways of submergents. Soil properties in current conditions are not suitable for submerged plants. Presumably, we'll have to deal with this implicitly in our other sectors – related to the durability of carbon storage. It's about how we maintain durability.

►Be explicit about the fate of carbon that was stored in locations where we gain or lose vegetative habitat (especially if that transition is from vegetated to unvegetated).

►Consider sediment delivery in two forms – upriver (up estuary), or inland via tidal connection. In NC, concerned that sediment delivery upriver is insufficient to provide emergent wetlands enough soil supply to maintain levels above sea level rise. Projects are underway to consider thin layers exposed on marshes to mitigate for sediment starvation. Sediment budget issue is important, and challenging. But it's where a lot of the action is. If you aren't delivering adequate sediment to emergent wetlands to keep up with sea level rise, there will be high likelihood of degradation, erosion, and retreat of those wetlands. Lateral movement of carbon will be a challenge. We should be looking at this as a whole system versus compartmentalizing it (submergent and emergent). Carbon is moving back and forth (likely more forth than back).

Other Comments

Tidal Maintenance, Reconnection and Restoration of Tidal Flow—Tidal maintenance will be important for both submergent and emergent vegetation because maintaining inlets and waterways affects circulation of water and water quality. People are talking about this as a way of gaining CO_2e tonnes (mostly on the methane side). Acres to include in inventory – acres within salinity ranges – will need to tackle methane with acres in intermediate salinity ranges.

Note: "Maintenance" was not added to the practice title.

B. Rangelands Practices and Metrics

After the completion of the first draft of rangelands practices and metrics, significant concern was expressed by external reviewers that the practices and associated metrics were narrow in scope and specific to one habitat type in Oregon. As a result of that initial feedback, the rangeland technical team invited broader scientific input, which resulted in significant overhaul of the document.

Concepts from external reviewers incorporated into practices and metrics

►Rangeland types—There are numerous types of rangelands in Oregon, however, the document focuses almost exclusively on sagebrush steppe rangelands, and the proposed practices do not reflect current and emerging techniques to improve grazing distribution and estimate available forage. Focus on sagebrush habitat, particularly old growth sagebrush.

►Metrics—How one arrives at the metrics is unclear. Tools to assess aboveground biomass are not accurate; tools are needed to assess rangeland carbon pools at large scales.

►Riparian—This section focused on locations where cattle were excluded from poorly managed and degraded riparian areas, but ignores areas where cattle management was improved and sites recovered. Suggest landowners develop a riparian management plan.

►Exotic annual grasses—Landscapes dominated by exotic animal grasses are often at risk of significant soil and nutrient losses that result in a loss of carbon overall.

►Remote sensing—The success of treatments can be tracked using a variety of techniques, including remote sensing.

►Grazing management—Grazing management can maintain or enhance deep-rooted perennial grasses. Virtual fencing using GPS collars and reception/signaling towers allow land managers to control animal movements in range and pasture situations.

►Success of practices—Success of practices is highly variable in time and space, with higher success on higher elevation, higher annual precipitation, and lower stress sites.

►Juniper encroachment—Prevent conversion of grasslands and shrublands to junipers, acknowledging the ecosystem function effects, including those associated with the capture, storage, and release of carbon.

►Beaver—Restore incised streams using beaver dam analogs.

Other Comments

Biochar—Implementing biochar, particularly juniper, will improve root growth, help with grasslands, etc. Turn juniper waste into biochar for soil amendments. This practice was not recommended as an amendment to rangeland soils because there was low confidence in its efficacy based on published literature.

C. Forest Lands Practices and Metrics

Concepts from external reviewers incorporated into practices and metrics

►The metric for preventing conversion of forest to non-forest land uses should include:

$$\text{Metric} = [(SLT_a - SLT_b) + (SDT_a - SDT_b)] * L + HWP_a - HWP_b$$

Where:
a/b subscripts = actual project as proposed vs. baseline
SLT = standing live trees
SDT = standing dead trees
L = market leakage factor
HWP = hardwood products

►Planting should consider species composition, density, and spatial patterns to promote ecological resilience (i.e., context makes sense).

►Reforestation can be problematic if planting is not done with some realization of carrying capacity.

►Improved Forest Management—A publicly available published approach to consistently calculating forest carbon stocks can be found here.

►Incorporate recommendations from recent studies on adjusting baselines, quantifying additionality, and accounting for leakage.

►Forest-dependent communities—Consequences to mills, forest operators, and communities dependent on reliable and consistent returns from working forestlands must be evaluated when considering large-scale adjustments to contemporary forest management timelines.

►Extended rotation ages will not always result in greater carbon sequestration.

►Leakage—Incorporate a sensitivity analysis that includes a range of half lives versus specific numbers.

►Release of carbon—Over time, a portion of carbon is released from the HWP pool back to the **atmosphere through natural decay and burning.**

Other Comments

Notes: Incentivizing/Policy Suggestions (not included in practices and metrics, but tracked separately and included in Appendix E.

- Long-lived wood products—Expanding the use of long-lived wood products in more applications will result in storing more carbon in the built environment. Additionally, increasing the use of long-lived wood products in the built environment will increase investment in the entire wood products value chain from manufacturers to forest landowners to forest operators. Each segment of the supply chain will be motivated to increase efficiencies and productivity as part of the market process.
- Incentives—Incentivize forest landowners and managers to invest in set aside areas to expedite meeting carbon sequestration and storage goals.

D. Agricultural Lands Practices and Metrics

External reviewers interested in commenting on the agricultural practices and metrics convened as a group with the facilitators, primarily to ask questions about process, and to make a few additional comments. Several organizations provided comments in writing on letterhead. These letters were given to the Commission.

Other Comments

The recommended practices in the agricultural lands section focus primarily on reducing GHG emissions, yet there is a growing body of science related to sequestration and the positive contributions of a wide variety of agricultural crops and practices, which should be considered in the overall assessment of working lands, including starting baseline.

There should be alignment among practices the federal agencies promote as climate-smart practices as their modeling has demonstrated carbon sequestration benefits. Cover cropping, crop rotation, and livestock integration are examples of those practices. In addition, yield enhancements, improving disease and pest management, and minimum tillage, conservation tillage, and no till should be considered.

There was no support for the practice recommended by the agriculture technical team regarding promoting dietary shifts. External reviewers were concerned about supporting any practices that represent consumer choices, or promoting one commodity versus another.

E. Urban and Suburban Lands Practices and Metrics

Concepts from external reviewers incorporated into practices and metrics

►Increase Net Carbon Sequestration in Urban and Suburban Soils—This practice is not recommended, including "replacing decorative lawns in yards or parks with a prairie with deep-rooted perennial grasses mowed only occasionally." Current perennial turf grasses can be managed in ways to build soil carbon without disturbing the existing sequestered soil carbon to replace it. When establishing new areas, the intended use should be determined and the most appropriate plants for the use should be used. A policy approach that prioritizes some commodities over others, particularly based on a single outcome (GHG emissions) cannot be supported. Many factors should be considered when determining what to plant in urban and suburban settings, such as intended use, soil, climate, and water use.

►Promote green roofs and planters and reducing pavement when possible. The positive effect of grasses in urban environments to help combat urban heat islands, reduce runoff, and remove excess nutrients from runoff is well documented and should not be discounted. Note: The new practices, "Maintain and expand forest vegetation cover in urban and suburban areas" includes a primary practice focused on replacing pavement with patches of soil and planting more street trees, particularly in more intensely developed areas.

Other Comments

The practice to promote green roofs and planters was considered, but not recommended as a practice.

Appendix E-4. References Cited by the Advisory Committee's Forestry Subcommittee

These references were cited by the Advisory Committee's Forestry Subcommittee during their discussions about the initial proposed practices and metrics.

Clark, J., et al. 2011. Impacts of Thinning on Carbon Stores in the PNW: A Plot Level Analysis. College of Forestry, Oregon State University. https://www.nrdc.org/sites/default/files/ene_13041704a.pdf

Donato, D. et al. 2006. Post-wildfire logging hinders regeneration and increases fire risk. *Science* 311(5759): 352. https://doi.org/10.1126/science.1122855

Franklin, J. F., and K. N. Johnson. 2012. A restoration framework for federal forests in the Pacific Northwest. *Journal of Forestry* 110: 429–439. http://dx.doi.org/10.5849/jof.10-006

Ganguly, I., F. Pierobon, and E. Sonne Hall. 2020. Global warming mitigating role of wood products from Washington State's private forests. *Forests* 11(2). https://doi.org/10.3390/f11020194

Gower, S., et al. 2006. Following the Paper Trail: The Impact of Magazine and Dimensional Lumber Production on Greenhouse Gas Emissions. Washington, D.C.: The H. John Heinz III Center for Science, Economics and the Environment. Not in print; no longer in stock.

Gundersen, P., et al. 2021. Old-growth forest carbon sinks overestimated. *Nature* 591: E21–E23. https://doi.org/10.1038/s41586-021-03266-z

Gustavsson, L., et al. 2017. Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels. *Renewable and Sustainable Energy Reviews* 67: 612–624. http://dx.doi.org/10.1016/j.rser.2016.09.056

Harmon, M.E., et al. 1996. Modeling carbon stores in Oregon and Washington forest products: 1900–1992. *Climatic Change* 33: 521–550. https://doi.org/10.1007/BF00141703

Heil, L.J., and L.A. Burkle. 2018. Recent post-wildfire salvage logging benefits local and landscape floral and bee communities. *Forest Ecology and Management* 424: 267–275. https://doi.org/10.1016/j.foreco.2018.05.009

Hudiberg, T, et al. 2019 Meeting GHG reduction targets requires accounting for all forest sector emissions. Environmental Research Letters 14 (9). https://doi.org/10.1088/1748-9326/ab28bb

Hurteau, M.D., et al. 2016. Restoring forest structure and process stabilizes forest carbon in wildfire-prone southwestern ponderosa pine forests. *Ecological Applications* 26: 382–391. http://dx.doi.org/10.1890/15-03371.1/

Ingerson, A. 2007. U.S. Forest Carbon and Climate Change. Washington, D.C. The Wilderness Society. https://www.nrcm.org/wp- content/uploads/2013/10/TWS_US-Forest-Carbon-and-Climate-Change_2007.pdf

IPCC 2018 Global Warming of 1.5ºC. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/sr15/

IPCC 2021 Synthesis Report of the Sixth Assessment Report A Report of the Intergovernmental

Panel on Climate Change. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/ar6-syr/

Janowiak, M., C. Swanston, and T. Ontl. 2017. Carbon Benefits of Wood-Based Products and Energy. USDA, Forest Service, Climate Change Resource. https://www.fs.usda.gov/ccrc/topics/forest-mgmt-carbon-benefits/wood

Kauppi, P.E., et al. 2022. Managing existing forests can mitigate climate change. *Forest Ecology and Management* 513. https://doi.org/10.1016/j.foreco.2022.120186

Kreye, M., et al. 2023. Forest Carbon Pools: Where are They? Penn State Extension. https://extension.psu.edu/forest-carbon-pools-where-are-they

Levine, J.K., et al. 2022. Higher incidence of high-severity fire in and near industrially managed forests. *Frontiers in Ecology and the Environment* 20(7): 397–404. https://doi.org/10.1002/fee.2499

Lewis, S.L., et al. 2019. Restoring natural forests is the best way to remove atmospheric carbon. *Nature* https://www.nature.com/articles/d41586-019-01026-8

Loomis, J., et al. 2019. Do Fuel Treatments in U.S. National Forests Reduce Wildfire Suppression Costs and Property Damage? *Journal of Natural Resources Policy Research* 9. https://doi.org/10.5325/naturesopolirese.9.1.0042

Newton, M., et al. 2006. Comment on "Post-Wildfire Logging Hinders Regeneration and increases Fire Risk." *Science* 313(5787): 615. https://doi.org/10.1126/science.1126478

Peterson, D.W., E.K. Dodson, and R.J. Harrod. 2015. Post-fire logging reduces surface woody fuels up to four decades following wildfire. *Forest Ecology and Management* 338: 84–91. https://doi.org/10.1016/j.foreco.2014.11.016

Peterson, D.W., and R.J. Harrod. 2011. Post-fire Logging: An Effective Tool for Managing Future Fuels in Coniferous Inland Northwest Forests. - U.S. Joint Fire Science Program Briefs. JFSP Project Number 06-3-4-16. https://www.firescience.gov/projects/briefs/06-3-4-16_FSBrief146.pdf

Prichard, S.J., et al. 2021. Adapting western North American forests to climate change and wildfires: 10 common questions. *J. Ecological Applications* 31(8). https://doi.org/10.1002/eap.2433

Prissley, S. 2020. NCASI Review of Carbon Implications of Proforestation. Available at https://tinyurl.com/4fjcduw8

Sample, V.A. 2017. Potential for additional carbon sequestration through regeneration of non-stocked forest land in the United States. *Journal of Forestry* 115(4): 309–318. https://doi.org/10.5849/jof.2016-005

Smith, J., et al. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. United States Department of Agriculture Forest Service Northeastern Research Station. https://www.fs.usda.gov/ecosystemservices/pdf/estimates-forest-types.pdf

Starrs, C.F., et al. 2018. The impact of land ownership, firefighting, and reserve status on fire probability in California. *Environmental Research Letters* 13(3): 034025. http://dx.doi.org/10.1088/1748-9326/aaaad1

Thompson, J.R, T.A. Spies, and L.M. Ganio. 2007. Reburn severity in managed and unmanaged vegetation in a large wildfire. Proceedings of the National Academy of Sciences. PNAS. https://doi.org/10.1073/pnas.0700229104

Tubbesing, C.L., et al. 2019. Strategically placed landscape fuel treatments decrease fire severity and promote recovery in the northern Sierra Nevada. *Forest Ecology and Management* 436: 45–55. https://doi.org/10.1016/j.foreco.2019.01.010

van Minnen, J., et al. 2008. Quantifying the effectiveness of climate change mitigation through forest plantations and carbon sequestration with an integrated land-use model. *Carbon Balance and Management* 3(3): https://doi.org/10.1186/1750-0680-3-3

World Resources Institute. 2023.The Global Land Squeeze: Managing the Growing Competition for Land. 170pp. https://doi.org/10.46830/wrirpt.20.00042

Zald, H., and C. Dunn. 2018. Severe fire weather and intensive forest management increase fire severity in a multi-ownership landscape. *Ecological Applications* 28(4): 1068–1080. https://doi.org/10.1002/eap.1710

Appendix F. Proposed Natural and Working Lands Community Impact Metrics Framework

The Commission's Natural & Working Lands Proposal recommended that Oregon establish community impact metrics:

> "Community impact metrics should be developed to inform and evaluate the co-benefits and impacts of natural and working lands strategies. Environmental justice considerations should be prioritized throughout carbon sequestration programs, in line with recommendations from Oregon's Environmental Justice Task Force, the Racial Justice Council and Oregon's Interagency Workgroup on Climate Impacts to Impacted Communities. The community impact metrics and goals should be designed to evaluate the benefits and burdens associated with different strategies, practices, and programs. These metrics should include effects on jobs, local economies, public health, and access to programs, among other factors."

Impact measurement is a process of collecting and analyzing data to assess the effect of a program, intervention, or policy on a particular population.[315] Community impact metrics measure the benefits and burdens on communities associated with strategies for carbon sequestration in natural and working lands and waters[316] (Oregon Senate Bill 1534). Science-based targets should incorporate consistent and continual reporting processes, transparency in data sources and calculation methodologies, and interoperability with evolving standards and regulations.[317] Place-based community change efforts are geographically targeted initiatives that operate across systems (Brown 1996) and measure the extent to which the initiative causes or leads to changes in outcomes.

Criteria to consider when developing social and cultural metrics (Bessette and Gregory 2020):

- Incorporate impacts based on discussions with stakeholders and the recognition of both individual and community-level effects.
- Incorporate proxy[318] and constructed metrics[319] to help overcome measurement difficulties and provide information about context-specific impacts.
- Seek to meaningfully engage the diverse potentially affected interests.
  Develop measures that are readily understood, concise, and operational to facilitate implementation in decisions.

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[315] https://www.sopact.com/

[316] https://www.oregon.gov/lcd/Commission/Documents/2021-11_Item-10_OGWC_Attachment-A_Natural-and-Working-Lands-Carbon-Sequestration-and-Storage-Proposal-OGWC.pdf

[317] https://tideline.com/wp-content/uploads/2022/10/Tideline_Truth-in-Climate-Impact-FINAL-Oct-2022.pdf

[318] Proxy metrics are metrics introduced to help overcome measurement difficulties or a lack of data.

[319] Constructed metrics rely on quantitative or qualitative indices that reflect different levels of a specific value.

- Adopt a values-focused approach that allows for personal experience and facilitates analysis of alternatives.
- Document values trade-offs and key risk tolerances.
- Adopt best practices regarding risk and impact communication to highlight impact assessments.
- Incorporate stakeholder perceptions into assessments and inventories.
- Acknowledge that some co-benefits are difficult to quantify or monetize (NOAA 2015) (e.g., habitat, open space, increased property values, improved water quality), but should be described, included, and considered in overall community impacts.

Key issues associated with the development of social and cultural metrics include neglect of important impacts, difficulty in identifying clear and evaluable metrics, metrics that ignore formal regulatory, legal, or cultural criteria, measurements perceived as an overtly technical undertaking, and measures considered unimportant by decision makers or stakeholders (Bessette and Gregory 2020). Even when reasonable metrics are identified, measuring and comparing the outcomes across scales can be challenging because of the dynamic and complex nature of social-ecological systems, such as shifts in political support or ecosystem condition (Ostrom 2009, Nuno et al. 2014, van der Jagt et al. 2017). Context-specific metrics will increase understanding of nature-based solution effectiveness at the local level (Sutton-Grier et al. 2015).

Tradeoffs

Assessing tradeoffs (Henrique et al. 2022) of a policy is important because of ethical concerns, to identify potential barriers to acceptability and public support, and to ensure the long-term sustainability of the policy (Penasco et al. 2021). How individuals navigate tradeoffs is crucial for community deliberation; adaptation policy and practice must recognize the diverse values, interests, and experiences of those directly affected by climate change (Eriksen et al. 2020). Climate-smart land management strategies depend on the local character of the landscape as well as community goals (CNRA 2022).

Well adapted agricultural systems contribute to safe drinking water, health, biodiversity, and equity goals (DeClerck et al. 2016). However, tradeoffs may occur. For example, there may be increased risks for human health or reduced access to water if fertilizer and pesticides are used without regulation, or if irrigation reduces water availability for other purposes. Agricultural adaptations may increase workloads, may result in loss of income or culturally inappropriate food if crop mixes change, or may benefit farmers with more land.

Afforestation and/or bioenergy supply can compete with food production and raise food security concerns, and single-minded climate policy (aiming solely at limiting warming without concurrent measures for the food sector) can have negative impacts for global food security. Food price supports, improving productivity and efficiency of agricultural production systems, and programs focused on forest land-use change can add benefits to mitigation, improving resilience and livelihoods (Roy et al. 2018).

Karlsson et al. (2020) documented five types of tradeoffs:

- **Ecological** – Biodiversity, landscape, and land use. Direct land use changes (new crop system at a site) and indirect land use change (pressure on agriculture due to displacement of a previous activity of the use of biomass, which induces land use changes on other land areas to maintain previous level of food production) – also called leakage or displacement effect (Karlsson et al. 2020).

- **Environmental** – Balanced nitrogen fertilizer application can reduce acidification, nitrate leaching, and N_2O emissions (Oenema and Velthof 2007), but can trigger changes in fluxes of other GHGs, especially nitrous oxide and methane (Powlson et al. 2011). The negative environmental side effects of a measure are often referred to as pollution swapping (e.g., meat industry replaces plastic packaging with alternative packaging that reduces the shelf life of the meet, causing waste, and pollution).

- **Economic** – Private economic impacts to a landowner, such as changes in yields, labor requirements, or investments in technology as well as education and training. Some examples of tradeoffs include:

    - Changes in consumer energy bills
    - Changes in the total energy budget of consumers or governments
    - Rural areas experiencing higher welfare losses from energy taxes compared with urban areas (Callan et al. 2009, Flues and Tomas 2015).
    - Increase in labor-intensive agricultural activities (e.g., mulching), which may increase costs.
    - Increase in prices for agricultural products because of mitigation costs borne by the sector or increase in land prices (Melillo et al. 2012).
    - Private economic impacts to farmers through changes in yields or input purchases, labor requirements, or investments in technology (Freibauer et al. 2004, Beach et al. 2008, Breen, 2008, del Prado and Scholefield 2008, MacLeod et al. 2010).

- **Societal** – Mitigation measures in agricultural production may have societal impacts re: animal or public health and food security.

- **Political** – Mitigation measures can be legal instruments, incentive-based, or information and capacity building (Prager et al. 2011). These can result in private transaction costs for landowners and public transaction costs for government.

The identification and measurement of tradeoffs by multiple stakeholders, and potential compensation intervention is key to reduce potential conflict and enhance long-term effectiveness of mitigation strategies (Giordano et al. 2020, Dasgupta 2021).

Complementary policy packages can mitigate adverse side effects of climate change strategies (Liu et al. 2019). For example, in China, land and food security indicators worsened under simple climate mitigation but remained near baseline with a food and forest protection policy package consisting of subsidies. By 2050, policy packages were cost-negative. Implementing only the forest policy worsened food security because it tightened the land market and forced decreases in food production. Likewise, implementing only the food subsidy increased deforestation risk.

The Broader Social and Environmental Impacts of Carbon Removal

In 2015, the United Nations member states endorsed 17 sustainable development goals to assess carbon removal's economic, social, and environmental impacts.

Examples of metrics used for#11, Sustainable Cities and Communities are:

- % of population that breathes polluted air (using World Health Organization Air Quality Guidelines of $PM_{2.5}$<5 UG/M^3).
- % of city dwellers that have convenient access to public transportation

Figure 5. The United Nations member states endorsed these 17 sustainable development goals to assess carbon removal's economic, social, and environmental impacts.

Appendix A lists the goals and targets for each of the 17 indicators, which can serve as a resource for communities considering developing community impact metrics for climate-smart practices on Oregon's natural and working lands.

Barry and Seamus (2021) documented the environmental, economic, and social/cultural impact indicators of climate change (Figure 3).

Newell et al. (2018) expressed the co-benefits and trade-offs associated with specific climate actions strategies using models illustrating the strategies, co-benefits and trade-offs. For example, in urban areas, urban trees and vegetation produce co-benefits, such as viewshed and microclimate (no tradeoffs identified) whereas gardens and local agriculture produce co-benefits of social interaction, food bank services, tourism, economic development, and food security, but also produce transport requirement tradeoffs (Figure 4). Use of this type of model allows individual communities to consider tradeoffs and co-benefits specific to their local community via collaborative government/stakeholder workshops that discuss the implications of climate practices (Newell et al. 2018).

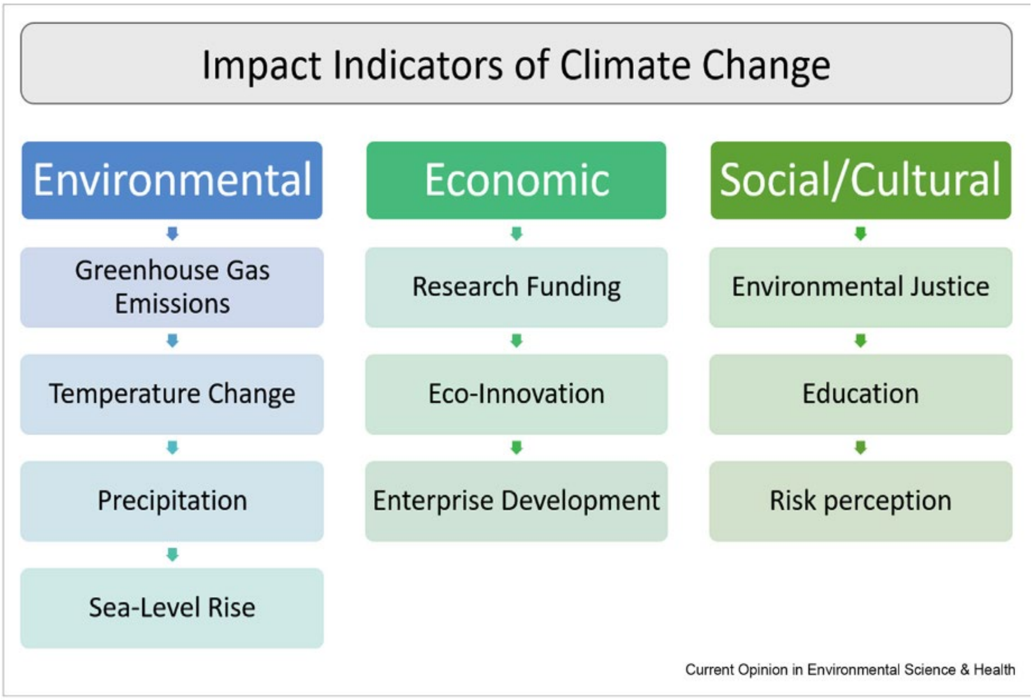

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Figure 6. List of indicators that can be developed to assess the impacts of climate change.

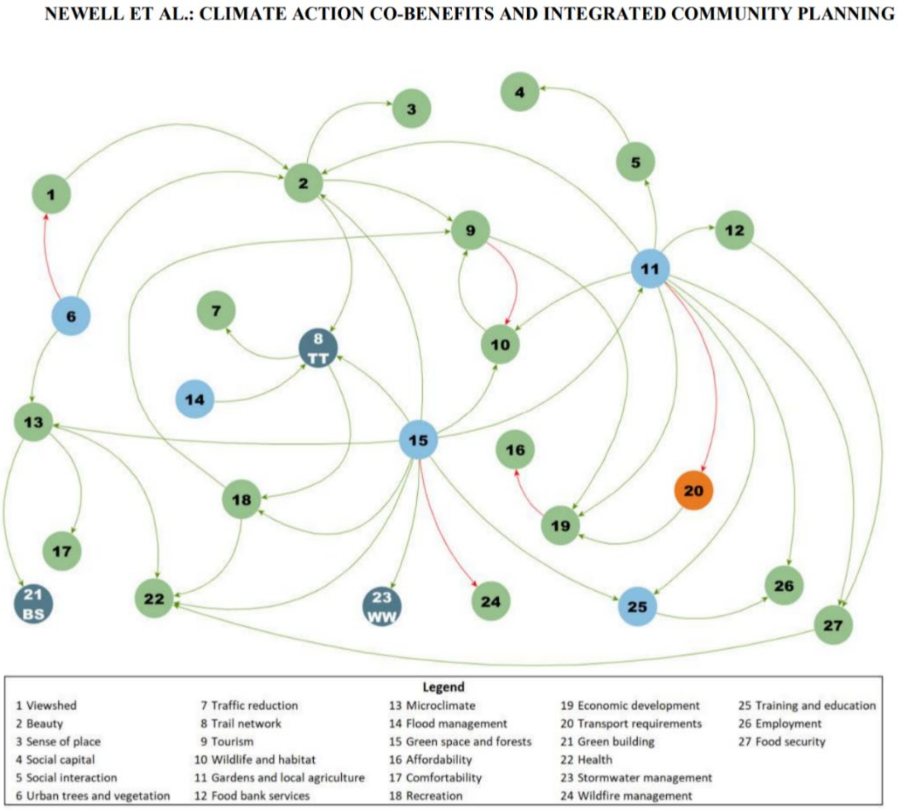

Figure 7. Urban trees and vegetation produce co-benefits and no identified tradeoffs whereas gardens and local agriculture produce numerous co-benefits and one identified tradeoff (Newell et al. 2018).

Theory of Change

Oregon will sequester an additional 5 MMTC02E annually by 2030 and at least 9.5 MMTC02E annually by 2050 by implementing practices on natural and working lands.

The following are examples of ecological, economic, infrastructure, social justice/equity, public health:

Ecological Indicators

- Acres of land under durable conservation easements that include climate-smart management requirements
- Acres of land with restoration efforts underway
- Average trend of high severity wildfire patch size and occurrence
- Acres of land covered with landscape-level planning
- Total % of an area or community covered by urban tree canopy
- % decrease in ambient temperature during high heat months in urban areas, particularly in vulnerable communities
- % of agricultural acres with on-farm technical assistance, demonstration projects, and incentives
- % change in soil organic matter

- % change in soil moisture content
- % of infrastructure projects that incorporate nature-based solutions
- Quantifying land cover and land use changes as part of a monitoring framework
- Presence of pollinators
- Presence/distribution of native species/species richness
- Absence of nuisance/invasive species, pests, and disease
- Maintenance of current patterns of biodiversity
- Presence of multiple migration pathways for animals and plant species
- Native plant and animal dominance and presence/distribution of native species/species richness
- Lack of anthropogenic stream barriers
- Topographic diversity
- No net loss of biodiversity
- Maintenance or enhancement of conservation values important to conserving globally, regionally, or nationally significant biodiversity
- Land coverage
    - Acreage and continuity of freshwater and coastal wetlands
    - Acreage and distribution of protected land
    - Acreage and distribution of water resources, permeable soils, and recharge zones
    - Acreage and linear miles of protected riparian corridors
    - Acreage of different forest stand types (oak woodland, riparian, redwood/Douglas fir, pine)
    - Acreage of forestland by age and late seral forest characteristics
    - Acreage of regulated and protected land within a property (e.g., forestland acres with exclusion zones, riparian buffers, Northern Spotted Owl core areas)
    - Acreage and diversity of working lands using climate-resilient practices
    - Acreage of land devoted to food production using regenerative practices
    - Acreage of urban and suburban neighborhood-based gardens that contribute to local food production and benefit pollinator habitat
    - No net loss of open space and native ecosystems on publicly owned land, or in targeted priority areas, including historically marginalized communities
    - Trees and green spaces are distributed equitably across neighborhoods and communities in urban and suburban areas
    - Net increase in urban and suburban green infrastructure to reduce climate risk
    - No net loss or conversion of cropland/rangeland/grassland/forestland in Oregon
- Land Management
    - Acreage and diversity of fuels treatment and management projects
    - Acres of fire suppressed areas (with consideration of historic fire return intervals)
    - Acreage of forest treatments by silviculture type
    - Acreage of agricultural land stewarded using climate-resilient practices (e.g., practices that increase water retention, increase soil nutrients, decrease erosion,

promote plant health and resilience to climate impacts, encourage native pollinators, etc.)

- Diversity of production on agricultural lands/food system diversity
- # of landowners using climate-resilient management practices (including grazing, croplands and vineyards practices, and timber practices)
- Enhanced incentives for local food production (e.g., purchase of equipment to enable precision farming/machine harvesting resilient to extreme weather conditions, rebates for residential chickens)
- Agricultural practices incorporate Indigenous and local knowledge
    - Reduction and reversion of land degradation at a variety of scales
    - Improved management of cropland and grazing lands
    - Improved and sustainable forest management
    - Increased soil organic carbon content
    - % of land sector-based businesses that supply all or a portion of their electrical needs with solar, or alternative climate-friendly energy sources

Economic Indicators

- #of workers contributing to climate smart land management
- # of workers trained and placed into jobs, disaggregated by race, ethnicity, geography, with wages and other job quality indicators
- # of jobs in climate-smart related trades created or maintained
- Units of durable wood products (derived from woody material generated through forest health and resilience projects) sold
- # of accessible training opportunities that provided meaningful, transferrable skills for nature-based career development
- New investment motivated by nature-based climate solutions.
- Economic multipliers associated with investment in nature-based climate solutions

Infrastructure Indicators

- Regional, local, and traditional food harvesting, food processing, storage, and related infrastructure to support the agriculture industry and food security
- Managed Aquifer Recharge capacity, particularly in critically over-drafted basins and other areas in need of long-term groundwater storage
- Changes in the timing of watershed runoff, and number of projects implemented to address these changes
- Compost infrastructure capacity
- Percentage increase in hard infrastructure investments that incorporate nature-based solutions

Social Justice/Equity Indicators

- # of acres managed, co-managed, transferred to, and owned by Oregon Native American tribes.
- Availability and use of programs that engage and support nature-based solutions that deliver environmental, equity, and economic benefits in communities most vulnerable to climate change.
- Prioritization of communities most vulnerable to climate change for financial incentives, technical assistance, and other supportive resources.
- # of nature-based solutions implemented in climate vulnerable communities.
- % of socially disadvantaged farmers and ranchers with on-farm technical assistance, demonstration projects, and incentives.
- Farmworker quality of life (including wages, health, and wellbeing).
- Access to capital and opportunity.
- Access to food and supply chain resilience.
- Access to parks/greenspace.
- Acres of community co-managed or owned properties managed for climate benefits.
- <u>Management, ownership, and capacity</u>
  - Capacity and access for broad participation in scoping, planning, design and implementation
  - Capacity for ongoing monitoring, maintenance, and adaptive management
  - Development of shared decision-making frameworks with tribal partners to identify tribal cultural properties and resources, as well as other conservation priorities and strategies
  - Incorporation of traditional ecological knowledge and tribal expertise into management
  - Increased partnerships among tribes and landowners/land management entities
  - Diverse land ownership and management—public, private, tribal
  - Ongoing, meaningful consultation and engagement with tribes regarding resilience priorities and actions related to advancing the strategy
  - Participation of prescribed burn associations, cooperative burning, and fire training availability
  - Strengthened partnership with RCDs and SWCDs to identify needs and opportunities of small farms
  - Support for diverse organizations and individuals to own, manage, and steward land
  - Support for small farmers to implement climate-resilient agricultural practices and shift to regenerative and ecological practices

Public Health Indicators

- # of emergency department visits / hospitalizations associated with heat, wildfires, wildfire smoke, etc.
- Excess deaths
- Physical activity levels associated with outdoor activities, e.g., hiking, walking, cycling, etc.
- Food security.
- Water security.
- Acreage of lands used for community/ urban farms.
- Market saturation with locally produced/ grown food.
- Access to nature or green spaces.
- Air quality.
- Water quality.
- Number of nature-based solution projects that reduce health risks.

Socioeconomic Indicators

- Contribution of natural and working lands to the state's economy and employment
- Contribution of natural and working lands to tribal economies and employment
- Health, safety, and capacity of workers (e.g., loggers, heavy equipment operators, and forest field staff and vegetation managers) to make a living wage and access housing in the community in which they work
- Health and capacity of workforce/number of workers
- Health, safety, and capacity of tribal communities
- Improved air quality (the following sub-bullets are from JLARC-Washington State Joint Legislative Audit and Review Committee)
    - Prevent air pollution from reaching levels that impact human health or air quality meeting or exceeding NAAQS and standards
    - Healthier air quality; fewer days of unhealthy air quality
    - Fewer air quality-related health problems and impacts
    - Reduced environmental damage to species and property
    - Healthier ecosystems
    - Reduced haze, and improved visibility, especially in parks and wilderness areas
- Increased livability
- Improved public health
- Implementation of community-based processes to strengthen capacity and increased participation (e.g., workforce development, access to green jobs, technical assistance)
- Protection of workers to climate hazards (e.g., worker exposure to wildfire smoke, heat, and chemicals)
- Prioritization and protection of tribal cultural resources and properties
- Tourism levels

- Amount of consumer incentives that reward people for taking steps to reduce their use of fossil fuels
- Increased local income generated in communities within and adjacent to natural and working lands
- No increase in energy costs to low-income households in communities within and adjacent to natural and working lands (via creation of climate rebates that assist with higher energy prices as well as other products and services that are sensitive to energy costs).
- Reduction in poverty and hunger in communities within and adjacent to natural and working landscapes
- Tax incentives available to landowners to support greenhouse gas emission reductions and promote carbon storage
- Short- and long-term sufficiency wage land sector jobs created
- Sufficiency wage employment in land sector jobs representative of the diversity of the local communities
- Increased student and teacher access to sustainability and land sector-based education and training
- Training for existing low-income workers for sufficiency wage "green jobs" that promote energy efficiency
- Increased community investments in training and education programs that create new jobs and emerging technologies that lead to reductions in greenhouse gas emissions and increased carbon storage
- Development and implementation of urban agriculture training programs to train new urban farmers in climate-resilient agriculture and business practices
- No net increase in resource insecurity among historically marginalized communities in Oregon
- Supply, diversity, and affordability of market-rate housing (e.g., # of new units by type and area median income, availability of units appropriate for families and multi-generational households, availability of lower-cost ownership units and qualitative discussion on availability to equity priority groups)*
    - Supply of income-restricted housing (# of net income-restricted units by type and AMI)*
- Residential displacement (e.g., estimated physical displacement, qualitative discussion of effect on economic displacement, citywide and in specific areas)*
- Exposure to air, noise, ground, and water pollution (amount and demographics of population living in areas with high exposure to air pollution, amount and percentage of population living near highways, arterials, flight paths, and industrial areas, and amount and % of population living in areas with high exposure to contaminated sites)*
- Vulnerabilities to the impacts of climate change (e.g., drought, fire, smoke) (e.g., amount and % of population living in areas with high exposure to flooding and landslides, amount and % of population living in areas with high temperatures, amount and % of population

living in areas with low tree canopy coverage, amount and % of population living in areas affected by sea-level rise)*[320]

- Access to resources, food, water, healthcare, and other critical services in rural communities
- Equitable access to healthful, nutritious, fresh food (ideally locally grown for increased resilience to disruption, maximum nutrition, and local economic benefit)
- Equitable access to parks and open spaces and jobs opportunities
- Prioritization and protection of access (ingress and egress) to tribal lands through state and county roads during disasters
- Access to resources, food, water, healthcare, and other critical services in rural communities
- Equitable access to healthful, nutritious, fresh food (ideally locally grown for increased resilience to disruption, maximum nutrition, and local economic benefit)
- Equitable access to parks and open spaces and jobs opportunities
- Prioritization and protection of access (ingress and egress) to tribal lands through state and county roads during disasters
- Provision of green corridors and connections, as well as buffers, to provide access to nature and protection and relief from climate hazards
- Proximity of natural resource benefits to underserved and under-resourced communities
- Proximity to green spaces and green infrastructure within the County's developed lands to underserved and under-resourced communities
    - Improved access to land-sector based education and training in communities within and adjacent to natural and working lands
    - Mobility and reduced vehicle miles traveled (e.g., access to jobs via transit analysis, VMT and VMT per capita, access to pedestrian network, access to all ages and abilities bicycle network)*

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[320] https://www.seattle.gov/documents/Departments/OPCD/SeattlePlan/OneSeattlePlanEquityClimateMetrics.pdf

Examples of Place-based Community Impact Socioeconomic Metrics

The Framework

Impact metrics measure the benefits and burdens on communities associated with strategies for carbon sequestration in natural and working lands and waters (Senate Bill 1534). Impact measurement is a process of collecting and analyzing data to assess the effect of a program, intervention, or policy on a particular population.[1] Community impact metrics measure the benefits and burdens associated with different strategies, practices, and programs that may inform and evaluate the co-benefits and impacts of GHG emissions reductions and increased carbon storage strategies on natural and working lands.[2] Science-based targets should incorporate consistent and continual reporting processes, transparency in data sources and calculation methodologies, and interoperability with evolving standards and regulations.[3]

Criteria to consider when developing social and cultural metrics[4]:

- Incorporate impacts based on discussions with stakeholders and the recognition of both individual and community-level effects.
- Incorporate proxy and constructed metrics to help overcome measurement difficulties and provide information about context-specific impacts
- Seek to meaningfully engage the diverse potentially affected interests
- Develop measures that are readily understood, concise, and operational to facilitate implementation in decisions.
- Adopt a values-focused approach that allows for personal experience and facilitates analysis of alternatives.
- Document value trade-offs and key risk tolerances.
- Adopt best practices regarding risk and impact communication to highlight impact assessments.
- Incorporate stakeholder perceptions into assessments and inventories.

[1]https://www.sopact.com/

[2]https://www.oregon.gov/lcd/Commission/Documents/2021-11_Item-10_OGWC_Attachment-A_Natural-and-Working-Lands-Carbon-Sequestration-and-Storage-Proposal-OGWC.pdf

[3]https://tideline.com/wp-content/uploads/2022/10/Tideline_Truth-in-Climate-Impact-FINAL-Oct-2022.pdf
[4] Bessette and Gregory (2020)

Economic Stability

Employment
- Reductions in land sector unemployment/ increased employment
- Equitable access to green job opportunities
- Improved access to land-sector based education and training
- Investments in workforce development and local skilled jobs
- Short- and long-term sufficiency wage land sector jobs created and representative of the diversity of local communities
- Capacity of land sector workforce and number of workers
- Contribution of natural and working lands to the state's economy and employment
- # of individuals receiving land sector-based job training

Income
- Increases in medium household income
- Increased local income in communities within and adjacent to natural and working lands

Business Growth
- % change in business establishments
- $ invested in projects that enhance carbon storage and reduce GHG emissions
- Tax incentives available to landowners to support GHG emission reductions and support carbon storage
- Increase in tourism levels

Poverty and low-income
- % of children under 18 years of age in poverty
- No increase in low-income households in communities\

Energy
- Lower consumer energy bills

Neighborhood/ Physical Environment

Housing
- Increases in home ownership across racial and ethnic groups
- Population spending more than 30% of income on housing
- # subsidized housing units per 1,000
- % vacant housing units
- Worker access to housing in the community in which they work
- # of new green roofs

Transportation
- Access to all ages and abilities bicycle network
- % of community members with access to high-frequency public transportation choices within 1/2 mile

Parks
- Equitable distribution and access to parks and open spaces (including walkability)
- Green corridors and connections as well as buffers that provide access to nature and protection and relief from climate hazards
- Proximity to green spaces and green infrastructure within developed lands
- # of citizens benefitting from and using green corridors
- Increase in scenic values

Food

Food security
- % of population that is food insecure
- # of people whose calorie intake falls below FAO-defined specified values

Food quality
- Equitable access to healthy options (fresh food)

Education

Literacy
- % of 3rd graders reading at grade level

Training
- Access to technological and other training for farmers
- Access to vocational training

High School Education
- % CCSD high schools

Higher Education
- Population aged 25 and older with a bachelor's degree or higher

Health

Medical bills
- % of population 18-64 years of age with health insurance
- # of primary care physicians per 100,000

Life expectancy/quality
- Increases in life expectancy of residents
- Fewer air quality-related health problems and impacts

Workers
- Protection of workers to climate hazards

Hospital Visits
- # of asthma emergency department visits by children

Sustainability

Water
- # gallons per capita per day
- Enhanced water quality
- Volume of water reused
- # of violations of Safe Water Drinking Act
- Flood risk reduction

Recycling
- % of municipal waste recycled
- Reduction in total waste disposed

Air quality
- % of good air quality days annually
- Fewer days of unhealthy air quality
- Air pollution that does not exceed NAAQS and standards
- Reduced haze and improved visibility

Incentives
- Annual investment in weatherization, electric heat pump, and community solar incentive/subsidy programs
- Support for farmers to implement climate-resilient agricultural practices
- Amount of consumer incentives that reward people for taking steps to reduce their use of fossil fuels

Fossil Fuel Alternatives
- % of land sector-based businesses that supply all or a portion of their electrical needs with solar, or alternative climate-friendly energy sources
- # of electric vehicle charging stations

Temperature
- Relative decrease in local temperatures during summer period

Management, ownership, and capacity

Public engagement
- Capacity and access for broad participation in land sector-based scoping, planning, design, and implementation
- Inclusion of small farmers in program development and design
- Development of shared decision-making frameworks with tribal partners
- Incorporation of traditional ecological knowledge and tribal expertise into management
- Strengthened partnerships with RCDs and SWCDs to identify needs and opportunities of small farms, woodlands, and landowners
- % of private property owners and developers that implement climate change preparation measures (e.g., reducing impervious areas)

Land ownership
- Diverse land ownership and management
- Support for diverse organizations and individuals to own, manage, and steward land

References

Barry, D., and H. Seamus. 2021. Sustainable measurement indicators to assess impacts of climate change: Implications for the New Green Deal Era. *Environmental Science and Health* 22: https://doi.org/10.1016/j.coesh.2021.100259

Beach, R.H., et al. 2008. Mitigation potential and costs for global agricultural greenhouse gas emissions. *Agr Econ* 38(2): 109–115. https://doi.org/10.1111/j.1574-0862.2008.00286.x

Bessette, D.L., and R. Gregory. 2020. The promise and reality of social and cultural metrics. *Ecology and Society* 23(3): 11. https://doi.org/10.5751/ES-11730-250311

Breen, J. P. 2008. Simulating a market for tradable greenhouse gas emissions permits amongst Irish farmers. Agricultural economics society 82nd annual conference. Royal Agricultural College, Cirencester, UK: Agricultural Economics Society. pp.21 Cirencester, UK: Agricultural Economics Society.

Brown, P. 1996. Comprehensive Neighborhood-Based Initiatives. *Cityscape* 2 (2): 161–76. http://www.jstor.org/stable/20868414

Bryan, E., et al. 2017. Making climate change adaptation programmes in sub-Saharan Africa more gender responsive: insights from implementing organizations on the barriers and opportunities. *Climate and Development* 10(5): 417–431. https://doi.org/10.1080/17565529.2017.1301870

California Natural Resources Agency. 2022. Natural and Working Lands Climate Smart Strategy. 109pp. link to report

Callan, T., et al. 2009. The distributional implications of a carbon tax in Ireland. *Energy Policy* 37: 407–412. https://doi.org/10.1016/j.enpol.2008.08.034

Cascadia Partners. 2021. Natural and Working Lands Element: Technical Report. 130pp. link to report

Cohen, B., et al. 2022. Co-benefits and trade-offs of climate change mitigation actions and the Sustainable Development Goals. *Sustainable Production and Consumption* 30: 1096–1097. https://doi.org/10.1016/j.spc.2020.12.034

Congdon, W., et al. 2020. Assessing the Impact of Community-Level Initiatives: A Literature Review, OPRE Report #2021-4, Washington, DC: Office of Planning, Research, and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services. https://www.acf.hhs.gov/opre/report/assessing-impact-community-level-initiatives-literature-review

Dasgupta, P. 2021. The Economics of Biodiversity: The Dasgupta Review. London: HM Treasury. https://www.gov.uk/government/publications/final-report-the-economics-ofbiodiversity-the-dasgupta-review

Dawson, J., et al. 2010. Integrative management to mitigate diffuse pollution in multi-functional landscapes. *Curr Opin Environ Sustain* 2(5–6): 375–382. https://doi.org/10.1016/j.cosust.2010.09.005

DeClerck, F.A.J., et al., 2016. Agricultural ecosystems and their services: the vanguard of sustainability? *Current Opinion in Environmental Sustainability* 23: 92–99, https://www.doi.org/10.1016/j.cosust.2016.11.016

del Prado, A., and D. Scholefield. 2008. Use of SIMSDAIRY modelling framework system to compare the scope on the sustainability of a dairy farm of animal and plant genetic-based improvements with management-based changes. *J Agr Sci.* 146: 195–211. https://doi.org/10.1017/S0021859608007727

Eriksen, S., et al. 2020. Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance, or irrelevance? *World Dev.* 141: 105383. https://doi.org/10.1016/j.worlddev.2020.105383

Flues, F., and A. Tomas. 2015. The Distributional Effects of Energy Taxes Taxation Working Paper (OECD). https://doi.org/10.1787/5js1qwkqqrbv-en

Freibauer, A., et al. 2004. Carbon sequestration in the agricultural soils of Europe. *Geoderma* 122(1): 1–23. https://doi.org/10.1016/j.geoderma.2004.01.021

Giordano, R., et al. 2020. Enhancing nature-based solutions acceptance through stakeholders' engagement in co-benefits identification and trade-offs analysis. *Science of The Total Environment* 713: 136552. https://doi.org/10.1016/j.scitotenv.2020.136552

Henrique, K.P., et al. 2022. Navigating loss and value trade-offs in a changing climate. *Climate Risk Management* 35: https://doi.org/10.1016/j.crm.2022.100405

Karlsson, M., et al. 2020. Climate policy co-benefits: a review. *Climate Policy* 20(3): https://doi.org/10.1080/14693062.2020.1724070

Littlefield, C.E., and A.W. D'Amoto. 2022. Identifying trade-offs and opportunities for forest carbon and wildlife using a climate change adaptation lens. *Conservation Science and Practice* https://doi.org/10.1111/csp2.12631

Liu, J., et al. 2019. Identifying trade-offs and co-benefits of climate policies in China to align policies with SDGs and achieve the 2 degree C goal. *Environmental Research Letters* 14: 124070. https://doi.org/10.1088/1748-9326/ab59c4

MacLeod, M., et al. 2010. Developing greenhouse gas marginal abatement cost curves for agricultural emissions from crops and soils in the UK. *Agr Syst* 103(4): 198–209. https://doi.org/10.1016/j.agsy.2010.01.002

Melillo, J.M., et al. 2012. J.M. Melillo, T.C. Richmond, G.W. Yohe (Eds.), Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program, Washington, DC.

National Oceanic and Atmospheric Administration. 2015. A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction. 30pp.

Newell, R., et al. 2016. Climate action co-benefits and integrated community planning: Uncovering the synergies and trade-offs. *International Journal of Climate Change Impacts and Responses* 10(4): 1–23. https://doi.org/10.18848/1835-7156/CGP/v10i04/1-23

NRCS. 2022. Climate change adaptation plan. 33pp.

Nuno, A., et al. 2014. Managing social-ecological systems under uncertainty: implementation in the real world. *Ecol. Soc.* 19(52). https://doi.org/10.5751/ES-06490-190252

Oenema, O., and G.L. Velthof. 2007. Analysis of international and European policy instruments: pollution swapping. *In*: Integrated measures in agriculture to reduce ammonia emissions. Wageningen, The Netherlands: Alterra, Wageningen UR, p. 104.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325: 419–422. https://doi.org/10.1126/science.1172133

Panichelli, L., and E. Gnansounou. 2008. Estimating greenhouse gas emissions from indirect land-use change in biofuels production: concepts and exploratory analysis for soybean-based biodiesel. *J Sci Ind Res* 67(11): 1017–1030.

Penasco, C., et al. 2021. Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments. *Nature Climate Change* 11: 257–265. https://doi.org/10.1038/s41558-020-00971-x

Powlson, D.S., et al. 2011. Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *Eur J Soil Sci.* 62(1): 42–55. https://doi.org/10.1111/j.1365-2389.2010.01342.x

Prager, K., et al. 2011. Soil degradation, farming practices, institutions and policy responses: an analytical framework. *Land Degrad Dev.* 22(1): 32–46. https://doi.org/10.1002/ldr.979

Reilly, J, et al. 2012. Using land to mitigate climate change: Hitting the target, recognizing the tradeoffs. *Environmental Science and Technology* 46(11): 5572–5679. http://dx.doi.org/10.1021/es2034729

Roy, J., et al. 2018. Sustainable Development, Poverty Eradication and Reducing Inequalities. *In*: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 445-538. https://doi.org/10.1017/9781009157940.007

Shackleton, S., et al. 2015. Why is socially just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. Wiley Interdisciplinary Reviews: *Climate Change* 6(3): 321–344. https://doi:10.1002/wcc.335

Sutton-Grier, A.E., et al. 2015. Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. *Environ. Sci. Policy* 51: 137–148. https://doi.org/10.1016/j.envsci.2015.04.006

United Nations. 2022. The Sustainable Development Goals Report. 66pp.

Van Stappen, F., et al. 2011. Direct and indirect land use changes issues in European sustainability initiatives: state-of-the-art, open issues and future developments. *Biomass & Bioenergy* 35(12): 4824–4834. https://doi.org/10.1016/j.biombioe.2011.07.015

Van der Jagt, A., et al. 2017. The nature of innovation for urban sustainability. Naturvation report, Copernicus Institute for Sustainable Development, Utrecht University, The Netherlands.

Verspecht, A., et al. 2012. Review of trade-offs and co-benefits from greenhouse gas mitigation measures in agricultural production, *Journal of Integrative Environmental Sciences* 9:sup1: 147–157. https://doi.org/10.1080/1943815X.2012.698989

Appendix G. Request for Information for Workforce Development and Training Needs Assessment and Gap Analysis of NWL Sectors in Oregon

State of Oregon

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Cover Page

DEPARTMENT OF ENERGY

REQUEST FOR INFORMATION (RFI)

Seeking Information About:

Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Lands Sectors in Oregon

RFI #23-XXX

Single Point of Contact (SPC):

Address:	550 Capitol St. NE
City, State, Zip	Salem, OR 97301
Phone (voice)	503-508-8190
E-mail:	Odoe.contracts@energy.oregon.gov

The State of Oregon promotes equal opportunity for all individuals without regard to age, color, disability, marital status, national origin, race, religion or creed, sex or gender, sexual orientation, or veteran status.

INTRODUCTION

The State of Oregon, acting by and through the Oregon Department of Energy (ODOE), is issuing this Request for Information (RFI) for entities that have the capacity and experience to provide a suggested methodology and estimated costs to conduct a *Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Lands in Oregon*. ODOE is seeking input to inform the development of a solicitation (Request for Proposal) by the State of Oregon.

BACKGROUND

1.1 Program Overview and Background

The Oregon Global Warming Commission (Commission), formerly known as the Oregon Global Warming Commission, was created by the 2007 Oregon Legislature through House Bill 3543. ODOE provides staff support to the Commission. The mission of the Commission is to recommend ways to coordinate state and local efforts to reduce Oregon's greenhouse gas emissions, and to help state and local governments, businesses, and Oregonians prepare for the effects of climate change. The Commission is working to analyze and identify actions across all sectors that can reduce greenhouse gas emissions while continuing to grow Oregon's economy and simultaneously enhancing equity and quality of life for all Oregonians.

The Commission Biennial Report to the Oregon Legislature (2020) documented the potential of natural and working lands to reduce Oregon emissions by an additional 18 percent through climate-smart policies, programs, and practices that capture and store carbon. Avoiding conversion of natural and working lands, restoring habitats, mitigating fire effects, and modifying land management practices can contribute to climate mitigation and/or adaptation, while providing co-benefits, including economic, health, and environmental, to name a few. Achieving these goals requires a trained, skilled, and diverse workforce throughout Oregon.

The following questions are presented to help inform the development of a Request for Proposal to conduct the workforce development and training needs assessment and gap analysis. Your responses will not be published but will be part of the record and therefore subject to a public records request. Please read all the questions before providing answers to ensure a targeted response.

PROJECT BACKGROUND

1.2 Project Background

In 2021, the Commission published a Natural & Working Lands Proposal (hereinafter referred to as "Proposal") that highlights the need for increasing the pace and scale of workforce development and training as well as technical assistance across numerous Oregon natural and working land sectors. New and expanded land sector workforce programs are needed that create pathways that ensure family-wage employment for all people living and working in communities[321] with current and potential land sector employment (consider communities of color as well as all historically underserved communities).

This Request for Information (RFI) is being solicited to determine potential methodologies and estimated costs to conduct a *Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Land Sectors in Oregon* to evaluate current technical assistance capacity and projected future technical assistance capacity needs associated with implementing the strategies outlined in the Commission's Natural & Working Lands Proposal for achieving natural and working lands sequestration and storage outcomes.

1.3 Project Specific Definitions

COMMISSION is the Oregon Global Warming Commission

ODOE is the Oregon Department of Energy

Proposal is the Commission Natural & Working Lands Proposal

Natural and Working Lands include agricultural lands, forestlands, urban/suburban lands, grasslands and rangelands, and blue carbon.

RFQ is a Request for Quotation

RFP is a Request for Proposal

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[321] The use of the term "Communities" in this scope of work is intended to be defined as: A unified body of individuals, such as people with common interests living in a particular area; a group of people with a common characteristic, or interest living together within a larger society; a body of persons of common and especially professional interests scattered through a larger society; a body of persons or nations having a common history or common social, economic, and political interests; a group linked by a common policy; interacting populations of various kinds of individuals in a common location; a social state or condition; joint ownership or participation; social activity; or society at large.

OBJECTIVES

The objective of this RFI is to obtain information to inform the development of a Request for Proposal to conduct a needs assessment and gap analysis of natural and working land sectors in Oregon. The assessment and gap analysis has two key components:

1. **A comprehensive assessment and gap analysis that defines workforce needs associated with achieving Proposal natural and working lands goals, including conducting an inventory of existing resources, analyzing gaps, and developing an implementation plan for action, with metrics to assess implementation success. This would include:**
   i. Identifying other states conducting similar studies, and aligning to minimize duplicative work.

   ii. Compiling Baseline Inventory Information on Oregon's businesses, industries, and workers in Oregon's natural and working lands economy, characterizing them by land sector segment, and documenting associated growth trajectories.

   iii. Inventorying existing resources, assessing Oregon's capacity to recruit, prepare, place, and or retrain, retain, and advance workers for jobs that are created, or transformed, by greenhouse gap capture and carbon sequestration goals on natural and working lands. Training and Technical Assistance should be included.

   iv. Projecting future land sector workforce needs in current and emerging markets.

   v. Analyzing workforce and labor market dynamics that affect Oregon's achievement of Proposal and land sector goals, including the feasibility of private land ownership and management as well as projected effects on the economy and environment.

2. **Develop a Quality Jobs Framework that includes an implementation roadmap of short- and long-term strategies to bridge workforce development and training gaps and achieve Proposal goals for Oregon's five land sectors – agricultural lands, forestlands, urban/suburban lands, grasslands and rangelands, and blue carbon. This does not result in the creation of a new program, or a program that operates parallel to existing programs. Rather, it streamlines and accelerates solutions through partnerships and knowledge share with a new, interconnected system.**

SCOPE OF WORK

The scope of work for this project is to solicit, compile and evaluate information from entities with the experience to propose methodologies and estimate costs associated with a *Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Land Sectors in Oregon*. Responses to this RFI will inform the design of a Request for Proposal to be issued by the State of Oregon.

INSTRUCTIONS TO RESPONDENTS

Information and responses should be succinct providing the reviewer adequate information to determine what the Respondents' current services are and abilities to perform services described in this RFI.

1.4 Respondents submit information to Single Point of Contact (SPC):

Name:
Address: 550 Capitol Street NE
Salem, OR 97301
Telephone: (503) 508-8190
E-mail: Odoe.contracts@energy.oregon.gov

1.5 Respondents must submit the following information:

Respondents are asked to provide responses to the following questions. Your responses will not be published but will be part of the record and therefore subject to a public records request. Please read all the questions before providing answers to ensure a targeted response.

1. Workforce Development and Training

ODOE would like to gain a better understanding of the methods used and estimated costs associated with conducting a *Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Land Sectors in Oregon*. The following questions will help ODOE understand the suite of methodologies possible to achieving the goals of the needs assessment and gap analysis as well as estimated costs.

Questions:

1. Do you have existing partnerships with entities that could inform the outcomes of this workforce needs and gap analysis? Describe these partnerships and how they could inform desired deliverables.

2. On a scale of 1 to 10 (1 – no familiarity; 10 – very familiar), how familiar are you with Oregon's workforce and associated training needs, and in particular those associated with natural and working land sectors? What approach would you use to describe those

workforce and training needs?

3. Can you identify or propose one or more specific workforce development training programs that could be scaled up and/or modified to potentially meet Oregon's workforce development needs associated with achieving Proposal goals? If so, what is that program(s)?

4. Are you aware of any other states that have conducted, or are conducting similar analyses associated with workforce development needs and training, particularly on natural and working lands? If so, please list.

5. Compiling baseline inventory information is foundational to the needs assessment and gap analysis.
    a. How would you assess the current status of Oregon's land sector workforce?
    b. How would you assess regional wage estimates by land sector occupation and industry?
    c. How would you assess local, regional, and statewide labor demand forecasts while highlighting equity gaps?

6. How would you assess Oregon's workforce development system and its collective capacity to recruit, prepare, place, and/or retrain, retain, and advance workers for jobs created by activities associated with the Proposal (jobs associated with greenhouse gas emission reductions and carbon sequestration on natural and working lands)? What specific elements would you assess relative to training and technical assistance?

7. How would you project potential future workforce needs on natural and working lands, including future market size and workforce growth? How would you assess Oregon's potential and challenges to creating, retaining, expanding, attracting, supporting, and sustaining land sector sufficiency-wage jobs?

8. How would you assess Oregon's workforce and labor market dynamics relative to achieving the Proposal and land sector goals?

2. Quality Jobs Framework

A Quality Jobs Framework should include an implementation roadmap of short- and long-term strategies to bridge workforce development and training gaps and achieve Proposal goals for Oregon's five land sectors. What key elements do you believe should be foundational to such a framework?

3. Estimated Cost Sheet

ODOE seeks to understand what the costs would be to conduct a *Workforce Development and Training Needs Assessment and Gap Analysis of Natural and Working Lands in Oregon* to ensure adequate resources are available to conduct a formal solicitation. Please provide a cost sheet that provides budget estimates for what you consider to be the core elements of this project needs assessment and gap analysis.

4. Additional Comments

1.6 Please share any additional comments regarding your organization's potential to conduct a workforce development and training needs assessment and gap analysis of natural and working land sectors in Oregon.

All inquiries must be sent electronically to Odoe.contracts@energy.oregon.gov by the deadline published in the section 6.4. Reference the RFI name and number.

1.7 Schedule

The following are key dates specific to this RFI:

RFI Issued	
Questions for clarifications	
Closing	

1.8 Responder Participation

This document shall not be construed as a request or authorization to perform work at the expense of ODOE. Any work performed by a Respondent to respond to this RFI will be at the Respondent's own discretion and expense. All costs associated with Responder's preparation and submission of this RFI are the sole responsibility of the Responder and shall not be borne by ODOE or the State of Oregon.

This RFI may or may not result in an RFQ or RFP. Responses provided to this RFI will be used for general information purposes and will not be considered binding on any party. Responses provided to this RFI will also not have any impact on any RFQ or RFP selection process.

Submission of a response to the RFI does not constitute an agreement between the State and the Respondent, nor does it secure or imply that Respondent will be selected or given any preferential access or availability to future funding opportunities that may arise as a result of this RFI.

Submission of a response constitutes acknowledgement that the Respondent has read and agrees to be bound by such terms.

PUBLIC RECORDS NOTICE & TRADE SECRETS

This RFI and one copy of each original response received to it shall be kept by ODOE and made a part of a file or record that may be open to public inspection. If an RFI response contains any information that is considered a trade secret or is otherwise exempt from disclosure under the Oregon Public Records Law (ORS 192.410 through 192.505), if applicable, the Proposer shall complete and submit the *Disclosure Exemption Affidavit* (Attachment A) and a fully redacted version of its response, clearly identified as the redacted version.

If applicable, the Oregon Public Records Law exempts from disclosure only bona fide trade secrets, and some exemptions from disclosure apply only "unless the public interest requires disclosure in the particular instance." Therefore, non-disclosure of documents or any portion of a document submitted as part of a response to this RFI may depend upon official or judicial determinations made pursuant to the public records laws and requirements. If applicable, ODOE may give Proposer notice of any required disclosure and cooperate with Proposer, at Proposer's expense, in seeking reasonable protective arrangements. However, ODOE shall not be required to act in a manner which would result in any sanctions or other penalties.

Proposers are cautioned that cost information generally is not considered a trade secret under Oregon Public Records Law (ORS 192.311 through 192.478) and identifying the submission, in whole, as exempt from disclosure is not acceptable.

Appendix H. NWL GHG Inventory Definitions

Introduction

Note: **Red text** includes recommended additions by Advisory Committee; **Blue text** includes recommended additions by Technical Teams. **Black text** are definitions from California GHG inventory glossary – with some modifications. Other sources of definitions may be found here.[322]

Definitions

Activity Data
Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, land areas, management systems, lime and fertilizer use, and waste arisings are examples of activity data. (IPCC)

Adaptation
The process of modifying and adjusting to a new or changing environment. (OWEB)

Additionality
Additionality represents the greenhouse gas (GHG) removals or reductions that occur in addition to what would otherwise occur in a business-as-usual (BAU) scenario. Additionality can mean adding a new practice that would not have occurred normally but may also mean discontinuing/excluding practices already implemented on the property.

Afforestation
Planting of new forests on lands that historically have not contained forests. (IPCC2)

Air Pollutant
Any man-made and/or natural substance occurring in the atmosphere that are likely to directly result in adverse human health outcomes, or to the degradation of natural ecosystems. (CARB)

Anthropogenic
The term "anthropogenic", in the context of greenhouse gas inventories, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities. (USEPA2)

Atmosphere
The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active

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[322] Glossary — IPCC; Glossary of Climate Change Terms | Climate Change | US EPA; Glossary | National Institute of Food and Agriculture (usda.gov)

greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapor, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols. (IPCC2)

Acceptable Uncertainty

A determined interval around a measured value such that any repetition of the measurement will produce a new result that lies within this interval.

Baseline Scenario

A baseline is a measurement, calculation, or time used as a basis for comparison to current conditions. Baseline estimates are needed to determine the effectiveness of emission reduction programs (also called mitigation strategies). (See base year definition below.)

Base Year

The starting year for the inventory. Targets for reducing GHG emissions are often defined in relation to the base year.

Biomass

Either (1) the total mass of living organisms in a given area or of a given species usually expressed as dry weight; or (2) Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material. (IPCC1)

Blue Carbon

Carbon stored in coastal and marine ecosystems including estuarine wetlands, such as scrub shrub and forested tidal wetlands, tidal marshes, submerged aquatic vegetation (eelgrass, kelp) and tidal mudflats (TNC).

Carbon Cycle

All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of natural carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). In addition, a fully closed-loop cycle included a fifth reservoir of natural carbon sequestered in biomass and stored in the built environment or landfilled. The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere. (NASA)

Carbon Dioxide (CO_2)

A naturally occurring gas the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1. (IPCC2)

Carbon Dioxide Equivalent (CO_2e)
A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

Carbon Equivalent (CE)
A metric measure used to compare the emissions of the different greenhouse gases based upon their global warming potential. Carbon equivalents can be calculated from to carbon dioxide equivalents by multiplying the carbon dioxide equivalents by 12/44 (the ratio of the molecular weight of carbon to that of carbon dioxide). The use of carbon equivalent is declining in GHG inventories.

Carbon Pool
A component of the climate system that has the capacity to store, accumulate, or release carbon.

Carbon Sequestration, Capture, and Storage
Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (USGS). Carbon capture is the process of trapping carbon dioxide produced by burning fossil fuels or other chemical or biological processes. Carbon storage is the storage of carbon in plants, soils, geological formations, and the ocean.

Biological Carbon Sequestration: The removal of carbon from the atmosphere by plants and microorganisms and storage of carbon dioxide in vegetation such as grasslands or forests, as well as in soils and oceans.

Terrestrial Carbon Sequestration
The process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The term "sinks" is also used to refer to forests, croplands, and grazing lands, and their ability to sequester carbon. Agriculture and forestry activities can also release CO_2 to the atmosphere. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period. (USEPA3)

Soil Carbon Sequestration The storage of atmospheric carbon dioxide in soil pools.

Geological Carbon Capture: The removal of carbon dioxide from the atmosphere and injected into porous rocks for long-term storage.

Technological Carbon Capture: The removal of carbon dioxide from the atmosphere using other innovative technologies.

Carbon Stock

Total absolute mass of carbon in a sample of known volume. Typically reported as volume per unit area.

Climate smart[323]

The consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities.[324] It entails anticipating and actively managing for uncertain yet plausible future climate conditions. The challenge is to manage for acceptable outcomes, with uncertainty clearly in mind, AND/OR the intentional consideration of climate change, and application of strategies that improve resilience, increase carbon sequestration, and/or reduce greenhouse gas emissions or otherwise confer a net climate benefit.[325]

Climate-smart agriculture and forestry (CSAF) practices[326]**:**

Activities that sequester (store) carbon, reduce greenhouse gas emissions, increase the net climate benefits of closed-loop carbon systems improve on-farm energy efficiency, and/or improve agricultural and forest management to increase climate adaptation, resilience, and health AND/OR refers to agriculture that sustainably increases productivity, enhances resilience, reduces/removes greenhouse gasses where possible, and enhances achievement of national food security and development goals.[327]

Climate Mitigation

A human intervention to reduce or avoid emissions or enhance greenhouse gas sequestration and storage.[328]

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[323] Sydoriak, C. 2022 Adapting to Climate Change: An Introduction to the Climate-Smart Conservation Approach. https://socan.eco/wp-content/uploads/2021/08/20220528_Intro-to-climate-smart-adaptation.pdf.

[324] Glick, P., B.A. Stein, and K.R. Hall. 2021. Toward a Shared Understanding of Climate-Smart. https://www.nwf.org/ClimateSmartRestoration.
Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.) (2014). Climate-Smart Conservation: Putting Adaptation Principles into Practice. https://www.nwf.org/ClimateSmartGuide.

[325] OWEB's climate resolution

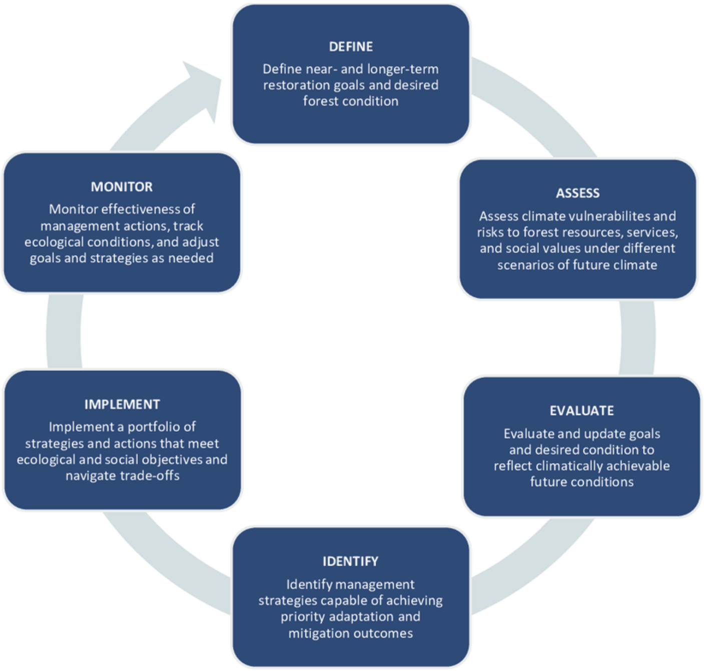
[326] Examples of practices from USDA NRCS: Full list of practices acknowledged by USDA as having GHG reduction benefit: Climate-Smart Agriculture and Forestry (CSAF) Mitigation Activities List [1] FY2023 (usda.gov), Landing page shows the following categories of practices: NRCS Climate-Smart Mitigation Activities | Natural Resources Conservation Service (usda.gov); Climate-smart agriculture: United Nations: Climate-Smart Agriculture | Food and Agriculture Organization of the United Nations (fao.org), World Bank: Climate-Smart Agriculture (worldbank.org), California: CDFA - Office of Environmental Farming & Innovation (OEFI) (ca.gov) CDFA's Climate Smart Agriculture (CSA) programs include the Healthy Soils Program (HSP), the State Water Efficiency and Enhancement Program (SWEEP) and the Alternative Manure Management Program (AMMP) and Dairy Digester Research and Development Program (DDRDP)

[327] Source: https://usnature4climate.org/term-categories/agricultural/

[328] Ibid.

Climate resilience
The capability to anticipate, prepare for, respond to and recover from significant climate-related threats with minimum damage to social well-being, the economy and the environment.[329]

Climate-smart planning cycle
An adaptive planning framework that emphasizes the need to clearly define and articulate restoration goals and objectives, to understand how current and future climatic conditions may affect resources and the services they provide, and to re-evaluate and update goals that may be climate-compromised and unachievable under projected future conditions.[330]



Consistency
Consistency means that an inventory should be internally consistent in all its elements over a period of years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. (IPCC)

Cover crop
A plant that is used primarily to slow erosion, improve soil health, enhance water availability, smother weeds, help control pests and diseases, and increase biodiversity.[331]

Deforestation
Those practices or processes that result in the change of forested lands to non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: the burning or decomposition of the wood releases carbon dioxide; and trees that once removed carbon dioxide from the atmosphere in the process of photosynthesis are no longer present and contributing to carbon storage. (UNFCC)

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[329] Legislative concept for Natural and Working Lands Bill Oregon 2023 legislative session.
[330] Glick et al. 2021
[331] https://www.sare.org/resources/cover-crops/

Durability
The expected duration of carbon storage in a carbon pool; can also be expressed as the risk of reversal/loss of carbon storage due to anthropogenic or natural disturbances. Related to *Permanence.*

Emissions
The release of various gases, either from natural or anthropogenic sources, that results in increased atmospheric GHGs (e.g., carbon dioxide [CO_2], methane [CH4], nitrous oxide [N2O]).

Scope one emissions: A company's direct emissions from owned or controlled sources.

Scope two emissions: A company's indirect emissions associated with purchase of power, heat, steam or cooling.

Scope three emissions: A company's indirect emissions that occur in their value chain, including both upstream and downstream emissions.

Emission Factor
A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions. (IPCC)

Emission Inventory
An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year. (CARB)

Emission Rate
The weight of a pollutant emitted per unit of time (e.g., tons / year). (CARB)

Environmental Justice
Equal protection from environmental and health hazards and meaningful public participation in decisions that affect the environment in which people live, work, learn, practice spirituality and play[332].

Environmental Justice Communities
Communities of color, communities experiencing lower incomes, tribal communities, rural communities, communities with limited infrastructure, and other communities traditionally underrepresented in public processes and adversely harmed by environmental and health hazards, including seniors, youth and persons with disabilities.[333]

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[332] https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2021/Enrolled

[333] Ibid.

Estimation
The assessment of the value of an unmeasurable quantity using available data and knowledge within stated computational formulas or mathematical models.

Flux
The rate of flow of any liquid or gas, across a given area; the amount of this crossing a given area in a given time. (IPCC)

Forest Regeneration
The act of renewing tree cover by establishing young trees, naturally or artificially. (CSU)

Global warming potential
The global warming potential of a gas refers to the total contribution to global warming over a defined time frame resulting from the emission of one unit of that gas relative to one unit of the reference gas, carbon dioxide, which is assigned a value of one.

Greenhouse Gas
Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). (UNFCC)

Greenhouse Gas Inventory
Greenhouse Gas Inventory is a process that accounts for all human-caused emissions and removals of greenhouse gases (GHG) associated with a specific entity (e.g., a country, a company). The inventory essentially acts as a climate change balance sheet, tracking the total volume of GHG emitted from sources like fossil fuel consumption and agricultural production alongside the volume of GHG removed by sequestration in plants and soils or through technological means. (WRI/USCA)

Greenhouse Gas Flux
The change in storage of greenhouse gas emissions from one time point to the next.

Inorganic Carbon
Carbon derived from mineral matter (e.g., minerals, rocks, and non-biological sediment processes).

Intercropping
The practice of growing two or more crops in close proximity: in the same row or bed, or in rows or strips that are close enough for biological interaction. Mixed cropping, companion planting, relay cropping, interseeding, overseeding, underseeding, smother cropping, planting polycultures, and using living mulch are all forms of intercropping (SARE).

Land Use and Land Use Change
Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have a radiative forcing and/or other impacts on climate, locally or globally. (IPCC2)

Leakage

Increased emissions outside of project boundaries as a result of project activities that are intended to reduce or remove GHG emissions (e.g., if net carbon sequestration results in lower productivity, expansion of land under agricultural production may result, increasing emissions and representing leakage).

LULUCF/ AFOLU
IPCC-defined sector referring to Agriculture, Forestry, and Other Land Use (IPCC2).

Measurement, Reporting and Verification
A system or protocol for tracking specific methods and outcomes, transparently communicating specific information, and validating that the information is accurate and complete. Often abbreviated as MRV.

Methane (CH_4)
A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 25 times that of carbon dioxide (CO_2). Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, flooded rice fields, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion. The GWP is from the IPCC's Fourth Assessment Report (AR4).

Metric Ton
The tonne (t) or metric ton, sometimes referred to as a metric tonne, is an international unit of mass. A metric ton is equal to a Megagram (Mg), 1000 kilograms, 2204.6 pounds, or 1.1023 short tons.

Million Metric Tons (MMT)
Common measurement used in GHG inventories. It is equal to one Teragram (Tg).

Model
A model is a quantitatively-based abstraction of a real-world situation which may simplify or neglect certain features to better focus on its more important elements. (IPCC)

Natural and Working Lands (NWL)
(a) Lands:

(A) Actively used by an agricultural owner or operator for an agricultural operation, including, but not limited to, active engagement in farming or ranching;
(B) Producing forest products;
(C) Consisting of forests, woodlands, grasslands, sagebrush steppes, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas or the submerged and submersible lands within Oregon's territorial sea and marine habitats associated with those lands;
(D) Used for recreational purposes, including, but not limited to, parks, trails, greenbelts and other similar open space lands; or
(E) Consisting of trees, other vegetation and soils in urban and near-urban areas, including, but not limited to, urban watersheds, street trees, park trees, residential trees and riparian habitats; and

(b) Lands described in paragraph (a) of this subsection that are:

(A) Held in trust by the United States for the benefit of any of the nine federally recognized Indian tribes in this state;
(B) Held in trust by the United States for the benefit of individual members of any of the nine federally recognized Indian tribes in this state;
(C) Within the boundaries of the reservation of any of the nine federally recognized Indian tribes in this state; or
(D) Otherwise owned or controlled by any of the nine federally recognized Indian tribes in this state.[334]

Natural climate solution
An activity that enhances or protects the ability of natural and working lands to sequester and store carbon or reduces greenhouse gas emissions from natural and working lands, while maintaining or increasing climate resilience, human well-being and biodiversity.[335]

Natural Lands Conservation
Avoided loss of natural ecosystem functions from both deliberate and unintended but anticipated conversion and degradation.

Natural Sources
Non-manmade emission sources, including biological and geological sources, wildfires, and windblown dust. (CARB)

Nature-based Solutions
Actions to protect, sustainably use, manage and restore natural or modified ecosystems, which address societal challenges, effectively and adaptively, providing human well-being and biodiversity benefits".[336]

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[334] SB 530 (Natural Climate Solutions Bill) Oregon 2023 legislative session
[335] SB 530 (Natural Climate Solutions Bill) Oregon 2023 legislative session
[336] IUCN Global Standard for Nature-based Solutions™ page 2

Net-Zero
A target of completely negating the amount of greenhouse gases produced by human activity, to be achieved by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere (net0.com).

Nitrogen Fixation
Conversion of atmospheric nitrogen gas into forms useful to plants and other organisms by lightning, bacteria, and blue-green algae; it is part of the nitrogen cycle. (UNFCC)

Nitrogen Oxides (NO_x)
Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced in the emissions of vehicle exhausts and from power stations. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants. (NASA)

Nitrous Oxide (N_2O)
A powerful greenhouse gas with a global warming potential of 298 times that of carbon dioxide (CO_2). Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, manure management, fossil fuel combustion, nitric acid production, and biomass burning. (AR4)

Permanence
In the context of land-based carbon offset projects, permanence is a condition in which carbon emissions that are reduced or removed from the atmosphere remain out of the atmosphere long-term. (Verra)

Carbon Market Permanence: A requirement in many carbon markets that any issued carbon credits in that market represent long-term reductions in emissions or removals that are durable (i.e., that measures are in place to mitigate the risk that the reduction or removal may be reversed).

Ecosystem Permanence: Evaluates to what degree the health of the ecosystem can be self-sustained under human and environmental pressures, including climate change, pollution and natural disasters. Indicators include non-native species (weeds), climate change adaptation, soil sealing, and many others. (Dendra)

Photosynthesis
The process by which plants take carbon dioxide from the air (or bicarbonate in water) to build carbohydrates, releasing oxygen in the process. There are several pathways of photosynthesis with different responses to atmospheric carbon dioxide concentrations. (IPCC2)

Protection – Natural Lands
Vegetative communities that have been protected from development through acquisition or regulatory mechanisms and are managed for conservation purposes.

Radiative Forcing

A change in the balance between incoming solar radiation and outgoing infrared (i.e., thermal) radiation. Without any radiative forcing, solar radiation coming to the Earth would continue to be approximately equal to the infrared radiation emitted from the Earth. The addition of greenhouse gases to the atmosphere traps an increased fraction of the infrared radiation, reradiating it back toward the surface of the Earth and thereby creates a warming influence. (UNFCC)

Reforestation

Planting of forests on lands that have previously contained forests but that have been converted to some other use. (IPCC2)

Regenerative Agriculture

Holistic farming systems that, among other benefits, improve water and air quality, enhance ecosystem biodiversity, produce nutrient-dense food, and store carbon to help mitigate the effects of climate change. These farm systems are designed to work in harmony with nature, while also maintaining and improving economic viability. The top five principles include: minimizing soil disturbance, keeping soil covered, increasing plant diversity, keeping living roots in the soil and integrating animals into the farm.[337]

Resilience

The ability to prepare for, respond to, and recover from disruptions.[338]

Respiration

The process whereby living organisms convert organic matter to carbon dioxide, releasing energy and consuming molecular oxygen. (IPCC2)

Restoration – Natural Lands

The process of returning the land to health using scientific knowledge and recognized techniques to create an ecosystem that supports a diversity of native plants and animals. The goal of natural lands restoration is to return a degraded ecosystem to its historic trajectory. (SER)

Reversal

A loss in carbon that was previously sequestered, due to clearing, weather or management practices. Reversal risk is directly related to permanence.

Short Ton

Common measurement for a ton in the United States. A short ton is equal to 2,000 lbs or 0.907 metric tons. (USEPA1)

Sink

Any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a

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[337] Regenerative Agriculture - Chesapeake Bay Foundation (cbf.org)

[338] OWEB's climate resolution

greenhouse gas or aerosol from the atmosphere in an amount that exceeds the rate of greenhouse gas respiration or release from the process, activity, or mechanism. (IPCC2)

Soil Health
The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.[339]

Source
Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere. (IPCC2)

Sustainable Agriculture
Seeks to sustain farmers, resources and communities by promoting farming practices and methods that are profitable, environmentally sound and good for communities.[340]

Total Carbon
Sum of organic and inorganic carbon (e.g., total soil carbon is the sum of soil organic carbon and soil inorganic carbon).

Tidal wetland restoration
Reestablishing complex structure and natural processes in degraded or converted tidal wetlands including full tidal flooding, sediment delivery and retention, recruitment of plant propagules leading to the establishment of native plant communities, nutrient processing, water quality maintenance, carbon sequestration and other ecosystem services.

Tidal wetlands
Coastal wetlands subject to regular or irregular tidal flooding by saline, brackish or fresh water (e.g., mudflats, seagrass beds, emergent marshes, scrub-shrub tidal wetlands, and forested tidal wetlands).

Tidal wetland conservation
Avoided loss of tidal wetlands (mudflats, eelgrass beds, emergent marshes, scrub-shrub tidal wetlands, and forested tidal wetlands) from both deliberate (e.g., wetland fills) and unintended but anticipated (e.g., sea level rise) conversion and degradation.

Total Organic Gases (TOG)
Gaseous organic compounds, including reactive organic gases and the relatively unreactive organic gases such as methane. (CARB)

Transparency
Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported

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[339] NRCS

[340] SARE

information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information. (IPCC)

Trend

The trend of a quantity measures its change over a time period, with a positive trend value indicating growth in the quantity, and a negative value indicating a decrease. It is defined as the ratio of the change in the quantity over the time period, divided by the initial value of the quantity, and is usually expressed either as a percentage or a fraction. (IPCC)

Verification

The process whereby an accredited third-party verifier examines or reviews a proposed carbon sequestration or storage project, including the methodology and attendant emission reduction or removal calculations, to ensure that the proposed practices are actually occurring at a specified location according to project specifications and that greenhouse gas stocks and fluxes are being properly accounted for.