Methodology to Value Benefits of Agricultural Conservation Practices

July 2024

Prepared for:

Oregon Agricultural Heritage Program

Prepared by

About Highland Economics:

Highland Economics is a small, woman-owned firm specializing in the economics of natural resources and the environment, business planning and feasibility assessment, and the socioeconomic impact of industries, policies, or management actions. We are a team of five economists, based in Oregon and Montana. We work with non-profits, agricultural interests, tribes, water districts, private companies, and local, state, and federal agencies on a wide range of land, air, water, recreation, agriculture, and habitat issues. This study was led by principal and senior economist Barbara Wyse, who has nearly 20 years of experience analyzing the economics of agricultural production and the socioeconomic impacts of proposed actions or regulatory changes. We aim to provide rigorous, even-handed analysis that uses economic insights to transform complex data into clear and actionable information. We often serve as expert witnesses on economic issues, including numerous cases on agricultural economics and demographic analysis for the U.S. Department of Justice.

This analysis was prepared for:

Oregon Agricultural Heritage Program (OAHP)

The Oregon legislature established the OAHP to provide voluntary incentives to farmers and ranchers to support practices that maintain or enhance both agriculture and natural resources. OAHP helps farmers and ranchers protect and maintain or enhance conservation on working land. Oregon Watershed Enhancement Board (OWEB) administers the program. Federal matching funds come from the Natural Resources Conservation Service's Agriculture Conservation Easement Program. OAHP currently funds four grant programs: working land conservation easements and covenants, conservation management plans and activities, succession planning education, and technical assistance for support organizations.

Highland Economics is solely responsible for the contents of this report. We thank the following reviewers who improved the report through their comments:

Dr. David Lewis, Professor, Oregon State University
Louis Landre, State Agricultural Economist, Oregon Natural Resources Conservation Service
Rose Graves, Conservation & Climate Scientist, The Nature Conservancy, Oregon Chapter

1 Table of Contents

1 INTRODUCTION

Agricultural lands have long been recognized in Oregon as providing a host of benefits to the public. Oregon's land use laws and the efforts of numerous organizations around the state have protected working lands for the many values they provide, including provisioning of food and fiber, open space amenities, and fish and wildlife habitat. Agricultural lands also play a large role in the quality and quantity of water in our waterways and have recently been recognized for their important role in sequestering and storing carbon. Given the importance of agricultural lands and practices on a diverse array of ecosystem services, there is a large body of research from scientists in our state and throughout the Nation on environmental effects of agricultural land management and the ecological benefits of specific agricultural conservation practices. To a lesser extent, there is research on the social and economic value of these ecological effects and associated ecosystem services resulting from conservation practices.

PAYMENT FOR ENVIRONMENTAL SERVICES: OAHP PROGRAM GOALS

1. INCENTIVIZE COST-EFFECTIVE AND ENVIRONMENTALLY BENEFICIAL PRACTICES ON OREGON FARMS AND RANCHES BY PAYING FOR ENVIRONMENTAL OUTCOMES.
2. ENCOURAGE PROGRAM PARTICIPATION BY:
   A. MAKING PARTICIPATION AS EASY AS POSSIBLE.
   B. PROVIDING CERTAINTY (IN PAYMENT VALUE AND TERMS) FOR LANDOWNERS.

1.1 PURPOSE

In recognition of the importance of agricultural land management on the level and quality of ecosystem services available for public enjoyment and benefit, the Oregon Agricultural Heritage Program (OAHP) is developing a payment program to compensate farmers and ranchers for environmental outcomes that provide value to the public (i.e., ecosystem services). Building on a feasibility analysis completed in 2019, this report documents a methodology for valuing conservation practices that provide desired environmental outcomes. The methodology is based on the value to the public of ecosystem services provided by each conservation practice.

1.2 TARGET PUBLIC BENEFITS

The purpose of the proposed OAHP payment program is to incentive conservation outcomes with public benefit. The key outcomes providing public benefit that OAHP aims to incentivize with this payment program are:

- Water quality enhancement,
- Aquatic habitat provision,
- Terrestrial habitat provision, and
- Carbon sequestration/reduced emissions.

Water conservation practices and water transactions are not included in the methodology. They are an important project type in other OWEB grant programs, which cover both permanent and short-term water conservation activities. Other OWEB grant programs require that increased irrigation efficiency or other on-farm practices translate to reduced total on-farm water use, increased availability of water for instream flows or other uses, or water quality improvements. Several studies on the effects of increased irrigation efficiency on total farm water use indicate that efficiency improvements can translate into higher crop production per unit of water use (and higher farm income) but the same level of overall agricultural water use (see, for example, (Ward & Pulido-Velazquez, 2008) (Perez-Blanco, Hrast-Essenfelder, & Perry, 2020). As such, farm conservation practices that enhance water irrigation efficiency have benefits but may not provide direct public benefit in terms of enhanced instream flows. The purchase or transfer of water rights, such as those completed by non-profit organizations engaged in water transactions, is expected to be the most certain and permanent way to ensure desired environmental outcomes regarding instream flows.

Several conservation practices reduce air contaminants or odors and can thus improve air quality, which is a public benefit. However, improved air quality was not identified by OAHP or key partners as having as high a priority as improvements to habitat, carbon, and water quality, and was thus not included in the valuation methodology.

1.3 Payment Program Desired Attributes and Outcomes

Interviews with conservation specialists and planners, OAHP Commissioners, and other stakeholders identified a set of desirable attributes and outcomes of a payment for ecosystem services program. Specifically, OAHP and key partners identified the following desired attributes of a payment methodology:

- Easy and inexpensive to implement.
- Transparent and easy to understand.
- Flexible and adaptable to diverse practices and farms.
- Perceived as fair by a broad array of partners.
- Consistent with Natural Resources Conservation Service (NRCS) conservation practice definitions.

Further, OAHP and key partners identified the following payment methodology desired outcomes:

- Provide certainty (in payment value and terms) for landowners.
- Encourage participation by farmers and ranchers by making participation as easy as possible.
- Incentivize cost-effective and environmentally beneficial outcomes, such that significant environmental benefit is delivered per conservation dollar.
- Identify reasonable and conservative payment values commensurate with the benefits to the public of each eligible practice, recognizing that payment for practices is a new approach that OAHP aims to explore and adaptively manage over time.

As noted in the last bullet, the purpose of the payment program is to compensate and provide incentives to agricultural landowners and managers for voluntary practices that provide value (in terms of enhanced ecosystem services) to the *public* at large. The value of *private* benefits to the farmer or rancher of a conservation practice are not included in the valuation methodology.

1.4 Valuation Process & Data Sources

Developing the methodology to value the public value of ecosystem services provided by conservation practices in Oregon required four steps. These four steps, and the data sources and important limitations for each step, are:

1) **Identify agricultural conservation practices that result in habitat, carbon, and water quality improvements**. The primary data source for this step is the NRCS physical effects rating for conservation practices. Interviews with conservation practice professionals in Oregon, including experts at NRCS, regional soil and water conservation districts, and Oregon Department of Agriculture also informed this step.

2) **Quantify the biophysical or environmental effect expected from implementation of each conservation practice in terms of changes in ecosystem services** (e.g., tons of reduced in sediment conveyed to waterbodies or change in carbon dioxide equivalents in the atmosphere). The primary data sources for this step included published scientific literature in peer-reviewed journals, in government publications, and agricultural extension publications. The estimated effects on ecosystem services of a given conservation practice can vary substantially by data source due to a) differences between studies in how ecosystem services are measured (i.e., methodological differences) and b) differences in the level of ecosystem services produced by a practice in any given location due to variation in site-specific conditions and practice implementation/management effects. The estimates of ecosystem service effects by practice presented in this document are intended to reflect average expected ecosystem service effects throughout the State. The actual level of ecosystem service provided at any one site will likely differ from the values estimated in this report.

3) **Quantify the economic value of the expected effects on habitat, carbon, and water quality**. Published economic literature in peer-reviewed journals, government publications, and agricultural extension publications were the primary data sources for this step. This step was also supported by analysis of existing payment for ecosystem service values and methodologies. As with measurement of ecosystem service effects, the economic value of changes in ecosystem services varies by study, due to a) methodological differences in studies (how value is measured) and b) differences between sites and locations in the value of a given level of ecosystem service provision.

4) **Value benefits of the 'final' ecosystem services directly enjoyed by people that result from enhanced habitat, water quality, and carbon sequestration.** Biophysical or environmental changes from conservation practices are most easily measured in terms of sediment, nitrogen, carbon, and such measurements. However, what provides

benefit to people and economic value is the effect of these measures on 'final' ecosystem services people directly care about such as fish populations or drinking water purity in downstream areas. Since there are not data available that directly link and quantify the effects of conservation practices on these 'final services' (e.g., there are not data that indicate how many more salmon are produced for every acre of additional riparian habitat), for each type of benefit the methodology estimates value by extrapolating data from available studies together with reasonable assumptions and professional judgement. In this process, one pitfall of not being able to directly quantify and value final ecosystem services such as fish populations is that double counting can occur if the methodology values several intermediate services based on the same final service: for example, if both water quality improvements and aquatic habitat improvements are valued based on the same expected fish population effects.[1] To address this, the methodology aims to separate the types of benefits and associated final ecosystem services that are valued due to changes in habitat versus water quality versus carbon. The methodology also aims to separate the incremental effects of different intermediate services on final services such as fish populations (i.e., the effects of nutrients versus temperature or sediment). Finally, to avoid double counting or overestimating, the methodology also uses conservative assumptions and estimates. This last step in the valuation process enables the benefit values derived for water quality, habitat, and carbon to be added together.

Unless otherwise noted, all dollar values presented in this report are in 2023 dollars. Values from earlier years were adjusted for inflation using the Gross Domestic Product Implicit Price Deflator (GDPIPD).

1.5 Practice-Based vs. Outcome-Based Valuation

While grounded in expected outcomes, the proposed methodology is a practice-based valuation system. A purely outcome-based valuation system would require measurement of environmental outcomes, and payments would only be made to farms and ranches that achieve a measurable change in environmental outcomes. In contrast, the proposed practice-based valuation system provides a uniform value for a given practice.[2]

The primary goal of the OAHP program is to pay for environmentally beneficial outcomes, with payments commensurate to the benefit of environmental outcomes. This seems to indicate that the methodology should be outcome-based, where payments are only made once environmentally beneficial outcomes are achieved and quantified. The outcome-based approach,

[1] Double counting would not occur in there were data available for the independent effects of sediment vs nutrients vs riparian shading on fish populations.

[2] The exception is for some practices where payments are higher if the practice is implemented in a riparian zone. For example, if trees and shrubs are established outside the riparian zone, the payment is lower than if they are planted in a riparian zone. Table 2-3 summarizes payments by practice type and shows that payments for practices in riparian zones may be eligible for a higher per acre payment due to higher expected benefits.

however, has multiple challenges and drawbacks that are counter to the desired features of the payment methodology identified in Section 1.3. Namely, a purely outcome-based approach is expected to result in uncertainty for landowners (as payments are not guaranteed), be less easy to understand, and be more costly and resource-intensive to implement.

The practice-based methodology was also chosen as there are practical challenges to base payments on measured outcomes. For many types of environmental benefits, the desired environmental outcomes of a given conservation practice may not accrue until numerous years after the practice is implemented. For example, riparian forest buffers may require years to reach a certain level of maturity before water quality benefits may be experienced. As another example, it can take years (e.g., 6 to 10 years) for conservation practices that enhance soil carbon to have a measurable effect (Smith, 2004), and there can remain significant uncertainty in the ability to measure year-to-year change, which would be necessary in an outcome-based annual payment program. Similarly, for water quality, as noted by the Oregon Department of Agriculture (ODA) regarding measurements of water quality: “Many factors make it difficult to assess a specific land use’s nonpoint source contribution to water quality impairment, or to document improvements in water quality” (Oregon Department of Agriculture, 2017).[3]

It is possible for a payment scheme to be based on modeled outcomes, rather than field measurement of outcomes. There are several NRCS-sponsored tools (Nutrient Tracking Tool and Comet-FARM) available to estimate the environmental outcomes in terms of changes in water quality or carbon of a conservation practice. For a given conservation practice the estimates of environmental benefit in these tools are typically based on a wide array of factors including the specific crops grown (historically and currently), the soil type of the parcel, the past management practices on the parcel (such as tillage and nutrient use), irrigation application, slope, and the precipitation patterns. The quantified environmental effects in these tools are estimates of environmental change based on these site-specific variables, many of which are management variables that may vary from year to year. The modeled outcomes can vary significantly based on these management variables. A payment system based on modeled outcomes would thus require historic and current management data to run the model to estimate outcomes, and modeled outcomes could vary from year to year. Thus, relying on outputs from these tools may lessen the certainty and simplicity of a payment system. Additionally, relying on modeled output may lessen the perceived fairness of the payment system as difference in modeled outcome does not necessarily mean difference in delivered outcome for a given conservation practice.

[3] “Confounding factors include: • Natural variability. • Multiple human and natural sources of pollutants • Localized increases and decreases in pollutant levels (or changes that occur over short periods of time) that are not detected by existing monitoring. • Legacy effects, such as stream channelization or flow modification, that may prevent water quality from achieving standards. • Upstream conditions that prevent downstream reaches from achieving water quality goals.”

2 Overview of Valuation Methodology

The desired attributes and outcomes outlined in Section 1.3 drove the methodology development process and shaped the key features of the methodology. This section provides an overview of these key features, including valuation structure, types of practices valued, required level of practice effectiveness, and the expected role of the conservation management plan review committee in prioritizing and selecting projects for funding. There are tradeoffs between valuation complexity and certainty in delivering benefits versus program ease and cost of program administration.

KEY METHODOLOGY ELEMENTS

1. VALUATION STRUCTURE
2. TYPES OF PRACTICES VALUED
3. REQUIRED EFFECTIVENESS OF VALUED PRACTICES
4. PRIORITIZATION OF PRACTICE FUNDING

2.1 Valuation Structure

To meet the desired methodology features that payments be easy to understand, provide certainty and ease for the landowner, be easy and inexpensive to implement by OAHP, and be perceived as fair by landowners, the proposed methodology provides a guaranteed payment for each eligible practice.

To maximize the value of environmental benefits provided per dollar invested in conservation practices and ensure payments are commensurate with benefits, the valuation methodology has the following structure:

- **Valuation is based on expected environmental outcomes,** in terms of changes to carbon, water quality, and habitat.
- **Expected environmental outcomes are quantified** using the following metrics:
  - Carbon: metric tons of carbon dioxide equivalent,
  - Water quality: tons of sediment and kilograms of nitrogen,
  - Terrestrial habitat: acres of habitat, and
  - Aquatic habitat: acres of riparian habitat (that benefits aquatic habitats).
- **Environmental outcomes for each practice type are estimated based on comprehensive review of the scientific literature**; due to expected variation in outcomes (between sites and through time) the methodology applies a conservative estimate of average benefits per acre. Direct measurement of environmental outcomes is not required in the methodology, so a conservative estimate of average benefits is used.[4] Environmental outcomes are estimated on a per acre basis, and value is also estimated on a per acre basis.

---

[4] Not requiring measurement and monitoring reduces certainty in the outcomes delivered but is expected to result in significant cost savings. For carbon payment programs, in some cases the cost of precisely measuring the change in carbon stocks may exceed the value of the increase in carbon stock (World Agrofrestry Centre, n.d.)4 As an example of a monitoring protocol, the CarbonNow market for

- **Only the most effective practices are valued.** The valuation methodology uses strict eligibility criteria such that the only practices with high reliability and high effectiveness in providing benefits are valued.
- **Practices with multiple types of benefits have higher value**, based on the expected value of each type of benefit provided. By incentivizing practices with multiple benefits, the likelihood of the program delivering environmental benefits commensurate with payments is higher. With multiple types of benefits provided, even if one type of benefit underperforms expectations, another type of benefit may outperform expectations and still deliver benefits commensurate with payments.
- **Values for each type of benefit are intended to be conservative.** The proposed values err on the conservative (lower value) side, while still aiming to provide a healthy incentive for practice adoption. Environmental outcomes can vary significantly between sites, and the economic and social value of even the same environmental outcome can also vary significantly between sites. Recognizing this variation, the valuation methodology aims to use reasonable but conservative estimates of both environmental benefit delivered and economic valuation of the expected environmental benefit, considering the full range of potential environmental outcomes and associated economic value.
- **The OAHP Conservation Management Plan (CMP) advisory committee is expected to review each farm or ranch funding application and only plans and associated practices that are approved by the committee will receive funding.** While the valuation methodology proposed a value per acre for each eligible conservation practice, site-specific factors and the role of the proposed practices in addressing known conservation issues and challenges will be considered in the CMP review process. This review process will enhance cost effectiveness and benefit maximization as the review committee will have the discretion to prioritize funding to practices on farms and ranches that are expected to provide the most environmental benefit per conservation dollar.

All values presented in this report are in 2023 dollars, unless noted otherwise.[5]

---

soil organic carbon requires three to five years of historical data and annual soil organic carbon and bulk density tests at 12 inch depth along with carbon modelling in its outcome-based program (LOCUS Agriculture, 2023). Costs can also be high for water quality monitoring. An analysis of transaction costs for eight projects in the Medford water quality trading program to reduce stream temperature estimated that average transaction costs amounted to 85% of total project costs (Guillozet, 2016). By minimizing the measurement and monitoring costs, the proposed payment methodology can dedicate funding to achieve environmental benefits and increase total acreage covered by the program.4 On balance, with the safeguards and limits in place to enhance cost effectiveness of the program, the hope is that the proposed payment methodology will be the most cost-effective methodology for delivering benefits for a given dollar investment.

[5] Values from prior years have been converted to 2023 dollars using the Gross Domestic Product Implicit Price Deflator (GDPIPD).

2.2 Types of Eligible Practices

In consultation with the OAHP, the scope of the valuation methodology covers the following types of conservation practices. These are the types of practices that are expected to be eligible for payments (and for which this valuation methodology has estimated a public value per acre of implementation):

- Rangeland and agricultural lands practices, but not forestland practices or in-stream restoration practices.
- Practices that have beneficial impacts on water quality, aquatic or terrestrial habitat, and/or carbon sequestration/reduced emissions.
- Non-structural practices (i.e., practices related to facilities/ infrastructure or equipment are not included).

Partners interviewed at the outset of the analysis differed on whether equipment or facilities/infrastructure should be eligible. In keeping with a focus on incentivizing outcomes and maximizing environmental benefits for a given conservation dollar, funding of equipment is not included, as the acquisition of the equipment does not guarantee environmental outcomes (rather the use of the equipment in a conservation practice provides the environmental outcome). Therefore, the methodology focuses on the value of practices.[6] Further, practices related to facilities/infrastructure are not included as the up-front costs of these practices is generally quite high and OAHP determined that it was preferable to have more numerous, lower-cost projects than deplete program funds on a limited number of infrastructure projects.

2.3 Required Effectiveness of Eligible Practices

As noted in Section 1.3, numerous conservation professionals and partners interviewed at the outset of the methodology development process indicated that it was important for the methodology to be consistent with NRCS practice definitions. NRCS has defined 167 conservation practices. For each of these conservation practices, NRCS has also developed a "physical effects" rating for the expected benefit of the practice in 45 categories of environmental outcomes. The types of outcomes evaluated are related to soil health, water conservation, habitat, water quality, air quality, livestock health, and erosion. NRCS rates practices on a scale from -4 (moderate to substantial worsening) to 5 (substantial improvement), as shown in Table 2-1.

[6] For instance, environmental outcomes of a no till drill would depend on the acreage that converts to no till conservation practice. Therefore, instead of paying for the drill, the methodology pays for acreage that is converted to no till.

Table 2-1: NRCS Physical Effects Rating Categories

NRCS Physical Effects Rating	Description of Physical Effect Level
5	Substantial Improvement
4	Moderate to Substantial Improvement
3	Moderate Improvement
2	Slight to Moderate Improvement
1	Slight Improvement
0	No Effect
-1	Slight Worsening
- 2	Slight to Moderate Worsening
- 3	Moderate Worsening
- 4	Moderate to Substantial Worsening

In the methodology, only practices with at least a moderate to substantial expected average benefit rating (i.e., a 4 or 5 rating) per the 2023 NRCS Physical Effects rating matrix are valued for water quality, aquatic habitat, or terrestrial habitat improvements. For carbon practices, the methodology establishes a value for all practices with a rating of moderate improvement or higher (3, 4, or 5 rating). Carbon has a different requirement for eligibility to increase the consistency between the proposed methodology and the practices eligible for payment under the Oregon Global Action Commission's recommended practices to reduce greenhouse gas emissions and sequester carbon in Oregon's natural and working lands sectors.

Of the 45 environmental outcomes rated in the NRCS Physical Effects matrix, the methodology focuses on the ratings for eight outcomes that careful review indicated are the most pertinent to the environmental benefits (water quality, terrestrial habitat, aquatic habitat, and carbon/greenhouse gases) that OAHP aims to incentivize through the program. Table 2-2 summarizes the NRCS benefit categories that are used to identify which practices qualify for payment for providing carbon, water quality, or habitat benefits. If there are two qualifying categories, then the highest rating in each of the two categories is used.

The last row of Table 2-2 also shows the two NRCS physical effects categories that are used to determine whether a practice provides moderate to substantial soil health benefits. Payments are proposed for practices that enhance soil health only as they provide benefit to the public through improved water quality, carbon storage, and habitat. However, as soil health enhancement is a key policy objective to enhance the productivity and resiliency of Oregon's agricultural lands, information regarding the effects of practices on soil health is included.

Table 2-2: NRCS Physical Effects Criteria Used for Each Environmental Benefit

Environmental Benefit Type	NRCS Physical Effect Qualifying Category 1	NRCS Physical Effect Qualifying Category 2
Carbon	Emissions of Greenhouse Gases – GHG's[1]	
Water Quality – Sediment	Sediment Transported to Surface Water	
Water Quality – Nutrients	Nutrients Transported to Surface Water	Nutrients Transported to Groundwater
Aquatic Habitat	Elevated Water Temperature	Aquatic Habitat for Fish and other Organisms
Terrestrial Habitat	Terrestrial Habitat for Wildlife and Invertebrates	
Soil Health[2]	Organic Matter Depletion	Soil Organism Habitat Loss or Degradation

1/This rating category also includes sequestration of greenhouse gases, such as through tree or shrub establishment or soil sequestration.
2/Payments are proposed for practices that enhance soil health only as they pertain to water quality, carbon, and habitat, which are captured in the other benefit categories. However, as soil health enhancement is a key policy objective to enhance the productivity and resiliency of Oregon's agricultural lands, information regarding the effects of practices on soil health is included.

2.4 Annual Value By Benefit Type

Table 2-3 summarizes the estimated annual per acre value for each type of environmental benefit. The number of years that the practice will receive payment will be determined by OAHP and the CMP advisory committee.

Practices are only valued for a benefit type if they qualify as providing at least a "moderate to substantial" benefit (except for carbon, which qualifies with a moderate or better rating), as described in Section 2.3. As shown in Table 2-3, value of a practice differs based on whether a practice is an edge-of-field practice or if it is an in-field practice. For edge-of-field practices, values also differ based on the type of habitat provided in the edge of field area, whether it is trees/shrubs, wetlands, or grass/shrub habitat.

As highlighted in the introduction to this report, there is uncertainty in quantifying the ecosystem services provided by agricultural conservation practices and in estimating the value of the ecosystem services. Our knowledge and understanding of the effects and value of practices continues to evolve, and more research is being conducted in Oregon and elsewhere to further our understanding. We recognize that numerous factors will affect the value of any given practice in any given location. Rather than predicting the exact value that can be expected from a conservation practice in any one location, the values in Table 2-3 are intended to be defensible and conservative values that are representative of expected average outcomes from conservation practices across the State of Oregon.

Table 2-3: Per Acre Per Year Value for Eligible Agricultural Conservation Practices

<table>
<tr><th>Type of Eligible Practice</th><th>Water Quality (Sediment)[1]</th><th>Water Quality (Nutrients)[1]</th><th>Carbon</th><th>Aquatic (Fish) Habitat</th><th>Terrestrial Habitat</th><th>Maximum Value (if all services provided)</th></tr>
<tr><td>In-Field Practice</td><td>$6</td><td>$9</td><td>$15</td><td></td><td>$100</td><td>$130</td></tr>
<tr><td colspan="7">Edge-of-Field Practice</td></tr>
<tr><td>Trees/Shrubs</td><td rowspan="3">$90</td><td rowspan="3">$135</td><td>$30</td><td>$150 (if riparian)</td><td>$100</td><td>$505 (if riparian), $355 (if not riparian)</td></tr>
<tr><td>Wetland</td><td>$15</td><td></td><td>$150</td><td>$390</td></tr>
<tr><td>Grass/shrub habitat</td><td>$15</td><td></td><td>$100</td><td>$340</td></tr>
</table>

Note: For edge of field practices, multiple practices do not increase the maximum value per acre (e.g., for an acre of riparian forest restoration, the value per acre would be $505, not $505 for riparian forest buffer plus $505 for tree/shrub establishment.) Acreage for edge of field is estimated as the acreage of land exclusively covered by the conservation practice and exclusively dedicated to the conservation practice (such as the area planted in trees and shrubs).
1/To avoid overestimating the value of benefits related to fish abundance (which are captured under aquatic habitat but are also related to sediment and nutrients), water quality benefits from reduced sediment and nutrients are focused on benefits related to on aesthetics, drinking water quality, avoided water treatment costs, and non-fish related recreation benefits of water quality. Conservative values are also used to avoid overestimating.

For water quality, an edge-of-field practice can trap nutrients and sediments from all lands draining through the edge-of-field area. As such, the value is higher for an edge-of-field practice than an in-field practice. The literature indicates that a catchment area ratio of 20:1 (20 acres draining through each acre of the edge-of-field area) is a reasonable estimate. To be conservative, water quality benefits of edge-of-field practices are estimated at 15 times the value of in-field practices (see Appendix B for a more in-depth discussion). So, for an in-field practice with physical effects ratings that qualify it only as providing water quality-sediment benefits, the value would be $6 per acre per year. For an edge-of-field practice with physical effects rating that qualifies the practice as providing only water quality-sediment benefits, the value would be $90 per acre per year (20 times higher than the in-field practice). For an in-field practice that provides sediment and nutrient water quality benefits, the water quality-related value would be $15 per acre, while for an edge-of-field practice that provides sediment and nutrient water quality benefits, the water quality-related value would be $225 per acre (15 times higher).

If that same edge of field practice includes planting trees/shrubs and qualifies as providing a carbon benefit, it would receive an additional $30 per acre value, and if it also qualifies as providing terrestrial habitat it would also receive a $100 per acre value. Finally, if this edge-of-field practice is in the riparian zone (such as a riparian forest buffer) and qualifies as a practice benefiting aquatic habitat, it would also qualify for an extra $150 per acre. Adding together the values for this edge of field practice providing all types of benefits, the water quality ($225), carbon ($30), aquatic habitat ($150), and terrestrial habitat ($100) equals $505 per acre per year. Riparian habitat areas can qualify as enhancing both aquatic habitat (through shade/temperature regulation of waterways and other effects) and terrestrial habitat.

For edge of field practices, only one practice will be valued per acre (such that stacking associated practices such as riparian buffer and tree/shrub establishment is not allowed). As such, the maximum value per acre per year would be $505.

Appendix B through Appendix E provide detailed information on the research and economic analysis supporting all values in Table 2-3. Tables 2-4 and 2-5 provide more detail on the value per unit of environmental improvement and estimated effectiveness of each qualifying carbon and water quality practice, respectively. For habitat, no additional detail is provided as the methodology provides a flat value per acre, with no differentiation in effectiveness.

Table 2-4: Summary of Estimated Average Carbon Quantification and Value Per Practice Type

Practice Type/Vegetation Type	Tons C / Hectare / Year	Tons CO_2e / Acre / Year	Value per Metric Ton of CO_2e[7]	Value Per Acre/Year	Eligible Practices
Soil Sequestration Practices (In-Field Practices/Grassland)	0.35	0.5	$30	$15	Conservation Cover, Pasture/Hay Planting, Soil Carbon Amendment, Range Planting, No Till Management, Reduced Till Management, Nutrient Management
Habitat-Based Practices					
Grassland	0.35	0.5	$30	$15	Wildlife Habitat Planting
Tree/Shrub	0.7	1.0	$30	$30	Tree/Shrub Establishment, Windbreak/Shelterbelt, Riparian Forest Buffer, Forest Stand Improvement
Wetland	0.35	0.5	$30	$15	Wetland Creation, Wetland Restoration

[7] The economic value of reduced carbon dioxide is based on the reduction in damages across the globe associated with global warming and is known as the social cost of carbon (SCC). The SCC has recently been estimated at approximately $220 (in 2023 dollars) by the US Environmental Protection Agency. To value carbon storage in agricultural conservation practices we do not use the SCC. Rather, we use a lower value based on market values of carbon (in markets where the quantity of additional carbon storage is measured and verified and deemed to be long-term). There is uncertainty in carbon quantification, permanence, and additionality from agricultural conservation practices participating in the OHAP program. As the OAHP program is not expected to include measurement of carbon, there is uncertainty in the additionality and the permanence of increased carbon stored due to agricultural conservation practices. Due to this uncertainty, the proposed value for carbon is not the SCC value.

Table 2-5: Estimated Effectiveness and Value for Water Quality Conservation Practices

Water Pollutant	Unit	Estimated Reduced Pollutant Loading Per Acre of Practice		Value Per Unit	Eligible Practices
		In-Field Practices	Edge-of-Field Practices		
Sediment	Ton /Acre	1	15	$6	Riparian Forest Buffer, No Till, Critical Area Planting, Riparian Herbaceous Cover, Grazing Land Mechanical Treatment, Grassed Waterway, Forest Farming, Filter Strip, Vegetative Barrier, Constructed Wetland
	Value / Acre	$6	$90		
Nitrogen	Kilogram / Acre	0.75	11.25	$12	Riparian Forest Buffer, Nutrient Management, Conservation Cover, Riparian Herbaceous Cover, Vegetated Treatment Area, Filter Strip, Constructed Wetland, Saturated Buffer
	Value / Acre	$9	$135		
Value / Acre, Sediment & Nutrient Qualifying Practices		$15	$225	N/A	

3 Eligible Practices

As shown in Table 3-1 below, there are 14 practices for which values have been estimated for carbon. Practices with carbon value are those that have an NRCS physical effects rating for greenhouse gas emissions reduction of 3, 4, or 5 (practices meeting this rating are highlighted in green in the table for the carbon column). All but four of these practices have other benefits related to water quality or habitat, which increase the total practice value. Table 3-1 also identifies an additional 15 practices that do not qualify as a carbon practice but that are expected to be eligible as a water quality and/or habitat practice. Practices eligible for water-quality or habitat-based payments must have an NRCS physical effects rating of a 4 or 5; these practices are highlighted in green in the table for the water quality and habitat columns. Table 3-2 provides a crosswalk of the OAHP carbon eligible practices, and the Oregon Climate Action Commission's (OCAC) recommended practices to reduce greenhouse gas emissions and sequester carbon in Oregon's natural and working lands sectors.

There are several practices that provide at least moderate terrestrial habitat improvements according to the NRCS physical effects rating but are not valued at this initial valuation stage. These include access control, prescribed burning, pest management, and herbaceous weed control. The estimated value for terrestrial habitat is based on providing additional quantity of habitat, and all these practices are related to quality of habitat. To be conservative, these in-field practices were consequently not included. The valuation methodology could be applied to these or other practices that OAHP desires to be eligible in the future. Feed management is another practice that is not included. This practice can be effective at reducing greenhouse gas emissions; it was not included in the carbon valuation as it is not conducive to a per acre payment methodology. In the future, a per cow carbon value could be developed.

Table 3-1: NRCS Practices Qualifying for Payment by Benefit Category (Based on NRCS Physical Effects Rating)

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat for Fish & Invertebrates)	Terrestrial Habitat (Habitat for Wildlife and Invertebrates)	Soil Health (Max of Organic Matter, Soil Organism Habitat)
Carbon Eligible Practices							
Conservation Cover	327	Qualifying	Qualifying	Qualifying			Qualifying
Pasture and Hay Planting	512	Qualifying				Qualifying	Qualifying
Tree/Shrub Establishment	612	Qualifying			Qualifying	Qualifying	Qualifying
Windbreak/Shelterbelt Establishment and Renovation	380	Qualifying			Qualifying		Qualifying
Nutrient Management	590	Qualifying		Qualifying			
Residue and Tillage Management, No Till	329	Qualifying	Qualifying				Qualifying
Riparian Forest Buffer	391	Qualifying	Qualifying	Qualifying	Qualifying	Qualifying	Qualifying
Wildlife Habitat Planting	420	Qualifying			Qualifying	Qualifying	
Soil Carbon Amendment	336	Qualifying					Qualifying
Forest Stand Improvement	666	Qualifying					
Range Planting	550	Qualifying					Qualifying
Residue and Tillage Management, Reduced Till	345	Qualifying					
Wetland Creation	658	Qualifying					
Wetland Restoration	657	Qualifying					

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat for Fish & Invertebrates)	Terrestrial Habitat (Habitat for Wildlife and Invertebrates)	Soil Health (Max of Organic Matter, Soil Organism Habitat)
Water Quality or Habitat Eligible Practices							
Critical Area Planting	342		Qualifying				Qualifying
Grazing Land Mechanical Treatment	548		Qualifying				
Riparian Herbaceous Cover	390		Qualifying	Qualifying			Qualifying
Upland Wildlife Habitat Management	645					Qualifying	
Constructed Wetland	656		Qualifying	Qualifying			
Filter Strip	393		Qualifying	Qualifying			
Forest Farming	379		Qualifying		Qualifying		
Grassed Waterway	412		Qualifying				
Restoration and Management of Rare or Declining Habitats	643				Qualifying	Qualifying	
Vegetated Treatment Area	635			Qualifying			
Vegetative Barrier	601		Qualifying				
Wetland Wildlife Habitat Management	644					Qualifying	
Early Successional Habitat Development/Mgt.	647					Qualifying	
Saturated Buffer	604			Qualifying			
Stormwater Runoff Control	570		Qualifying				

Table 3-2: Qualifying Practices, Crosswalk with USDA and Oregon Climate Action Commission (OCAC)

Practices	NRCS "GHG Emissions" Improvement Rating	Included in USDA Climate Smart Practices?	Included in the Oregon NWL Recommended Practices	
			Agricultural Lands	Rangelands
Tree/Shrub Establishment	Moderate to Substantial	Yes	Yes	
Conservation Cover	Moderate to Substantial	Yes	Yes	
Pasture and Hay Planting	Moderate to Substantial	Yes	Yes	
Windbreak/Shelterbelt Establishment and Renovation	Moderate to Substantial	Yes	Yes	
Soil Carbon Amendment	Moderate to Substantial	Yes	Yes?	
Riparian Forest Buffer	Moderate	Yes	Yes	
Range Planting	Moderate	Yes		Yes
Forest Stand Improvement	Moderate	Yes	Yes (forest lands)	
Wetland Creation	Moderate			
Wetland Restoration	Moderate	Yes	Yes (tidal wetland)	
Residue and Tillage Management, No Till	Moderate	Yes	Yes	
Wildlife Habitat Planting	Moderate	Yes	Yes	
Nutrient Management	Moderate	Yes	Yes	
Residue and Tillage Management, Reduced Till	Moderate	Yes	Yes	

4 ESTIMATED VALUE BY PRACTICE

Table 4-1 applies the values described in Section 2 to the 167 NRCS conservation practices. Values range from $505 per acre per year for riparian buffers to $15 per acre per year for some in field practices that are only expected to be eligible for carbon-related payment.

For comparison purposes, the table also provides per-acre cost share rates used by a USDA program, the Environmental Quality Incentives Program (EQIP). EQIP is a conservation program administered by NRCS that offers farmers and ranchers financial cost-share and technical assistance to implement conservation practices. For comparison, the final column in Table 4-1 provides information on the fiscal year 2024 Environmental Quality Incentives Program (EQIP) reimbursement rate for Oregon per acre (or other unit as indicated in the column) based on the cost to implement practices (Natural Resources Conservation Service, 2024). Generally, EQIP may provide up to 75% cost share (or up to 90% cost share for socially disadvantaged farmers) for materials and services to implement a conservation practice.

Table 4-1: Payments by Practice Per Acre Per Year

Conservation Practice	NRCS Practice Code	Edge of Field Habitat Type	Edge of Field	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic (Habitat (if Riparian Trees)	Terrestrial Habitat	Annual Payment per Acre		EQIP Oregon Cost Share per Acre
									If Riparian	If not Riparian	
Carbon Eligible Practices											
Conservation Cover	327	Grass/Shrub	Yes	$15	$90	$135			**$240**	**$240**	$117 to $848
Pasture & Hay Planting	512	Grass/Shrub	No	$15				$100	**$115**	**$115**	$102 to $684
Tree/Shrub Establishment	612	Tree/Shrub	Yes	$30			$150	$100	**$280**	**$130**	$294 to $5,380
Windbreak/Shelterbelt Establishment and Renovation[1]	380	Tree/Shrub	Yes	$30			$150		**$180 ($2.30/tree)**	**$30 ($0.38/ tree)**	$0.55 to $7.58/ tree
Nutrient Management	590		No	$15		$9			**$24**	**$24**	$8 to $38
Residue & Tillage Management, No Till	329		No	$15	$6				**$21**	**$21**	$16 to $42
Riparian Forest Buffer	391	Tree/Shrub	Yes	$30	$90	$135	$150	$100	**$505**	**$355**	$1,882 to $7,536
Wildlife Habitat Planting	420	Grass/Shrub	Yes	$15			$150	$100	**$265**	**$115**	$399 to $4892
Soil Carbon Amendment	336		No	$15					**$15**	**$15**	$72 to $2,000
Forest Stand Improvement	666	Tree/Shrub	Yes	$30					**$30**	**$30**	$113 to $2,265
Range Planting	550		No	$15					**$15**	**$15**	$127 to $379
Residue & Tillage Management, Red. Till	345		No	$15					**$15**	**$15**	$20 to $43
Wetland Creation	658	Wetland	Yes	$15					**$15**	**$15**	$3,428 to $4,055
Wetland Restoration	657	Wetland	Yes	$15					**$15**	**$15**	$932 to $4123

Conservation Practice	NRCS Practice Code	Edge of Field Habitat Type	Edge of Field	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic (Habitat (if Riparian Trees)	Terrestrial Habitat	Annual Payment per Acre		EQIP Oregon Cost Share per Acre
									If Riparian	If not Riparian	
Water Quality or Habitat Eligible Practices											
Critical Area Planting	342		Yes		$90				**$90**	**$90**	$332 to $1,231
Grazing Land Mechanical Treatment	548		No		$6				**$6**	**$6**	$13 to $97
Riparian Herbaceous Cover	390		Yes		$90	$135			**$225**	**$225**	$817 to $9,315
Upland Wildlife Hab Mgmt.	645		Yes					$100	**$100**	**$100**	$10 to $309
Constructed Wetland	656		Yes		$90	$135			**$225**	**$225**	$8,117 to $13,924
Filter Strip	393		Yes		$90	$135			**$225**	**$225**	$174 to $244
Forest Farming	379		No		$6		$150		**$156**	**$6**	$4 to $6
Grassed Waterway	412		Yes		$90				**$90**	**$90**	$1,259 to $2,497
Restoration and Management of Rare or Declining Habitats	643		Yes				$150	$100	**$250**	**$100**	$16 to $2,906
Vegetated Treatment Area	635		Yes			$135			**$135**	**$135**	$7,989 to $17,793
Vegetative Barrier[2]	601		Yes		$90				**$90 ($0.005/ft)**	**$90 ($0.005 /ft)**	$0.14 to $1.13/ ft
Wetland Wildlife Habitat Mgmt.	644		Yes					$100	**$100**	**$100**	$10 to $504
Early Successional Habitat Development/Mgmt.	647		Yes					$100	**$100**	**$100**	$29 to $360
Saturated Buffer	604		Yes			$135			**$135**	**$135**	N/A
Stormwater Runoff Control	570		Yes		$90				**$90**	**$90**	N/A

1/Conversion from per acre values to per tree values for windbreak / shelterbelt establishment or renovation is based on NRCS suggested spacing between trees and 17.5 feet between rows (NRCS suggests 15 to 20 feet spacing between rows), and 2 rows of trees for approximately 78 trees per acre. Dividing the per acre payment values by this many trees provides the payment per tree.
2/Conversion to per foot values assumes a 2-foot-wide barrier, so an estimated 21,780 feet length is required to make an acre of coverage.

APPENDIX A: NRCS PHYSICAL EFFECTS RATING

Table A-1 below shows for all NRCS practices (not just ones eligible for payments in this methodology as shown in Table 3-1), the physical effects ratings for each benefit category, as well as for soil health. If the CMP advisory committee chooses to provide payments for practices not qualifying as eligible for payment in Table 3-1, then payment according to the values in Table 2-3 could be made for every benefit type (such as water quality-sediment or aquatic habitat) that the CMP advisory committee concludes would result in a "moderate to substantial" improvement.

Table A-1: Physical Effects Rating for NRCS Practices by Benefit Category

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Carbon Eligible Practices							
Conservation Cover	327	4	4	4	1	3	5
Pasture and Hay Planting	512	4	1	1	0	4	4
Tree/Shrub Establishment	612	4	3	1	4	5	5
Windbreak/ Shelterbelt Establishment and Renovation	380	4	1	1	4	3	5
Nutrient Management	590	3	0	5	0	0	2
Residue and Tillage Management, No Till	329	3	4	2	0	1	4
Riparian Forest Buffer	391	3	5	5	5	5	5
Wildlife Habitat Planting	420	3	1	1	4	5	0
Soil Carbon Amendment	336	4	1	1	0	0	4
Forest Stand Improvement	666	3	0	1	1	2	1
Range Planting	550	3	2	1	1	2	4
Residue and Tillage Management, Reduced Till	345	3	3	2	0	1	3
Wetland Creation	658	3	2	3	0	2	2
Wetland Restoration	657	3	2	3	0	2	1
Water Quality or Habitat Eligible Practices							
Critical Area Planting	342	2	4	2	1	2	5
Grazing Land Mechanical Treatment	548	2	4	3	0	1	3
Riparian Herbaceous Cover	390	2	4	5	2	2	4
Upland Wildlife Habitat Management	645	2	2	0	0	5	0
Constructed Wetland	656	1	5	4	0	0	0
Filter Strip	393	1	5	5	2	1	1

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Water Quality or Habitat Eligible Practices (Continued)							
Forest Farming	379	1	4	1	4	3	3
Grassed Waterway	412	1	5	2	1	1	3
Restoration and Management of Rare or Declining Habitats	643	1	2	0	5	5	0
Vegetated Treatment Area	635	1	2	4	0	0	3
Vegetative Barrier	601	1	4	1	1	1	1
Wetland Wildlife Habitat Management	644	1	3	0	0	5	0
Early Successional Habitat Development/Mgt.	647	0	0	0	0	5	0
Saturated Buffer	604	0	0	5	0	0	0
Stormwater Runoff Control	570	0	4	2	0	0	1
Other NRCS Practices, Not Eligible for Payments (Insufficient Benefits)							
Alley Cropping	311	2	3	3	2	3	5
Cover Crop	340	2	2	2	0	1	2
Energy Efficient Agricultural Operation	374	2	0	0	0	0	0
Prescribed Grazing	528	2	2	1	1	2	4
Recreation Area Improvement	562	2	1	0	0	0	1
Silvopasture	381	2	3	3	3	2	3
Amendments for Treatment of Agricultural Waste	591	1	0	2	0	0	1
Brush Management	314	1	2	0	0	3	0
Conservation Crop Rotation	328	1	3	3	0	1	4
Contour Buffer Strips	332	1	3	2	1	1	1
Contour Orchard and Other Perennial Crops	331	1	3	2	1	0	2
Cross Wind Trap Strips	589C	1	1	1	0	0	1

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Other NRCS Practices, Not Eligible for Payments (Insufficient Benefits) (Continued)							
Drainage Water Management	554	1	0	1	0	0	2
Emergency Animal Mortality Management	368	1	0	2	0	0	0
Field Border	386	1	3	1	2	1	4
Field Operations Emissions Reduction	376	1	0	0	0	0	0
Firebreak	394	1	-1	0	1	1	-2
Fuel Break	383	1	-1	0	0	0	0
Hedgerow Planting	422	1	0	2	1	2	2
Herbaceous Wind Barriers	603	1	1	1	1	1	1
Irrigation Water Management	449	1	2	2	0	0	1
Salinity and Sodic Soil Management	610	1	0	0	0	0	0
Waste Recycling	633	1	0	2	0	0	1
Waste Treatment	629	1	0	2	0	0	1
Wetland Enhancement	659	1	2	3	0	2	1
Woody Residue Treatment	384	1	1	0	0	0	1
Amending Soil Properties with Gypsum Products	333	0	0	-2	0	0	0
Clearing & Snagging	326	0	-2	0	0	0	0
Contour Farming	330	0	2	2	1	0	1
Controlled Traffic Farming	334	0	0	0	0	0	2
Cross Wind Ridges	588	0	1	1	0	0	1
Deep Tillage	324	0	0	0	0	0	0
Dust Control on Unpaved Roads and Surfaces	373	0	1	-1	0	0	0
Dust Management for Pen Surfaces	375	0	0	1	0	0	0
Forage Harvest Management	511	0	0	1	0	1	3

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Other NRCS Practices, Not Eligible for Payments (Insufficient Benefits) (Continued)							
Groundwater Testing	355	0	0	0	0	0	0
Heavy Use Area Protection	561	0	2	1	0	0	0
Irrigation and Drainage Tailwater Recovery	447	0	1	2	0	0	0
Mulching	484	0	2	2	0	1	2
Row Arrangement	557	0	2	-2	0	0	1
Spoil Disposal	572	0	2	0	0	0	1
Spring Development	574	0	1	0	0	0	0
Stripcropping	585	0	3	2	1	1	2
Surface Drainage, Field Ditch	607	0	1	-2	0	0	0
Surface Drainage, Main or Lateral	608	0	-1	-2	0	0	0
Surface Roughening	609	0	3	0	0	0	0
Terrace	600	0	2	2	0	0	2
Tree/Shrub Pruning	660	0	0	1	1	2	2
Tree/Shrub Site Preparation	490	0	-1	0	0	0	-1
Water Harvesting Catchment	636	0	0	0	0	0	0
Land Clearing	460	-1	-1	-1	-1	-2	-3
Recreation Land Improvement and Protection	566	-1	2	0	0	-2	1
Ineligible Infrastructure or Construction-Related or In-Stream Practices, or Per Acre Estimated Payment Potentially Not Applicable							
Anaerobic Digester	366	4	0	2	0	0	0
Feed Management	592	4	0	2	0	0	0
Roofs and Covers	367	4	0	0	0	0	0
Prescribed Burning	338	2	1	2	0	4	1
Access Control	472	1	3	1	3	4	1
Fishpond Management	399	1	0	0	5	0	0

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Ineligible Infrastructure or Construction-Related or In-Stream Practices, or Per Acre Estimated Payment Potentially Not Applicable (Continued)							
Herbaceous Weed Treatment	315	1	1	1	0	4	1
Land Reclamation, Abandoned Mined Land	543	1	4	0	1	1	3
Land Reclamation, Currently Mined Land	544	1	4	0	0	0	3
Stream Habitat Improvement and Management	395	1	2	2	5	3	0
Anionic Polyacrylamide (PAM) Erosion Control	450	0	4	2	0	0	0
Aquatic Organism Passage	396	0	0	0	5	2	0
Bivalve Aquaculture Gear and Biofouling Control	400	0	0	2	4	0	0
Fish Raceway or Tank	398	0	0	-1	4	0	0
Land Reclamation, Landslide Treatment	453	0	4	0	0	0	2
Lined Waterway or Outlet	468	0	5	0	0	-1	0
Pest Management Conservation System	595	0	2	0	2	4	2
Pond	378	0	2	2	4	2	0
Sediment Basin	350	0	4	5	0	-1	0
Shallow Water Development and Management	646	0	2	1	0	5	1
Structure for Water Control	587	0	1	0	4	0	0
Structures for Wildlife	649	0	0	0	3	4	0
Trails and Walkways	575	0	2	0	4	0	0
Water and Sediment Control Basin	638	0	4	0	0	2	0
Watering Facility	614	0	2	4	1	2	0
Short Term Storage of Animal Waste and Byproducts	318	-1	0	4	0	0	1

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Ineligible Infrastructure or Construction-Related or In-Stream Practices, or Per Acre Estimated Payment Potentially Not Applicable (Continued)							
Waste Storage Facility	313	-1	0	4	0	0	1
Waste Treatment Lagoon	359	-3	0	4	0	0	1
Air Filtration and Scrubbing	371	2	0	0	0	0	0
Combustion System Improvement	372	2	0	0	0	0	0
Energy Efficient Building Envelope	672	2	0	0	0	0	0
Animal Mortality Facility	316	1	0	2	0	0	0
Composting Facility	317	1	0	2	0	0	0
Fence	382	1	0	0	1	1	1
Irrigation System, Microirrigation	441	1	1	2	0	0	0
Irrigation System, Surface & Subsurface	443	1	0	1	0	0	0
Mine Shaft & Adit Closing	457	1	0	0	0	0	0
Pumping Plant	533	1	0	0	0	0	0
Road/Trail/Landing Closure and Treatment	654	1	3	1	1	1	5
Rock Wall Terrace	555	1	2	0	0	0	0
Sprinkler System	442	1	1	2	0	0	0
Streambank and Shoreline Protection	580	1	2	1	2	2	0
Waste Facility Closure	360	1	0	0	0	0	0
Waste Separation Facility (no)	632	1	0	2	0	0	1
Access Road	560	0	1	0	0	0	1
Agrichemical Handling Facility	309	0	0	0	0	0	0
Aquaculture Ponds	397	0	0	-2	2	0	0
Channel Bed Stabilization	584	0	1	0	1	0	0
Dam	402	0	2	0	2	1	1
							1
Dam, Diversion	348	0	0	0	-1	-1	0

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Ineligible Infrastructure or Construction-Related or In-Stream Practices, or Per Acre Estimated Payment Potentially Not Applicable (Continued)							
Dike and Levee	356	0	0	0	0	0	0
Diversion	362	0	2	3	0	0	0
Dry Hydrant	432	0	0	0	0	0	0
Energy Efficient Lighting System	670	0	0	0	0	0	0
Forest Trails and Landings	655	0	0	1	1	0	-1
Grade Stabilization Structure	410	0	2	0	1	1	2
High Tunnel System	325	0	-1	0	0	0	0
Hillside Ditch	423	0	2	-1	0	0	0
Irrigation Canal or Lateral	320	0	0	-2	0	0	0
Irrigation Ditch Lining	428	0	1	1	0	0	0
Irrigation Field Ditch	388	0	0	0	0	0	0
Irrigation Land Leveling	464	0	1	2	0	0	0
Irrigation Pipeline	430	0	1	1	0	0	0
Irrigation Reservoir	436	0	2	0	0	0	0
Land Reclamation, Toxic Discharge Control	455	0	0	0	0	0	0
Livestock Pipeline	516	0	0	0	0	0	0
Livestock Shelter Structure	576	0	0	3	0	0	0
Monitoring Well	353	0	0	0	0	0	0
Obstruction Removal	500	0	0	0	0	0	1
On-Farm Secondary Containment Facility	319	0	0	0	0	0	0
Open Channel	582	0	0	-1	0	0	0
Pond Sealing or Lining - Geomembrane or Geosynthetic Clay Liner	521	0	0	2	0	0	0

Conservation Practice	NRCS Practice Code	Carbon	Water Quality - Sediment	Water Quality - Nutrients	Aquatic Habitat (Max of Water Temperature OR Aquatic Habitat)	Terrestrial Habitat	Soil Health (Max of Organic Matter, Soil Organism Habitat, Compaction)
Ineligible Infrastructure or Construction-Related or In-Stream Practices, or Per Acre Estimated Payment Potentially Not Applicable (Continued)							
Pond Sealing or Lining, Compacted Soil Treatment	520	0	0	2	0	0	0
Pond Sealing or Lining, Concrete	522	0	0	2	0	0	0
Roof Runoff Structure	558	0	1	2	0	0	0
Sinkhole Treatment	527	0	2	2	0	0	0
Stream Crossing	578	0	2	1	1	0	0
Subsurface Drain	606	0	2	-2	0	0	2
Underground Outlet	620	0	0	-1	0	0	0
Vertical Drain	630	0	1	1	0	0	0
Waste Transfer	634	0	0	2	0	0	0
Water Well	642	0	0	0	0	0	0
Waterspreading	640	0	0	2	0	0	1
Well Decommissioning	351	0	0	0	0	0	0
Denitrifying Bioreactor	605	-1	0	3	0	0	0
Precision Land Forming and Smoothing	462	-1	1	1	0	0	-2

APPENDIX B: DATA TO SUPPORT CARBON VALUES

This appendix presents the data and sources for the values for carbon sequestration practices. Carbon dioxide is the most prevalent greenhouse gas (GHG) emitted by human activity, but other GHGs also contribute to climate change. These other GHGs are converted into CO_2e based on their global warming potential compared to carbon dioxide. For example, in terms of global warming potential, one ton of methane is equivalent to approximately 25 tons of carbon dioxide, so one ton of methane is equal to 25 tons of carbon dioxide equivalent, or CO_2e. Throughout this appendix we present sequestration by conservation practice as the metric tons of carbon sequestered per hectare per year, as this is the metric most often used in the literature. We then convert this to tons of CO_2e per acre per year, as carbon prices are typically expressed in terms of dollars per metric tons of CO_2e.

As shown in Table B-1, we establish carbon values based on an estimated annual sequestration rate of approximately 0.35 to 0.7 metric tons carbon (C) per hectare per year, or 0.5 to 1.0 metric tons $C0_2$e per acre per year.[8] We couple this with a carbon value of $30 per metric ton of CO_2e to estimate a carbon value per acre that varies from $15 to $30 per acre. The sections below provide the supporting data for this value level; as with all other values used in the methodology, the carbon value aims to be a reasonable but conservative estimate of public benefits of conservation practices.

Table B-1: Summary of Carbon Quantification and Values Per Practice Type

Practice Type/Vegetation Type	Tons C / Hectare / Year	Tons $C0_2$e / Acre / Year	Value per Metric Ton of CO_2e	Value Per Acre/Year	Eligible Practices
Soil Sequestration Practices (In-Field Practices/Grassland)	0.35	0.5	$30	$15	Pasture/Hay Planting, Soil Carbon Amendment, Range Planting, No Till Management, Reduced Till Management, Nutrient Management
Habitat-Based Practices					
Grassland	0.35	0.5	$30	$15	Wildlife Habitat Planting, Conservation Cover
Tree/Shrub	0.7	1.0	$30	$30	Tree/Shrub Establishment, Windbreak/Shelterbelt, Riparian Forest Buffer, Forest Stand Improvement
Wetland	0.35	0.5	$30	$15	Wetland Creation, Wetland Restoration

8 This conversion is based on a conversion ratio of 3.67 tons of CO_2e for every ton of carbon, and 2.47 acres for every hectare.

Effectiveness of Conservation Practices (Level of Carbon Sequestration)

Table B-2 summarizes key sources of literature on the effectiveness of agricultural conservation practices in enhancing soil and woody vegetation carbon sequestration. In-field practices, such as no-till, conservation cover, establishment of grassland (range planting or pasture/hay planting), or wetlands can increase soil carbon storage. The average annual soil organic carbon (SOC) sequestration rate is estimated at 0.35 tons of carbon per hectare per year based on a variety of sources. Different studies of soil carbon sequestration rates on farmland and in grassland/wetland ecosystems vary widely in their estimates of annual sequestration, both in terms of magnitude and in terms of sequestration rate over time.

Table B-2: Summary of Data on Carbon Sequestration by Practice Type, Metric Tons C per Hectare per Year

Practice	Biardeau et al. (from COMET-Planner), 2016	Soil Carbon Chambers et al., 2016 (NRCS review)	Canqui et al., 2022 (Meta-Analysis)	Cai et al., 2022 (Meta-Analysis)	Fargione et al., 2018 (Natural Climate Solutions)	Gattinger et al., 2012 Meta Analysis	US EPA Greenhouse Gas Inventory, 2022	Oregon Forest Carbon Inventory	USDA Forest Carbon Data
Riparian forest buffers & tree/shrub establishment or afforestation	1.5 to 1.7							0.5 to 1.5[B]	0.2 to 0.7[C]
Other tree/shrub establishment, including hedgerow/alley cropping/multi-story cropping	1.2 to 1.4								
Herbaceous Cover (conservation cover, herbaceous wind barriers, vegetative barriers, contour buffer strips, field borders, etc.)	1.2	0.42 to 0.96			1.2 [D]		0.3[A]		
No Till	0.3	0.15 to 0.27		~0					
Cover crops (Not Eligible)	0.3	0.15 to 0.22	.12						
Forage and biomass planting	0.3	.02 to 0.17							
Prescribed grazing (Not		0.17 to 0.44							
Range planting		0.22 to 0.35							
Organic soil amendments (replacing synthetic fertilizer)	1.8					0.27 to 0.45[E]			
Mulching (Not eligible)	0.2	0.07 to 0.18							

A/Estimated annual average flux (net sequestration) throughout the US for cropland converted to grassland.
B/Data on annual average above ground flux (net sequestration) in all Oregon forests, excluding corporate ownership.
C/Data on average annual carbon sequestration (soil and all above ground biomass) in first 10 years of afforestation for different Oregon tree types.
D/Estimated annual average flux (net sequestration) throughout the US for cropland converted to native grassland.
E/Estimated differences in a meta-analysis of conventional versus organically farmed soils. (Gattinger, et al., 2012)

Much of the literature focuses on soil carbon sequestration on agricultural lands (soy and corn cropping) in the Midwest, which may have very different SOC sequestration rates than agricultural lands in Oregon. The rate at which SOC stocks change is a function of climate, cropping history, type of plants seeded, landscape position, hydrology, soil characteristics, and time. Table B-2 presents carbon sequestration values from different meta-analyses of agricultural management practices, as well as data from national and Oregon carbon inventories. Data from other studies is also presented in the text below.

For establishment of grass cover, estimates are highly varied for sequestration rates. However, one review of available studies by NRCS concluded that conversion of cropland to grassland on Conservation Reserve Program lands results in carbon sequestration rates of approximately 0.22 to 0.45 tons per acre per year (Natural Resources Conservation Service, 2012).[9] Within this range, the 2022 US EPA National Greenhouse Gas Inventory estimates an annual sequestration rate of 0.3 metric tons carbon per hectare for lands converted from agricultural land use to grassland (Environmental Protection Agency, 2022).[10] These studies support a value of approximately 0.35 metric tons carbon per hectare sequestered per acre of grass cover, the value used in the payment methodology.

Estimates are more varied for studies of in-field practices. Some studies show a significant effect on soil organic matter from no till, while others show little effect. A 2006 EPA review concluded that published carbon sequestration rate estimates for conversion of cropland from conventional tillage to no-till range from 0.22 to 0.33 ton per acre per year, with an estimated saturation time range[11] of 15 to 50 years (US Environmental Protection Agency, 2006). However, a recent review of 144 studies over the past 50 years (including 1,061 pairs of published data on till and no-till) found that no till increases SOC at shallow soil depths in the first years of practice implementation, but that these gains may be offset by diminishing amounts of carbon stored in deeper soil depths (ranging from 0.28 to 2.29 metric tons C per hectare) (Cai, et al., 2022).[12] This study found that over 14 years the net change in soil carbon approached zero, indicating that no till is not a guaranteed solution from increasing SOC in agricultural soils.

Similarly, another recent review of 77 cover crop comparisons in the United States found that only 29% (22 of the 77) resulted in an increase in SOC (0.41 metric ton C per hectare per year); taking into account all 77 comparisons, the average increase in SOC was 0.12 metric tons per hectare, or 0.05 metric tons C per acre (note that cover cropping is not included as an eligible carbon practice). Increased SOC from cover cropping was correlated with more cover crop biomass (greater than 2 metric tons per acre) in the cover crop, a longer timeframe of practice

9 This is based on the following study: Follet, R.F., Pruessner, E.G., Samson Liebig, S.E., Kimble, J.M. and Waltman, S.W., 2001. Carbon sequestration under the Conservation Reserve Program in the historic grassland soils of the United States of America. I R. Lal, ed. Carbon Sequestration and Greenhouse Effect. Soil Science Society of America Special Publication No. 57. pp. 27 – 40

10 EPA. 2022. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. U.S. Environmental Protection Agency, EPA 430-R-22-003. https://www.epa.gov/ghgemissions/draft-inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.

11 Saturation time range refers to the number of years of increased soil carbon sequestration before SOC has reached maximum or saturation levels.

12 Cai, A., Han, T., Ren, T., Sanderman, J., Rui, Y., Wang, B., Smith, P. and Xu, M., 2022. Declines in soil carbon storage under no tillage can be alleviated in the long run. *Geoderma*, *425*, p.116028.

implementation (more than five years of cover cropping), and low baseline SOC (Blanco-Canqui, 2022), (Jordon, et al., 2022). Several meta-analyses of soil organic carbon have also found that SOC concentrations often accrue over time and that there are additive effects of multiple BMPs on SOC and soil health, with SOC responding to combining of conservation practices (such as no-till, cover cropping, and organic amendments) (Crystal-Ornelas, Thapa, & Tully, 2021)(Allam et al., 2022). As a potential example of additive effects, one study in eastern Oregon compared the combined effects on soil carbon of winter cropping and no-till compared to conventionally tilled and winter fallow, and estimated a change in soil carbon of 1.7 to 2.6 metric tons C per hectare per year in the soil zone of 0 to 40 cm (Machado, et al., 2006).[13]

Permanence of carbon storage is an issue with all soil or plant-based carbon sequestration (as trees can release carbon through wildfire events or harvest, or soils can be disturbed and release carbon). However, permanence is particularly an issue for in-field soil carbon practices as changes in annual management practices (such as introducing till on formerly no-till lands) can result in release of carbon stored in prior years. Based on these types of uncertainties, we establish a conservative estimate of value for soil-based carbon sequestration practices of 0.35 metric tons carbon per hectare, the same value used for grassland.

Wetlands, which store the majority of carbon in soils, are designated the same level of carbon sequestration (0.35 metric tons C per hectare per year) as in-field management practices and grassland establishment. For wetlands, we review values from four different publications on carbon stocks in US wetlands (Nahlik & Fennessy, 2016) (Tan Z. , Liu, Sohl, & Young, 2015), and compare these against values from a different set of five studies on carbon stocks in US agricultural lands (see Tables B-3 and B-4). These data indicate carbon stocks in wetlands vary substantially, but in the western US may average approximately 200 tons of carbon per hectare (with tidal saline wetlands averaging approximately 350 tons of carbon per hectare), while agricultural land may average approximately 40 tons per hectare. One study estimates that it can take wetlands 20 to over 60 years to return to natural conditions (Tangen & Bansal, 2020). Peatland in particular accumulates carbon very slowly. For example, one recent study estimated that the average time for a degraded wetland to move from a carbon source to a carbon sink through restoration could be 141 years (for a non-peatland wetland) to 525 years (for a peatland wetland) (Schuster, Taillardat, Macreadie, & Malerba, 2024). A 50-year period to move from 40 metric tons carbon per hectare to 200 to 350 metric tons carbon per hectare equates to approximately 3 to 6 metric tons carbon per hectare.

However, several assessments of annual wetland carbon sequestration indicate that approximately 0.35 metric ton to 1 metric ton carbon per hectare may be more accurate (see Table B-5). A study of wetlands in the Prairie Pothole Region of the US estimated sequestration rates on wetlands ranging from 0.35 to 1.1 tons of carbon per hectare per year (Tangen & Bansal, 2020). Another study of restoring peatland ecosystems through the United States estimated that restored peatlands in the Western US would result in total annual storage of 0.95 ton of carbon equivalent per hectare (after accounting for carbon dioxide and methane flux) (Fargione,

[13] Machado, S., Rhinhart, K., & Petrie, S. (2006). Long-term cropping system effects on carbon sequestration in eastern Oregon. Journal of Environmental Quality, 35(4), 1548-1553.

et al., 2018). Similarly, a 2022 study of carbon sequestration on restored freshwater, mineral soil wetlands in an agricultural landscape in Ontario, Canada, found organic carbon sequestration rates of 0.89 metric tons per hectare per year, with soil restored over 40 years. Although several of these studies indicate higher levels of carbon storage in wetland, we take into account that methane emissions from wetlands may rise with increased warming (although wetlands are still expected to provide a net benefit in mitigating climate change, see (US Geological Survey, 2023)), so we use an estimate of 0.35 tons per carbon per hectare per year for wetlands. Given the uncertainty in timing for wetlands to become carbon sinks, this rate of sequestration may not occur immediately after practice implementation.

Table B-3: Estimated Carbon Stock of Wetlands, Metric Ton Carbon per Hectare

Study	Geography	Data Year	Carbon Stock (Metric Ton Carbon Per Hectare)
Tan et al., 2015	National, federal forest	2001 to 2005 average	151
	National, federal forest	2050	138
	National, nonfederal forest	2050	**206**
Nahlik and Fennessy, 2016	Tidal Saline	2011	345
	Coastal Plains	2011	197
	E Mts & Upper Midwest	2011	477
	Interior Plains	2011	194
	West	2011	**214**
	National	2011	299
Adhikari et al. 2019	Wisconsin	1990 to 2010	243

Sources: (Adhikari, et al., 2019) (Nahlik & Fennessy, 2016) (Tan Z. , Liu, Sohl, & Young, 2015)

Table B-4: Estimated Carbon Stock of Cropland Soils, Metric Ton Carbon Per Hectare

Study	Geography	Data Year	Carbon Stock (Metric Ton Carbon Per Hectare)
Spawn et al. 2019, inferred from % change	US Croplands	2008 to 2012	23
Lal 2004, inferred	Global	2000	45
Tan et al., 2015 (cropland/agricultural may include grassland, pasture, hay, and other land uses)	National, federal cropland	2001 to 2005 average	37
	National, federal agricultural land	2050	40
	National, nonfederal agricultural land	2050	48
Dangal et al. 2022 (Calibrated model with sampling of US	US Croplands	2001 to 2005	35

cropland soils)			
USGS 2011	Great Plains Region agricultural land	2001 to 2005	37

Sources: Highland Economcis analysis of (Spawn, Lark, & Gibbs, 2019); (Zhang, Lark, Clark, Yuan, & LeDuc, 2021), (Tan Z. , Liu, Sohl, Wu, & Young, 2015), (Dangal, et al., 2022) (Bouchard, et al., 2011)

Table B-5: Data on Annual Carbon Sequestration by Wetlands

Study	Year	Location	Metric Ton Carbon / Hectare / Year
Creed et al.	2022	Ontario	0.89
Tangen and Bansal	2020	Prairie Pothole Region	0.35 to 1.1
Fargione et al.	2018	Western Wetlands	0.95
Estimate Used for Oregon Payments for Carbon			0.35

Sources: (Creed, et al., 2022), (Fargione, et al., 2018), (Tangen & Bansal, 2020)

For practices with tree establishment, we use values from the US Forest Service on average carbon stocks in afforestation projects (Hoover, Bagdon, & Gagnon, 2021) and data from the Oregon Forest Carbon Inventory (US Forest Service, Oregon Department of Forestry, 2019). The US Forest Service estimates metric tons of carbon stocks stored per afforested hectare by tree type and by region (the Pacific Northwest is divided into two subregions: East and West). The estimated carbon stocks per hectare of forest are estimated at year 0 and then at selected later decades of tree age (Year 10, Year 30, Year 50, and Year 100). Estimates are provided for the amount of carbon stored in live trees, in other aboveground biomass (including standing dead trees, understory, down dead wood, and the forest floor) as well as for soil carbon, see Table B-6.

Table B-6: Metric Ton Carbon Stock Per Afforested Hectare Per Year

Tree Type/Region	Aboveground (Non-Soil) Stock Metric Ton Carbon / Hectare / Year			Soil Stock Metric Ton Carbon / Hectare / Year			Total Metric Ton Carbon / Hectare / Year		
	Year 0	Year 10	Year 30	Year 0	Year 10	Year 30	Year 0	Year 10	Year 30
Western Pacific Northwest									
Alder/Maple	2.7	6.3	77.8	86.4	87.6	95.1	89.1	93.9	172.9
Douglas Fir	2.7	5.7	140.9	71.1	72	78.2	73.8	77.7	219.1
Douglas fir, high productivity	2.7	6.7	193.2	71.1	72	78.2	73.8	78.7	271.4
Eastern Pacific Northwest									
Douglas Fir	1.1	7.1	77.7	71.1	72	78.2	72.2	79.1	155.9
Lodgepole Pine	1.1	4.5	39.4	39	39.5	42.9	40.1	44	82.3
Ponderosa Pine	5.4	7	34.8	38	38.5	41.8	43.4	45.5	76.6

Source: Highland Economics analysis of (Hoover, Bagdon, & Gagnon, 2021)

We use the total aboveground and belowground carbon stock estimates at each point in time, and then subtract out the total carbon stock estimates at Year 0 to estimate total accumulation through time. To convert this to an annual average carbon sequestration estimate for the first decade of afforestation, we then divide the estimate total increase in carbon stock by the age of the forest to estimate average annual carbon accumulation during the first decade after planting (years 0 to 10). We also estimate the average annual carbon accumulation in the second two decades after planting (years 10 to 30) and cumulatively across the first three decades after planting (years 0 to 30), see Table B-7. We conservatively rely on the data on the total annual average carbon sequestration in approximately the first ten years after planting, which varies from 0.2 to 0.7 metric tons of carbon per hectare, depending on the tree type and region within the Pacific Northwest. For riparian vegetation, it is primarily deciduous trees and shrubs (which tend to have lower carbon levels) that dominate throughout most of the state, while conifers are predominant at higher elevations.[14] We assume that conservation practices that are establishing forest/tree shrubs are using plants slightly older than seedlings, such that the sequestration levels achieved during the CMP payment period is slightly greater than the average during years 0 to 10. **As an average value, we assume 0.7 metric tons of carbon per afforested hectare, which equates to 1.0 metric ton of CO_2e per afforested acre in Oregon.**[15] If the conservation practice is continued such that the trees mature (and if trees are the majority of vegetation rather than shrubs), then on average over 30 years, the annual average carbon sequestration achieved per acre would be much higher. However, we use the conservative value of 0.7 metric tons per hectare per year as this is the approximate expected sequestration during the period of the payments for newly established trees/shrubs.

Table B-7: Average Annual Sequestration Per Afforested Hectare

Tree Type/Region	Annual Average Sequestration (Metric Ton Carbon / Hectare / Year)		
	Year 0 to 10	Year 10 to 30	Year 0 to 30
Western Pacific Northwest			
Alder/Maple	0.5	4.0	2.8
Douglas Fir	0.4	7.1	4.8
Douglas fir, high productivity	0.5	9.6	6.6
Eastern Pacific Northwest			
Douglas Fir	0.7	3.8	2.8
Lodgepole Pine	0.4	1.9	1.4
Ponderosa Pine	0.2	1.6	1.1

Source: Highland Economics analysis of (Hoover, Bagdon, & Gagnon, 2021)

[14] (Oregon Department of Fish and Wildlife, 2016)
[15] There are 2.47105 acres in a hectare and 3.67 metric tons of CO2e per metric ton of carbon.

Table B-8: Oregon Forest Ecosystem Carbon Inventory Report (2019), Net Annual Change in Aboveground Live Tree carbon between 2001-2006 and 2011-2016[1]

Forest Ownership	Annual Average Sequestration	
	Metric Ton CO_2e / Acre / Year	Metric Ton Carbon / Hectare / Year
Private – Corporate	0.18	0.12
Private-Noncorporate	0.95	0.64
Other Federal	2.29	1.54
State and Local Gov.	0.79	0.53
National Forests	1.17	0.79
All Ownerships	1.04	0.70

1/Accounts for growth, harvest, and mortality from fire, insects/disease and natural factors.
Source: Table 4.4 in the Oregon Forest Carbon Ecosystem Carbon Inventory Report (Christensen, Gray, Kuegler, & Yost, 2019).

Carbon Value

This section summarizes information on the value of GHG reduction. This value, often referred to as the price of carbon, is typically expressed as dollars per metric ton of CO_2e. The economic value of reduced GHG is the value of avoiding damages caused by climate change, which is often called the 'social cost of carbon' (SCC). There is substantial variation in the available estimates of SCC. This is due to the numerous uncertainties affecting SCC value, including 1) the timing and magnitude of climate change effects, 2) society's ability to mitigate climate change effects, 3) the difficulty in expressing in monetary terms the many environmental and social change impacts of climate change, and 4) the difficulty in expressing future costs in today's dollars (related to the discount rate chosen).

SCC damage values used by federal agencies have varied over the years. At first, federal agencies developed and applied their own estimates. Then, the Office of Management and Budget convened an Interagency Working Group (IWG) on the Social Costs of Greenhouse Gases, which in 2013 developed a set of SCC estimates that could be used across federal agencies (Interagency Working Group on Social Cost of Greenhouse Gases, 2013). In February 2021, the IWG updated its estimates of the SCC. They estimated that in the year 2022, at a 3-percent discount rate, the SCC value was $51 per metric ton in 2020 dollars (Interagency Working Group on Social Cost of Greenhouse Gases, 2021). Adjusting this value for inflation equates to roughly $60 per metric ton in 2023 dollars using the Implicit Price Deflator for Gross Domestic Product (IPDGDP) (Bureau of Economic Analysis, 2023). More recently, the U.S. Environmental Protection Agency (EPA), a member of the IWG, released in November of 2023 a new estimate of the social cost of carbon emissions occurring in the year 2020 at $120 to $340 per metric ton, with a central value of $190 (in 2020 dollars) (Environmental Protection Agency, 2023). The U.S. EPA central value of $190 per metric ton for emissions in 2020, equates to approximately $220 per metric ton in 2023 dollars.

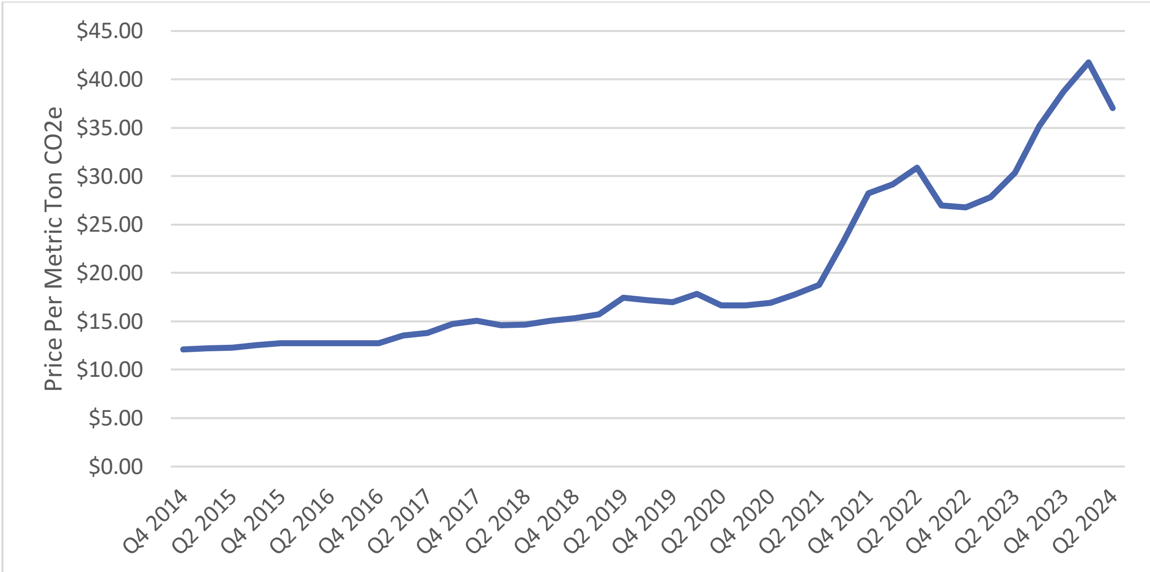
Market prices for carbon are not based on the SCC but rather are generally based on the cost of carbon abatement (reduced emissions) or cost of increased carbon sequestration, as well as the level of demand for carbon credits. Carbon prices also vary substantially based on the type of carbon credit offered (reducing emissions or increasing sequestration), whether it is a voluntary carbon credit or a credit in a compliance market, the volume of carbon traded at a time, the geography of the project, the year of credit delivery, and other factors. Credits are also typically evaluated based on the following factors to be eligible for sale in a carbon market:

- Additionality: the carbon is removed from the atmosphere because of the market and is additional to the emissions reduction or carbon sequestration what would happen without the market,
- Quantification Certainty: the amount of carbon removed from the atmosphere is measured and certain,
- Permanence: the amount of carbon removed won't be released back into the atmosphere soon.

For several reasons we base our value for carbon on the current market value of carbon credits from agricultural lands and other nature-based credits, including the cost of carbon offsets from other types of carbon sequestration projects such as afforestation, as well as the current market price of the California cap and trade carbon market. These costs represent the costs to the State of Oregon of investing in other nature-based carbon sequestration projects, such as timber offsets in the State of Oregon. Further, we use the lower carbon prices from carbon markets rather than the SCC values as the market prices reflect uncertainty in carbon quantification, permanence, and additionality from agricultural conservation practices. As we are not requiring measurement of carbon in the proposed methodology, and as there is uncertainty in the additionality and the permanence of carbon stored in agricultural conservation practices, we propose a value of $30 per metric ton of carbon as a reasonable value for compensation of agricultural landowners.

A value of $30 per metric ton is slightly less than the value currently being paid in the California compliance market. Recent average prices in this market, which is a cap-and-trade market mandated by regulation, have averaged approximately $35 per metric ton of CO_2e in 2023 and the first half of 2024, see Figure B-1. This is the price paid for emission credits traded amongst regulated entities. In the California carbon market, a small percentage of a regulated entity's compliance obligation may be met with reduced emissions or sequestered carbon in the agricultural or forestry sectors. These agricultural or forestry sector offsets must be quantifiable enforceable, permanent (100 years+), and additional reductions of GHGs, as verified by a third-party.

Figure B-1: 2023 California Carbon Market Auction Settlement Price, $/CO2e



Source: (California Air Resources Board, 2024)

Prices in the voluntary compliance markets, which sell carbon credits to non-regulated entities, are much lower. Figure B-2 summarizes data on voluntary carbon market pricing for different types of projects as of July 2023. As shown in the figure, prices in the voluntary market vary from approximately $2 to $11 per credit (metric ton of CO_2e).

Figure B-2: 2023 Voluntary Carbon Market Credit Price Range, 2023

Carbon Credit Pricing by Type

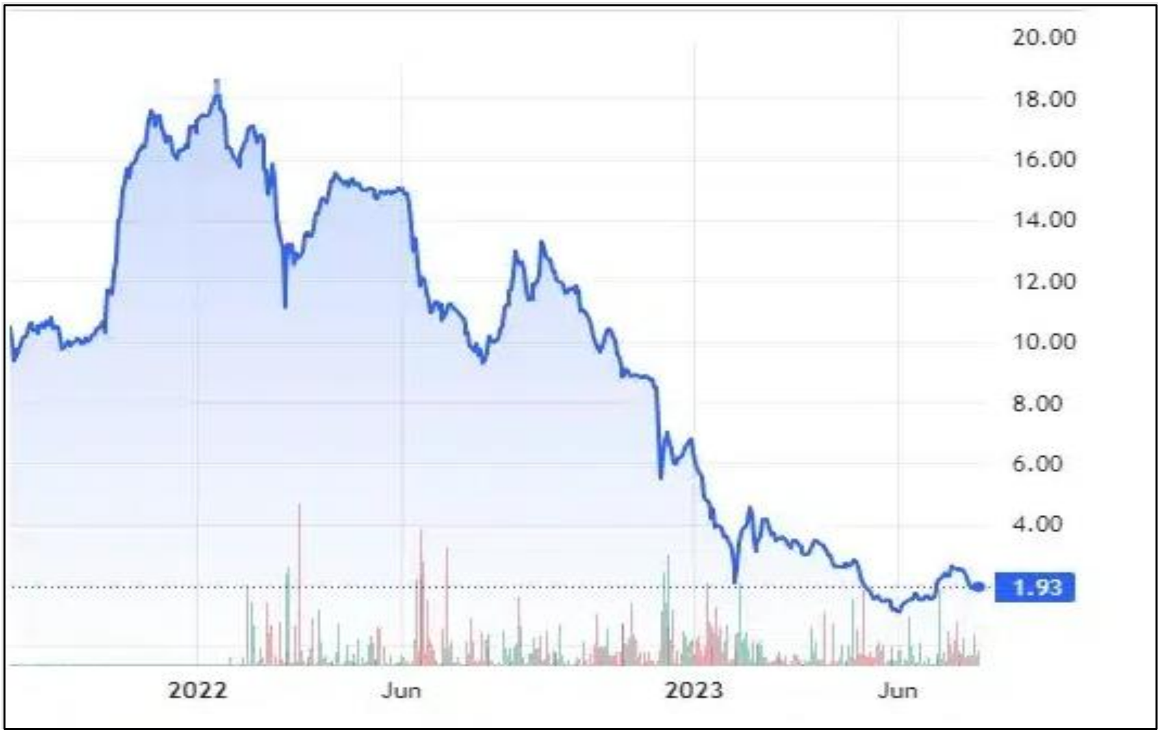
Project Type:	Volume Sold (MtCO2e):	Average Price:	Price Range:
Wind	12.8	$1.9	$0.3 - $18
REDD+	11	$3.3	$0.8 - $20+
Landfill methane	7.9	$2	$0.2 - $19
Tree planting	3	$7.5	$2.2 - $20+
Clean cookstoves	3	$4.9	$2 - $20+
Run-of-river hydro	1.5	$1.4	$0.2 - $8
Water/purification	1.2	$3.8	$1.7 - $9
Improved forest management	0.8	$9.6	$2 - $17.5
Biomass/biochar	0.7	$3	$0.9 - $20+
Energy efficiency - industrial-focused	0.7	$4.1	$0.1 - $20
Biogas	0.6	$5.9	$1 - $20+
Energy efficiency - community-focused	0.6	$9.4	$3.3 - $20+
Transportation	0.5	$2.9	$2.2 - $6.8
Fuel switching	0.5	$11.4	$3.5 - $20+
Solar	0.3	$4.1	$1 - $9.8
Livestock methane	0.2	$7	$4 - $20+
Geothermal	0.1	$4	$2.5 - $8
Agro-forestry	0.1	$9.9	$9 - $11

8 Billion Trees .com

Source: (Opanda, 2023)

Recent trends in the voluntary nature-based carbon offset market are shown in Figure B-3 below. Nature-based carbon credits have diminished in price in the last year, with some analysts concluding that the timing of the decline in prices is related to some news stories criticizing the validity and effectiveness of rainforest carbon projects (CarbonCredits.Com, 2023).

Figure B-3 Recent Trends in Pricing for Nature-Based Carbon Offsets



Source: (CarbonCredits.Com, 2023)

The cost of alternative carbon sequestration projects is also pertinent because it represents the cost to Oregonians of other methods to sequester an equivalent amount of carbon. In other words, if Oregon were not to pay for agricultural conservation practices, what price would Oregon have to pay instead to purchase afforestation or other carbon sequestration credits to remove an equivalent level of carbon dioxide from the atmosphere? One analysis (Sohngen & Brown, 2008) published in 2008 estimated that the cost to extend timber rotations in some Pacific Northwest forests to increase carbon sequestration was approximately $10 per metric ton CO_2e.[16] A 2017 study in Washington state reported that ten-year historic prices for forest carbon credits sold in voluntary markets were also approximately $10 per credit, or per metric ton CO_2e (Fischer, Cullen, & Ettl, 2017). However, this same analysis indicated that the breakeven price to compensate landowners for increasing timber rotations by 20 years (from 45

[16] The original study value was $7 per metric ton, converted from 2008 to 2023 dollars, this is roughly equivalent to $10 per metric ton.

to 65 years) would be approximately $62 per metric ton of CO_2e.[17] Our proposed value of $30 per metric ton falls a bit under the mid-point of this range.

Specific to agricultural carbon markets, there are several carbon payment programs active in the American Midwest to pay farmers for conservation practices. These programs pay approximately $3 to $45 per acre for increased soil carbon storage. Indigo Agriculture pays an estimated $3 to $12 per acre, with 0.1 to 0.4 credits expected on average for tillage, cover cropping, and nitrogen inputs. Indigo Agriculture values carbon at $30 per credit (metric ton) (Indigo, 2021), similar to our proposed rate. Another program, Carbon Now, guarantees farming payments of $12 per acre per year (Locus Agriculture, 2020). Farmers are paid $15 per verified metric ton of CO_2e. For comparison, as shown in Table B-1, the proposed value is $15 per acre per qualifying practice for in-field practices using a value of $30 per metric ton of CO_2e. As such, the proposed valuation methodology is in the same ballpark of value as the agricultural carbon payment schemes in the Midwest that require measurement and in-field verification of increased carbon storage.

[17] The original value in 2017 was $50 per metric ton.

APPENDIX C: DATA TO SUPPORT WATER QUALITY VALUES

The methodology values two types of water quality pollutants that are related to agriculture: sediment and nutrients. Agricultural runoff can erode agricultural soils, resulting in sediment, nutrients, and other contaminants being transported to adjacent streams and other waterbodies. Reducing sediment loading to waterbodies is important to reduce clogging of stream channels, silting up of reservoirs and reductions in reservoir capacity, deterioration of water clarity/aesthetics/recreation, and adverse impacts on fish, including salmonids.[18] Sediments can also carry nutrients and pesticides to waterbodies, further reducing water quality. Nutrients are important as excess nutrient levels (primarily nitrogen and phosphorus) can lead a eutrophication and excess algal growth which can smell and look bad, adversely impact aquatic habitat conditions (including low levels of dissolved oxygen), and release toxins detrimental to human health.

The Oregon Department of Environmental Quality provides an annual assessment of water quality throughout the state. The 2022 Integrated Report found that for assessment units throughout the state for which there are data, 87% are impaired by one or more pollutants. The greatest number of impairments are for temperature, dissolved oxygen (related to nutrients), and *E. coli.* In terms of beneficial uses of waterbodies, fish and aquatic life use impairment is the most common unsupported beneficial use (largely driven by nonattainment of temperature criteria) (Oregon Department of Environmental Quality, 2023). The value of conservation practices (specifically riparian buffers) to improve aquatic habitat and regulate water temperatures is addressed in the next section.

Because reducing water-borne erosion is the primary mechanism to reduce sediment and nutrient loading in waterways, the methodology focuses on quantifying the change in water quality based on the effectiveness of conservation practices in reducing erosion and filtering water-borne sediment and nutrients. The methodology for quantifying water quality benefits includes the following steps:

1. Estimate the average annual reduction in sediment and nutrient loading from each acre of conservation practice implemented, focusing on two categories of practices: in-field soil erosion control practices and edge of field buffer practices. This requires combining data from three sub-steps:
    a. Quantify average water-related erosion rates on agricultural land in Oregon, and the associated average annual per acre nutrient and sediment loading to waterways.
    b. Estimate the effectiveness (in terms of percent reduction) of various conservation practices in reducing water-related erosion and loading.
    c. Estimate the drainage area for edge of field practices that filter sediment and nutrients and reduce the loading to waterways from multiple acres (as opposed

[18] Soil removed from fields also has costs to the farm, as it results it lost topsoil, nutrients, and can affect agricultural fertility and productivity.

to in-field practices that reduce erosion and loading only from the acreage on which the practice is implemented).

2. Estimate the economic value of improved water quality per ton of reduced sediment loading per kilogram of reduced nutrient loading.
3. Combine the data from Step 1 and 2 to estimate the economic value (dollar per acre per year) of each type of conservation practice. In other words, multiply the unit value of reducing loading (dollar per ton or per kilogram) from Step 2 by the estimated reduction in sediment and nutrient loading from each type of conservation practice (tons or kilograms per acre per year) from Step 1.

Findings from this process are summarized in Table C-1. As shown in the table, for in-field practices, **the annual per acre value is $6 for practices eligible as sediment loading reduction practices and is $9 for practices eligible as nutrient loading reduction practices, for a combined potential value of up to $15 for eligible in-field water quality practices**. For edge-of-field practices, we estimate that each acre of practice filters and reduces sediment and nutrients from 15 acres (i.e., the drainage area is 15 acres for each acre of practice). As such, for each acre of edge of field practice, we estimate a 15-fold value of the in-field practices. **The annual per acre payment is $90 for edge-of-field practices eligible as sediment loading reduction practices and is $135 for edge-of-field practices eligible as nutrient loading reduction practices, for a combined potential payment of up to $225 for eligible edge-of-field water quality practices**.

Table C-1: Summary of Water Quality Quantification and payment Per Acre Values

Column	Practice Type/Vegetation Type	Water-Related Sediment Erosion Tons/Acre	Nitrogen Loading per Acre (Kg/Acre/Year)	Phosphorus Loading per Acre (Kg/Acre/Year)
A	Loading Per Cropland Acre Per Year	2	3	0.2
B	BMP Effectiveness (% Reduction in Loading)	50%	25%	25%
C= A*B	Reduction in Loading Per Acre Covered by Practice	1	0.75	.05
D	Value Per Unit Load Reduction	$6	$12	To avoid possible overestimation of value, we do not value phosphorus in addition to nitrogen as many studies focus on the value from nutrient reduction rather than separate values for P and N.
E = C *D	Value per Covered Acre, In Field Practice	$6	$9	
F	Covered Acres (Drainage Area) per Edge of Field Buffer	15	15	
G= E*F	Value per Acre of Edge-of-Field Practice	$90	$135	

Source: Highland Economics analysis, data sources provided in sections below.

Table C-2: Value by Practice Per Acre Per Year

Practice Type/Vegetation Type	Value per Acre for Sediment Reduction	Value per Acre for Nutrient Reduction	Total Value per Acre	Eligible Practices (Based on NRCS Physical Effects Rating)
In-Field Practices				
Sediment Loading Reduction Only	$6	N/A	$6	Residue and Tillage Management, No Till; Grazing Land Mechanical Treatment; Critical Area Planting; Forest Farming
Nutrient Loading Reduction Only	N/A	$9	$9	Nutrient Management
Buffer/Edge-of-Field Practices				
Sediment Loading Reduction Only	$90		$90	Grassed Waterway, Vegetative Barrier, Stormwater Runoff Control
Nutrient Loading Reduction Only		$135	$35	Saturated Buffer, Vegetated Treatment Area
Sediment & Nutrient Loading Reduction	$90	$135	$225	Riparian Forest Buffer, Riparian Herbaceous Cover, Conservation Cover, Filter Strip, Constructed Wetland

Source: Highland Economics analysis, data sources provided in sections below.

Effectiveness of Conservation Practices

As noted above, sediment and nutrient pollutant loading of waters is closely tied to rates of erosion.[19] We first present data on total erosion rates from agricultural lands, and then the level of sediment and nutrients loading to waterways from agricultural lands (see Table C-3). We then present data on the effectiveness of conservation practices in reducing sediment and nutrient loading to waterways (see Table C-4).

To estimate sediment and nutrient loading from agricultural lands with and without conservation practices, we rely on data on erosion on Oregon agricultural lands and data on total phosphorus and nitrogen loading from a variety of sources. Table C-3 summarizes available data on agricultural land erosion in Oregon and the Pacific Northwest and associated sediment and nutrient loads. Erosion rates vary widely throughout the state depending on such factors as rainfall, slope, vegetation, soil characteristics, and tillage and irrigation management practices.

Based on the data sources presented in Table C-4, we establish water quality value based on an estimated annual erosion rate of approximately 5 tons per cropland acre per year (Oregon State

[19] It can also be related to livestock presence, however the NRCS physical effects rating does not highly rate access control or other livestock conservation practices as highly or moderately effective in reducing transport of sediment or nutrients to surface waterways.

University Extension, 2003). Of this, we estimate that 40%[20], or 2 tons is carried to waterways, consistent with estimates from the National Resources Inventory on the average water-related erosion from cultivated cropland in Oregon (U.S. Department of Agriculture, 2020). We further estimate, on an average annual basis per acre of cultivated cropland *without conservation practices,* that the nutrient loading from each acre of cropland is approximately 3 kilograms of nitrogen and 0.2 kilograms of phosphorus per acre per year.

[20] This sediment delivery ratio is consistent with data from US Department of Agriculture, see https://efotg.sc.egov.usda.gov/references/public/IA/Erosion_and_sediment_delivery.pdf.

Table C-3: Data on Erosion Rates and Loading from Agricultural Lands

Source	Publication Year	Location	Total Sediment Erosion (Tons/Acre/ Year)	Water-Related Sediment Erosion (Tons/Acre/ Year	Nitrogen Loading (Kg/Acre/ Year)	Phosphorus Loading (Kg/Acre/ Year)
USDA, Natural Resources Inventory	2020 (based on 2017 data)	Oregon Statewide: Cultivated cropland	3.92	2.13		
USDA, Natural Resources Inventory	2020 (based on 2017 data)	Oregon Statewide: CRP Land	1.1	1.1		
Oregon State Extension	2003	Oregon Statewide	Less than 1 to over 15, medium rate of 4 to 6 tons per acre per year			Medium value of 0.1[a]
Wise and Johnson	2011[b]	Oregon and Washington, estimated average stream nutrient loading per agricultural acre			1.5 to 6.0	0.15 to 0.4
Schillinger et al.	2010	Columbia Basin and Columbia Plateau, furrow irrigated	35 to 55 tons			
Schillinger et al.	2010	Columbia Basin, conservation tillage, water erosion	11 to 13 tons			
Kok et al.	2009	Dryland Inland PNW	5 to 20 tons, depending on tillage system			

Sources: (U.S. Department of Agriculture, 2020), (Oregon State University Extension, 2003), (Wise & Johnson, 2011), (Schillinger, Papendick, & McCool, 2010), (Kok, Papendick, & Saxton, 2009)

a/Oregon State Extension publication provides data (based on oil test values) that the concentration of phosphorus in agricultural soils varies across the state, but that medium levels are 60 mg/kg in soils west of the Cascades and 40 mg/kg in soils east of the Cascades. We assume 50 mg/kg on average for agricultural soils statewide. Applying this concentration to an estimated 2 tons of water-related erosion results in an estimated 0.1 kilogram per acre per year of P loading.

b/ Note that these data are from 2011 (See Table 6 in Wise and Johnson), but a recent USDA review of nutrients from agricultural lands notes that nutrient loading has increased nationwide over the last decade, so these estimates may be less than current values.

The literature indicates that the effectiveness of conservation practices can vary widely by site based on factors such as topography, field and crop type, sediment characteristics, climatic conditions, soil water content, surface versus overland flow of water, and buffer vegetation type and width (Helmers, Isenhart, Dosskey, Dabney, & Strock, 2006). Based on numerous literature sources (see Table C-4), we assume an average effectiveness of OAHP program eligible conservation practices in reducing loading of waterbodies by 50% for sediment and 25% for nutrients.

Table C-4: Data on Effectiveness of Conservation Practices in Reducing Erosion and Loading from Agricultural Lands

Source	Publication Year	Location	Practice Type	% Sediment Removal	% Total Nitrogen Removal
Environmental Protection Agency	2021	Nationwide	Riparian Forested Buffer, Grass Buffer, Filter Strips	75% to 97%	25% to 91%
Environmental Protection Agency	2021	Nationwide	Reduced Tillage Systems	55%	45% to 55%
Helmers et al.	2015	Nationwide	Riparian Herbaceous or Forest Buffers, Vegetative Filter Strips, Vegetative Barrier, Grassed Waterways	41% to 100%, average of approximately 50%	7% to 100%
Natural Resources Conservation Service	2007	Nationwide	Filter Strip, Riparian Forest Buffer, Riparian Herbaceous Cover Buffer	40% to 70% are typical	10% to 100%
The Nature Conservancy	2021	Nationwide	Vegetated buffer, Prairie Strip, Saturated Buffer, Wetland, Grassed Waterway	22% to 96%	44% to 84.5%
National Resources Inventory	2020	Oregon	Vegetation Cover (forest planting and critical area planting)	50%[a]	
Salceda et al.	2022	Michigan	Tree and grass buffers on grazed slopes		62% to 85%
Srivastava et al.	2023	Review of Studies	No Till	48% to 72%	
Srivastava et al.	2023	Review of Studies	Filter strips, field borders, grassed waterways	40% to 45%	Up to 80%
Seitz et al.	2019	Switzerland	Reduced tillage in organic farming	61%	
USDA, Rust and Williams		Columbia Plateau, dryland	No till	~50% to nearly 100%	

Source	Publication Year	Location	Practice Type	% Sediment Removal	% Total Nitrogen Removal
Schilling and Wolter	2009	Illinois	Nutrient Management Plan		38%
Hu et al.	2007	Ohio	Nutrient Management Plan		43%
Srivastava et al.	2023	Review of Studies	Nutrient Management Plans		30%

Sources: (Helmers, Isenhart, Dosskey, Dabney, & Strock, 2006); (Oregon Department of Agriculture, 2012) (Environmental Protection Agency, 2021), (Natural Resources Conservation Service, 2007), (The Nature Conservancy, Meridan Institute, Soil and Water Conservation Society, 2021), (U.S. Department of Agriculture, 2020), (Seitz, et al., 2019); (Srivastava, Basche, Traylor, & Roy, 2023), (Rust & Williams)
a/Calculated based on the average reduction in the soil erosion rate reported from cultivated cropland versus CRP lands, assuming that these lands are comparable in other characteristics.

For edge of field buffers that filter sediments and nutrients from a broader drainage area, we estimate that each acre of buffer installed will effectively reduce sediment and nutrient loading from 15 acres at the same level of effectiveness as an in-field conservation practice on 1 acre (i.e., each acre of an edge of field buffer practice will reduce the same amount of sediment and nutrients reaching waterways as 1 acre of in-field practice). Studies on the effectiveness of buffers often vary greatly in the upslope drainage area to buffer area ratio, ranging from 50:1 to 1.5:1 (Helmers, Isenhart, Dosskey, Dabney, & Strock, 2006). The US Department of Agriculture Manual for the design of conservation buffers notes that "lower ratios (e.g., 20:1) can provide substantially greater pollutant removal than higher ratios (e.g., 50:1) in many cases" (USDA National Agroforestry Center, 2008). **We conservatively assume 15 acres of upland drainage area for every 1 acre of buffer, or a ratio of 15:1.** This implies **that each acre of buffer provides the same level of water quality benefit as 15 acres of an in-field conservation practice.**

Overview of Water Quality Benefits & Current Water Quality in Oregon

Improved surface-water quality has many benefits to Oregonians, including:

1. Human health and well-being value from high quality drinking water and household water supplies. People value access to high quality residential water supplies that are both odorless and clear, and do not pose a health threat. Water quality contaminants that pose a health threat include nitrates and heavy metals. High particulates and turbidity can also treatment costs, and if very high, can result in residential and municipal diverters ceasing to draw from a surface water supply, disrupting urban water supplies (McFadin, 2019).
2. Recreational and aesthetic values of clean water bodies. People value clean water bodies, particularly when participating in water-based and shoreline recreation and other shoreline activities where they can see the water. Clean water increases these aesthetic and recreational values.
3. Enhanced income from economic activities reliant on high quality water supplies. This includes the economic value of good quality water for agriculture, and for industrial or commercial activities. Poor quality water, such as high levels of salinity or particulates,

can reduce crop yields, increase treatment costs to industrial or commercial users, and increase costs related to maintenance of reservoirs and rivers (sediment can clog stream channels and reduce storage capacity of reservoirs).

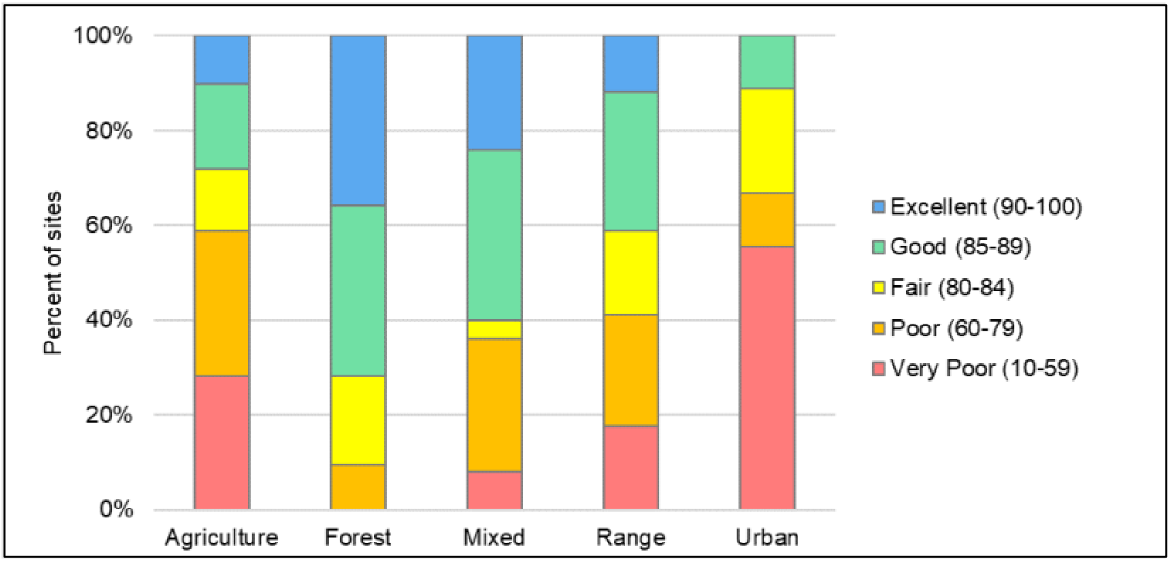
People also value species that are dependent on clean water supplies. This includes the intrinsic value to people of biodiversity, including endangered species, as well as the human use values for species that are commercially important (e.g., for fishing etc.). Fish abundance benefits related to water temperature and other riparian habitat effects are discussed in Appendix D. This section focuses on the non-fish habitat value of water quality listed in points 1 through 3 above in an effort to avoid over-estimating the combined value of water quality and riparian habitat in enhancing fish abundance. To the extent that fish habitat benefits are included in this section, the focus is on nutrient and sediment-specific benefits.

Most studies of the value of water quality improvements are based on the benefits provided by a certain percent improvement in water quality or a change in a water quality index at the watershed level. Nearly all study findings indicate that:

- Americans are willing to pay (through taxes or other measures) for water quality improvement.
- Americans care about water quality because it affects aesthetics of water bodies, aquatic habitat quality and species diversity/abundance, drinking water quality and treatment costs, and recreation opportunity and quality.
- People value local water quality improvements most highly (i.e., water quality improvements in their own watershed), although they also highly value water quality improvements throughout their own state as well as in other states.
- The value of water quality improvements varies depending on the baseline water quality in surface waters; the lower the current quality of water, the more people are generally willing to pay to improve water quality.

As noted in the last bullet above, the value of water quality improvements is typically greatest when water quality is currently impaired. According to the Oregon Department of Environmental Quality, nearly 60% of sites in agricultural areas have an Oregon Water Quality Index rating of "poor" or "very poor", see Figure C-1. Further, according to a 2014 report on Oregon's nutrient management program, the "presence of hazardous algal blooms, primarily in lakes and reservoirs, is an emerging issue at least partially related to excess nutrients in Oregon". The report notes that "while there are no widespread nutrient concerns in the state, excess nutrient loads contribute to localized water quality issues in certain streams, lakes and estuaries. DEQ's overarching objective is to address nutrient inputs where they are contributing to water quality impairments for nuisance algal blooms, dissolved oxygen, chlorophyll and pH." DEQ has developed nutrient load reduction goals for at least 16 waterbodies (with at least two more in development) through development of total maximum daily loads. DEQ identified 32 lakes and reservoirs as impaired due to algal blooms in its 2010 Integrated Report. Table C-5 summarizes current impairments in Oregon waterbodies. These data indicate that water quality improvements in Oregon would likely have significant value.

Figure C-1: Influence of Land Use on Oregon Water Quality Index Scores



Source: From (Oregon Department of Environmental Quality, 2023)

Table C-5: Number of Waterbodies by Basin on Oregon Impaired Waterbody List (303d) by Water Quality Impairment Category

Basin	Number of Waterbodies on 303-List by Impairment									
	BioCriteria	Dissolved Oxygen-Spawning	Dissolved Oxygen-Year-Round	Harmful Algal Blooms	Nitrates-Human Health Criteria	pH	Phosphorus-Aquatic Life Criteria	Sediment-ation	Temperature-Spawning	Temperature-Year-Round
Columbia River	0	0	1	0	0	2	0	0	1	13
Deschutes	23	16	8	7	0	18	10	14	5	119
Goose & Summer Lakes	7	2	2	0	0	0	1	0	0	52
Grande Ronde	10	3	2	0	0	0	1	19	24	105
Hood	9	3	0	0	0	0	0	9	10	16
John Day	36	0	0	0	0	3	0	45	25	159
Klamath	5	0	2	2	0	2	0	17	0	1
Malheur	8	0	2	0	0	0	0	2	0	37
Malheur Lake	8	2	5	0	0	2	0	0	0	45
Mid Coast	34	23	7	3	0	3	0	12	40	107
North Coast	43	12	10	0	0	0	0	0	0	7
Owyhee	0	3	1	0	0	1	1	1	0	16
Powder	2	7	5	0	0	1	1	12	0	59
Rogue	23	3	21	6	0	2	1	10	35	147
Sandy	5	2	1	0	0	0	0	0	14	24
South Coast	27	9	17	1	0	6	0	0	8	139
Umatilla	5	12	3	1	4	0	3	1	1	18
Umpqua	61	0	0	7	0	0	0	0	52	202
Willamette	93	91	39	16	1	12	3	7	77	281
Total	399	188	126	43	5	52	21	149	292	1547

Source: Highland Economics analysis of impaired waterbodies in Oregon's 303d list, accessed at: https://www.oregon.gov/deq/wq/tmdls/pages/default.aspx.

VALUE OF NUTRIENT WATER QUALITY IMPROVEMENTS

Several studies conducted within the last 10 years regarding U.S. household willingness to pay for water quality improvements related to nutrients are summarized in Table C-6 below. **While the values estimated range widely, these studies indicate that the public generally values reducing nutrients to maintain or improve water quality by at least $100 on average per household per year.** As of 2022, there were an estimated 1,726,340 households in Oregon (US Census Bureau, 2022). As such, we expect that, in total, Oregon households value nutrient-related water quality maintenance or improvement (and are willing to pay for it) by at least $172.6 million annually. Given that several values in Table C-6 are for a 25% reduction in nitrogen, this value may equate to a 25% reduction in nitrogen loading in the State of Oregon.

Table C-6: Value to the Public of Water Quality Benefits from Nutrient Reduction (Household Willingness to Pay), 2023 Dollars

Study	Year	Location	Improvement Being Valued	Value per Household per Year
Parthum & Ando	2020	Upper Sangomon River Basin, Illinois	Reduce algal blooms, meet nutrient target, and increase fish populations/diversity	$100
Jakus et al.[a]	2013	Utah	Improve water quality through statewide nutrient reductions in Utah waters (paid for through increased water bill)	$104 to $404
Jakus et al.[a]	2013	Utah	Maintain nutrient conditions/water quality in Utah waters (paid for through increased water bill)	$46 to $190
Yau-Huo and Zhan	2022	Iowa	25% less nitrate in source water, 50% less algal toxin detected in source water and HAB-related beach closure, 10% increase in lake water clarity	$180

Sources: Highland Economics analysis of (Parthum & Ando, 2020), (Jakus, et al., 2013), (Shr & Zhang, 2022)
a/ Original values were $35 to $142 per household per year to maintain water quality and $78 to $303 per year to improve water quality in 2011 dollars. These values were derived by taking the total annual value in Table 5-11 in the report and dividing by the total number of households (user plus non-user) for both the lower bound and the upper bound.

Based on this value, we estimate the potential value to Oregonians of reduced nutrient loading. To reduce possible double counting (since phosphorus and nitrogen have similar types of effects on water quality), we focus on one nutrient: nitrogen. Several of the studies in the literature presented in Table C-6 above are based on a 25% decrease in nitrogen. We use data on the total nitrogen aggregated load (load being defined as exceeding the assimilative capacity of the state's watersheds) in Oregon from the Environmental Protection Agency (EPA)[21] to estimate how many kilograms of nitrogen would equate to a 25% reduction in loading. The EPA estimates that there are 58.5 million kilograms of nitrogen aggregated load in Oregon waterways (US

[21] The EPA website notes that these data are from a US Geological Survey model known as SPARROW.

Environmental Protection Agency, 2023). A 25% reduction of this load would be approximately 14.6 million kilograms less of aggregated nitrogen load entering Oregon waterways.

To estimate the value per kilogram of reduced load, we use the estimate we derived above for the potential value to Oregon residents of a 25% nutrient reduction: $172.6 million. Dividing the $172.6 million value by 14.6 million kilograms of nitrogen yields a value of approximately $12 per kilogram of reduced nitrogen load. This value is similar to a value estimated in a study in Virgina of the value of floodplains in retaining nitrogen of approximately $16 per kilogram per year; with this value based on the minimum cost of alternative methods (by wastewater treatment plants) to reduce nitrogen in waterways (Hopkins, et al., 2018).[22]

Although we don't separately and additively value phosphorus nutrient reduction (to avoid the potential for double counting), we apply the same methods to compare our approach to values from the literature for phosphorous reduction. Using the same methods as for nitrogen, we estimate the water quality value of phosphorus based on 7.97 million kilograms of phosphorus aggregate load in Oregon watersheds statewide (US Environmental Protection Agency, 2023). A 25% reduction in phosphorus would equal approximately 2 million tons of reduced phosphorus entering Oregon waterways. Dividing $172.6 million by 2 million kilograms yields a value of approximately $88 per kilogram of reduced phosphorus load. This is very similar to the benefit value of approximately $83 per kilogram per year estimated in a study in Wisconsin of reducing phosphorus by improving manure management (Sampat, Hicks, Ruiz-Mercardo, & Zavala, 2021).[23]

Finally, another method of valuing reduced nutrient loading is to examine the cost of alternative methods of nutrient load reduction. According to the Environmental Protection Agency (EPA) and other sources, average costs of reducing nutrient runoff from agriculture and urban areas may vary from $4 to $29 per kilogram of nitrogen reduction and can be approximately $99 for phosphorus, see Table C-7 (US Environmental Protection Agency, 2015) (Shaik, Helmers, & Langemeier, 2002).[24]

Based on the consistency between our estimated value and other values from the literature, we estimate a value of $12 per kilogram of nitrogen nutrient reductions from conservation practices.

[22] Original value was $12.69 in 2014 dollars.
[23] Original value was $74.50 in 2021 dollars.
[24] Original values were $1 in 2002 dollars to $9 per pound of nitrogen in 2015 dollars, and $35 per pound of phosphorous in 2015 dollars. These were converted to values per kilogram and expressed in 2023 dollars.

Table C-7: Value of Reduced Nutrient Loading (Per Kg Per Year, 2023 Dollars)

Author	Year	Location	Type of Benefit Analyzed	Cost per kg N	Cost per kg P
Hopkins et al.	2018	Virginia	Sediment/nutrient retention on floodplain, minimum cost of wastewater treatment for N	$16	
Sampat et al.	2021	Wisconsin	Recreation/aesthetic/health benefit of reduced algal blooms from better management of livestock manure		$83
Environmental Protection Agency	2015	Nationwide	Minimum cost of urban nitrogen pollution prevention in stormwater	$29	$99
Shaik et al.	2002		Cost of nitrogen pollution abatement in Nebraska	$4 to $9	

Sources: (US Environmental Protection Agency, 2015), (Shaik, Helmers, & Langemeier, 2002) (Sampat, Hicks, Ruiz-Mercardo, & Zavala, 2021), (Hopkins, et al., 2018)

Value of Sediment Water Quality Improvements

In 2008, the Economic Research Service of the US Department of Agriculture published a study estimating the value of agricultural soil conservation and reduced erosion (Economic Research Service, US Department of Agriculture, 2008). Their study, entitled "Economic Measures of Soil Conservation Benefits: Regional Values for Policy Assessment" estimates values specific to each region of the country for 14 benefit economic categories. Despite capturing wide-ranging benefits, the study does not include several key types of benefits: those related to endangered species, coastal recreational activities, and people's willingness to pay to know that water quality is improved. Another caveat to using the values from this study is that several categories of benefits were estimated several decades ago, and while the values have been adjusted for inflation, the level of benefit may have changed through time. That said, this study is one of the only available direct estimates of the value of sediment reduction and was developed specifically to value the benefits of agricultural conservation, so we use it as the basis for our valuation.

Table C-8 summarizes the values for the Pacific region, which includes Oregon, Washington, and California. As shown in the bottom row of the table, **reduction in water-related erosion in the Pacific region is valued at approximately $6 per ton per year**. This is the value we use in the methodology for the water quality benefit of reduced sediment loading. As a second source, we draw from a 1987 study of the avoided costs in the Willamette Valley of reduced sedimentation (Moore & McCarl, 1987). This study quantified fewer benefit categories, focusing on benefits related to dredging, roads, ditches, water treatment plants, and hydropower, and estimated a value of approximately $2 per ton per year. For comparison to the 2008 US Department of Agriculture study, we sum only the values from the benefit categories in the 2008 study that were included in McCarl and Moore's estimate of $2 per ton per year. Summing the values from the 2008 study for 'irrigation ditches and canals', 'road drainage ditches', 'municipal water treatment', and 'steam power plants' results in a corresponding value of $2.90 per ton per year, which is fairly compatible with the $2 per ton per year estimate from the Willamette Valley study. While these two studies were either completed several decades ago or partially rely on data that is several decades old, the similarity of findings gives some reassurance that our estimate of $6 per ton per year for reduced sediment loading may be approximately accurate.

Table C-8: Value of Reduced Sediment Loading (Per Ton Per Year, 2023 Dollars)

Category	Pacific Region Estimated Value (ERS, USDA, 2008)
Irrigation ditches and canals	$1.71
Road drainage ditches	$0.34
Municipal water treatment	$0.79
Flood damages	$0.55
Marine fisheries	$0.71
Freshwater fisheries	$0.00
Marine recreational fishing	$0.82
Municipal and industrial use	$0.29
Steam powerplants	$0.07
Soil productivity	$0.67
Dust cleaning	$1.91
Total wind-related	$2.59
Total water-related	$5.94

Source: (Economic Research Service, US Department of Agriculture, 2008)

Value Per Acre of Wetland Water Purification Services

Finally, as an alternative reference point, we estimate value based on findings in the literature on the value of water quality services provided by wetlands, as constructed wetlands are an eligible water quality conservation practice. Numerous economic studies have estimated the value of wetlands, with many of them focusing on the value of water quality services provided by these areas – typically based on the replacement cost of alternative water quality treatment facilities or surveys of the value that households are willing to pay for clean water. Two meta-analyses indicate that the value of wetlands for water quality varies tremendously from study to study. A 2001 review of 39 studies estimated that with 90% confidence, the value of water quality enhancement from wetlands likely ranges between approximately $260 and $2,800 per acre per year, with an average value of $560 per acre (Woodward & Wui, 2001). A 2006 review of 80 studies found an even larger range of water quality values form wetlands: approximately $120 to $30,000 per acre per year (Brander, Raymond, Florax, & Vermaat, 2006).[25] As noted by one of the studies, "From our analysis it is clear that the prediction of a wetland's value based

[25] The $120 per acre per year value (in 2023 dollars) was a median value of wetland services in literature Brander et al. and presented in the original study as approximately $26 per hectare per year in 1995 values. Woodward and Wui (2001) cited values of$126, $417, and $1,378 per acre per year in 1990 dollars for the lower limit, average, and upper limit values, respectively, which were adjusted to 2023 values.

on previous studies is, at best, an imprecise science" (Woodward & Wui, 2001). While predicting a single wetland's value using the available literature is highly uncertain, these two literature reviews indicate that our estimated value of up to $225 per acre for wetlands and other similar practices that provide water filtration services is a reasonable and conservative value.

Appendix D: Data to Support Aquatic Habitat Values

Numerous NRCS conservation practices can be effective for aquatic habitat. However, most of these are in-water restoration measures that are not expected to be eligible practices in the proposed payment for ecosystem services program. The primary land-based conservation practice that is most relevant for aquatic habitat value is riparian restoration. This includes riparian forest buffers, as well as the following practices, if they are in the riparian zone: windbreak/shelterbelt establishment and renovation, tree/shrub establishment, restoration and management of rare or declining habitats, forest farming, and wildlife habitat planting. These are the practices that the NRCS physical effects system rated as providing substantial improvement (a 5 rating) or moderate to substantial improvement (a 4 rating) for 'elevated water temperature' or for 'aquatic habitat for fish and other organisms'.

This section focuses on the effectiveness and value of riparian habitat to provide shade/ lower stream temperatures and provide key stream inputs such as large woody debris to support fish and other aquatic species. Riparian buffers also provide (and are valued for, as discussed in Appendix C) nutrient and sediment reductions that improve water quality and provide aquatic habitat benefits. So as to not over-value the combined benefit of buffers related to water quality and aquatic habitat, we use a conservative value of $150 per acre to estimate the additional habitat value (i.e., additional to sediment and nutrient water quality benefits) provided by practices that establish riparian forest vegetation.

There is strong precedent for public investments in riparian preservation and restoration. The State of Oregon has invested significantly in conserving riparian habitats to enhance and preserve aquatic habitat. As a recent example, the program costs of the 2022 draft Habitat Conservation Plan for western Oregon State forests is estimated at $3.6 million annually, or a total of $250 million over the 70-year permit term; this plan covers 10 species of fish, 2 birds, 3 salamanders and 2 mammals (ICF, 2022). Riparian zones are the focus for fish species while habitat conservation areas are the primary focus for other species.

Effectiveness of Riparian Conservation Practices

The Oregon Conservation Strategy defines flowing water and riparian habitat together as a strategy habitat because their "conservation roles are interconnected". As noted in the Strategy, healthy riparian vegetation "protects banks from erosion, influences in-channel aquatic habitats, maintains favorable water temperature for fish through shading, filters runoff, and provides nutrients to support terrestrial and aquatic life (Oregon Department of Fish and Wildlife, 2016)."

A separate publication about riparian areas from the Salmon and Trout Enhancement Program of the Oregon Department of Fish and Wildlife notes that "shade created by the riparian vegetation moderates water and air temperatures...Stream food chains depend on organic debris for nutrients. In small headwater streams, 99% of the energy for organisms comes from the vegetation along the stream, and only 1% from photosynthesis. The leaves, needles, cones, twigs, wood, and bark dropped into a stream are a storehouse of readily available organic material that is processed by aquatic organisms and returned to the system as nutrients and energy" (Oregon Department of Fish and Wildlife).

Several entities in Oregon are restoring riparian vegetation with the goal of reducing stream temperatures and improving aquatic habitat. These efforts follow on the heels of an innovative program in the Tualatin River watershed. In 2004, the Oregon Department of Environmental Quality approved a plan for a wastewater and stormwater utility to invest in the restoration of 35 river miles of riparian habitat to meet a temperature water quality requirement. The utility discharges effluent from four wastewater treatment plants into the Tualatin River. Restoration included planting riparian forests (of 45-foot buffer width on each side of the stream) to provide shade to water upstream of the wastewater facilities and to augment stream flows. Comparatively, installing and operating two water chillers would have cost the utility $93.7 million; as such riparian restoration provided cost savings of $75.8 million[26] (Niemi, Lee, & Raterman, 2006).

While people value many aspects of healthy aquatic habitats, fish population diversity and abundance are of key importance for many Oregonians. As such, this analysis focuses on the effectiveness of riparian vegetation conservation practices in enhancing fish populations, and the associated value to the public of fish population diversity and abundance as indicated by surveys of household values and data on the value of recreational fishing.

The scientific literature indicates that there is a strong link between riparian vegetation, water temperature, and fish abundance. Additionally, several studies in the Pacific Northwest have noted the increasing importance of riparian vegetation to help mitigate adverse effects on cold water fishes such as salmonids of rising temperatures from climate change. Table D-1 summarizes findings from several studies conducted in the Pacific Northwest evaluating how riparian buffer restoration in the Pacific Northwest influences fish abundance. As shown in the table, fish abundance response varies by species, timeframe of restoration, and type restoration. However, several studies indicate that for every one percent of riparian area restoration in a basin or river, some salmon species respond with an approximate one percent increase in fish abundance, or even greater.

[26] The source cited cost savings of $50.5 million in 2005 dollars; this study adjusted value to 2023 dollars.

Table D-1: Summary of Literature: Fish Abundance Response to Riparian Buffer Restoration

Study	Year	Geography	Riparian Restoration Area	Fish Population Response
Justice et al.	2017	Upper Grande Ronde River, OR	Buffers in entire watershed at full maturity (benefits increase most dramatically in first 25 years)	(Spring Chinook) 46,000 fish to 222,000, (377% increase)
			Buffers in highest 25% priority riparian areas at full maturity	(Spring Chinook) 46,000 to 93,000 (100% increase)
		Catherine Creek	Buffers in entire watershed at full maturity	(Spring Chinook) 55,000 to 88,000 (61% increase)
			Buffers in highest 25% priority riparian areas at full maturity	(Spring Chinook) 55,000 to 71,000 (30% increase)
Battin et al.[a]	2007	Snohomish River Basin, Western WA	Riparian restoration on 30% or less of watershed (to bring buffers to 40% to 84% of riparian area), off-channel habitat, barrier removal,	Baseline of ~6100 fish. Increase of 49% to 58% in population over no restoration scenario with climate change
Opperman & Merenlender[b]	2004	Mendocino County, CA	Riparian restoration and exclusionary fencing	Improved large woody debris, temperature, channel morphology
Lewis et al.	2022	Salmon River, Oregon Coast	Barrier removal, off channel habitat area, hatchery removal on 50 miles	0.79% increase in statewide coho salmon population
Sievers et al.	2017	Global meta-analysis	Riparian restoration (livestock exclusion, large woody debris); Too limited data to draw conclusion on riparian revegetation	Average increases: 87.7% trout increase for livestock exclusion; 66.6% trout increase for large woody debris
Fullerton et al.	2022	Snoqualmie River, WA	Full or partial riparian restoration for shading	~30% increase in mass of potential Chinook yearlings under climate change around Year 2090. ~12% to 15% increase in mass of potential yearlings under historical climate (1995-2005). Very limited effect on sub yearlings.

Study	Year	Geography	Riparian Restoration Area	Fish Population Response
Fogel et al.	2022	Chehalis River Basin, WA	Riparian tree planting and protection for temperature reduction	All populations expected to decline by mid-century (spring Chinook, fall Chinook, steelhead, and coho) due to climate change. Relative to current population size, riparian restoration reduced the adverse impact of climate change on populations by ~5% to 30%.
Jones et al.	2006	Georgia	Riparian buffers (30 m versus 15 m)	Wider buffers have lower temperatures, less fine sediment and higher trout populations (expected 87% higher population).

Sources: Highland Economics analysis of (Justice, White, McCullough, Graves, & Blanchard, 2017), (Battin, et al., 2017) (Opperman & Merenlender, 2004), (Sievers, Hale, & Morrongiello, 2017), (Fullerton, Sun, Baerwalde, Hawkins, & Yan, 2022), (Fogel, et al., 2022), (Jones, Poole, Meyer, Bumback, & Kramer, 2006), (Lewis, Kling, Dundas, & Lew, 2022)

a/ The study estimated effects on salmon population with two models. In one model, the starting population was 6,096 fish, which the study modeled would decrease by 40% under climate change but with restoration would decrease by 5%. The other model starting population was 6,174 fish, and under climate change and no restoration would decrease by 20%, but with restoration and climate change would increase by 19%. Applying these percents to the starting population and comparing the projected future salmon population with and without restoration, we estimate results in a 49% salmon population increase in one model (7,347 fish compared to 4939 fish) and a 58% population increase in the other model (5,865 fish compared to 3,704 fish).

b/ This study noted that positive riparian change may attract fish from elsewhere rather than increase total population.

Conservation Value of Aquatic Habitat & Fish

Table D-2 summarizes the value to households of a few recent water quality studies that focus on the value to households of improving aquatic habitat conditions. As shown in the table, the values in these studies range from approximately $130 to $300 per household per year. If we assume that this value includes the value for nutrient-related water quality of $100 per household per year discussed in Appendix C, then the non-nutrient value to households may be approximately $30 to $200 per household per year of minimum to 25% improved aquatic conditions statewide.

Table D-2: Value to the Public of Improving Aquatic Habitat Conditions or Fish Populations (Household Willingness to Pay, $2023)

Study	Year	Location	Improvement Being Valued	Value per Household per Year (2023 values)
Habitat Conditions				
Vossler et al.	2023	Midwest	One-level improvement in biological condition gradient (a water quality index) through a multi-state study area	$300
Vossler et al.	2023	Midwest	Achieve minimum water quality statewide to support biological uses	$268
Haefen et al.	2023	North Carolina	Urban stream water quality improvement through 25% increase in urban stream canopy and decreased runoff	$127
Fish Abundance				
Lewis et al.	2022	Oregon and Washington	One year increase in Coho abundance in Pacific Northwest by 1,000 fish, or a 0.67% increase in fish abundance	$0.08 (no college degree) to $0.19 (college degree)

Sources: (Vossler, et al., 2023) (Haefen, et al., 2023) Highland Economics analysis of (Lewis, Kling, Dundas, & Lew, 2022).
a/Derived based on a value of $252 per mile, assumption of a 50-foot buffer on each side of the river for 12 acres per river mile, applied to the population of the county in the year 2000.

Table D-2 also showcases a recent study of Pacific Northwest households that valued an increase of 1,000 fish (0.67 percent increase) in coho salmon populations at $0.08 (no college degree) to $0.19 (four-year college degree) per household per year. Focusing specifically on Oregon, we apply Census data that approximately 36 percent of Oregonians older than 25 years have a four-year college degree and estimate a weighted average value to Oregon households of $0.12 per household per year per 1,000 coho fish. As noted above in Appendix C, there are approximately 1,726,000 households in Oregon as of 2022. Thus, this study indicates that Oregon households would value an annual increase of 1,000 coho fish (or a 0.67% increase) at approximately $206,000 annually.

Several older studies have also examined the value of fish to residents of the Pacific Northwest. In Olsen *et al.* (1991), researchers surveyed residents on their values for salmon and steelhead in the Pacific Northwest. Households that do not fish had an average willingness to pay of approximately $65 per year to double the population of fish, while households that do fish had an average willingness to pay of approximately $180 (Olsen, Richards, & Scott, 1991).[27] While

[27] The study's original values ($26.52 and $74.16, respectively, in 1989 dollars) were updated to 2023 dollars using the GDP price deflator.

this was roughly one-third the willingness to pay of fishing households, the study indicates that non-anglers in the Pacific Northwest still value improvements to fish populations.

In 1996, Loomis measured the value to survey respondents of removing two dams on the Elwha River in Washington State, which would restore an anadromous fishery. Surveyed households included those in the dams' host county (Clallam), those in the State of Washington, and those in the rest of the country. Households were asked if they would be willing to vote for a referendum that would increase their taxes to pay for the dams' removal, effectively measuring their willingness to fund efforts to restore the fish population. Results indicated that Clallam County residents would be willing to pay approximately $120 per year, Washington residents would be willing to pay approximately $145 per year, and US residents outside of Washington would be willing to pay an average of approximately $135 per year (Loomis, 1996).[28]

In 1998, Layton *et al.* surveyed over 1,600 Washington State households to elicit household values for programs that increase the populations of migratory, freshwater, and saltwater fish in the Columbia River and the Puget Sound area. The results showed that Washington households, on average, were willing to pay approximately $20 to $60 per month to increase fish populations by 50 percent (Layton *et al.*, 1999).[29] In Bell *et al.* (2003), researchers surveyed five coastal communities in Oregon regarding their willingness to pay for local coho salmon enhancement programs. Findings indicate that households were willing to pay approximately $70 to $200 per year to prevent the species from going extinct to $140 to $210 per year to double the population, depending on the community and the household income (Bell *et al.*, 2003).[30]

In summary, these studies show that households may be willing to pay from approximately $50 to over $200 per year for increasing local, regional, or state-wide populations of all migratory fish populations by 50 percent to 200 percent (Bell, Huppert, & Johnson, 2003; Layton, Brown, & Plummer, 1999). In contrast, the value estimated just for Coho from the more recent 2023 study by Lewis et al. would estimate a value of $8 to $30 per household of an improvement of 50 percent to 200 percent of coho populations. Comparing these studies indicates that the value to Oregonians of increased abundance for all salmonid species may be much higher than the value estimated by Lewis et al. for just coho species abundance.

To apply these estimated conservation values to potential fish population increases that would result from riparian restoration is highly uncertain. However, doing so will give a sense of the potential magnitude of value to Oregon households of riparian restoration. **Considering all the values presented above regarding the potential value to households of improved aquatic habitat conditions and salmonid fish abundance, we estimate that the habitat value to households of riparian restoration throughout the state may be approximately $75 per**

[28] The study's original values ($59, $73, and $68, respectively, in 1994 dollars) were updated to 2023 dollars using the GDP price deflator.

[29] The study's original values ($9.92 and $31.28, respectively, in 1998 dollars) were updated to 2023 dollars using the GDP price deflator.

[30] The study's original values ($41.13, $115.54, $78.15, and $121.81, respectively, in 2000 dollars) were updated to 2023 dollars using the GDP price deflator.

household per year. Applying this value to the estimated 1.73 million households in the state translates to approximately $129.5 million in value annually.

To express this value on a per acre basis for riparian areas, we first approximate the potential riparian acreage in Oregon, assuming all streams are buffered at 25 feet on both sides or 50 feet on one side. According to the Department of Fish and Wildlife, there are approximately 106,400 miles of rivers and streams in Oregon (Oregon Department of Fish and Wildlife, 2003). Assuming a riparian buffer width of 50 feet there are 6 acres of buffer per river mile, such that statewide there would be approximately 645,000 acres of riparian buffer. Dividing the estimated $129.5 million value to Oregon households by this acreage translates to approximately $200 per acre per year for the aquatic habitat benefit to salmonids of riparian areas; to account for the fact that some of this value may be captured in the water quality estimate for sediment and nutrients**, we propose a value of $150 per acre per year for additional aquatic habitat value from riparian restoration.** Also, as noted above, relatively high values are still held by households that do not fish, indicating that a relatively high portion of this value is for conservation value and not recreational value.[31]

This value per acre of riparian habitat is within the range of several other values from the economics literature. One study found that households were willing to pay an average of $443 per year[32] to restore a 45-mile section of the Platte River in Colorado, which would provide benefits of dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation (Loomis, Kent, Strange, Fausch, & Covich, 2000). A survey of households in North Carolina indicated that households were willing to pay around $60 per year[33] to restore just a six-mile section of the upper Little Tennessee River (to enhance presence of game fish, water clarity, wildlife habitats in the riparian buffer, recreational opportunities, and ecosystem integrity (Holmes, Bergstrom, Huszar, Kask, & Orr III, 2004).

Recreation Fishing Value of Aquatic Habitat & Fish

As another approach to estimating the value to society of improved aquatic habitat, we examine the value of recreational fishing in Oregon. Numerous studies have found that the value of recreational fishing generally increases with increased abundance of fish (because per trip value is higher or because total trips taken is higher) and with enhanced scenery (Melstrom, Lupi,

[31] These non-use or existence values are generally higher for rare habitats or species (such as those classified as Threatened or Endangered), due to their relative scarcity, than for abundant species or habitats. Additionally, existence values are higher for iconic species, such as salmon. People's non-use values for salmon may be based on personal beliefs and moral ethics (i.e., believe enhancing salmon populations is the right thing to do), altruism (i.e., believing salmon should be abundant so that others can use it or benefit from salmon), and/or a desire to bequest the resource (i.e., believing salmon should be abundant for future generations). The most common way to measure value of a species such as salmon to people is through surveys in which people are asked about their willingness to pay to protect the species. These surveys are highly challenging to develop and implement well, and results from different surveys aiming to measure similar changes in resources can be highly variable.

[32] The source cited a value of $252 per year in 1998 dollars; this study adjusted value to 2023 dollars.

[33] The source cited a value of $34 per year in 1998 dollars; this study adjusted value to 2023 dollars.

Esselman, & R, 2014) (Solomon, et al., 2020). Both these attributes can be enhanced by riparian vegetation.

We estimate the total value of fishing trips in Oregon based on data on the number of fishing trips taken and the value per fishing trip. Table D-3 summarizes the estimated number of fishing trips in Oregon for salmon, steelhead, and trout fishing based on existing survey data and previous studies. Freshwater fishing trips are based on data from the following two studies: the 2011 US Fish and Wildlife Service Survey of Hunting, Fishing, and Wildlife Viewing in Oregon and a 2008 study sponsored by ODFW on Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon. Using these studies, we estimate that there are approximately two million fishing trips annually for freshwater salmon/steelhead fishing and approximately the same number for trout fishing. For saltwater salmon angling, we use the estimate developed by the Oregon Ocean Salmon Management Program at ODFW: 67,000 annual saltwater salmon fishing trips.

Table D-3: Oregon Recreational Fishing Effort, Angler Trips (2023 Dollars)

Data	Source			Estimated Total Trips
	US Fish and Wildlife Service Survey, 2011 (Anglers 16+)	Dean Runyan Associates Survey (for ODFW), 2008	Ocean Salmon Management Program, ODFW, 2010-2020	
Salmon & Steelhead Fishing (Freshwater)	2,396,000[a]	1,859,000		2,000,000
Trout Fishing	2,175,000[a]	1,713,000		2,000,000
Salmon Fishing (Saltwater)	270,000[b]	328,000	67,000	67,000[c]

Source: Highland Economics analysis of (Ocean Salmon Management Program, Oregon Department of Fish and Wildlife, 2020), (Dean Runyan Associates, 2009) (Pacific Fishery Management Council, 2021).
a/ Data were presented as fishing days; this is converted to the estimated number of trips based on the average number of days fishing on all freshwater fishing trips for all species.
b/ Data were presented as fishing days; this is converted to the estimated number of trips based on the average number of days fishing on all saltwater fishing trips for all species.
c/ ODFW Ocean Salmon Management Program data is expected to be more accurate than the other sources, which are surveys of licensed anglers. Note that relative to freshwater fishing, where there are many more anglers and fishing days, the % error of margin in surveys for saltwater fishing estimates is expected to be larger.

There is a large body of literature estimating the net economic value of recreational fishing trips to anglers. This analysis focuses on studies of angling in the Pacific Northwest. The value of a fishing trip or a fish caught can vary widely depending on the target species, the abundance of fish and associated catch rate, the aesthetics and quality of the surrounding environment, and the characteristics and demographics of the angler. The economics literature generally presents the net value of recreational fishing two ways: the extra value to the angler for each additional fish caught, and the value to the angler per fishing day or per fishing trip. We focus on the economic value to the angler per fishing trip.

Estimates of the economic value of recreational angling in the Pacific Northwest tend to fall between $70 and $90 per day. For example, a 2017 review conducted for the US Forest Service of diverse types of outdoor recreation found that across many studies of different target species, bodies of water and angling techniques, the average value estimated for the recreation net benefit of freshwater fishing in the Pacific Northwest is $89 per day (Rosenberger, White, Kline, & Cvitanovich, 2017).[34] Similarly, a 2018 study sponsored by the Oregon Parks and Recreation Department used a value of approximately $97 per fishing day[35] (saltwater and freshwater) to estimate the net economic value of fishing participation in Oregon (Rosenberger, 2018). A 2008 study sponsored by WDFW estimated the value of a salmon/steelhead fishing day (freshwater and saltwater) at approximately $85 per day, and the value of trout fishing at approximately $75 per day[36] (TCW Economics, 2008).

Most fishing trips in the Pacific Northwest are day fishing trips, so the value per trip is similar (although slightly higher since some fishing trips are multiple days) than the value per fishing day. We conservatively assume that the value per Oregon fishing trip is similar to the per day values cited above and apply a mid-range value per fishing trip of $85 per salmon/steelhead fishing trip and $75/trout fishing trip. With these data, we estimate that recreational fishing in the State of Oregon has an annual net value to recreators of approximately $320 million (see Table D-4).

Table D-4: Estimated Annual Net Value to Anglers of Recreational Fishing in Oregon

Type of Fishing Trip	Estimated Value per Trip	# of Annual Trips	Estimated Current Annual Net Economic Value to Anglers
Salmon/Steelhead	$85	2,000,000	$170,000,000
Trout	$75	2,000,000	$150,000,000
Total		4,000,000	$320,000,000

Source: Highland Economics analysis of (Ocean Salmon Management Program, Oregon Department of Fish and Wildlife, 2020), (Dean Runyan Associates, 2009) (Pacific Fishery Management Council, 2021), (TCW Economics, 2008), (Rosenberger, White, Kline, & Cvitanovich, 2017).[37]

We assume that statewide recreational fishing value would increase with additional riparian restoration and the associated fish abundance increase. In other words, we expect that fishing value increases with fish abundance and that fish abundance increases with riparian restoration. As presented above in Table D-1, the data indicate that at least for some fish species, there may be a 1:1 ratio of the percent riparian area restored and the percent increase in fish abundance in a basin (i.e., for every 1% increase in riparian arear there may be a 1% increase in fish abundance). As the precise relationships is not known, in Table D-5 we present potential combinations of statewide riparian restoration acreage with increases in statewide fishing value. Depending on the relationship between recreational fishing value and riparian restoration, the value may be as low as $50 per acre of riparian (if there is only a 5% increase in fishing value from 50% of riparian areas statewide restored) to over $1,200 (if there is a 25% increase in

[34] The study value was $71.52 in 2017 dollars.
[35] The study value was $81.37 in 2018 dollars.
[36] The study values were $58 per day and $50 per day in 2006 dollars for salmon/steelhead and trout fishing, respectively.
[37] The study value was $71.52 in 2017 dollars.

fishing value from 10% of statewide riparian buffers are restored). As highlighted in bold values in the table, **an increased value to recreational anglers of approximately $150 to $500 per restored riparian acre per year restored appears reasonable** (assuming a 1% increase in recreational fishing value for every 2% to 4% of statewide riparian area restored). This provides further support for the estimated $150/riparian acre/year value used for additional aquatic habitat benefits, over and above benefits related to nutrients and sediment.

Table D-5: Approximate Potential Sport Fishing Value Per Acre per Year of Riparian Buffer Restoration (2023 Dollars)

% Riparian Buffers Restored on Oregon Streams and Rivers (Increased Riparian Acreage)	Potential % Increased Sport Fishing Value (Increased $ value)				
	5% ($16,000,000)	**10% ($32,000,000)**	**15% ($48,000,000)**	**20% ($64,000,000)**	**25% ($80,000,000)**
10% (64,485 acres)	**$248**	**$496**	$744	$992	$1,241
20% (128,970 acres)	$124	**$248**	**$372**	$496	$620
30% (193,455 acres)	$83	**$165**	**$248**	**$331**	$414
40% (257,939 acres)	$62	$124	**$186**	**$248**	$310
50% (322,424 acres)	$50	$99	$149	**$198**	**$248**

Source: Highland Economics analysis.

APPENDIX E: DATA TO SUPPORT TERRESTRIAL HABITAT VALUES

The Oregon Conservation Strategy identifies 11 native strategy habitats of conservation concern and 249 species of greatest conservation need. Habitats of conservation concern include aspen woodlands, coastal dunes, estuaries, flowing water and riparian habitats, grasslands, late successional mixed conifer forests, natural lakes, oak woodlands, ponderosa pine woodlands, sagebrush habitats, and wetlands. These habitats and species are distributed across the state, with 206 priority conservation areas identified across the state, as shown in red in the figure below from the Oregon Conservation Strategy. Each of Oregon's eight ecoregions has at least four habitats of conservation concern that provide important benefits to strategy species (Oregon Department of Fish and Wildlife).

Figure E-1: Oregon Habitat Conservation Opportunity Areas

Source: https://www.oregonconservationstrategy.org/conservation-opportunity-areas/

As shown in Table E-1, conservation practices expected to be eligible for payment are practices that either establish or maintain vegetated habitat areas, and that the NRCS physical effects rating identifies as providing 'moderate to substantial improvement' or 'substantial improvement'. Several NRCS conservation practices that are rate highly for effectiveness for terrestrial habitat that do not establish or maintain natural vegetation areas are not included. As such, this methodology focuses solely on areas managed for terrestrial habitat.

Table E-1: Proposed Habitat Value for Eligible Agricultural Conservation Practices

Type of Eligible Practice	Aquatic (Fish) Habitat	Terrestrial Habitat	Maximum Habitat Value	Eligible Practices
In-Field Practice		$100	$100	Pasture and Hay Planting
Edge of Field Practice				
Riparian Trees/Shrubs	$150	$100	$250	Riparian Forest Buffer, Tree/Shrub Establishment, Wildlife Habitat Planting Forest Farming, Restoration and Management of Rare or Declining Habitats
Riparian Trees/Shrubs	$150			Windbreak/Shelterbelt Establishment and Renovation, Wetland Wildlife Habitat Management
Non-Riparian Trees/Shrubs		$100		Wildlife Habitat Planting, Restoration and Management of Rare or Declining Habitats
Wetland		$150	$150	Wetland Creation, Wetland restoration
Grass/shrub habitat		$100	$100	Wildlife Habitat Planting, Upland Wildlife Habitat Management, Wetland Wildlife Habitat Management, Restoration and Management of Rare or Declining Habitats, Early Successional Habitat Development/Mgt.

Note: Estimated habitat value per acre is equal to the maximum value listed in Table E-1; multiple habitat practices implemented on one acre will not increase the habitat payment.

We include both an aquatic value (presented in Appendix D) and a terrestrial value for riparian habitats (presented in this Appendix). In discussing riparian habitats, in addition to discussing their value for fish and other aquatic organisms, the Oregon Conservation Strategy notes: “riparian habitats often have high species diversity and are critical for wildlife. These habitats are important to species that prefer moist shrubby or forested habitats. Riparian areas provide essential wintering habitat and travel corridors for birds, amphibians, reptiles, mammals, and other wildlife. In arid areas, such as the Blue Mountains and Columbia Plateau ecoregions, riparian habitats can provide abundant insects, plants, and moisture throughout the year. Riparian meadows include natural spring-seep habitats that are extremely important for a wide variety of species, including Greater Sage-Grouse chicks and butterflies” (Oregon Department of Fish and Wildlife, 2016). As such, this methodology includes both a value for terrestrial habitat and value for aquatic habitat for riparian areas.

Forests and Grasslands Habitat Value

A meta-analysis of 12 US studies conducted in 2008 (Randall, Kidder, & Chen, 2008) examined 23 valuations of terrestrial habitat to estimate the value of the Conservation Reserve Program (now referred to as the Conservation Reserve Enhancement Program), a program of the US Department of Agriculture that removes land from agricultural production in order to enhance habitat, water quality, and soil quality.[38] The study found that the average value per acre per year of each type of service provided by this type of land, in 2023 dollars, is $85 for open space provision, $66 for aesthetic viewing, and $100 for habitat. For habitat, the confidence interval was $30 to $330 per acre per year. We focus on the habitat benefit alone as open space and aesthetic benefits may accrue from all farmlands and may not increase with habitat-enhancing conservation practices.

Similarly, a 2022 global review of the value of grassland ecosystem services estimated the value of habitat services from temperate grasslands at $262 per acre per year (Liu, Hou, Kang, Nan, & Huang, 2022). This value is based on the genetic diversity value of habitat. Other types of ecosystem services separately valued in this study (and therefore are not encompassed in the $262 per acre per year value) include services related to water quality, water quantity regulation, climate regulation, soil fertility and food supply, and recreation.

Specific to forestland, an analysis of the habitat value (among many other ecosystem services) of private forestland in Georgia found that habitat services may vary from approximately $0 to acre to $346 per acre per year, depending on forest characteristics. This value includes values for overall biodiversity but does not include the value of habitat in terms of maintenance of game species and the associated recreation benefit. A review conducted for valuation of forests in Europe concluded that forestland value for habitat may have a mean value of $167 to $229 per acre per year.

Actual payments in Oregon by the Conservation Reserve Enhancement Program (CREP)[39] vary by county based on soil type and dryland cash rent values. In 2023, the CREP rental rate in Oregon was as high as $117 per acre (and as low as $13 an acre) (Farm Service Agency, US Department of Agriculture, 2023). Since these cash rents are based on the value of land in agricultural uses, they don't directly reflect the value of conserving the land for wildlife habitat. However, the payments do indicate that the state and federal governments are willing to pay at least $117 for the habitat and other ecosystem service benefits that accrue from these lands.

Table E-2 summarizes the habitat value of grassland and forestland estimated in these data sources. Based on these sources, we propose a conservative habitat value of $100 per acre per year.

---

[38] With the aim of improving soil and water quality and wildlife habitat, the CRP "removes environmentally sensitive land from agricultural production and plants species that improve environmental health and quality" (Farm Service Agency, US Department of Agriculture, 2023).

[39] CREP is a collaboration between state and federal governments and is part of the Conservation Reserve Program. CREP is only applicable in certain states, including Oregon.

Table E-2: Trees/Shrubs/Grassland Habitat Values by Source (2023 Dollars)

Source	Year	Location	Study Type	Habitat	Habitat / Biodiversity Services ($/Acre/Year)	Other Services Separately Valued[1]
Randall et al.[2]	2008	US	Meta-Analysis	Terrestrial	$100	Aesthetics, Open Space
Liu et al.[3]	2022	Global	Meta-Analysis	Grassland	$253 (Genetic Diversity)	Water treatment, recreation, food and water supply, climate regulation
Farm Service Agency (Conservation Reserve Enhancement Program in Oregon)	2023	Oregon	Cash payments for grasslands	Grassland	$13 to $117	N/A
Moore, et al.	2011	Georgia	Survey	Forests	$0 to $346	Timber products, recreation, water quantity, water quality, soil stabilization/formation, pollination, aesthetic/cultural/passive use
Grammatikopoulou and Vackarova	2021	Forests in Europe	Meta-Analysis		$167 to $229 (mean values)	Timber, air quality, climate regulation, leisure, erosion control, water quantity/quality

Sources: (Randall, Kidder, & Chen, 2008), (Liu et al. 2022) (Farm Service Agency, 2023), (Briceno et al 2023), (Moore, Williams, Rodgriuez, & Hepinstall-Cymmerman, 2011), (Grammatikopoulou & Vackarova, 2021)
1/Separately valued and not included in the habitat value.

WETLANDS HABITAT VALUE

Values of wetland habitat from the economic literature vary broadly, ranging from a few dollars per acre up to hundreds of thousands of dollars per acre. Value varies depending on the type and location of the wetland, types of ecosystem services provided, and study methodology. In general, the highest values provided by wetlands are associated with the provision of the following ecosystem services: a) water quality enhancement (as discussed in Appendix C), b) carbon storage (as discussed in Appendix B), and biodiversity and habitat (discussed in this Appendix). Other key benefits of wetlands include flood regulation and storm buffering and aesthetic views and open space. Depending on the population, socioeconomic activities, and land uses near the wetland location, habitat and biodiversity ecosystem services from wetlands can translate into economic, social, and cultural benefits related to recreation, food provision (e.g., from hunting), and the scenic amenity of habitat. Additionally, many people directly value habitat function and species preservation. The following section summarizes the magnitude of these values as estimated in the natural resource economics literature.

One 2008 review and meta-analysis of US wetland valuation studies aimed to use values from the economics literature to quantify the economic benefits of U.S. agricultural conservation programs (Randall, Kidder, & Chen, 2008). For wetland habitat, the study identified 72 valuations of wetland habitat from 34 US studies. This study found that the average value per acre per year of all services provided by freshwater wetlands was approximately $600 per acre per year.

A 2006 review of 215 wetland value observations obtained from 80 studies found an *average* value of habitat and nursery services from wetlands of approximately $4,700 annually, but a much lower *median* value of approximately $270 per acre per year (Brander, Raymond, Florax, & Vermaat, 2006). Further, a 2001 review of 39 wetland valuation studies estimated average wetland value for habitat services per acre at $630 per acre per year (Woodward & Wui, 2001), with a 90 percent confidence interval of $200 to $2,000 per acre per year.

As another approach, we review the value per acre that the NRCS is paying for wetlands as part of the Wetland Reserve Easement (WRE) program. As part of its Agricultural Conservation Easement Program, NRCS purchases WRE on private farmland. The easement value is based on the lowest of the following three values: an appraisal, a Geographic Area Rate Cap (GARC), or a landowner offer. In Oregon for Fiscal Year 2024, the GARC for WRE payment for a permanent easement in Oregon is $5,000 per acre (Natural Resources Conservation Service, 2023). However, payment may exceed this cap if there is a high likelihood of successful restoration that will provide habitat needs for federally listed Threatened and Endangered species. Converting the one-time payment value of $5,000 per acre to an annual value (over 50 years using a 3% discount rate), indicates that NRCS is willing to pay approximately $195 per acre per year for an acre of wetland in Oregon. This payment is based on the agricultural value of the land but indicates that NRCS expects that the value of all ecosystem services from wetlands on farms is at least $195 per acre.

WRE payments are intended to compensate landowners for the value of their land in exchange for restoring habitat areas; by enrolling in the WRP, landowners sell most of their use rights with the exception of hunting, fishing, and other recreational use. In other words, WRE payments do not represent the value of the wetland habitat, but rather the difference in the market value of the land with and without the easement. However, the WRE payments nonetheless indicate government agencies' willingness to pay for the habitat and other benefits provided by wetlands.

As another approach, we review the price of credits in regional wetland mitigation banks. Wetland mitigation banks are wetlands that have been created or restored to offset the loss of wetlands elsewhere in the region due to development or other causes. The price of wetland mitigation banking provides a useful reference point because it indicates the cost of providing wetland benefits through alternative means. Because wetland mitigation is typically required by law to ensure continued provision of ecosystem services, the public policy of requiring mitigation indicates that the perceived value of benefits of ecosystem services provided by mitigated wetlands outweigh the costs of mitigation.

The Oregon Department of State Lands (DSL) administers the State's wetland mitigation program and provides a calculator to compute the costs of DSL-provided wetland mitigation for payment in-lieu of mitigation. According to this calculator, the cost of purchasing DSL-provided wetland mitigation credits that fund restoration projects throughout the State ranges from roughly $34,000 to $65,000 per acre, assuming 1 mitigation credit per acre (Oregon Department of State Lands, 2021).[40] The value range reflects different costs of restoration in different basins of Oregon where the restoration occurs. Amortizing over 50 years at a 3 percent discount rate, this equates to a cost of approximately $1,300 per acre per year to $2,500 per acre per year.

Table E-3 summarizes the values described above from the literature. As noted above, wetlands differ in type and quality, and both ecological and economic benefits from their protection vary by location. In addition, wetland benefits are not constant for every acre, but vary depending on size and configuration. The values presented in Table E-3 however indicate that the proposed value for habitat services from wetlands, $150 per acre per year, is likely a conservative estimate of habitat value.

[40] This calculation is based on a real market value of land conservatively set at $900 per acre, which is the 2022 value of pasture in the state (cropland was valued at an average of $3650 per acre in 2022). As with other values in this report, the mitigation cost in the calculator was adjusted for inflation to 2023 dollars using the GDP Implicit Price Deflator. The default value in the calculator is 3.5 for the number of mitigation credits for each mitigated acre; we converted this to 1 to show the cost of restoring 1 acre.

Table E-3: Wetland Values from Economic Literature, 2023 dollars

Source	Year	Location	Study Type	Service Valued	Value ($/Acre/Year)
Randall et al.	2008	US	Meta-Analysis	All wetland services	\$360 (10th percentile value) \$600 (average value) \$1,000 (90th percentile value)
Brander et al.	2006	Global	Meta-analysis	Habitat and nursery services	\$270 (Median value) \$4,700 (Average value)
Woodward & Wui	2001	US	Meta-Analysis	Habitat	\$200 (10th percentile value) \$630 (Average value) \$2,000 (90th percentile value)
NRCS	2023	Oregon	GARC Payment for Permanent Wetland Easement, Annualized	All services	\$195
Oregon Department of State Lands	2021	Oregon	In-Lieu Payment / Cost per Acre of Wetland Mitigation	All Services	\$1,300 (lease cost basin) \$2,500 (max cost basin)

Sources: (Randall, Kidder, & Chen, 2008) (Woodward & Wui, 2001) (Brander, Raymond, Florax, & Vermaat, 2006) (Natural Resources Conservation Service, 2023) (Oregon Department of State Lands, 2021)

Appendix F: Potential Role of the CMP Review Committee: Prioritization of Funding/Project Selection

Only practices on farms and ranches vetted and approved through the OAHP Conservation Management Plan (CMP) advisory committee are expected to receive funding. While the valuation methodology establishes a flat value for each eligible conservation practice, site-specific factors and the role of the proposed practices in addressing known conservation issues and challenges could be considered in the CMP review process. We recommend that the committee take the following site-specific factors into account:

- **Practice implementation specifics.** A given conservation management practice may have many implementation options, with differing levels of value provided. For example, riparian buffers can be planted using bare-root trees or large container trees. Large container trees are more expensive but would be expected to provide environmental benefits and economic value much more quickly. Further, pasture and hay planting or range planting can establish a non-native or native stand. CMP advisory committee discretion in selecting and funding of the most appropriate implementation level of a given practice will enhance value provided per conservation dollar.

- **Additionality.** To what extent would OAHP funding increase environmental benefits provided? What would likely happen without OAHP funding of practices? The methodology allows payment for practices that are already in place to allow compensation of early adopters and current environmental stewards, but the program effect on environmental outcomes may be more limited if many payments are made to support existing practices or land uses.

- **Existing conditions of the farm/ranch.** Certain sites may be particularly degraded and provide opportunities for the greatest environmental uplift from a given practice. For example, for water quality, a small proportion of lands often have an outsized effect on water quality. Paying for water quality-related practices on these lands will have the greatest environmental benefit and economic value. Similarly, implementing habitat enhancement practices on sites currently providing little habitat value would be expected to provide higher environmental uplift and associated economic value, all else equal. Similarly, soils with low current carbon content may provide the greatest opportunity for increased soil carbon from a given practice.

- **Site-specific/location value considerations**. For habitat and water quality, certain sites may have a much greater potential value per acre. For habitat, properties in key migratory corridors or providing scarce habitat types may have higher value for habitat restoration or enhancement. For water quality, farms and ranches located in watersheds with threatened/endangered fish bearing streams, high recreation values, or municipal water supply values that are impacted by water quality impairments may have higher economic value for a given level of environmental benefit.

- **Regional considerations / cumulative effects**. For habitat and water quality, the role and importance of the proposed conservation practices in each CMP relative to the cumulative restoration actions being conducted at the watershed level or regional level should also be considered. CMP's that play a key role in supporting a larger-scale restoration or conservation effort will likely have greater value.

This type of review process will enhance cost effectiveness and benefit maximization as the review committee will have the discretion to prioritize funding to practices on farms and ranches that are expected to provide the most environmental benefit for the conservation dollar.

REFERENCES

Adhikari, K., Owens, P. R., Libohova, Z., Miller, D. M., Wills, S. A., & Nemecek, J. (2019). Assessing soil organic carbon stock of Wisconsin, USA and its fate under future land use and climate change. *Science of The Total Environment*, 833-845.

Battin, J., Wiley, M., Ruckelshaus, M., Palmer, R., Korb, E., Bartz, K., & Imaki, H. (2017). Projected impacts of climate change on salmon habitat restoration. *PNAS*, 6720-6725.

Blanco-Canqui, H. (2022). Blanco-Canqui, H. (2022). Cover crops and carbon sequestration: Lessons from US studies. *Soil Science Society of America Journal*, 501-519.

Bouchard, M., Butman, D., Hawbaker, T., Li, Z., Liu, J., Liu, S., . . . Sohl, T. (2011). *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in the Great Plains Region of the United States.* Reston, VA: U.S. Geological Survey.

Brander, L., Raymond, J., Florax, G., & Vermaat, J. (2006). The Empirics of Wetland. Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature. *Environmental and Resource Economics*, 223-250.

Bureau of Economic Analysis. (2023). National Income and Product Accounts, Table 1.1.9. Implicit Price Deflators for Gross Domestic Product. Retrieved from https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey

Cai, A., Han, T., Ren, T., Sanderman, J., Rui, Y., Wang, B., . . . Xu, M. (2022). Declines in soil carbon storage under no tillage can be alleviated in the long run. *Geoderma*, 116028.

CarbonCredits.Com. (2023, August 1). *ICVCM's New Framework: Raising the Bar for Carbon Credits*. Retrieved from Carbon Credits: https://carboncredits.com/icvcms-new-framework-raising-the-bar-for-carbon-credits/

California Air Resources Board. (2024). *Cap-and-Trade Program Data Dashboard*. Retrieved from California Air Resources Board: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/program-data/cap-and-trade-program-data-dashboard

Christensen, G. A., Gray, A. N., Kuegler, O., & Yost, A. C. (2019). *Oregon Forest Ecosystem Carbon Inventory: 2001-2016.* Oregon Department of Forestry and US Forest Service.

Creed, I. F., Badiou, P., Enanga, E., Lobb, D. A., Pattison-Williams, J. K., Lloyd-Smith, P., & Gloutney, M. (2022). Can Restoration of Freshwater Mineral Soil Wetlands Deliver Nature-Based Climate Solutions to Agricultural Landscapes? *Frontiers in Ecology and Evolution*, 932415.

Crystal-Ornelas, R., Thapa, R., & Tully, K. (2021). Soil organic carbon is affected by organic amendments, conservation tillage, and cover cropping in organic farming systems: A meta-analysis. . *Agriculture, Ecosystems and Environment*, 107356.

Dangal, S. R., Schwalm, C., Cavigelli, M. A., Gollany, H. T., Jin, V. L., & Sanderman, J. (2022). Improving Soil Carbon Estimates by Linking Conceptual Pools Against Measurable Carbon Fractions in the DAYCENT Model Version 4.5. *Journal of Advances in Modeling Earth Systems*, e2021MS002622.

Dean Runyan Associates. (2009, May). *Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon: 2008 State and County Expenditure Estimates.* Retrieved from Oregon Department of Fish and Wildlife: https://www.dfw.state.or.us/agency/docs/report_5_6_09--final%20(2).pdf

Economic Research Service, US Department of Agriculture. (2008, September). *Economic Measures of Soil Conservation Benefits: Regional Values for Policy Assessment.* Retrieved from Economic Research Service, US Department of Agriculture: https://www.ers.usda.gov/webdocs/publications/47548/11516_tb1922.pdf?v=0

Economic Research Service, US Department of Agriculture. (2008, September). *Economic Measures of Soil: Regional Values for Policy Assessment.* Retrieved from Economic Research Service, US Department of Agriculture: https://www.ers.usda.gov/webdocs/publications/47548/11516_tb1922.pdf?v=0

Environmental Protection Agency. (2021, December). *Stomrwater Best Management Practices: Riparian/Forested Bufer.* Retrieved from Environmental Protection Agency: https://www.epa.gov/system/files/documents/2021-11/bmp-riparian-forested-buffer.pdf

Environmental Protection Agency. (2022). Land Use, Land-Use Change, and Forestry. In *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020* (pp. 422-600). Washington, D.C.

Environmental Protection Agency. (2023, November). *Report on the Social Cost of Greenhouse Gases: Incorporating Recent Scientific Advances.* Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

Fargione, J., Bassett, S., Boucher, T., Birdgham, S., Conant, R., Cook-Patton, S., . . . Griscom, B. (2018). Natural Climate Solutions for the United States. *Science Advances*.

Farm Service Agency, US Department of Agriculture. (2023). *Final 2023 Grassland Rental Rates.* Retrieved from Conservation Reserve Program Statistics: https://www.fsa.usda.gov/programs-and-services/conservation-programs/reports-and-statistics/conservation-reserve-program-statistics/index

Fischer, P. W., Cullen, A. C., & Ettl, G. J. (2017). Fischer, P. W., Cullen, A. C., & Ettl, G. J. (2017). The effect of forest management strategy on carbon storage and revenue in western washington: a probabilistic simulation of tradeoffs. *Risk Analysis*, 173-192.

Fogel, C., Nicol, C., Jorgensen, J., Beechie, T., Timpane-Padgham, B., Kiffney, P., . . . Winkowski, J. (2022). How riparian and floodplain restoration modify the effects of increasing temperature on adult salmon spawner abundance in the Chehalis River, WA. *PLOS ONE*.

Fullerton, A., Sun, N., Baerwalde, M., Hawkins, B., & Yan, H. (2022). Mechanistic Simulations Suggest Riparian Restoration Can Partly Counteract Climate Impacts to Juvenile Salmon. *JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION*.

Gattinger, A., M. A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., . . . Niggli, U. (2012). Enhanced top soil carbon stocks underorganic farming. *PNAS*, 18226–18231.

Grammatikopoulou, I., & Vackarova, D. (2021). The value of forest ecosystem services: A meta-analysis at the European scale and application to national ecosystem accounting. *Ecosystem Services*.

Guillozet, K. (2016). Understanding restoration and transaction costs in a payment for ecosystem service water quality market in Oregon, USA. *Vertigo*.

Haefen, R., Van Houtven, G., Naumenko, A., Obenoui, D., Miller, J., Kenney, M., . . . Waters, H. (2023). Estimating the benefits of stream water quality improvements in urbanizing watersheds: An ecological production function approach. *Environmental Sciences Sustainabilty Science*, 1-10.

Helmers, M. J., Isenhart, T., Dosskey, M., Dabney, S., & Strock, J. (2006, August 24). *Buffers and Vegetative Filter STrips.* Retrieved from Environmental Protection Agency: https://www.epa.gov/sites/default/files/2015-07/documents/2006_8_24_msbasin_symposia_ia_session4-2.pdf

Holmes, T., Bergstrom, J., Huszar, E., Kask, S., & Orr III, F. (2004). Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration. *Ecological Economics, 49*, 19-30. Retrieved from https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=42604&content=PDF

Hoover, C. M., Bagdon, B., & Gagnon, A. (2021). *Standard Estimates of Forest Ecosystem Carbon for Forest Types of the United States.* Madison, WI: US Forest Service, General Technical Report NRS-202.

Hopkins, K., Noe, G., Franco, F., Pindilli, E., Gordon, S., Metes, M., . . . Hogan, D. (2018). A method to quantify and value floodplain sediment and nutrient retention ecosystem services. *Journal of Environmental Management*, 65-76.

ICF. (2022, February). *Western Oregon State Forests Habitat Conservation Plan Public Draft.* Retrieved from Oregon Department of Forestry: https://media.fisheries.noaa.gov/2022-03/wosf-hcp-feb-2022.pdf

Indigo. (2021). *Enrich your soil, improve your profit potential with Carbon by Indigo*. Retrieved from Indigo: https://www.indigoag.com/carbon/for-farmers

Jakus, P., Kealy, M., Loomis, J., Nelson, N., Ostermiller, J., Stanger, C., & von Stackelberg, N. (2013, April). *Economic Benefits of Nutrient Reductions in Utah's Waters.* Retrieved from Utah Department of Environmental Quality: https://documents.deq.utah.gov/water-quality/standards-technical-services/DWQ-2020-000676.pdf

Jones, K., Poole, G., Meyer, J., Bumback, W., & Kramer, E. (2006). Quantifying Expected Ecological Response to Natural Resource Legislation: a Case Study of Riparian Buffers, Aquatic Habitat, and Trout Populations. *Ecology and Society*.

Jordon, M., Willis, K., Bürkner, P., Haddaway, N., Smith, P., & Petrokofsky, G. (2022). Temperate Regenerative Agriculture practices increase soil carbon but not crop yield—a meta-analysis. *Environmental Research Letters*, 093001.

Justice, C., White, S. M., McCullough, D. A., Graves, D. S., & Blanchard, M. R. (2017). Can stream and riparian restoration offset climate change impacts to salmon populations? *Journal of Environmental Management*, 212-227.

Kok, H., Papendick, R. I., & Saxton, K. E. (2009). STEEP: Impact of long-term conservation farming research and education in Pacific Northwest wheatlands. *Journal of Soil and Water Conservation*, 253-264.

Lewis, D. J., Kling, D. M., Dundas, S. J., & Lew, D. K. (2022). Estimating the value of threatened species abundance dynamics. *Journal of Environmental Economics and Management*.

Liu, H., Hou, L., Kang, N., Nan, Z., & Huang, J. (2022). The economic value of grassland ecosystem services: A global meta-analysis. *Grassland Research*.

Locus Agriculture. (2020). *The carbon farming program farmers have been waiting for*. Retrieved from Locus Agriculture: https://locusag.com/CarbonNOW/

LOCUS Agriculture. (2023). *When Do Farmers Get Paid*. Retrieved from LOCUS Agriculture: https://locusag.com/carbonnow/#:~:text=With%20CarbonNOW%2C%20growers%20get%20paid,after%20year%2Dend%20data%20collection.

Loomis, J., Kent, P., Strange, L., Fausch, K., & Covich, A. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological Economics, 33*, 103-117. Retrieved from http://rydberg.biology.colostate.edu/bz580/readings/7%20-%20Social%20Perspective/Loomis%20et%20al.%20(2000).pdf

McFadin, B. (2019). Planning, Stewardship & Compliance Assurance North Coast Region Water Quality Control Board.

Melstrom, R., Lupi, F., Esselman, P., & R, S. J. (2014). Valuing recreational fishing quality at rivers and streams. *Water Resources Research*.

Moore, R., Williams, T., Rodgriuez, E., & Hepinstall-Cymmerman, J. (2011, January). *Quantifying the value of non-timber ecosystem services from Georgia's private forests.* Retrieved from Georgia Forestry Foundation: https://gatrees.org/wp-content/uploads/2020/02/Quantifying-the-Value-of-Non-Timber-Ecosystem-Services-from-Georgias-Private-Forests.pdf

Moore, W., & McCarl, B. (1987). Off-Site Costs of Soil Erosion: A Case Study in the Willamette Valley. *Western Journal of Agricultural Economics*, 42-49.

Nahlik, A. M., & Fennessy, M. S. (2016). Carbon storage in US wetlands. *Nature Communications*.

Natural Resources Conservation Service. (2007, June). *Technical Note: Riparian Buffer Design and Species Considerations.* Retrieved from Natural Resources Conservation Service: https://www.nrcs.usda.gov/plantmaterials/idpmstn7248.pdf

Natural Resources Conservation Service. (2012, December). *Conserving Prairie Pothole Wetlands: Evaluating Their Effects on Carbon Sequestration in Soils and Vegetation.* Retrieved from Natural Resources Conservation Service: https://www.nrcs.usda.gov/publications/ceap-wetland-2012-PrairiePotholeWetlandsCarbonSequestration.pdf

Natural Resources Conservation Service. (2023, June). *OTAC Review of FY24 Geographic Area Rate Cap and Wetland Restoration Criteria Guide.* Retrieved from Natural Resources Conservation Service: https://www.nrcs.usda.gov/sites/default/files/2023-06/ACEP%20Presentation%20for%20OTAC%20June%202023.pdf

Natural Resources Conservation Service. (2024). *Oregon Payment Schedule.* Retrieved from Natural Resources Conservation Service: https://www.nrcs.usda.gov/conservation-basics/conservation-state/oregon/payment-schedule

Niemi, E., Lee, K., & Raterman, T. (2006). *Net Economic Benefits of Usign Ecosystem Restoration to Meet Stream Temperature Requiremetns.* Eugene: EcoNorthwest.

Ocean Salmon Management Program, Oregon Department of Fish and Wildlife. (2020, November 25). *Angler Effort Table.* Retrieved from Ocean Salmon Management Program, Oregon Department of Fish and Wildlife: https://dfw.state.or.us/MRP/salmon/Historical_Data/docs/AngEffTable.pdf

Opanda, S. (2023, July 10). *Carbon Credit Pricing Chart: Updated 2023*. Retrieved from 8 Billion Trees: https://8billiontrees.com/carbon-offsets-credits/new-buyers-market-guide/carbon-credit-pricing/

Opperman, J., & Merenlender, A. (2004). The Effectiveness of Riparian Restoration for Improving Instream Fish Habitat in Four Hardwood-Dominated California Streams. *North American Journal of Fisheries Management*, 822-834.

Oregon Department of Agriculture. (2012, September). *Oregon Agricultural Water Quality Report* . Retrieved from Oregon Department of Agriculture: https://www.oregon.gov/oda/shared/Documents/Publications/NaturalResources/ORAgWaterQualityReport.pdf

Oregon Department of Agriculture. (2017, December). *Agricultural Water Quality Management Program: Monitoring Strategy.* Retrieved from Oregon Department of Agriculture: https://www.oregon.gov/oda/shared/Documents/Publications/NaturalResources/AgWQStrategy.pdf

Oregon Department of Environmental Quality. (2023). *2022 Integrated water Quality Report*. Retrieved from Oregon Department of Environmental Quality: https://storymaps.arcgis.com/stories/88524b36780f4a4f8169d9f2a699da33

Oregon Department of Environmental Quality. (2023, February). *Oregon Water Quality Index Data Summary Water Years 2013-2022.* Retrieved from https://www.oregon.gov/deq/wq/Documents/WQ2022datasummary.pdf

Oregon Department of Fish and Wildlife. (2003, August). *LIttle Known Facts About Oregon's STreams*. Retrieved from Natural Resources Information Managemnet Program: https://nrimp.dfw.state.or.us/nrimp/feature/2003/08-2003.htm

Oregon Department of Fish and Wildlife. (2016). *Flowing Water and Riparian Habitats*. Retrieved from Oregon Conservation Strategy: https://www.oregonconservationstrategy.org/strategy-habitat/riparian-habitats-and-flowing-water/

Oregon Department of Fish and Wildlife. (2016). *Flowing Water and Riparian Strategy*. Retrieved from The Oregon Conservation Strategy: https://oregonconservationstrategy.org/strategy-habitat/riparian-habitats-and-flowing-water/

Oregon Department of Fish and Wildlife. (n.d.). *Riparian areas: The Stream Scene: Watersheds, Wildlife and People.* Retrieved from The Salmon and Trout Enhancement Program, Oregon Department of Fish and Wildlife: https://www.dfw.state.or.us/fish/STEP/docs/SS6_RiparianAreas.pdf

Oregon Department of State Lands. (2021, June 1). *Compensating for Permanent Impacts: Payment Calculator for DSL-provided Wetland Mitigation.* Retrieved from Oregon Department of State LAnds: https://www.oregon.gov/dsl/wetlands-waters/pages/mitigating-impacts.aspx

Oregon State University Extension. (2003). *Agricultural phosphorus management: Using the Oregon/Washington Phosphorus Indexes, EM 8848-E.* Retrieved from Oregon State University Extension: https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8848.pdf

Pacific Fishery Management Council. (2021, February 16). *Review of 2020 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan.* Retrieved from Pacific Fishery Management Council: https://www.pcouncil.org/documents/2021/02/review-of-2020-ocean-salmon-fisheries.pdf/

Parthum, B., & Ando, A. (2020). Overlooked Benefits of Nutrient Reductions in the Mississippi River Basin. *Land Economics*, 589-607.

Perez-Blanco, C. D., Hrast-Essenfelder, A., & Perry, C. (2020). Irrigation Technology and Water Conservation: A Review of the Theory and Evidence. *Review of Environmental Economics and Policy*.

Randall, A., Kidder, A., & Chen, D.-R. (2008). Meta Analysis for Benefits Transfer – Toward Value Estimates for Some Outputs of Multifunctional Agriculture. *12th Congress of the European Association of Agricultural Economists (EAAE).*

Riley, A. L. (2009). *Putting a Price on Riparian Corridors as Water Treatment Facilities.* Oakland, CA: San Francisco Bay Regional Water Quality Control Board.

Rosenberger, R. S. (2018). *Oregon Outdoor Recreation Metrics: Health, Physical Activity, and Value 2019-2023 Oregon Statewide Comprehensive Outdoor REcreation Plan Supporting Documentation Part B: Total Net Economic Value from Residents' Outdoor Recreation Participation in Oregon.* Oregon Parks and Recreation Department, State of Oregon, Oregon State University.

Rosenberger, R. S., White, E. M., Kline, J. D., & Cvitanovich, C. (2017). *Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits from the National Forest System.* US Forest Service.

Rust, B., & Williams, J. (n.d.). *Technical Note: How Tillage Affects Soil Erosion and Runoff.* Retrieved from US Department of Agriculture: https://www.ars.usda.gov/ARSUserFiles/20740000/PublicResources/How%20Tillage%20Affects%20Soil%20Erosion%20and%20Runoff.pdf

Sampat, A., Hicks, A., Ruiz-Mercardo, G., & Zavala, V. (2021). Valuing economic impact reductions of nutrient pollution from livestock waste. *Resources, Conservation and Recycling*.

Schillinger, W., Papendick, R., & McCool, D. (2010). Soil and Water Challenges for Pacific Northwest Agriculture. In T. Zobeck, & W. Schillinger, *Soil and Water Conservation Advances in the United States* (pp. 47-79). Madison, WI: SSSA Special Publication 60.

Schuster, L., Taillardat, P., Macreadie, P., & Malerba, M. (2024). Freshwater wetland restoration and conservation are long-term natural climate solutions. *Science of the Total Environment*.

Seitz, S., Goebes, P., Puerta, V. L., Pereira, E. I., Wittwer, R., Six, J., . . . Scholten, T. (2019). Conservation tillage and organic farming reduce soil erosion. *Agronomy for Sustainable Development*.

Shaik, S., Helmers, G., & Langemeier, M. (2002). Direct and Indirect Shadow Price and Cost Estimates of Nitrogen Pollution Abatement. *Journal of Agricultural and Resource Economics*, 420-432.

Shr, Y.-H., & Zhang, W. (2022, July). *Omitted Downstream Attributes and the Economic Benefits of Nutrient Reductions: Working Paper 21-WP 620.* Retrieved from Center for Agricultural and Rural Development Iowa State University: https://www.card.iastate.edu/products/publications/pdf/21wp620.pdf

Sievers, M., Hale, R., & Morrongiello, J. (2017). Do trout respond to riparian change? A meta-analysis with implications for restoration and managemen. *Freshwater Biology*.

Smith, P. (2004). How long before a change in soil organic carbon can be detected. *Global Change Biology*.

Sohngen, B., & Brown, S. (2008). Extending timber rotations: Carbon and cost implications. *Climate Policy*, 435-451.

Solomon, C., Dassow, C., Iwicki, C., Jensen, O., Jones, S., Sass, G., . . . Whittaker, D. (2020). Frontiers in modelling social–ecological dynamics o frecreational fisheries: A review and synthesis. *Fish and Fisheries*.

Spawn, S. A., Lark, T. J., & Gibbs, H. K. (2019). Carbon emissions from cropland expansion in the United States. *Environmental Research Letters*, 045009.

Srivastava, S., Basche, A., Traylor, E., & Roy, T. (2023). The efficacy of conservation practices in reducing floods and improving water quality. *Frontiers in Environmental Science*.

Tan, Z., Liu, S., Sohl, T. L., & Young, C. J. (2015). Ecosystem carbon stocks and sequestration potential of federal lands across the conterminous United States. *Ecology*, 12723-12728.

Tan, Z., Liu, S., Sohl, T. L., Wu, Y., & Young, C. J. (2015). Ecosystem carbon stocks and sequestration potential of federal lands across the conterminous United States. *Proceedings of the National Academy of Sciences*, 12723-12728.

Tangen, B., & Bansal, S. (2020). Soil organic carbon stocks and sequestration rates of inland, freshwater wetlands: Sources of variability and uncertainty. *Science of the Total Environment*.

TCW Economics. (2008, December). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Retrieved from Washington Department of Fish and Wildlife: https://wdfw.wa.gov/sites/default/files/publications/00464/wdfw00464.pdf

The Nature Conservancy, Meridan Institute, Soil and Water Conservation Society. (2021, February). *Leading at the Edge.* Retrieved from The Nature Conservancy: https://www.nature.org/content/dam/tnc/nature/en/documents/EOF_Report_LORES_SPREADS.pdf

U.S. Department of Agriculture. (2020, September). *2017 National Resources Inventory Summary Report.* Retrieved from Natural Resources Conservation Service: https://www.nrcs.usda.gov/sites/default/files/2022-10/2017NRISummary_Final.pdf

US Census Bureau. (2022). *US Census Bureau*. Retrieved from DPO2 Selected Social Characteristics in the United States from American Community Survey 1-Year EStimates Data Profiles: https://data.census.gov/table?q=oregon+households&g=010XX00US

US Environmental Protection Agency. (2006). *Carbon Sequestration in Agriculture and Forestry: Representative Carbon Sequestration Rates and Saturation Periods for Key Agricultural and Forestry Practices.* US EPA.

US Environmental Protection Agency. (2015, May). *A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution.* Retrieved from US Environmental Protection Agency: https://www.epa.gov/sites/default/files/2015-04/documents/nutrient-economics-report-2015.pdf

US Environmental Protection Agency. (2023, July 5). *Estimated Total Nitrogen and Total Phosphorus Loads and Yields Generated within States*. Retrieved from Nutrient Policy and Data: https://www.epa.gov/nutrient-policy-data/estimated-total-nitrogen-and-total-phosphorus-loads-and-yields-generated

US Forest Service, Oregon Department of Forestry. (2019, October 29). *Oregon Forest Carbon Inventory: 2001-2016.* Retrieved from Oregon Department of Forestry: https://www.oregon.gov/odf/ForestBenefits/Documents/Forest%20Carbon%20Study/OR-Forest-Ecosystem-Carbon-2001-2016-Report-FINAL.pdf

US Geological Survey. (2023, March). *Climate Warming is Likely to Cause Large Increases in Wetland Methane Emissions*. Retrieved from US Geological Survey: https://www.usgs.gov/news/featured-story/climate-warming-likely-cause-large-increases-wetland-methane-emissions

USDA National Agroforestry Center. (2008, September). *Conservation Buffers: Effective Buffer Area Ratio.* Retrieved from Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways: https://www.fs.usda.gov/nac/buffers/docs/conservation_buffers.pdf

Vossler, C., Dolph, C., Finlay, J., Keiser, D. A., King, C. L., & Phaneu, D. (2023). Valuing improvements in the ecological integrity of local and regional waters using the biological condition gradient. *Environmental Sciences*.

Ward, F. A., & Pulido-Velazquez, M. (2008). Water conservation in irrigation can increase water use. *PNAS*, 18215-18220.

Wise, D. R., & Johnson, H. M. (2011). Surface-Water Nutrient Conditions and Sources in the United States Pacific Northwest. *Journal of the American Water Resources Association*, 1110-1135.

Woodward, R., & Wui, Y.-S. (2001). The economic value of wetland services: a meta-analysis. *Ecological Economics*, 257-270.

Woodward, R., & Wui, Y.-S. (2001). The economic value of wetland services: a meta-analysis. *Ecological Economics*, 257-270.

World Agrofrestry Centre. (n.d.). *Measurement and Monitoring Soil Carbon: How much will it cost*. Retrieved from https://apps.worldagroforestry.org/soc/index5.html

Zhang, X., Lark, T. J., Clark, C. M., Yuan, Y., & LeDuc, S. D. (2021). Grassland-to-cropland conversion increased soil, nutrient, and carbon losses in the US Midwest between 2008 and 2016. *Environmental Research Letters*, 054018.