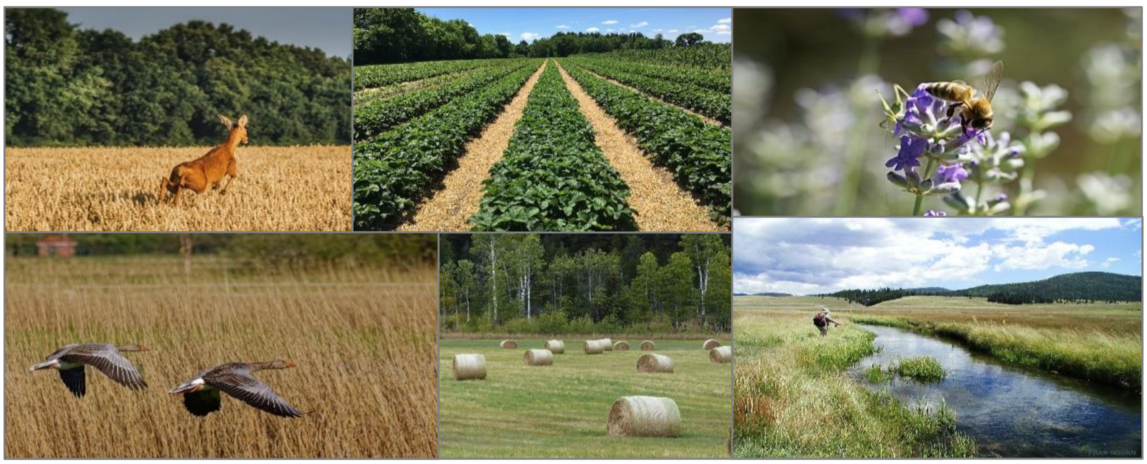
Review & Feasibility Determination of Methodologies for Valuing Agricultural Conservation Management Actions

June 29, 2019



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EXECUTIVE SUMMARY

The Oregon Agricultural Heritage Program (OAHP) was established by the State Legislature in 2017 (State of Oregon, n.d.). The OAHP authorizes a new grant program for farmers and ranchers to help protect farmland and maintain agricultural working lands in the State of Oregon. The OAHP includes the Oregon Agricultural Heritage Fund that will provide grants for working lands conservation easements (permanent and temporary), as well as conservation management plans that support one or more natural resource values (including maintaining or enhancing fish and wildlife habitat, improving water quality, or supporting other natural resource values consistent with the social and economic interests of the agricultural owner/operator). In determining how to value implementation of conservation management plans, the Oregon Agricultural Heritage Commission, which oversees OAHP investments, identified two methods of paying landowners: 1) payment based on land lease rates, management costs, and foregone income, 2) payment based on the value to the public of environmental benefits, or public benefits, provided by conservation practices (Oregon Agricultural Heritage Commission, 2019). The purpose of this report is to determine whether this second, outcome-based payment option is feasible with currently available science and methodologies.

Environmental benefits are environmental goods and services that people care about, including open space amenities, water supplies, water quality, fish and wildlife habitat, and sequestration and storage of carbon to mitigate climate change. Agriculture can both positively and negatively affect the quality and quantity of these environmental goods and services (adverse effects may include use or depletion of water supplies or runoff from agricultural fields that decreases water quality in adjacent waterbodies), and conservation practices can both enhance positive impacts and mitigate adverse impacts.

Given the importance of agricultural lands and agricultural practices on the provision of environmental benefits, there is a large body of research from scientists in our state and throughout the Nation on agricultural land management and the environmental benefits of specific agricultural conservation practices. To a lesser extent, there is research on the social and economic value of these environmental benefits resulting from conservation practices. This research serves as the basis for the

Key Terms

Conservation Management Plans: Plans that identify conservation practices that will help steward the resources on a farm or ranch, including soil, water, air, plant and animal resources.

Agricultural conservation practices: Practices implemented by farmers and ranchers that improve resource management and either enhance environmental benefits from agricultural landscapes or minimize adverse environmental effects of agricultural production.

Environmental benefits: Provision of environmental goods and services that people care about, including water supplies, water quality, wildlife habitat, climate regulation, and flood reduction/water storage.

Public value of conservation practices: The economic and social value to the public of enhanced environmental benefits resulting from conservation practices. While many conservation practices enhance agricultural productivity and increase private economic value to the farmer/rancher, this analysis focuses exclusively on the value to the public of environmental benefits and does not evaluate the value of increased agricultural income/productivity.

determination of feasibility of a payment system based on benefits provided by agricultural conservation practices.

Project Purpose

The goal of this report is to review the available science and economics research in order to determine whether it is feasibility to value the environmental benefits to the public of agricultural conservation practices in Oregon (and thereby implement a payment system based on public value). If feasible, the ultimate goal is to develop a methodology that will compensate and incentivize landowners to provide valuable environmental benefits, with the potential ancillary benefit of simultaneously enhancing the productivity and financial viability of working agricultural lands in the State (as many conservation practices can have a positive return on investment for ranchers and farmers). The criteria for such a valuation methodology, as established by the Oregon Agricultural Heritage Commission (OAHC), is that the methodology provide certainty for landowners and the OAHC, as well as be fair, transparent, and easy and inexpensive to implement statewide. Such a valuation methodology would have long-term policy, budget, and land use ramifications for the state, and would also be economically important for landowners and the public in general.

Agricultural lands have long been recognized in Oregon as providing a host of environmental benefits that are valued by the public.[1] While some agricultural practices can have negative environmental impacts, many agricultural producers go the extra mile in engaging in voluntary conservation practices that provide valuable environmental benefits to the public. The OAHC envisions a system to compensate agricultural producers for engaging in voluntary conservation practice, as identified in conservation management plans, that go above and beyond standard agricultural practices and that generate value for the public. Recognizing that funding would be limited, the program would seek to prioritize and compensate agricultural conservation practices that are most effective and provide the greatest public benefits. Such a program can provide a valuable win-win for farmers and the public by helping to incentivize and fund key conservation practices that increase agricultural productivity *and* provide significant environmental benefits valued by the public.

Scope of Work and Approach

The valuation methodology is focused on environmental benefits to the public of agricultural conservation measures. At the foundation, the OAHP-funded conservation management plan will identify farm practices and management that will lead to desired agricultural and environmental outcomes. The process by which this occurs includes several steps. First agricultural practices result in biophysical changes on the land. These may include changes in the location, quantity, and type of vegetation on the land; changes in the amount of water withdrawn from surface or groundwater sources, and changes in crop and animal management. These biophysical changes then translate into environmental goods and services such as changes in soil fertility, water quality, available water quantity, habitat and species abundance, flood and climate regulation, and protection of cultural assets. Finally, changes in these environmental goods and services can result in changes in social and economic values such as water supply costs, agricultural income, commercial fishing income, flood damage costs,

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[1] Environmental good and services from open space and natural areas that provide value to people are often referred to as ecosystem services, though this term is not used in this report,

recreation and aesthetic values, wildfire costs, and protection of threatened and endangered species. As such, it is important to focus the methodology review first on the biophysical effects of conservation practices, and second on the economic value of these biophysical effects.

A key challenge in economically valuing changes in agricultural conservation practices (or any conservation practice) is in making the link between the management action and the outcomes people actually care about and value. As such, the general approach in this review is to focus on the types of biophysical effects that can be quantified by available methodologies/tools with reasonable ease and accuracy, and the types of associated economic values and methods that can be applied to the estimated biophysical outcomes with reasonable ease and accuracy. For agricultural conservation practices, these biophysical outcomes and economic values are centered on specific water pollutants (sediment, nitrogen, phosphorus); measurement of carbon dioxide (or its greenhouse gas equivalent), water quantity made available through conservation or management for habitat or other consumptive uses; and functional acres of habitat (where a functional acre is estimated based on quality and quantity).

With this approach, nearly all social and economic benefits are valued through proxies (e.g., pollutant loads entering waterbodies), rather than through the actual outcomes people directly care about and value (e.g., water clarity or fish populations). For example, outcomes people directly care about include wildfire risks, recreation quality, species populations, flood damages, and drinking water costs. However, methodologies for these types of environmental outcomes are in general not reviewed as there are no reliable approaches or tools to quantify the biophysical effects of agricultural conservation measures in terms of these social/economically relevant outcomes. This introduces more uncertainty in the economic valuation, but is a practical and feasible approach given the constraints in conducting farm-level analyses that are easy to use and implement. Also, as a result of this approach, out of the diversity of economically and socially valuable outcomes possible from agricultural management practices, this review focuses on water quality, water quantity, habitat, and carbon (climate regulation) benefits.

Other types of economically and socially valuable benefits, including aesthetics and cultural benefits of farmland preservation values, are not included in the review as changes in these benefits as a result of farmland management practices are not readily measured through available methodologies that are more applicable to changes in overall land use (i.e., conversion of agricultural lands to developed lands rather than changes within agricultural land management). Similarly, while farmland management practices may affect the value of a wide variety of cultural assets (from traditional harvesting areas or historic structures), there are also very limited approaches and reliable values to use to quantify these assets and estimate their value. Finally, air quality is not included as air quality benefits of agricultural conservation measures may be limited in rural areas where there are typically few air quality impairments (outside of wildfire events, in which case changes in agricultural emissions would have little overall effect on air quality).

The conservation practices selected for analysis (shown in **Table ES-1** below) are those that have the potential to provide significant environmental benefits. They are based on the NRCS effectiveness ratings in the Conservation Practices Physical Effects (CPPE) matrix (Natural Resources Conservation Service, 2017). The NRCS effectiveness ratings range from -5 (most adverse effects) to +5 (most beneficial effects). Conservation practices that received a +4 or +5 for water quality/erosion control, habitat provision, water quantity, and carbon sequestration/greenhouse gas emission control were identified as significant providers of these types of benefits (as indicated by the bullet points in summary **Table ES-1** below). The selection of habitats to evaluate is based on the strategy habitats in the Oregon Conservation Strategy (Oregon Department of Fish and Wildlife, 2016).

Data Sources & Certainty

Key data sources for the analysis include:

- NRCS evaluations, methodologies, tools, and reviews. NRCS has focused significant effort and funding resources over recent decades on quantifying the environmental effects of conservation practices, including development of numerous user-friendly tools.
- Academic journals on all aspects of agricultural conservation practices, as well as on valuation of environmental goods and services.
- Oregon State agency publications and datasets on the location, use, and condition of natural resources, particularly habitat and water resources.

These data sources were supplemented with interviews with local and state resource agencies throughout the state and input from the Oregon Agricultural Heritage Commission Sub-Committee Members and Oregon Watershed Enhancement Board staff members overseeing this project.

There are numerous sources of uncertainty in developing a valuation methodology. These include uncertainty regarding:

a. The ability of available tools and methodologies to accurately predict the effectiveness of different agricultural conservation practices in delivering environmental benefits across the diverse agricultural and ecosystem contexts in the State of Oregon,
b. The ability to apply the available economic valuation methodologies and data in a way to appropriately accounts for how social and economic value for a given biophysical effect will vary by location throughout the state (for example, through the use of filters or screening criteria that prioritize locations in the state where a particularly type of social or economic value may be applied),
c. The feasibility of developing a methodology that appropriately accounts for synergies, tradeoffs and potential double counting of environmental goods and service values, and
d. The acceptance and interest by landowners in participating in a payment based on predicted environmental benefits and the associated estimated social and economic value.

The review of methodologies and data enclosed in this report addresses to some extent these sources of uncertainty and identifies potential methods to address them. However, we expect that the key to addressing uncertainty, throughout the development and adoption of a valuation methodology, will be to develop case study applications. These case study applications will help us better understand how results under a methodology will vary by region and agricultural system, and whether results from the methodology are adequately fair, certain, and reasonable.

Recommendations: Determination of Feasibility and Path Forward

Based on our review of the available methodologies for each key type of environmental benefit (water quality, water quantity, habitat, and carbon), we provide an assessment of the feasibility of developing a valuation methodology that meets the OAHC criteria (fairness, certainty, transparency, and easy/inexpensive to use). We add the criteria of a reasonable level of accuracy such that the public will, with a reasonable level of certainty, receive benefits at least equal to the payments resulting from a fully developed valuation methodology. While we believe that developing a valuation methodology is feasible for nearly all of the conservation practice/significant benefit combinations indicated by bullet points in **Table ES-1**, the *relative* feasibility does vary substantially by practice and benefit type. **Table ES-1** summarizes the initial relative feasibility findings (as high, medium, or low) for each conservation measure and benefit type. The high, medium, or low feasibility rating is intended to convey the relative certainty and accuracy of valuation among the practice/benefit combinations that could be included in a valuation methodology. There are a few conservation practice/significant benefit combinations that are not feasible to value; we find for these that there are not sufficient data to quantify biophysical benefits (environmental outcomes) of the conservation practices. In our feasibility assessment we assume that a valuation methodology would be used to provide annual payments, and that there would be a corresponding annual farm site visit to visually review conservation practices and outcomes.

Overall, and as shown in **Table ES-1,** we rate feasibility of a valuation methodology for carbon as high across all key conservation measures (practice-based measurement focused on carbon storage and GHG outcomes). We rate feasibility as high for valuation of riparian and wetland habitats on a per acre basis, and medium to low for grassland, woodland, and sage grouse habitats (outcome-based measurement during annual site-visit). We rate feasibility as high for water quantity benefits related to irrigation methods, land leveling, and water made available for wildlife. We rate feasibility as medium for water quality across all key conservation measures (practice-based measurement focused on key pollutant outcomes), other than for animal waste management for which there is little available quantification of conservation practice biophysical effects.

More specifically, overall feasibility is a composite rating of three feasibility factors:

1. **Availability of transparent, accepted (by experts and regulatory agencies), and reasonably accurate tools/methods to quantify biophysical estimates in an easy to use and understand manner.** The standard for easy to use and understandable is that with a one or two-day training, a conservation planner would be able to implement and apply the methodology using one annual site visit and some follow-up desktop analysis/review. *We rate the available tools for water quality, water quantity, and carbon as a high level of feasibility on this factor. We also rate the available tools that could be adapted for habitat evaluation at a high level of feasibility on this factor for wetland/riparian habitats, sagegrouse habitat, and Oakland prairie/savannah. Woodlands and grasslands are rated as medium level of feasibility on this factor due to less developed tools for habitat evaluation.*

2. **The inclusion of a particular agricultural conservation practice by each biophysical quantification tool/method.** In other words, we reviewed the conservation practices evaluated in the NTT, COMET-Farm/COMET-Planner, and the availability of existing habitat assessment tools to determine if evaluating that particular practice is feasible with the available

tools/methods. *The specific conservation measures listed in **Table ES-1** are based on the conservation practices included in these tools.*

3. **Availability of published (or derived) economic values for the environmental benefit type as quantified by biophysical tools.** We evaluated whether there are available published values, the degree to which these values may be representative/adjustable for the different agricultural regions of Oregon, and the degree to which these values actually represent economic benefits to Oregonians (as many published values are actually cost-based values). We again expect that convening a panel of professional agricultural and natural resource economists, together with representatives from the conservation planning community, would be a good path forward to review and confirm selected values that would be applied in a valuation methodology. The goal would be to reach general agreement and confirmation of values that provide a reasonable estimate of value to the public of changes in biophysical conditions. *At this stage, we rate high feasibility on economic valuation for carbon, water quantity, and riparian/wetland habitat. We rate water quality and grassland/sagegrouse/woodland habitat valuation with low to medium feasibility due to limited economic studies that can be appropriately applied/adapted to diverse Oregon agricultural regions.*

Table ES-1: Economically Quantifiable Benefits by Conservation Practice

Conservation Practice	Water Quality	Water Quantity	Habitat	Carbon
Vegetation (non-riparian)				
Vegetative Barrier/Shelterbelt		•		•
Filter strip/field border[1]	•		•	
Habitat Enhancement/ Preservation				
Flowing Water (flow improvement through water quantity method)			•	
Riparian Habitats[1]	•		•	•
Wetlands[1]	•		•	•
Woodlands *(water quality captured as buffer strip or riparian area)*			•	•
Grasslands *(water quality captured as buffer strip or riparian area)*			•	•
Sage-Grouse *(water quality captured as buffer strip or riparian area)*			•	•
Grazing/Animal Management				
Rotational/Prescribed grazing *(habitat benefits evaluated indirectly through grassland 'habitat' evaluation)*	•		•	
Compost application				•
Range/forage planting *(habitat benefits evaluated indirectly through grassland 'habitat' evaluation)*	•		•	•
Feed management				•
Animal Waste management *(water quality measured through crop nutrient management)*	•			•
Silvopasture				•
Crop Management				
Cover cropping	•			•
No Till/ Reduced Till	•			•
Nutrient management	•			•
Field Harvest Management *(habitat benefits evaluated indirectly through grassland/wetland 'habitat' evaluation)*			•	
Fertilizer Management	•			•
Irrigation/conveyance efficiency	•	•		
Land leveling	•	•		

1/Water quality add carbon benefits of these habits may be captured through the per acre habitat values. Care must be taken to ensure no double counting of value, depending on how the per acre habitat values are estimated and which services are included in the per acre habitat estimation methodology.

•	Conservation practice has potential significant impact on the benefit type
	Not feasible rating
	Low feasibility rating
	Medium feasibility rating
	High feasibility rating

1 INTRODUCTION

The Oregon Agricultural Heritage Program (OAHP) was established by the State Legislature in 2017. The OAHP is a new grant program for farmers and ranchers to help protect farmland and maintain agricultural working lands in the State of Oregon. The OAHP includes the Oregon Agricultural Heritage Fund that will provide grants for working lands conservation easements (permanent and temporary), as well as conservation management plans that support one or more natural resource values (including maintaining or enhancing fish and wildlife habitat, improving water quality, or supporting other natural resource values consistent with the social and economic interests of the agricultural owner/operator). In determining how to value implementation of conservation management plans, the Oregon Agricultural Heritage Commission, which oversees OAHP investments, identified two methods of paying landowners: 1) payment based on land lease rates, management costs, and foregone income, 2) payment based on the value to the public of environmental benefits provided by agricultural practices (Oregon Agricultural Heritage Commission, 2019). The purpose of this report is to determine whether this second, performance-based option is feasible based on currently available science and methodologies.

Agricultural lands have long been recognized in Oregon as providing a host of environmental benefits to the public. Oregon's land use laws and the efforts of numerous organizations around the state have also protected working lands for the many environmental benefits they provide. Environmental benefits are environmental goods and services that people care about, including open space amenities, water supplies, water quality, fish and wildlife habitat, and sequestration and storage of carbon to mitigate climate change. Agriculture can both positively and negatively affect the quality and quantity of these environmental goods and services (for example, adverse effects may include use or depletion of water supplies, or runoff from agricultural fields that decreases water quality in adjacent waterbodies), and conservation practices can both enhance positive impacts and mitigate adverse impacts.

Given the importance of agricultural lands and agricultural practices on the provision of environmental benefits, there is a large body of research from scientists in our state and throughout the Nation on agricultural land management and the environmental benefits of specific agricultural conservation practices. To a lesser extent, there is research on the social and economic value of these environmental benefits resulting from conservation practices. This research serves as the basis for the determination of feasibility of a payment system based on benefits provided by agricultural conservation practices.

The goal of this report is to review the available science and economics research and determine whether it is feasibility to value the environmental benefits to the public of agricultural conservation practices in Oregon. If feasible, the ultimate goal is to develop a methodology that will compensate and incentivize landowners to provide valuable environmental benefits, with the potential ancillary benefit of simultaneously enhancing the productivity and financial viability of working agricultural lands in the State (as many conservation practices can have a positive return on investment for ranchers and farmers). The criteria for such a valuation methodology, as established by the Oregon Agricultural Heritage Commission (OAHC), is that the methodology provide certainty for landowners and the OAHC, as well as be fair, transparent, and easy and inexpensive to implement statewide. Such a valuation methodology would have long-term policy, budget, and land use ramifications for the state, and would also be economically important for landowners and the general public.

As highlighted in the 2013 Oregon Values and Beliefs Survey, Oregonians highly value the State's farmland and want to conserve it (Oregon Values and Beliefs Project, 2013). Oregonians also highly value the state's natural environment, including clear air and water, recreation opportunities, and open spaces. Agricultural lands contribute to these environmental assets, with many agricultural producers going the extra mile in engaging in voluntary conservation practices that provide valuable environmental benefits to the public. The OAHC envisions a system to compensate agricultural producers engaging in voluntary conservation practices, as identified in conservation management plans, that go above and beyond standard agricultural practices and that generate value for the public. Recognizing that funding would be limited, the program would seek to prioritize and compensate the agricultural conservation practices that are most effective and provide the greatest public benefits. Such a program can provide a valuable win-win for farmers and the public by helping to incentivize and fund key conservation practices that increase agricultural productivity *and* provide significant environmental benefits valued by the public.

2 Approach & Key Considerations

This section provides an overview of the approach to the methodology review, including selection of the conservation practices and types of benefits to the public that are the focus of the valuation methodology, identified key challenges and potential approaches to a valuation methodology, and the key types of data sources relied upon throughout the review.

2.1 Overview of Approach & Benefit Analysis Scope

Figure 2-1 provides an overview of the thought process and approach in developing a methodology to value the benefits to all Oregonians of conservation actions on Oregon farms and ranches. At the foundation, the conservation management plan will identify farm practices and management that will lead to desired agricultural and environmental outcomes. The process by which this occurs includes several steps. First agricultural practices result in biophysical changes on the land. These may include changes in the location, quantity, and type of vegetation on the land; changes in the amount of water withdrawn from surface or groundwater sources, and changes in crop and animal management. These biophysical changes then translate into environmental goods and services such as changes in soil fertility, water quality, available water quantity, habitat and species abundance, flood and climate regulation, and protection of cultural assets. Finally, changes in these environmental goods and services can result in changes in social and economic values such as water supply costs, agricultural income, commercial fishing income, flood damage costs, recreation and aesthetic values, wildfire costs, and protection of threatened and endangered species.

Figure 2-1: Conservation Management Plans and Economic Value

CONSERVATION MANAGEMENT PLAN

Modifications to Farm Practices / Management

KEY CHANGES ON LAND

- Water drawn from surface or groundwater sources (Water Management)
- Amount, location, and type of vegetation and waterbodies (Landscape management)
- Methods of grazing and animal waste management (Animal Management)
- Crop rotation, tillage, and other practices (Crop management)
- Protection of cultural or historical assets

Enhanced Production of Goods & Services from Agricultural Lands

KEY GOODS & SERVICES PRODUCED

- Productivity of the land (yield/animal carrying capacity), and associated food security benefits
- Water quantity in aquifers and streams
- Water quality in aquifers and streams
- Habitat quality / species abundance and diversity
- Flood regulation
- Carbon storage
- Cultural resources

ESTIMATED OUTCOMES

- AF of water available for another use (reduced water use or provision of water for on-farm habitat)
- Acres of habitat, by type, weighted by quality
- Tons sediment, lbs nitrogen, lbs phosphorus
- Tons of CO_2 equivalent

Economic Value Generated

KEY ECONOMIC BENEFITS

- Farm profitability
- Food security
- Reduced water supply costs
- Reduced flood damage costs
- Intrinsic value of species & habitat preservation
- Recreation & aesthetic value
- Climate regulation / carbon value
- Cultural values
- Reduced wildfire costs

ESTIMATED BENEFITS

- Value of water/AF in waterbodies with low instream flow/ limited aquifers
- Value of improved water quality (per ton of pollutant) in impaired waterbodies
- Value per functional acre of priority habitats
- Value per CO_2 equivalent

2.1.1 Selection of Outcomes and Services to Review

A key challenge in economically valuing changes in agricultural conservation practices (or any conservation practice) is in making the link between the management action and the outcomes people actually care about and value. For example, to value water quality, ideally we would complete the following four steps:

1. Identify how a conservation management practice (or suite of practices) changes a variety of water quality parameters (e.g., concentrations of nutrients or sediment, temperature, etc.),
2. Determine the associated change in the aquatic ecosystem (e.g., water clarity, disease-causing bacterial population levels, fish population levels, etc.),
3. Establish a measure of this change in terms of social and economic parameters of importance (e.g., change in water treatment required, change in number of days swimming is affected by harmful levels of bacteria, change in number of fish caught, change in population of threatened species, number of boating visitor days improved because of increased water clarity, etc.), and
4. Value these changes economically.

However, even completing the first step is challenging. As such, the general approach in this review is to focus on the types of biophysical effects (estimated outcomes in **Figure 2-1**) that can be quantified by available methodologies/tools with reasonable ease and accuracy, and the types of associated economic values (estimated benefits in **Figure 2-1)** and methods that can be applied to the estimated biophysical outcomes with reasonable ease and accuracy. As highlighted in the figure, these outcomes and values are centered on specific water pollutants (sediment, nitrogen, phosphorus); measurement of carbon dioxide (or its greenhouse gas equivalent), water quantity made available through conservation or management for habitat or other consumptive uses; and functional acres of habitat (where a functional acre is estimated based on quality and quantity).

With this approach, nearly all social and economic benefits are valued through proxies, rather than through the actual outcomes people directly care about and value. For example, outcomes people directly care about include wildfire risks, recreation quality, species populations, flood damages, and drinking water costs. However, these methodologies for these types of outcomes are in general not reviewed as there are no reliable methodologies to quantify the biophysical effects of agricultural conservation practices in terms of these social/economically relevant outcomes. Other types of economically and socially valuable benefits, including aesthetics and cultural benefits of farmland preservation values, are not included in the review as changes in these benefits as a result of farmland management practices are not readily measured through available methodologies that are more applicable to changes in overall land use (i.e., conversion of agricultural lands to developed lands rather than changes within agricultural land management). Similarly, while farmland management practices may affect the value of a wide variety of cultural assets (from traditional harvesting areas or historic structures), there are also very limited approaches and reliable values to use to quantify these assets and estimate their value. Finally, air quality is not included as air quality benefits of agricultural conservation practices may be limited in rural areas where there are typically few air quality impairments (outside of wildfire events, in which case changes in agricultural emissions would have little overall effect on air quality).

2.1.2 Selection of Conservation Practices

The selection of conservation practices that have the potential to provide significant environmental benefits is based on the NRCS effectiveness ratings in its Conservation Practices Physical Effects (CPPE) matrix (Natural Resources Conservation Service, 2017). The NRCS effectiveness ratings range from -5 (most adverse effects) to +5 (most beneficial effects). Conservation practices that received a +4 or +5 from NRCS for water quality/erosion control, habitat provision, water quantity, and carbon sequestration/greenhouse gas emission control were included in this analysis as significant providers of these benefit types (as indicated by the bullet points in Table ES-1). Conservation practices that received a -5 to a +3 rating from NRCS for effectiveness for a relevant benefit type were assumed to not provide significant benefits for a given benefit type. The selection of habitats to evaluate is based on the Strategy Habitats identified in the Oregon Conservation Strategy (Oregon Department of Fish and Wildlife, 2016).

2.2 Data Sources

Sources are cited in detail throughout this document. However, in general, key data sources for the analysis include:

- NRCS evaluations, methodologies, tools, and reviews. NRCS has focused significant effort and funding resources over recent decades on quantifying the environmental effects of conservation practices, including development of numerous user-friendly tools.
- Academic journals on all aspects of agricultural conservation practices, as well as on valuation of environmental goods and services.
- Oregon State agency publications and datasets on the location, use, and condition of natural resources, particularly habitat and water resources.

These data sources were supplemented with interviews with local and state resource agencies throughout the state and input from the Oregon Agricultural Heritage Commission Sub-Committee Members and Oregon Watershed Enhancement Board overseeing this project.

2.3 Key Challenges & Available Approaches

This section describes some of the key challenges and available approaches for a valuation methodology.

2.3.1 Diversity of Oregon Agricultural Regions and Conservation Issues

Oregon agriculture is diverse and varies substantially across the state, with eight Oregon Agriculture Regions identified by the State Department of Agriculture, as described in **Table 2-1** (Oregon Department of Agriculture, 2017). In the Willamette Valley agricultural region alone there are more than 170 different crops grown, with other regions specializing more in dairy, beef, or in specific high value crops such as apples, or pears, or vineyards (Oregon Department of Agriculture, 2017). Correspondingly, there are diverse ecoregions, each with its own unique combination of climate, topography, habitat types, and species of concern (Oregon Department of Fish and Wildlife, 2016). This diversity is summarized in **Table 2-1.** A statewide valuation methodology needs to recognize and accommodate the diversity of agricultural production systems, crop types, and ecological conditions in order to be reasonably accurate and fair. The approach taken in this review is to identify and include the diversity of conservation practices that may be applicable in different agricultural regions across the state, as well as identify the Strategy Habitats across the state and review methods pertinent to those habitats. Secondly, the review focuses on locational factors that would affect the efficacy and prioritization of conservation practices in different regions of the state, based on the current and projected condition and use of resources.

Table 2-1: Oregon Agricultural Regions and Oregon Conservation Eco-Region, Strategy Habitats and Key Conservation Issues

OR Agricultural Region	Ecoregion	Counties	Chief Products	Ecoregion(s)	Strategy Habitats	Identified Habitat Improvement Actions by Agriculture	Key Conservation Issues
Willamette Valley	Willamette Valley	Columbia, Multnomah, Clackamas, Yamhill, Washington, Polk, Benton, Linn, Lane	Fruit, beef, eggs, trees, nuts, hops, milk, vegetables, grain, grass seed, nursery, grapes	Willamette Valley	Wetlands, flowing water/riparian, grasslands, oak woodlands	Mowing/controlled grazing to maintain open structured habitat; wetland/riparian and river/floodplain connections; conservation-friendly land management; control of invasive species	Land use changes (including change in crops or intensification of crop management), disruption of fire and floodplain function, invasive species, habitat fragmentation
Southern Oregon	Klamath Mountains	Douglas, Josephine, Jackson	Fruit, beef, hay, milk, potatoes	Klamath Mountains	Wetlands, flowing water/riparian, grasslands, oak woodlands, ponderosa pine woodlands	Reduce stream sedimentation, increase habitat connectivity in valley bottom habitats, conservation-friendly land management; enhanced riparian function, limit and control invasive species	Land use changes, disruption of fire regime, invasive species
Oregon Coast	Coast Range	Clatsop, Tillamook, Lincoln, Coos, Curry	Beef and Dairy Cattle, Cranberries	Coast Range	Wetlands, flowing water/riparian estuaries, grasslands, oak woodlands	As feasible, remove dikes/tide gates or replace with new innovations to improve fish passage/hydro function, limit invasive species.	Land use changes, invasive species

OR Agricultural Region	Ecoregion	Counties	Chief Products	Ecoregion(s)	Strategy Habitats	Identified Habitat Improvement Actions by Agriculture	Key Conservation Issues
Mid-Columbia Basin	Columbia Plateau, East Cascades	Hood River, Wasco	Fruit	Columbia Plateau, East Cascades	Wetlands, flowing water/riparian, grasslands, natural lakes, oak woodlands, ponderosa pine woodlands, sagebrush	Water conservation, no till-farming/, vegetation to control soil erosion/recharge, maintain/connect wildlife habitats including through riparian corridors, control invasive species, reduce vulnerability of property to fire, conservation-friendly land management; provide water for wildlife in arid areas and limit hazards to wildlife on water developments	Water quantity/quality, habitat connectivity, invasive species, land use change
Columbia Basin	Columbia Plateau	Umatilla, Morrow, Gilliam, Sherman, part of Wasco	Fruit, beef, grass seed, hay, milk, grain, potatoes	Columbia Plateau	Wetlands, flowing water/riparian, grasslands, sage brush	Water conservation, no till-farming/, vegetation to control soil erosion/recharge, maintain/connect wildlife habitats including through riparian corridors, control invasive species,	Water quantity/quality, habitat connectivity, invasive species
Northeast Oregon	Blue Mo3untains	Wallowa, Union, Baker, part of Grant	Beef, fruit, grain, hay, hops, potatoes, onions	Blue Mountains	Wetlands, flowing water/riparian, aspen woodlands, grasslands, ponderosa pine woodlands, sagebrush	Increase connectivity between habitat patches on private areas in lower elevations (grasslands/riparian areas/wetlands/shrublands); provide water for wildlife in arid areas and limit hazards to wildlife on water developments (avoid overhanging lines and provide escape ramps). Control invasives and use native plants in restoration/revegetation	Land use changes (habitat fragmentation), water quality/quantity, invasive species, disruption of fire regimes

OR Agricultural Region	Ecoregion	Counties	Chief Products	Ecoregion(s)	Strategy Habitats	Identified Habitat Improvement Actions by Agriculture	Key Conservation Issues
Southeast Oregon	Northern Basin and Range, Blue Mountains	Malheur, Harney, Lake, Klamath, Wheeler, part of Grant	Beef, grain, hay, milk, potatoes	Northern Basin and Range, Blue Mountains	Wetlands, flowing water/riparian, aspen woodlands, grasslands, natural lakes, ponderosa pine woodlands, sagebrush	Increase connectivity between habitat patches on private areas in lower elevations (grasslands/riparian areas/wetlands/shrublands); provide water for wildlife in arid areas and limit hazards to wildlife on water developments (avoid overhanging lines and provide escape ramps). Control invasives and use native plants in restoration/revegetation, controlling western juniper. Proactively manage livestock grazing and restore degrade habitat, minimize grazing during restoration of wetlands/riparian areas.	Land use changes (habitat fragmentation), water quality/quantity, invasive species, disruption of fire regimes
Central Oregon	East Cascades, Blue Mountains	Jefferson, Deschutes, Crook, part of Wasco	Beef, grain, hay, vegetable seed	East Cascades, Blue Mountains	Sagebrush, wetlands, flowing water/riparian, aspen woodlands, grasslands, natural lakes, ponderosa pine woodlands	Increase connectivity between habitat patches on private areas in lower elevations (grasslands/riparian areas/wetlands/shrublands); provide water for wildlife in arid areas and limit hazards to wildlife on water developments (avoid overhanging lines and provide escape ramps). Control invasives and use native plants in restoration/revegetation	Land use changes (habitat fragmentation), water quality/quantity, invasive species, disruption of fire regimes

Sources: (Oregon Department of Agriculture, 2017), (Oregon Department of Fish and Wildlife, 2016).

2.3.2 Synergies, Tradeoffs, and Double Counting Among Environmental Benefits

There are synergies and tradeoffs among environmental outcomes – nothing in an ecosystem functions in a vacuum. This methodology review recognizes this complexity and focuses on identifying where overlap may occur and which methodologies may provide the best accounting for valued outcomes. No system will be perfect, but we have tried to focus the methodology review for each conservation practice on the key valued environmental goods/services while avoiding potential double counting. For example, water quantity provides temperature water quality benefits, dilutes concentration of other pollutants, and increases fish habitat availability. Our approach is to focus on the valuation per acre-foot of water made available instream (or to wetlands or watering holes) on a per AF basis that should implicitly include these various habitat and water quality benefits. Similarly, the water quality benefits (temperature reduction and pollutant capture) provided by riparian habitats should implicitly (or sometimes explicitly) be included in the per acre values for this habitat from the economic literature.

For habitat in particular, there are numerous tradeoffs in the effects on habitat quality among conservation practices. Because of the complexity in linking habitat quality with conservation practices, we have focused our biophysical habitat methodology review on approaches that directly assess habitat condition – with the intent of holistically taking into account the potential positive and adverse effects of a suite of conservation practices and management conditions.

2.3.3 Varying Effectiveness and Value of Conservation Practices Across Locations

The level of environmental service provided, and the value of a given level of environmental services, is very location-specific. The type and magnitude of the effects of a specific conservation practice typically depend on geographic and environmental factors such as location in a watershed, topography, aspect, soil type, precipitation frequency and magnitude, local fauna and flora, and surrounding land uses. Further, the level of economic value depends on the size and values of the affected human population (i.e., the population that holds values for the environmental benefit), and the current quantity and quality of environmental services provided in the area. Recognizing the diverse agricultural and socioeconomic landscapes throughout the State, the review includes information on the 1) geographical and environmental factors affecting efficacy of any one conservation practice that may need to be incorporated into the valuation methodology, and 2) socioeconomic factors that may need to be incorporated into the valuation methodology.

2.3.4 Effects on Producers and Agricultural Lands of Conservation Practices

This methodology review focuses on the economic and social benefits to the public resulting from conservation practices. Changes in agricultural production and profitability as a result of management practices are not included in this review. These are the costs and the benefits borne by the landowner/producer. This is an area for which there is likely the most available data on the economic effects of agricultural conservation practices. As the landowner may indirectly be compensated economically for benefits to agricultural productivity (e.g., through receiving more revenue from higher yields or animal production), and there are many Natural Resources Conservation Service (NRCS) programs available for cost-sharing to offset foregone income or costs associated with many conservation practices, this methodology review does not incorporate costs and benefits to the producer.

The purpose of the OAHP is to help farmers and ranchers to maintain their farms and ranches as working agricultural lands. As such, while the methodology review does not focus on quantifying the agricultural productivity benefits of conservation practices, the purpose is to supplement and increase adoption of conservation practices that have both environmental benefits and production benefits. There will be some tradeoffs, where some management practices may reduce agricultural net income, particularly in the short-term. For example, habitat conservation and enhancement may reduce arable land in production. However, even for some habitat conservation practices there may be some long-term productivity offsetting benefits to the producer, including pollination, pest control, and soil fertility (from reduced erosion) benefits, particularly if these benefits are kept in mind when designing conservation management plans.

2.3.5 Landowner Participation

Participation of producers and landowners in the conservation management plan program would depend on many factors. There is an extensive literature on the factors affecting farmer and rancher participation in voluntary conservation practices, which may include: relative benefit of the practice (both economically to the producer and environmentally), program structure, farmer personal motivations/interests, farmer social networks, financial incentives, farm size/type and available equipment, and level of farmer outreach (Purdue University Extension, 2014) (Foley, 2013). Key to participation in the OAHP conservation management plan program will likely also be the extent to which the program is expected to affect producer flexibility (i.e., prescribed practices versus sought after outcomes as well as permanent versus short-term agreements), the extent to which the producer expects to experience a net agricultural productivity benefit, the time and effort required by the producer to participate, and how program participation may affect long-term regulatory oversight and burden on the producer (for example, if providing habitat may result in attraction of threatened or endangered species that would limit future farmland management options). Further meetings with stakeholders and landowners are needed to understand the dynamics of program participation, recognizing that designing a program with landowner needs and concerns in mind will affect the attractiveness of the program to potential participants.

2.3.6 Practice- Based vs. Performance-Based

There are two chief ways to structure payment programs for agricultural conservation programs: payment based on specific practices, and payments based on desired outcomes that result from a suite of practices. Conceptually, payment for desired outcomes is most flexible (farmers and conservation planners can identify the most effective and appropriate practices for a given farm rather than from a prescribed list), is more efficient (you only pay for what you actually get), and directly incentivizes the outcomes you actually want (versus paying for a practice that in a particular location, may not lead to desired outcomes, or may even lead to adverse outcomes).

However, an outcome-based payment program may be unpredictable for the landowner and OAHC, and may not be transparent in how the outcome is assessed. Furthermore, in practice, outcomes may be exceedingly challenging to measure, particularly outcomes that occur at a basin or subbasin-scale, such as overall water quality indices or species populations. Even outcomes that are measurable at the farm-level, such as carbon storage, often require extensive on-site work and/or repeated sampling and laboratory testing that may be expensive, time-consuming, and intrusive to the landowner. As such, this review takes a hybrid approach. An eventual valuation methodology is expected to primarily be based on practices, but provide clear guidance on valued outcomes; this will guide selection of practices that provide desired results.

For carbon, water quality, and potentially water quantity, payments would be linked to practices that are associated with the desired outcomes. There are tools and methodologies available to quantify how the identified key conservation practices affect the suite of identified desired outcomes (enabling incorporation of potential tradeoffs among outcomes). As such, for these benefits, an eventual methodology would be able to link practices to desired outcomes to values. However, for habitat quality/quantity and potentially water quantity, we expect that it is most feasible for the methodology to directly assess and value outcomes (i.e., quantity and quality of habitat available by type) through an annual site visit (and possible metering of water use). In both instances, payments for landowners would be relatively certain, and while payments would vary by farm and location, the payments would be based on transparent and fair methodologies.

3 Overview of Technical Approaches & Considerations to Value Environmental Benefits

This section provides an overview of the general methods available to quantify the economic value of environmental benefits, and the key factors that affect socioeconomic value of a given level of environmental benefit.

3.1 Technical approaches

Economic value or benefit is typically measured in terms of willingness to pay – how much would society as a whole be willing to pay for an environmental enhancement? Willingness to pay for most goods and services is typically measured by market prices. However, most environmental services are not sold in the marketplace, so environmental and natural resource economists have derived a number of different techniques, as described below. The appropriateness of using any technique varies with the type of resource being valued, the potential magnitude of the service in a particular case study, and the available, relevant data.

There are two primary methods for estimating the economic valuation of environmental goods and services: market-based or revealed preference methods that estimate value based on observed behavior and willingness to pay (these include market price methods, productivity methods, hedonic pricing methods, travel cost methods, avoided cost methods, and replacement cost and substitute cost methods), and stated preference methods where people are directly asked to express their willingness to pay for environmental goods and services.

3.1.1 Market Prices

The most reliable approach for estimating willingness to pay, or economic benefit, from an environmental good or service is to infer value from the market price. Market price methods estimate total value based on the sum of net value to producers and consumers, where the net value to producers is the market price less cost of production (i.e., profit), and the net value to consumers is their willingness to pay for the good or service, less market price. Net value can be challenging to estimate even for commodities and services with market prices. Moreover, many natural and cultural resources do not have a market price. Even for natural resource benefits such as carbon sequestration or habitat provision for which there are developing markets, the market price seldom represents the total economic value of the environmental benefit. Rather, the market price represents the cost of replacing the environmental good or service or is simply an indicator of the *minimum* value of an environmental good or service.

For example, the market prices for carbon, water quality, and habitat mitigation credits are tied closely to the cost of developing the mitigation credits, as well as the value to the credit purchaser of the economic activity requiring mitigation. While the cost of developing a carbon offset (or habitat credits, or water quality credits) and the value of emitting more carbon will vary from project to project, the value provided to society of a ton of carbon sequestration is equal to the avoided cost of climate change (and does not vary from project to project). Thus, prices from mitigation markets do not represent the actual value to society of the environmental services.[2] Rather, they more closely represent the cost of replacing those services (also known as a replacement cost, which is a valuation method discussed below).

Similarly, prices paid for water to enhance instream flow are typically closely tied to the value of foregone income, or cost, to the water seller (usually agricultural water users) of reduced water supplies. As such, prices paid for instream water rights typically reflect the value of water in agricultural production, or the cost to agricultural water users of enhanced water use efficiency. While the buyer of instream flow water rights must value the water at least as high as the transaction price (as this is typically a voluntary transaction driven by environmental values and not regulatory mitigation requirements), prices paid for instream flow enhancement do indicate that environmental value to the buyer is at least as high as the transaction price. However, since environmental water buyers are often non-profit organizations that represent only a fraction of the beneficiaries of water enhancement projects, the actual value to all beneficiaries is likely higher than the value incorporated into water transaction prices. As such, prices paid in water markets for instream flow water rights are likely lower bounds (minimum value estimates) of total value to the public of instream flow enhancement in the watershed where the market transaction occurred.

3.1.2 Productivity Methods

Productivity methods value environmental goods and services based on the value they provide as an input into an economic activity. The availability and quality of a resource can affect the costs or returns of a marketed good, thereby affecting the total net benefit of the commercial economic activity. For example, a common approach for valuing water in irrigation is to compare the costs and returns of dryland versus irrigated agriculture. The value of irrigation water for agriculture is equal to the increased profit, or net return, of irrigated agricultural production relative to dryland agriculture.

3.1.3 Replacement Cost, Substitute Cost, and Avoided Cost

Replacement, substitute, and avoided cost methods are methods that infer economic value based on expenses that would be incurred in the absence of the resource or service being valued. For example, consider the valuation of a wetland, or wetland services such as water quality. The replacement cost methods would estimate value based on the costs of developing an equivalent replacement wetland, while the substitute cost method (for estimating wetland water quality benefits) might be the cost of an engineered substitute (such as a water filtration plant) that provides the same service. The avoided cost method could be employed to estimate the value of wetland flood regulation services based on the change in flood damages with the wetland versus without the wetland. An important caveat for employing this methodology is that replacement or substitute resources would actually be paid for, or damages would be incurred, in the absence of the resource being valued. For example, if a wetland does not affect drinking water treatment costs or flood damages, it would not be appropriate to value the wetland water quality services based on alternative drinking water treatment, flood control infrastructure, or avoided flood damages.

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[2] Mitigation markets are typically driven by regulatory requirements for mitigation. While the fact that there is a regulation requiring mitigation implicitly underscores that society recognizes and values the environmental service being mitigated, there is typically no explicit quantification of the economic value provided by the environmental service.

3.1.4 Travel Cost Method

The value of outdoor recreation (such as boating, hunting, fishing, and wildlife viewing) and the value of environmental quality at specific recreation sites (such as improved water quality, habitat quality, fish/wildlife populations, etc.) are often estimated using the travel cost method. This method infers the value people place on a resource by the amount of money they are willing to pay to travel to use the resource. For example, while many hiking trails do not charge an admission price, the time and cost to travel to the site effectively acts as an admission price. The relative number of visits at a given recreation site relative to the travel cost to reach the site provides an indication of relationship between demand for the site and price, and enables estimation of the demand curve and overall willingness to pay for a visit to the site and its amenities. The net value of the recreation site to a recreator is estimated as willingness to pay less travel costs (i.e., benefit minus cost).

3.1.5 Hedonic Price Method

Recreational and aesthetic values are also estimated through hedonic methods. Hedonic pricing models are most often used to estimate the effect of an environmental or scenic amenity on the price of property. In other words, hedonic property value models analyze property values to tease out the contribution of environmental attributes to the sale price of a home. A hedonic model will include a wide variety of properties in an area, which sell for different prices based on traditional home attributes, like square footage, and environmental attributes, such as proximity to local parks and open space or the water quality in the area. A statistical model can measure the contribution of each attribute to sales price. This technique has been used extensively to estimate the value of water quality for properties along lakeshores and the value of proximity to open space for residential areas, as well as measure the effect of irrigation water supply on agricultural land prices.

3.1.6 Stated Preference Surveys on Willingness to Pay (Continent Valuation, Conjoint Analysis, Choice Experiments, etc.)

The final approach for estimating non-market values is to use stated preference methods. Stated preference methods directly ask consumers how much they are willing to pay for a particular resource or resource change. It is typically used when there are no other valuation methods that can be used to infer total value based on prices or costs. For example, the methods described above are difficult to use to estimate the value of protecting endangered species habitat. The obvious drawback with stated preference methods is that they represent hypothetical purchases, not real ones, and may be biased. The economic value of the natural resources provided by a site depends on a number of factors. Several of these factors are discussed below, including location of the natural area, the relative abundance or rarity of the resources in the natural area, and also the temporal and cultural context.

3.1.7 Benefits Transfer

To quantify the benefits of the conservation management actions, we anticipate that an Oregon state-wide valuation methodology would rely solely on existing data and valuation studies (i.e., a new travel cost study or replacement cost study would not be conducted). As such, there would be a heavy reliance on the existing valuation literature, with values from the literature applied to the conservation practices based on the expected effects of the conservation practices. Applying the results of existing economic valuation studies to a new policy context, such as to Oregon agricultural conservation programs, is called benefits transfer. The key to ensuring a successful benefit transfer is to carefully assess the soundness and similarity of studies selected for benefits transfer. To be considered sound, a study should have high-quality data collection procedures, adhere to best practices for empirical methodology, and be consistent with economic theory. Further, the study should provide enough information about the research to fully evaluate the data, modeling, and results. Similarity refers to how closely the context of the proposed transfer study resembles the "new" context (current study). Some aspects of similarity include the environmental goods being analyzed, the baseline level of environmental quality, the magnitude of change in environmental quality, the socio-economic characteristics of the affected population, and the property rights, culture, and institutional settings of the affected population.

3.2 General Determinants of Economic Value

The magnitude of the economic values provided by a given natural area depend on a number of factors. Several of these factors are discussed below, including location of the natural area, the relative abundance or rarity of the resources in the natural area, and also the temporal and cultural context. In the following section, we discuss socioeconomic value in relation to location, abundance, time and cultural context.

3.2.1 Location

The level of environmental services/goods provided by a resource and its associated value differs by location. First, the level of service provided by the same resource can differ based on other location-specific structural and physical attributes. Second, the value of the ecosystem service also typically differs by location, depending on the human activity and population in the area. Take for example, the service of soil retention or erosion control. Riparian vegetation will retain more soil in areas with steep slopes than in areas with gentle slopes. Likewise, the economic value of this erosion control service will depend on location. On rivers with sensitive salmon populations or are key sources for municipal water supplies, increased sedimentation and turbidity may have high costs, and the retention and stabilization of soil may be highly valued. In other areas, erosion control may have very little economic significance.

3.2.2 Abundance

Similar to most economic goods and services, the value of an environmental good or service usually depends on its abundance. If a good or service is really abundant, the value of each unit is typically less than the value would be if the good or service is relatively scarce. This idea of scarcity is related to the concept of *marginal* value of a good or service, or the value of one more unit, compared to the *average* value. Typically, the more we have of a good or service, the less we value each additional unit. Consider the value of water use in the home. The value of the first few gallons used for drinking and basic cleaning activities is very high, while the marginal value of the last gallon consumed for watering the lawn or washing the car has much lower value. This pattern of declining marginal value is often applicable for both use and non-use values. For example, the recreation use value of a particular natural area is lower if there are many substitute natural areas nearby. Likewise, people tend to hold higher non-use existence values for conservation of endangered species than conservation of species that are not threatened.

3.2.3 Temporal and Cultural Context

Economic value is estimated based on the preferences of individuals, with total societal value being the aggregation of individual values. As individual preferences and willingness to trade one good or service for another can change through time and also can vary by culture, value is defined relative to a particular time and place. For example, in earlier centuries, American attitudes and perceptions of natural habitat and wildlife species were quite different than they are now. This is a reflection not only of the change in abundance of habitat, but also a changing perception and awareness by the public of the benefits of these natural systems. In addition to the temporal context, cultural differences also play a role in the value placed by individuals on different ecological goods and services.

4 METHODOLOGY REVIEW BY BENEFIT TYPE

This chapter reviews and assesses the available methodologies to evaluate both the biophysical effects of conservation practices and the economic values of these effects. There are four subsections to this chapter that provide detailed review of the methodologies available for the four benefit types reviewed: water quality, water quantity, carbon, and habitat. Throughout each sub section, information and datasets that identify the locations in the state where biophysical effects may have greatest ecological and socioeconomic value are also described and identified.

The two tables below summarizes our findings regarding the available methodologies based on the valuation methodology criteria identified by the OAHC, as well as accuracy and ability to capture diversity of effects across geographies. **Table 4-1** summarizes key available methodologies/tools to estimate biophysical effects of agricultural conservation practices. **Table 4-2** summarizes the corresponding economic methodologies by benefit type.

Table 4-1: Summary of Biophysical Methodologies by OAHP Criteria

Methodology	Fair/Certain (Quantification is Predictable)	Transparent (Easy to Understand)	Easy/ Inexpensive (Easy to Apply)	Accurate & Captures Effects Well Across Geographies	Applicable Conservation Practices
Water Quality					
Nutrient Tracking Tool (NTT)	●	●	●	◍	Nearly all crop management practices and vegetation buffers
L-THIA (Long Term Hydrologic Impact Assessment Model)	●	●	●	○	Land use conversion, grass/pasture, wetland, and agricultural.
Soil and Water Assessment Tool (SWAT)	●	◍	○	◍	Nearly all crop management practices and vegetation buffers
Agricultural AGNPS (Agricultural Non-Point Source Pollution Model)	●	◍	◍	◍	Animal Practices, crop management
Riparian Ecosystem Management Model (REMM)	●	○	○	●	Riparian buffers
Revised Universal Soil Loss Equation [i]	●	◍	◍	◍	Ridging (contouring), vegetative strips & buffers, runoff interceptors, sediment basins
Shade-A-Lator	●	◍	◍	●	Riparian vegetation restoration
Water Temperature Transactions Tool	●	◍	◍	●	Flow Restoration

Methodology	Fair/Certain (Quantification is Predictable)	Transparent (Easy to Understand)	Easy/ Inexpensive (Easy to Apply)	Accurate & Captures Effects Well Across Geographies	Applicable Conservation Practices
Carbon					
CENTURY / DAYCENT, NREL	●	◐	○	●	Nearly all crop management practices and vegetation buffers.
COMET-planner/COMET-Farm (USDA)	●	●	●	◐	Most crop, grazing, and animal waste management measures
COMET-Energy	●	●	●	◐	Reductions in GHG emissions based on fuel savings
Carbon Sequestration in Western Ecosystems	●	●	●	○	Assessment of carbon (C) storage and flux of other greenhouse gases across land cover categories/regions.
COMPOST Planner	●	○	○	●	Compost addition to grazing lands
California Carbon Sampling and Measurement Protocol	●	●	◐	●	Performance monitoring of soil carbon storage
Habitat					
Oregon Rapid Wetland Assessment	●	◐	○	●	Wetland enhancement/ preservation
Quantify Habitat based on Existing Vegetation Maps (e.g., NW ReGAP)	●	●	◐	○	None explicitly, habitat quality is evaluated.
Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	●	◐	○	◐	Rangeland health measures
Salmon Safe Certification	●	◐	○	●	Riparian management, water quality/quantity management, connectivity
Wetland Plant Diversity Model	◐	◐	◐	◐	On-site evaluation of plant diversity.
Oregon Sage Grouse Habitat Quantification Tool	◐	◐	◐	●	Sage grouse habitat enhancement/ preservation
Counting on the Environment – Fish Passage	●	◐	○	●	In-stream habitat enhancement/ preservation
Counting on the Environment – Upland Prairie	●	◐	○	●	Prairie habitat enhancement/ preservation

Methodology	Fair/Certain (Quantification is Predictable)	Transparent (Easy to Understand)	Easy/ Inexpensive (Easy to Apply)	Accurate & Captures Effects Well Across Geographies	Applicable Conservation Practices
Water Quantity					
Desktop Review using crop water use and irrigation requirements, along with reports of water use	●	●	●	◐	On-farm water management measures
Metering water use	●	●	○	●	On-farm water management measures
Remote Sensing of ET using METRIC process, satellite imagery and climate data	●	●	◐	●	On-farm water management measures

Sources: (USDA, 2019; Texas A&M University, 2019; Colorado State University, 2019; USDA Agricultural Research Service, 2002; USDA Agricultural Research Service & Colorado State University, 2019; USDA NRCS Resource Inventory and Assessment Division, 2006; Oregon Department of State Lands, 2016; Oregon State University Institute for Natural Resources, 2019; USDA NRCS, 2018; Salmon-Safe, 2019) (US EPA, Stream Mechanics, US FWS, 2012)

●	Methodology/tool fulfills the OAHP criteria well
◐	Methodology/tool partially fulfills the OAHP criteria
○	Methodology/tool does not fulfill the OAHP criteria

Table 4-2: Summary of Economic Methodologies by Potential Criteria

Methodology	Necessary Biophysical Data Availability	Available Economic Literature/ Studies	Transferability between Locations	Accurately Reflects Economic Value to Oregonians
Habitat				
Replacement Cost to Restore Habitat Elsewhere	●	●	●	○
Market Price of Compensatory Habitat Mitigation	◐	●	●	○
Per-Acre Habitat Values from Economic Literature (Various Methods)	◐	◐	◐	◐
Surveys of Willingness to Pay for Habitat/Species Preservation	○	◐	◐	●
Recreation Quality/Opportunities*	○	◐	◐	●
Per Acre Habitat Value, based on above approaches	◐	◐	●	◐
Water Quality				
Water Quality: Avoided Cost of Water Treatment/Abatement	○	◐	○	◐
Willingness-to-Pay Surveys for Improvement in Water Quality Index	○	●	◐	●
Per Unit P, N, TSS from literature (and based on above approaches)	●	◐	◐	◐
Water Quantity				
Replacement/Substitute Cost to Obtain Alternative Water Supplies	●	●	○	○
Cost of Water Shortages/Instream Flow Depletion	◐	◐	◐	●
Market Price for Water	●	●	◐	◐
Per AF water conserved, based on above approaches	●	◐	◐	◐
Carbon (CO_2 equivalent)				
Carbon: Avoided cost of climate change	●	●	●	●
Market Prices: Carbon Credits, Taxes, Carbon Sequestration Offsets	●	●	●	○
Per Ton Carbon Value, based on above approaches	●	●	●	◐

*Studies of fish/wildlife-related recreation value on public lands (not agricultural lands) that may reflect value of improved species populations due to management on agricultural lands.

Note: Biophysical effects are based on field-level changes, but socioeconomic effects are experienced at the watershed level.

●	Methodology/tool fulfills the OAHP criteria well
◐	Methodology/tool partially fulfills the OAHP criteria
○	Methodology/tool does not fulfill the OAHP criteria

4.1 WATER QUALITY

Of more than 100,000 miles of rivers and streams in Oregon, water quality in about 24,500 stream miles is impaired and does not meet water quality standards (Oregon Department of Water Resources, 2017). According to the 2017 Oregon Integrated Water Resources Strategy, temperature, sedimentation, and nutrients are the most common types of pollution that impair Oregon's rivers and streams (Oregon Department of Water Resources, 2017). These pollutants affect the cost of water treatment and adversely impact fish and other aquatic species, drinking water, agriculture, and recreation.

Erosion control and water quality enhancement are a key focus of many agricultural conservation practices and programs (e.g., Soil and Water Conservation Districts, Oregon Department of Agriculture's Water Quality Program). Agricultural practices such as tillage, fertilization, cover cropping, irrigation, animal waste management, and residue management can affect the level of runoff from agricultural lands, soil erosion, and nutrient inputs to waterbodies (i.e., off-site movement of primarily nitrogen and phosphorus) and thereby affect water quality (Council for Agricultural Science and Technology, 2019). Likewise, stream temperature may be affected by agricultural practices that alter hydrology (either through affecting stream flows or channel morphology), or that alter the type and extent of riparian vegetation. Type and extent of riparian vegetation also affects the amount of sediment/nutrients/bacteria in runoff from agricultural lands that is captured and stored in riparian areas before entering waterways.

This analysis focuses on methodologies to measure and value the effects of agricultural management practices on sediment, nitrogen, and phosphorus. These three water quality parameters are among the most common type of pollutants impairing Oregon rivers and streams. There are available methodologies to measure changes in these parameters resulting from agricultural management practices, and there are available economic values/data for these parameters.

Temperature and bacteria (from animal waste) in water may also be affected by agricultural management practices. Water temperature is an important water quality parameter because it affects sensitive aquatic species such as salmon and trout that are culturally and economically important. Water temperature can also affect bacterial growth in waterbodies. Bacteria are an important water quality parameter because they can affect the human health risk of drinking water supplies and recreational uses of waterbodies. Methodologies to quantify effects on bacteria of conservation management practices are limited, and bacteria impairments are also more limited in the State of Oregon, so this water quality parameter is not separately analyzed.

As noted above, two key agricultural practices that affect water temperature are water use (affecting stream flow) and riparian vegetation management. The value of these two practices in affecting water quality may implicitly be included in several of the valuation methodologies for water quantity and riparian habitat.

While there are several tools and data sources available to quantify the effects of agricultural management practices on sediment and nutrient inputs to water bodies, the scientific literature emphasizes the complexity of biogeochemical processes and the variation in effectiveness based on site specific attributes such as soil type, precipitation, slope, crop type, etc. For example, findings in the peer-revised scientific literature on the role of riparian areas in improving water quality indicate that the efficacy of riparian areas depends on the specific slope, soil, and vegetation characteristics of the riparian area; the land use in the watershed, and the pollutants involved (Mayer, Reynolds, & Canfield, 2005; Hickey & Doran, 2004). Similarly, economic valuation is most certain and reliable when it can be applied directly to the things people sincerely care about – such as water treatment costs or fish populations. As just discussed, however, estimating the effect of agricultural practices on nutrient loading is difficult in itself; estimating how basin-wide water quality will change with different agricultural management practices and how this water quality change will affect water treatment costs, or fish populations, or recreation days is even more challenging. This methodology review identifies various methodologies for valuing water quality but focuses on methods that can be applied to directly value tons of sediment and pounds of nutrients being delivered to waterbodies, as this is likely the most feasible valuation approach (albeit less certain economically).

4.1.1 Biophysical Quantification

Table 4-1 summarizes several quantification tools and methodologies available for estimating the effects of agricultural conservation practices on water quality. The tools and methodologies vary in their scope, complexity, outputs, accuracy, and how user-friendly they are. A few tools are very focused in scope: the Riparian Ecosystem Management Model (REMM) and the Shade-A-Lator models focus solely on riparian buffers, the Long Term Hydrologic Impact Assessment (L-THIA) predicts how land use changes might affect runoff and pollutant loadings, and the Water Temperature Transactions Tool focuses solely on how changes in instream flow affect temperature. In contrast, several tools are more wide-ranging: the Nutrient Tracking Tool (NTT), the Soil and Water Assessment Tool (SWAT), and the Agricultural Non-Point Source Pollution Model (AGNPS) all enable analysis of the effects of a wide variety of agricultural management practices on soil and nutrient loadings.

Of these, the NTT appears to be particularly relevant for a state-wide methodology to estimate benefits of agricultural conservation practices. The NTT is a farm-scale tool developed by the Texas Institute of Applied Environmental Research (TIAER) at Tarleton State University in collaboration with USDA-NRCS. The NTT estimates how management changes affect farm losses of sediment, nitrogen, and phosphorus (through leaching and runoff), as well as changes in crop and pasture yields. NTT is based on the Agricultural Policy / Environmental eXtender (APEX) model, the same model used by the NRCS Conservation Effects Assessment Project (CEAP), which is a multi-agency effort to quantify the environmental effects of conservation practices and programs. It is also being used in Oregon by the Willamette Partnership to quantify nutrient in its developing water quality trading program (under the Ecosystem Credit Accounting System), and is approved by the Oregon Department of Environmental Quality for use in water quality trading (but it has not yet been applied) (Willamette Partnership, 2019).

The NTT is a user-friendly web-based tool that enables users to easily access simplified results from the underlying APEX model. NTT requires the user only to enter their field location (using an interactive map) and agricultural management characteristics (such as crop management and schedule, grazing management, fertilizer/manure management, tillage, and a diverse array of conservation practices[3]) under a baseline and a conservation scenario. The application draws from its database of soil and weather for the field location entered by the user, and estimates the nitrogen, phosphorus, and

[3] Management practices include: irrigation; surface and subsurface drainage; furrow diking; buffer strips; terraces; waterways; windbreaks; fertilization and manure management, lagoons and water retention reservoirs, crop selection and rotation; fertilizer, nutrient and pesticide fate and application; grazing management; tillage timing and intensity; confined feeding animal facilities; and harvest timing and methods.

sediment losses (pounds or tons per acre) from the analyzed agricultural lands under each scenario. Model estimates are based on a 30-year simulation based on historic weather and are presented as both monthly and annual estimates of nitrogen, phosphorus, and sediment (N, P, S) per acre.

Table 4-3: Water Quality Effect Quantification: Methodologies, Tools, and Data Sources

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Nutrient Tracking Tool (NTT) [a]	All cropland and pasture	Tillage/residue management, contour farming, cover crops, filter/buffer strips, fencing, prescribed grazing, forage management, riparian zone management tile drain, wetlands, ponds, land leveling, terrace system	N, P, S, water flow, crop yield	Soil, slope, weather, land management information (crop schedule, planting and harvesting dates, grazing operations, fertilizer/ manure operations and tillage operations)	Field locations, operational characteristics, web-based	Medium, very user friendly	Medium, intended to be used at farm/field level. Output provides a confidence interval for the estimates	Total N, P losses (lbs/ac), subsurface flow and other water info (inches of flow), total sediment (ton/ac), change in crop yield per acre.	USDA NRCS, US ARS, Texas Institute for Applied Environmental Research at Tarleton State University. Used by NRCS in its CEAP NTT is approved by Oregon DEQ for water quality trading.
L-THIA (Long Term Hydrologic Impact Assessment Model)	All	Land use conversion (commercial, industrial, residential, grass/pasture, wetland/water, agricultural, forest)	N, P, S, bacteria, Water Recharge	Daily precipitation, soil types, type and size of land use conversion	Location, land use, hydrologic soil group, land area. 3 versions available: spreadsheet, GIS, web-based	Low (quick, accessible)	Low	N (lbs), P (lbs), TSS (lbs), fecal coliform (millions), various metals (lbs)	Purdue University, US Army Corps of Engineers, Michigan State University; Great Lakes Tributary Modeling Program

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
SWAT (Soil and Water Assessment Tool)	All	Land management practices and many agricultural BMP's and practices	N, P, S and water balances for both surface and groundwater	Watershed level land use, soils, management conditions, vegetation, weather	Weather, soil properties, topography, vegetation, land management practices	Specialized training required. Model requires calibration and validation.	Watershed scale model not farm-level over long periods of time. Not appropriate for field or farm level scale.	Water balance outputs are presented in millimeters, sediment and chemical balances are generally presented in either kilograms per hectare or metric tons per hectare	Texas A&M University
Agricultural AGNPS (Agricultural Non-Point Source Pollution Model)	All	Animal practices, crop management	NPS	Hydrologic and hydraulic parameters, and topography.	Med/High data needs and level of effort	Medium	Medium	Surface water runoff with N, P, C, and sediment, annual loads and load reductions	USDA Agricultural Research Service

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
REMM (Riparian Ecosystem Management Model)	All	Riparian Buffers (including simulation of buffer size, vegetation type, and biomass harvesting)	Water Quality, Carbon Sequestration	Hydrology, soils, vegetation	C++. High data inputs. Upland loadings (from upland field model or use estimates, number of channels, channel side slope/overland flow area, daily precipitation, daily surface/subsurface flow from upslope areas, data for deep seepage, thalweg elevation	Specialized	P, N trapping, sequestration	In each of three buffer zones; Seepage (mm/ha), sediment (kg/ha) Nitrogen (kg/ha), phosphorus (kg/ha), carbon (kg/ha), nutrient soil water concentration, ground water concentration	USDA ARS
Revised Universal Soil Loss Equation (USDA) [i]	All	Ridging (contouring), vegetative strips & buffers, runoff interceptors, sediment basins	Water Quality	Land use, till method, production level, ecological maturity	User must download the application. The application is not very intuitive and requires an experienced user.	Medium. Application is used in several other models to estimate erosion	Unknown	Soil loss and sedimentation delivery in tons/acre/year	USDA

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Shade-A-Lator	All	Riparian vegetation restoration	Water quality (temperature)	Elevation, topography, height of vegetation (pre and post project)	ArcGIS, aerial photographs of site, digital elevation model (DEM) representing topography, spatial vegetation data (LIDAR or veg map/photo), planting plan	Medium. Application via ArcGIS, a collection of tools and GIS analyses required	High	Thermal credits: Kcal/day thermal load reductions from riparian shade restoration projects	Oregon Department of Environmental Quality, Component of HeatSource model
Water Temperature Transactions Tool	All	Flow Restoration	Water quality (temperature)	Vegetation, landforms, climate	Reach parameters (width/side slope/channel slope/manning roughness), Evaporation coefficients, meteorological data, topography, riparian vegetation width/height/ density, hydrodynamic characteristics, records of water temperature,	Medium	High?	Reach inflow and outflow temperatures, solar radiation	Watercourse Engineering with the National Fish and Wildlife Foundation, Farm Stream Solutions, The Freshwater Trust, and Willamette Partnership.

Sources: (Watercourse Engineering, Inc., 2013; Willamette Partnership, Ecosystem Credit Acounting System, 2014; USDA, 2019; Purdue University, 2016; Texas A&M University, 2019; USDA NRCS; USDA ARS, 2016)

4.1.2 Economic Valuation

Water quality directly and indirectly supports many social and economic values in Oregon, 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 (an oxide of nitrogen), and key sources of nitrates include fertilizers and animal wastes. Oregon has designated three Groundwater Management Areas (GWMAs) because of elevated nitrate concentrations in groundwater (Lower Umatilla Basin GWMA, Northern Malheur GWMA, and the Southern Willamette Valley GWMA) (Oregon Department of Environmental Quality, 2017).
2. Human health and recreational values of clean water bodies. People value clean water bodies, particularly when participating in water-based and shoreline recreation and other shoreline activities where people are in the water or can see the water. Clean water increases these aesthetic and recreation values, and recreational access can be restricted due to human health risk associated with water pollution. In particular, recreation access can be restricted due to harmful algal blooms (HAB), which are associated with nutrient pollution and warm water (as well as stagnant water, high pH, and lots of sunlight); are a health risk for humans, pets, and livestock; and are associate with low oxygen conditions that can kill fish and wildlife, as well. Oregon Department of Environmental Quality has identified subbasins throughout the state that are at risk for HAB; nearly every basin in the state has a subbasin that is at risk, including the Willamette, Sandy, Hood, John Day, Umatilla, Grande Ronde, Powder, Malheur, Owyhee, Klamath, Umpqua, Rogue, Deschutes, and North, Mid, and South Coast basins (Oregon Department of Environmental Quality, 2011).
3. Intrinsic value to people of habitat and 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 the fishing industry) or recreationally important (e.g., for angling, wildlife viewing, bird-watching, etc.). Water quality is an important issue for all strategy species identified in the Oregon Conservation Plan, including entire networks of migratory bird habitat and healthy populations of salmon and other native fishes (Oregon Department of Fish and Wildlife, 2016).
4. 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 or increase treatment costs to industrial or commercial users. Typically, agricultural, industrial, and commercial activities are less sensitive (than municipal, recreation, or environmental uses) to changes in water quality.

4.1.2.1 Locational Factors Affecting Water Quality Value & Available Data

There are two key factors that affect the socioeconomic value of water improvement. First, the current and projected future level of water quality a basin affects the value of improvements. For example, if water quality is already high in a basin and water quality is not adversely affecting uses, then there likely little economic value of improvements. Secondly, the type and number of water users in a basin (both human and other species), and the sensitivity of those water users to changes in water quality also determine economic value of water quality improvements. As summarized in the bullets below and in

Table 4-4, there are good data available on the current level of water quality, drinking water uses, habitat and species distribution. There is some readily available spatial information on waterbodies that may be recreationally important, but there is a data gap on the type/level of recreation usage and sensitivity to changes in water quality.

- Current water quality
  - *Data available: list of 303d impaired waterbodies, Oregon water quality index groundwater management areas, Oregon Department of Agriculture strategic implementation areas, Oregon waterbodies at risk for harmful algal blooms.*
- Drinking water uses
  - *Data available: source waterbodies and lands for drinking water, population affected by drinking water sources*
- Sensitive species and habitats use
  - *Data available: Fish distribution, Oregon Conservation Opportunities Areas with flowing waters/riparian/wetlands as key habitats and water quality as a key conservation issue.*
- Recreation use
  - *Data available: Oregon water trails, Oregon scenic waterways*

Table 4-4: Data to Indicate Socioeconomic Value of Water Quality Improvements

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Oregon Drinking Water Source Assessment (surface and groundwater)	All Oregon	Identify source lands for drinking water	GIS data, web-interface, excel tables	Data on landcover, ownership, soil erosion index (information on lands that may most affect water quality), water treatment system susceptibility, and population served by water source	Oregon Department of Environmental Quality
Agricultural Water Quality Plans	All Oregon	Identify priority conservation practices	Reports	38 area plans, committee identifies local agricultural water quality problems and opportunities for improvement, Identifies water quality limited streams (303d list), beneficial uses, priority conservation practices	Oregon Department of Agriculture
Agricultural Water Quality Strategic Implementation Areas	All Oregon	Identifies priority areas	Reports	Selected areas to receive outreach/education/funding to address priority water quality concerns	Oregon Department of Agriculture
DEQ 2012 Integrated Report Assessment Geodatabase (2019 version)	All Oregon	Impaired waterway data	GIS	Assessment of each waterbody in the state and Oregon statewide 303d list of waterbodies as water quality limited as approved in December 2018 by US EPA	Oregon Department of Environmental Quality

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Oregon Water Quality Index	Rivers of Oregon	Index of water quality from 10 to 100 based on many water quality variables (pH, DO, BOD, N, P, bacteria, temp, etc.)	GIS and report format	Excellent, Good, Fair, Poor, Very Poor rating system; Sub-index status for Temp, pH, dissolved oxygen, total solids, biochemical oxygen demand (BOD), nitrogen, phosphorus, and bacteria	Oregon Department of Environmental Quality
Groundwater Management Areas	All Oregon	Identify key areas with existing groundwater quality issues	Maps, GIS?	Basins with known groundwater contamination	Oregon Department of Environmental Quality
Oregon Fish Habitat Distribution Data	All Oregon	Indicate potential fish habitat benefits	GIS, web-viewer	Fish Habitat Distribution	Oregon Department of Fish and Wildlife
Conservation Opportunity Areas	All Oregon	Indicate potential habitat benefits	GIS, web-viewer	Identification of key habitat conservation areas in the state, particularly those with flowing waters/wetlands/riparian areas designated as key habitat	Oregon Department of Fish and Wildlife
State Scenic Waterways	All Oregon	High aesthetic value waterways	Map, GIS?	21 rivers and 1 lake designated as scenic	Oregon Parks and Recreation Department
State Water Trails	All Oregon	Recreation waterways	Map, GIS?	11 designated water trails	Oregon Parks and Recreation Department

Sources: (Oregon Department of Agriculture, 2018; Oregon Parks and Recreation Department, n.d.; Oregon Department of Environmental Quality, n.d.; Oregon Department of Agriculture, n.d.; Oregon Department of Environmental Quality, 2019; Oregon Department of Environmental Quality; Oregon Department of Fish and Wildlife, 2015; Oregon Department of Fish and Wildlife, n.d.; Oregon Parks and Recreation Department, n.d.)

4.1.2.2 Water Quality Valuation Approaches and Data Sources

As discussed in the introduction, ideally, economic valuation of water quality improvements includes four steps:

1. Identify how a conservation management practice (or suite of practices) results in a change in water quality parameters (e.g., concentrations of nutrients/sediment/etc.),
2. Determine the associated change in the aquatic ecosystem (e.g., water clarity, disease-causing bacterial population levels, fish population levels, etc.),
3. Measure this change in terms of social and economic parameters of importance (e.g., change in water treatment required, change in number of days swimming is affected by harmful bacteria levels, change in number of fish caught, change in population of threatened or endangered species, change number of boating visitor days improved because of increased water clarity, etc.), and
4. Value these changes economically.

However, as discussed above, completing even the first step is challenging. Given the complexity of the valuation process, there are numerous approaches in the economic literature for defining water quality and estimating the associated economic value, as summarized below.

- **Value of One Water Quality Parameter.** There are several studies that focus on valuing the effect of a single water quality parameter, often sediment, on all economic values, including navigation, recreation, species habitat, and municipal drinking water treatment costs. In its benefit-cost analyses of several programs, including the Environmental Quality Incentives Program (EQIP), the Natural Resources Conservation Service has estimated changes in sediment and applied a value per ton of reduced sediment in waterways (Natural Resources Conservation Service, 2010).
- **Water Quality Index Approaches.** Compared to valuing a single water quality parameter, a more comprehensive approach is to value economically a change in an overall water quality index (such as from 0 to 10 or 0 to 100) that integrates the effects of numerous water quality parameters. The Environmental Protection Agency (EPA) uses a water quality index to value the effect of regulatory measures on water quality. If using an overall water quality index, many economic studies make the index meaningful to people by identifying discrete points on the index where water quality is sufficient for specific designated activities or uses (e.g., on a 10-point scale, at a water quality index value of 2.5 the water is ‘‘boatable’’, 5.0 is ‘‘fishable’’, and 7.0 is ‘‘swimmable’’)**.** A 2007 study provides an overview of the water quality values found in the literature[4], and also identifies several important factors that cause willingness to pay for water quality improvements to vary between geographic locations (Van Houtven, Powers, Subhrendu, & Pattanayak, 2007). The study started with over 300 publications on water quality, and then analyzed 18 studies that contained 131 water quality value estimates based on people’s stated willingness to pay for water quality improvements (i.e., stated preference studies). Each of these studies also used a definition of water quality that could be converted to a comparable 10-point scale (1 to 10). In general,

[4] This is a meta-analysis study, which statistically estimates a valuation function using a database of studies with values (the dependent variable) and characteristics (independent variables) such as study location, degree of environmental quality changes, base environmental quality, local income characteristics, etc.

economic studies such as these that define an overall water quality index and incorporate the multi-dimensional aspects and potential values of water quality are expected to provide the most accurate estimates of the total value of water quality improvements (Griffiths, et al., 2012).

- **Damages/Avoided Costs of Water Quality on One Use**. There are also case studies and analyses of the economic value of water quality impacts on a single water use. Numerous studies evaluate changes in water treatment cost due to changes in water quality, changes in dredging costs due to sedimentation, or changes in recreation value or property values due to changes in water clarity. For example, following a flood in 1996 numerous western Oregon cities faced increased costs due to sedimentation in their water supply (US Government Accountability Office (GAO), 1998). Data from these events, and associated studies are very location-specific and provide an estimate of water quality value for only one use (not all water uses in a watershed). However, these types of studies can provide good comparison points for estimates of 'average' value for all benefits derived from other studies.
- **Water Quality Markets.** Finally, there are evolving water quality markets, where water quality credits (typically for nutrients or temperature) are traded, providing a market price. In Oregon, there are several water quality markets whereby water utilities are paying for temperature credits (City of Medford and Clean Water Services). These and other water quality market prices reflect most closely the cost of abatement, rather than the economic value of water improvement. However, these prices provide another point of reference for the potential value of water quality improvements (most applicable for basins where pollution abatement would be required by law).

In summary, there is significant uncertainty in estimating an economic value of water quality improvements, and even case study applications often focus on just one type of water use rather than the benefit of water quality improvements to all uses. For a statewide program, the studies that provide a value per unit of pollutant (e.g., per-pound of nutrient and per-ton of sediment) may be the most feasible to apply. These studies are typically based on the cost to drinking water treatment facilities of water quality impairments or the costs to abate contamination of waterways.[5] As such, these values are indicators rather than total estimates of the total economic value of water quality improvement.

It may also be feasible to 'cross-check' the per-unit values of pollutant reduction to ensure that results are consistent with estimates of the total value of water quality improvements (as estimated by the studies of household willingness to pay for improvements in water quality indices). This could be done by using average value results from the household willingness to pay studies[6], estimates of basin water quality from the Oregon Water Quality Index, and the number of households in the basin to estimate the total possible value of water quality improvements in a basin. This value could conceivably then be compared against the potential value resulting from a per unit of pollutant reduction approach applied to the possible pollutant reduction from farms in a given basin.

[5] Note that nutrient and sediment abatement costs are often based on the cost of agricultural conservation measures, which would be a rather circular approach of valuing conservation practices based on the costs of conservation practices.

[6] For example, in the 2007 Van Houtven et al. meta-analysis, the estimated annual household/individual willingness to pay from individual studies per unit of water quality change (on a 10 point scale) varied from $3.80 to $228 per year, with a mean of $45 per year.

4.2 Water Quantity

In many basins throughout the state, there is not enough flow in streams and rivers to meet agricultural, municipal, and industrial water demands and also sustain high quality aquatic habitat. There are also numerous basins in the state with declining groundwater levels, including the Umatilla, Hood River, Malheur, Deschutes, Summer Lake, and Willamette basins (Oregon Department of Water Resources, 2017). Population growth throughout the state and climate change may exacerbate water shortages in the future. By 2050, statewide consumptive water demand is expected to grow by 15%, while changes in hydrology may simultaneously decrease the volume of flows during high demand summer months (Oregon Department of Water Resources, 2017).

Agriculture, as the largest water user in the state (accounting for 86% of state-wide consumptive water demand in 2015 (Oregon Department of Water Resources, 2017)), has a major stake and role to play in making the most of our available water supplies. Agricultural water conservation has many potential benefits. For the producer, improved irrigation efficiency can enhance water supply reliability; potentially improve crop yield and quality through delivery of the right amount of water at the right time; and potentially decrease energy costs, irrigation costs, and nutrient management costs. For the public, agricultural water-use efficiency and conservation can provide the following benefits: increase water supply reliability for municipal, residential, and industrial uses; improve water quality through reduced runoff and reduced deep percolation of nitrates, nitrites and farm chemicals; and enhance instream flows for fish and wildlife populations and water-based recreation.

Conservation practices in agriculture that would positively impact water quantity, cropland management, and water use efficiency. This section describes these conservation practices in greater detail. To the extent that water conservation results in enhanced instream flows (or water for wetlands or other waterbodies), these practices have public benefits.

Cropland Management is a broad definition for any measure that would involve altering production practices. Deficit irrigation is a production practice whereby the producer voluntarily applies less water than the crop needs for full development. Typically, crops with deep roots such as wheat and corn can be deficit irrigated with only minimal yield losses.[7] Some crops actually benefit from deficit irrigation during part of the growing season, including almonds, wine grapes, and alfalfa seeds. Deficit irrigation is less successful with crops for which the proportion of the yield is monetizable or quality is significantly depressed with reduced water application such as potatoes, onions, and several other vegetable crops (Shock, 2013).

Water Use Efficiency measures in production agriculture such as precision irrigation techniques and upgrades to irrigation infrastructure are directly related to water quantity benefits. Precision irrigation techniques require the producer to monitor soil moisture and then utilize that information along with weather conditions to implement optimal irrigation techniques. These techniques can improve production and reduce overall costs to the producer while saving water. There are a variety of soil moisture probes and soil moisture monitors with data loggers available for purchase for measuring and monitoring soil moisture on a 'do-it-yourself' scale (e.g. Meter Group out of Pullman, Washington has a wide variety of soil moisture monitors) (METER Group, 2019). In addition, there are several monitoring systems (software and equipment) available that allow producers or crop consultants to view real time

[7] Quality may be impacted along with yield in certain situations.

data via web portals, these include: John Deere Field Connect, Lindsay Corporations' Growsmart, and Wildeye (Dorsey, 2017).

Investing in more efficient irrigation infrastructure is another water-use efficiency measure that would enhance water supply. This is a broad category that would involve converting an on-farm irrigation system to one with a higher efficiency or increasing the conveyance efficiency of the system. These investments will require less water while fully meeting crop water needs. Illustrative examples of these types of conservation practices are provided below, utilizing the desktop review approach as described in the section above:

- Flood systems without tailwater returns or cutbacks have efficiencies as low as 40%. If converted to a continuous move sprinkler (e.g. center pivot) the efficiency would likely more than double to at or above 85%. For an alfalfa crop in the Umpqua River area this could result in reductions of over three acre-feet (36 acre-inches) per acre (Cuenca, 1992).[8]
- Conversion of a graded border flood irrigated field with no tailwater return but with a cutback (efficiency of 70%) to a drip system would increase efficiencies to 90%. For an onion crop in the Pendleton area this would result in reductions of nearly nine acre-inches per acre (Cuenca, 1992).[9]
- Adding drip lines (90% efficiency) to an existing solid set sprinkler system (efficiency of 70%) in a pear orchard in the Hood River area would likely reduce water use by around 16 acre-inches per acre.[10] The solid set sprinkler would likely remain as a form of frost protection in the spring, but the addition of drip lines would likely result in substantial water savings (Penhallagon, 2019).
- Recent developments in irrigation infrastructure efficiency have focused on subsurface drip irrigation (SDI) which would be relevant to a wide range of crops. Malheur Experiment Station is investigating ways to leave drip tape in the ground through several cropping cycles, but research suggests efficiencies of subsurface irrigation could be around 95% (Shock C. , n.d.) (Shock, 2013).

While the above-mentioned conservation practices could provide additional water supply to other users in the watershed or provide additional flows for aquatic species or riparian habitat there are possibilities for unintended consequences associated with changing water usage. Examples include improving efficiency where flood irrigation or return flows provided high quality habitat. These situations may best be quantified based on changes in acreage of available habitat (Section 5.5) but the valuation of such habitat may still be presented in value per volume of water and thus there would potentially be overlap between the water quantity and habitat benefit calculations for certain measures.

4.2.1 Biophysical Quantification

There are varying levels of effort and accuracy with which a program like this could be structured, as presented in **Table 4-5**. At a state level it is reasonable to consider desktop reviews of water

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8 Irrigation requirement of 29 inches / 40% efficiency = 72.5 acre inches applied in flood irrigation scenario vs. 29 inches / 85% efficiency = 34 acre inches applied in a sprinkler application.

9 Irrigation requirement of 29 inches /70% efficiency = 41.4 acre inches applied in flood irrigation scenario vs. 29 inches / 90% efficiency = 32.2 acre inches applied in a drip application.

10 Irrigation requirement of 50 inches / 70% efficiency = 71.4 acre inches per acre in sprinkler application vs. 50 inches / 90% efficiency = 55 acre inches applied in a drip application.

management and associated conservation/availability of water for other uses (including instream uses). However, other (likely more accurate) metering tools and processes exist to evaluate water management. In general, a determination of what the ‘uplift’ is from standard water management practice would require a definition of the amount of water used or made available other uses (such as water for waterfowl in certain flood irrigation systems) in standard management practice; these could be based on historic practices on the farm, average per-acre water application in the region, or average per-acre water application for the relevant crop.

One method of desktop review would quantitatively evaluate water management using published reports of crop evapotranspiration (ET) for various regions across the state as published by Oregon State University (Cuenca, 1992) along with irrigation efficiencies. This approach would require a lower level of effort and cost relative to metering or remote sensing but would also have higher levels of uncertainty and lower levels of accuracy in its conclusions. The calculation of irrigation efficiency in a desktop review could utilize Oregon State University reports on irrigation requirements and system efficiencies to determine water use based on location, crop produced, and existing types of irrigation conveyance and on-farm system. The difference between the historic water use (without conservation practice) and projected water use (with conservation practice) would then equate to the expected water supply enhancements (water left in the stream or aquifer or made available to on-farm wetlands) from the conservation practice being implemented. This calculation would be most relevant to irrigation infrastructure retrofits and upgrades both on-farm and used in conveyance to the farm.

If instead the policy objective is to quantify the biophysical impacts of the conservation practice against regional standards, the calculation of an individual producer’s irrigation efficiency would need to be compared to regional standards for irrigation as reported to Oregon Water Resources Department (OWRD). The difference between the region or industry standard (as reported) and the calculation of water use for the individual producer would equate to water savings (water left in the stream or aquifer) above and beyond the typical operation in the region. This calculation would be most relevant to deficit irrigation, precision agriculture techniques, and possibly other conservation practices like transitioning to crops with lower ET requirements.

Metering is another tool that could be implemented in several different manners to accurately measure water applications on the individual grower or parcel level. Water meters could be provided (or possibly required by the conservation management plan) to measure flow (either as a direct water application or at diversion points). In the event that no baseline data exist for an individual grower or parcel on actual water use it would be possible to estimate a baseline water use through remote sensing of ET (see below) or estimated through desktop review (see above).

Flow measurement devices are available on the market with a variety of features and sizes. The general cost of flow measurement meters of 3 inches in diameter or larger range from $1,500 to $3,500 per meter (Instruments, n.d.) (Instrumart, June) (Netafim, 2019). The installation of flow meters would provide data on water usage by individual irrigator, where water is conveyed through a pipeline. Reduction in water use over time could be measured with high levels of accuracy. In the event that a participating producer is diverting from an open canal or stream directly, equipment is available to measure the upstream and downstream flows. The difference would then provide an estimate as to the amount of water diverted for irrigation purposes. One example of this type of equipment is the vented pressure transducer, which collects and automatically corrects data for barometric pressure. Typically, these transducers are placed in the water but are connected via cables to data loggers installed on land. This type of system generally costs about $200 to $1,000 per unit[11], depending on the features associated with the data logger.

Remote Sensing of Evapotranspiration (ET) involves using satellite imagery and climate information to map crop ET. Mapping ET at high Resolution with Internalized Calibration (METRIC) is one process available today that uses Landsat imagery and gridded climate data (PRISM Climate Group data from Oregon State University or AgriMet data) to estimate crop ET. When applied to irrigation efficiency values, this can be used to estimate water use for areas at the sub-field level. METRIC is generally used in the western United States for estimating crop ET or as a tool in improving irrigation management. It was originally developed by University of Idaho and Idaho Department of Water Resources. The METRIC methodology could be applied to any year in which satellite imagery are available. The actual geospatial analysis could be conducted by a number of consulting firms with access to climate data and satellite imagery or possibly by staff hydrologists at ODWR. This would likely require a higher level of effort (and possibly cost) than simply metering water flows prior to implementation of a conservation practice.[12] However, the process has proven to be highly accurate, and would not rely on producer reports or producer participation in a metering program.

[11] To measure upstream and downstream of a diversion point it would cost roughly $400 to $2,000.

[12] Oregon's Klamath Basin Rangeland Trust has applied METRIC in the Klamath River Basin to assist in mitigation of impacts of irrigated agriculture on Native American water rights on Pacific salmon endangerment (University of Idaho, 2010).

Table 4-5: Water Quantity Effect Quantification: Methodologies, Tools, and Data Sources

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Timing of Benefits Accounted for?	Developer/ Notable Uses
Remote Sensing of ET using METRIC process, satellite imagery and climate data	All	Any measure that would reduce ET	Water supply	Remote sensing approaches transform thermal and reflected spectral imagery from Landsat satellite images into evapotranspiration images.	Landsat, PRISM climate, AgriMet, or other climate data	High, must be familiar with the METRIC system for calculating ET and have access to climate data. Could use ET estimates to back into crop water application. Capabilities exist in OWRD and regional consulting firms.	METRIC is reported to be highly accurate.	METRIC is an energy balance model that computes and maps ET using Landsat images. The METRIC approach provides accurate water distribution information and identifies trends in agricultural water use.	Results of a remote sensing exercise like METRIC could be presented in terms of crop ET or annual water use.	Process was originally developed by University of Idaho and Idaho Department of Water Resources.
Desktop Review using Oregon crop water use and irrigation requirements, along with reports of water use	All	Any irrigation infrastructure, scheduling or land leveling practices.	Water supply, specifically Net Irrigation Requirements and System Efficiencies	Crop type, location, and precipitation during the growing season. Baseline information could also utilize reports of water use at the State level.	Matrices provided in the publication provide the necessary inputs.	Low level of effort to use tables of net irrigation and system efficiency to estimate water usage.	Likely the lowest accuracy and highest uncertainty of the methods considered for water quantity, but highest ease of use.	Net irrigation requirements by crop, location and type of water year. Results could be used to determine volume of water diverted on an annual basis.	Findings are presented in terms of acre inches of water per acre, on a monthly and annual basis.	. Information is somewhat dated (1992) but is expected to be relatively accurate.

METHODOLOGIES FOR VALUING AGRICULTURAL CONSERVATION MANAGEMENT ACTIONS

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Timing of Benefits Accounted for?	Developer/ Notable Uses
Metering	All	Any measure, and to establish baseline water usage	Water reductions at the field or diversion point	Meter readings	Wide range of types of meters and meter systems are available	Ranges from low expertise with high level of effort (manually recording) to high expertise with low level of effort (data loggers that are blue tooth or web enabled)	High, but would require participation from the producer.	Volume (acre feet) or flow (cfs) of water through time	Recording flows is done at various time intervals (e.g. hours or minutes)	There are a wide range of meter types and associated costs, depending on features of the meter accessibility of the data

Sources: (University of Idaho, 2010; State of Oregon, 2019; Cuenca, 1992; US Bureau of Reclamation, 2019; PRISM Climate Group, 2019)

4.2.2 Economic Valuation

Water quantity directly and indirectly supports many social and economic values in Oregon, many of them similar to the values related to water quality, including:

1. **Income**. Income from economic activities using water as an input, including agriculture, industrial facilities, and hydroelectric generation facilities relies on access to adequate and reliable water supplies.
2. **Reliability of residential and municipal water supplies**. Municipal water supply curtailments can cause diverse costs, including those related to inconvenience, aesthetics (for example, brown lawns and unwashed cars), damaged or lost landscape plants, and reduced economic activity by commercial water users. There are relatively few studies of the costs of water shortages, but there are some survey data from California and Colorado indicating residential water users' willingness to pay to avoid such shortages.
3. **Habitat/Species values**. Many species that are dependent on sufficient water in streams, wetlands, and at drinking water sources. As noted above, value for species and habitats 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 the fishing industry) or recreationally important (e.g., for angling, wildlife viewing, bird-watching, etc.).
4. **Recreation values**. Recreation value can vary depending on the level of water in reservoirs, lakes, and wetlands. Certain recreational activities, such as boating, require minimum levels of water, or have certain flow levels at which recreation value is maximized. Also, recreational aesthetics and access can be compromised when water levels recede from facilities such as campgrounds and boat launches or expose mud flats.

4.2.2.1 Locational Factors Affecting Value & Available Data

There are two key factors that affect the socioeconomic value of agricultural water conservation. First, the current and projected future level of water scarcity (for human uses and for fish and wildlife habitat) in a basin affects value. Secondly, the sensitivity and number of people and types of species and habitats affected by water scarcity also affects value. As summarized in the bullets below and in **Table 4-6**, there are good data available on the current level of water scarcity and the sensitivity of human uses. Information is also available on aquatic fish habitat and areas with potential for enhancement of fish habitat. Data gaps include how recreation activities may be impacted in water scarce conditions.

- Current and projected shortages for human uses
    - *Data available: Volume of water (AF) currently used for consumptive purposes across the state, projections through 2050; drought index with information on the occurrence of drought within particular basins.*
- Population affected by projected shortages
    - *Data available: Estimates of water use and projections by consumptive use type (volume of acre feet demanded annually), consumptive use index providing a measure of how much water in a basin is dedicated to consumptive uses relative to water available instream.*
- Types of human uses affected by water scarcity

    - *Data available: Uncertainty in future water supplies and demands is estimated through evaluation of how the range of potential future climates would affect consumptive uses as part of the long-term water demand forecast.*
- Current and projected future instream flow scarcity for aquatic habitat
    - *Data available: maps comparing diversions with instream flow rights in priority watersheds*
- Presence of aquatic T&E species
    - *Data available: presence or absence of fish species at a spatial and temporal scale*

Table 4-6: Data to Indicate Socioeconomic Value of Water Quantity Improvements

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Oregon Statewide Long-Term Water Demand forecast	All Oregon	Considering future conditions regarding water scarcity	Report	Volume of water by type of use and place of use, current and projected	Water supply and demand forecasts through 2050 based on population estimates, climate scenarios, and other variables
Basin Level Datasets for Anticipating Future Water Scarcity and Conflict in Oregon	All Oregon	Identifying areas of water shortage	GIS	Hydrologic data, including trends in supply and demand (drought index, consumptive use index), population, hydro political data	Oregon State University, Oregon Water Resources Department, Portland State University
Place Based Integrated Water Resource Planning	Four regions in Oregon currently: Mid-Coast, Lower John Day; Harney and Upper Grande Ronde	Information on location specific issues concerning water quantity	Being developed currently	Unknown but likely to compile location specific knowledge of land and water resources.	State of Oregon is sponsoring financial and technical assistance to four areas for developing a volunteer, locally initiated, collaborative approach to water planning.
Oregon statewide streams and fish presence	All Oregon	Indicate potential fish habitat benefits	GIS, web-interface, excel tables	Presence of absence of fish species, spatial and temporal scale	Oregon Department of Forestry, identify uses of where riparian buffer rules apply

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Oregon Fish Habitat Distribution Data and Fish Barrier Data	All Oregon	Indicate potential fish habitat benefits	GIS, web-viewer	Fish Habitat Distribution and Fish Barrier Data, including priority barriers. Fish species include: bull trout, fall/spring chinook, chum, coho, sockeye, summer/winter steelhead, green/white sturgeon lamprey, rainbow/redband/coastal cutthroat trout	Oregon Department of Fish and Wildlife
Priority areas for Streamflow Restoration	Statewide	Indicate areas of high surface flow restoration need for salmonids	GIS, maps	River basins ranked for restoration need (for recovery of salmonids), flow restoration optimism, and State's priorities for restoration activities. Summer streamflow restoration priorities provided	OWRD and ODFW Natural Resources Information Management Program, used to fulfill Oregon Plan Measure IV.A.8, Identify Instream Flow Priorities
Oregon Water Resources Department Strategic Management Plan	All Oregon	Water demand relative to supply		Water demand & projections for instream and out of stream uses	Oregon Water Resources Department
Oregon Groundwater Administrative Areas	All Oregon	Identify gw shortage areas.	Maps, GIS data	22 designated groundwater administrative areas with differing levels of restriction of uses, 7 designated critical gw areas with water supply issues.	Oregon Water Resources Department
State Scenic Waterways	All Oregon	Waterways with higher aesthetic/recreation potential	GIS, map	State Scenic Waterway Designation	Oregon Water Resources Department

Sources: (Oregon Water Resources Department, 2015; Oregon State University, Portland State University and Oregon Water Resources Department, 2019; Oregon Department of Water Resouces, 2019; Oregon Department of Fish and Wildlife, 1990-2002; Oregon Water Resources Department, 2007; Oregon Water Resouces Department, 2019; Oregon Department of Water Resources, 2019; State of Oregon, 2019)

The impact of additional water left instream or in a groundwater aquifer would also largely depend on other uses in the basin and if the basin is over-appropriated. Because of the doctrine of prior appropriation in the West, consumptive water use is on a "first in time, first in right basis." However, in several basins, during an average water year the appropriated use is greater than available (or sustainable) water supply. Thus, during a shortage the water flows to the most senior right. Theoretically, if conserved water were kept in the system on a voluntary basis, and shortages were occurring in that basin, the conserved water would flow to the next water user in line of seniority.

Caveats to this situation would be where regulated minimum instream flows are established and not being met or where consumptive water rights are junior to environmental water rights in the basin.

4.2.2.2 Water Quantity Valuation Approaches & Available Data

There are several approaches to valuing water quantity, as summarized below. The value of the conserved irrigation water can often be looked at in two ways: the value of increased water in waterbodies, or the value of maintaining irrigated agricultural production value. It is also feasible that municipal or commercial water supply value may be affected, but in most basins throughout the state, we expect that agriculture and fish and wildlife habitat (and recreation) uses and values are likely the most affected by the level of agricultural water use. Since value is specific to use, the methods are generally aligned with different types of water use. Ideally, there would be available methodologies to estimate the economic value per acre-foot of water used to support fish and wildlife habitat or recreation. However, as with water quality, the pathway of estimating how a conservation practice affects water quantity, to how it affects flows or water levels in a given water body, to how this affects biologically or recreationally important parameters (such as water temperature, number of fish), to how this affects economically important parameters (species abundance/catch rates, quality of boating experience) is complex and very challenging. As such, we draw from a variety of approaches that may implicitly capture the value of water for these uses on a per AF basis.

- **Market Values.** With increasing water scarcity, numerous water markets have developed in the West, including more recently in Oregon. Values from water markets likely represent the best method of estimating value of agricultural water management practices. In these markets, water is transacted between and among agricultural, municipal, and environmental uses. Values in transactions represent the value of the water in its present use to the seller (often agriculture), and the minimum value to the buyer of the intended water use. The value of any specific water right is dependent on many factors, including water right quantity/period of use, transferability to other uses/users, and most importantly, the location (basin and subbasin) and the uses of water and relative scarcity of water in that location. There are several sources of historic water transactions that provide information on the range and 'average' values of water right transactions, including those for environmental purposes (e.g. Bren School Water Transfer Database[13], which utilizes the former 'Water Strategist' publication and the Columbia Basin Water Transactions Program run by the National Fish and Wildlife Foundation).

  Also, the Oregon Department of Fish and Wildlife recently embarked on an effort to economically evaluate instream water rights, including preparation of a statewide geodatabase of environmental water transactions in Oregon that includes transaction prices (Oregon Department of Fish and Wildlife, 2019). These databases provide a good reference point for the value of water in various locations around the state. As agricultural water users are often the sellers in these transactions, the value of water reflected in these transactions often reflects the value of water in increasing agricultural profits (i.e., the cost or foregone income to the agricultural producer due to the reduction in water supply). This leads us to our next methodology.

[13] The Bren Water Transfer Database is the largest publicly available dataset of water transfers and includes information on 130 water transfers in Oregon between 1993 and 2009.

- **Value of Water to Agriculture: Agricultural Productivity Approaches (Land Price Differential and Income Capitalization):** The value of water in agriculture (and reflected in agricultural water markets) is often estimated based on income potential to farmland with and without water supplies. This is measured through two approaches: the land price differential and the income capitalization approach. The land price differential (a hedonic method) measures the difference in value of land (assuming all other land attributes are equal) with and without water rights. Assessed property values reported at the county or state level; as well as land values reported by National Agriculture Statistics Service (NASS) can be used for purposes of a land price differential analysis when considering value of water in specific basins. An example of this approach to water valuation in Oregon was reported in the Journal of the American Water Resources Association article "Valuing Water Rights in Douglas County Oregon, Using the Hedonic Price Method." The authors of this study reported a value of an acre-foot of irrigation water at $261 in 2007, based on 2001 land price data (Bustic, 2007). The challenge associated with this methodology is excluding other factors that drive land values besides water such as parcel size, location, and building improvements. This valuation approach is time and data intensive and while it is possible to conduct the valuation with this methodology it may not be the most efficient method.

  The income capitalization approach directly estimates the change in net income (profit) to an agricultural operation due to a change in water supplies. This method accounts for changes in revenues and costs due to changes in water supplies, and conceptually, is the basis for the minimum price irrigators would be willing to accept in a water rights transaction (see above).[14] This approach typically entails developing crop enterprise budgets for irrigated and dryland crop rotations commonly grown in the area or specific to the farm in question. Enterprise production budgets reported by Oregon State University along with NASS data on cropping patterns, yields, and prices received are key variables in estimating profit from irrigation for a specific region.

- **Water Replacement Cost/Substitute Cost: Costs of Alternative Water Supplies or Efficiency (Conservation):** This approach focuses on estimating the incremental cost of replacing an existing water source with a new source of water, or with the incremental cost of water conservation practices that reduce demand. As always with replacement costs, it is important to note that costs are not equivalent to economic value – and that for this approach to be applicable, these alternative measures would be implemented and these costs incurred if not for the agricultural conservation practices.

  Costs of developing new water supplies may be associated with well deepening, constructing additional storage such as dams (or increasing storage capacity of existing reservoirs), or developing additional groundwater storage through aquifer storage and recovery (ASR, whereby water supplies in periods of water abundance can be pumped into underground aquifers for later use during times of water scarcity). There are cases of these types of activities being engaged in throughout the State that can serve as reference points for the cost of supply

[14] When analyzed correctly, the income capitalization approach typically returns the minimum value of a water to an irrigator, as it is common for water users to require a premium above the income value to entice them to sell their asset, or change their behavior to voluntarily reduce water use.

development in water constrained basins. For example, the City of Prineville and Apple, Inc. recently announced intention of an ASR project that would cost $8.7 million with the potential to add 180 to 400 million gallons of storage volume (Central Oregonian, 2018).[15]

Alternatively, costs of agricultural or municipal conservation practices may take the form of improved irrigation infrastructure or in-home plumbing fixtures. For example, in the Deschutes Basin, environmental groups, federal agencies, and other funders of conservation have been willing to pay for irrigation water conservation projects (primarily piping of canals) that increase instream flows. While these values are in fact costs, rather than a measurement of benefit, the amounts paid in the past by public agencies for water conservation projects to enhance instream flow should represent the minimum value to the funding entities of conserved water projects (benefits as perceived by funding entities are expected to at least equal costs or funding would not be provided). Costs for these projects are available from the project planning and permitting documents.

Similarly, in Oregon many municipal water providers offer incentives and / or assistance to help water users conserve water. Examples include give away programs for low-flow showerheads, low-flow faucet aerators, and water gauges for lawn irrigation, or cost-share programs for purchasing high efficiency plumbing fixtures (Oregon Water Resources Department, 2015). Information on the effectiveness of these programs (water conserved) and cost of the conservation practices can be used to derive a per AF cost of conserved municipal water.

- **Recreation Values:** If conserved agricultural water enhances the amount of water in adjacent waterbodies, there may be substantial recreation benefit – either directly because of enhanced flow or water levels or indirectly because of enhanced fish and wildlife populations. The economic literature includes some case study analyses of how changes in water levels affect economic values for reservoir and river recreation, including both boating and angling. However, as values are very site-specific, and the reported values are often difficult to translate into per AF values, these are likely not a good source for the value of conserved agricultural water on a per AF basis.

- **Municipal Shortage Avoided Cost** In the event that no replacement supply is available, then water supplies present costs associated with shortages. The avoided cost approach estimates value of water based on the cost of avoiding shortages, which have been estimated through willingness-to-pay surveys in which respondents say how much they'd be willing to pay to avoid water shortages. There are no known willingness to pay surveys for avoiding water shortages in Oregon. However, there are several well-known, and still oft-cited, studies of the value to households of water supply reliability in California and Colorado that indicate household willingness to pay to avoid municipal water supply curtailments (usually limiting outdoor watering days). However, these values are typically on a per household basis and may be difficult to translate into a per AF value. Also, these values are only pertinent to basins where agricultural water use could result in municipal water supply shortages.

[15] This equates to a cost of between $7,000 and $15,750 per acre foot of storage.

In summary, market values from water transactions throughout the state, particularly environmental water transactions from agriculture to in-stream flow purposes, are likely the best representation of the value of agricultural water management measures. These transaction values reflect, at least partially, value of water in both agricultural and environmental uses. However, as with all benefit types, we recommend that multiple approaches be used to consider a range of reasonable values for water, particularly if alternative approaches yield values that may be less than those represented by market transactions.

4.3 Carbon/Climate Regulation

The Third and Fourth Oregon Climate Assessment Reports, released in 2017 and 2019 by the Oregon Climate Change Research Institute at Oregon State University describe changing temperatures, hydrology, and climate risks to Oregon (Dalton, Dello, Hawkins, Mote, & Rupp, 2017) (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019). Overall temperatures are expected to be warmer, particularly in summers, extreme heat and precipitation events are expected to be more frequent, and summer stream flow and soil moisture are expected to be lower. These climatic and hydrologic effects are expected to result in effects on forests (more frequent/severe wildfires, drought, and insect diseases), on coastal areas (more flooding and erosion of coastal areas due to sea level rise), on agriculture (longer grower season but less water available and potential higher insect and disease stress), and on aquatic and terrestrial ecosystems (warming and lower flow streams, ocean acidification, shifts in vegetation, greater presence of non-native species, and other effects will limit and change ranges for salmon, shellfish, and trout and other culturally and economically important species throughout the State) (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Oregonians' health may also be affected through more heat-related illnesses and death, more frequent wildfires and associated poorer air quality, and higher risk of exposure to insect- and water-borne diseases is expected to increase (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Oregon's Native American tribes may be particularly affected by the ecosystem changes expected to be wrought by climate change (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

Agricultural land management practices can affect greenhouse gas emissions (including nitrous oxides, carbon dioxide, and methane) and the level of carbon storage in soils and vegetation. In 2008, agriculture contributed 6.1 percent of total greenhouse gas emissions (GHG) in the United States, with nitrous oxide and methane releases accounting for 86% of agricultural GHG, and carbon dioxide from energy use accounting for 14% (United States Department of Agriculture, 2014). Agriculture can also serve as a carbon 'sink' by increasing sequestration of carbon in soils and plant matter. Conversion of lands to crop production using intensive tillage has resulted in reduced soil carbon on many agricultural lands, but with changes in management practices (such as conservation tillage) agriculture represents a significant carbon sequestration opportunity. In sum, conservation practices and other management changes can reduce GHG emissions and increase carbon storage.

Agricultural practices that can reduce GHG emissions include effective manure management that reduces emissions from animal waste, and replacement of synthetic fertilizers with nitrogen-fixing legumes to reduce carbon dioxide and nitrous oxide emissions (Power, 2010). Agricultural practices that increase soil carbon stores include conservation tillage and no-till cultivation, crop rotations and cover crops (that reduce degradation of subsurface carbon) and water management and erosion control practices that help maintain soils (Power, 2010). These practices improve soil health and can lead to gains in agricultural productivity and resilience (Natural Resources Conservation Service). Agricultural practices can also increase above-ground carbon stores through maintenance or planting of vegetation, particularly trees and shrubs.

4.3.1 Biophysical Quantification

There have been numerous national and regional inventories of GHG emissions and storage, and research into land use and management practices that affect GHG flux. Pertinent to agriculture, in 2014 the Climate Change Program Office of the USDA published an extensive review of methodologies to quantify greenhouse gas fluxes in agriculture and forestry (United States Department of Agriculture, 2014). This review provides estimation methods for quantifying GHG sources and sinks, and how this flux changes under different management practices, in the following land use systems: in cropland and grazing land systems, managed wetland systems, animal production systems, managed forest systems, as well as from land-use change. The data from this technical report was then converted by USDA and Colorado State University into a suite of user-friendly tools. COMET-Farm is for farmers, ranchers, and others to enable them to evaluate the GHG benefits of a diverse array of land management practices. COMET-Farm (updated to version 2.2 as of April 23, 2019), is described by USDA as a 'whole farm and ranch carbon and greenhouse gas accounting system'. The USDA also has a similar tool, COMET-Planner, with the same methods as COMET-farm, but is applicable for analyses conducted at broader levels (i.e., not farm-level analyses). Finally, the USDA has COMET-Energy that focuses on the GHG emissions from on-farm fuel use (differentiating by fuel type). The COMET models rely on another USDA model: Century/Daycent that simulates fluxes of carbon, nitrogen, phosphorus, potassium, and sulfur in vegetation, soils, and the atmosphere.

California, through its California Healthy Soils Initiative, has developed several additional tools to measure and monitor carbon sequestration in agricultural soils. California has worked with NRCS to develop the California Carbon Sampling and Measurement Protocol, as well as to develop a tool to measure the carbon benefits of composting (COMPOST-Planner, to supplement COMET as composting was not a conservation practice incorporated into COMET). The Healthy Soils Incentives Program provides financial assistance to producers to implement conservation management practices that sequester carbon and reduce GHG emissions; these payments are funded through proceeds from the California State GHG cap and trade program (California Department of Food and Agriculture, n.d.). Eligible practices include cover cropping, no till, reduced-till, mulching, compost application, and conservation plantings.

The suite of USDA developed COMET tools provides a user-friendly, farm-level assessment of changes in GHG emissions and carbon sequestration from a suite of agricultural management practices. These tools are feasible for use in a statewide program in Oregon to quantify the GHG benefits of carbon sequestration/emission reductions. To the extent that monitoring is deemed feasible and practical, the guidance developed for California by NRCS on soil sampling and monitoring would be appropriate for Oregon as well.

GHG's are often expressed in terms of ton of carbon dioxide equivalent, or CO_2e. Carbon dioxide is the most prevalent GHG emitted by human activity, but other GHG's 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 25 tons of carbon dioxide, so one ton of methane is equal to 25 tons of CO_2e.

Table 4-7: Carbon Quantity Effect Quantification: Methodologies, Tools, and Data Sources

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
COMET-Farm COMET-Planner	All	Changes in cropping/animal management practices (e.g. operational intensity, animal feed, manure management)	Type of agricultural land use; parcel location and size; historic management practices	Low, Web-based This model uses inputs on management practices (land use, tillage, nutrient use,etc.) together with spatially explicit info on climate and soil conditions (provided automatically) to run a series of models for potential source of GHG emissions.	Low	Expected to be High. This model is new and some features are still being developed. DAYCENT (field module of COMET) has proven accurate (see below) Uses DAYCENT at the field level, livestock calculations are done with recent research and estimates of energy are based on models used in the USDA / NRCS Energy Tool.	Tonnes CO_2 equivalent per year, including from methane and nitrous oxide sources. Total greenhouse gas balance of existing operations (CO2 emissions); taking into account sequestration of plants and emissions of operations.	USDA, Colorado State University
COMET-Energy	All	Reductions in GHG emissions based on fuel savings	Energy use by fuel type	Energy use by fuel type	Low, web interface	Medium	Pounds or tons of CO_2 equivalent	USDA, Colorado State University

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
CENTURY (annual)/ DAYCENT (daily)	All	Cropping pattern changes, cultivation practices (tillage v. no-till), fertilization, fire on the landscape, grazing, harvesting practices, irrigation practices, addition of organic matter, and planting of trees.	N, P, C.	Air temperature, precipitation, surface soil texture class, land cover / vegetation type, cultivation and planting schedules	High Level of Effort, specialized, trainings available from CSU (NREL)	High (within 10 percent)	Estimated pools of carbon and nutrients (N, P, and S) in the biomass, soil, water, and air (respiration) are presented in customizable metrics. 200 specific output variables are available (e.g. accumulation of carbon in straw removed from grass or crop / nutrients in top layer of soil before uptake by plants)	Colorado State University & National Resource Ecology Laboratory; EPA/USDA are using DAYCENT to develop an inventory of N_20 emissions from ag soils.

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Carbon Sequestration in Western Ecosystems	Major ecosystem types. Regions in OR include: Northern Basin and Range, Cascades, East Cascades, Willamette Valley, Coast Range, Columbia Plateau, Klamath Mountains, and Blue Mountains	None	Land Cover Type, including: agriculture, hay/pasture, shrubland/grass land. Average land use practices by county such as tillage, irrigation, fertilization, grazing/no grazing, manure application forest stand age, etc.	None.	Low	Low	Carbon storage (KgC/m^2) and flux (gC/m^2) by land cover type and ecoregion. Considers (carbon dioxide, dissolved inorganic carbon, methane, and nitrous oxide).	US Geological Survey, used to for a comprehensive national assessment of carbon (C) storage and flux of other greenhouse gases
CA Department of Food and Ag: COMPOST Planner	All	Compost application (not included in Comet)	Application rate, nitrogen level of compost	Tool appears to be in development	Tool appears to be in development	Tool appears to be in development	Carbon sequestration, tons CO_2	California Air Resources Board, used to calculate soil carbon benefits of compost application, may be used to financial incentivize producers
California Carbon Sampling and Measurement Protocol	All	Performance monitoring of soil carbon storage		Grid soil sampling to establish baseline, monitoring from new management	Medium	High – laboratory sampling	Tons organic carbon / acre	NRCS California

Sources: (United States Department of Agriculture, 2014) (Natural Resources Conservation Service, 2016) (Marin Carbon Project, 2018) (Colorado State University and Natural Resources Conservation Service, 2019)

4.3.2 Economic Valuation

4.3.2.1 Carbon Locational Factors Affecting Value & Available Data

While the soil productivity and potential air quality benefits of carbon sequestration and GHG emissions reduction are local (but not a focus of this analysis), the benefits in terms of climate regulation are not affected by location. A ton of carbon sequestered from the atmosphere anywhere in the state has the same state-wide and global benefits.

4.3.2.2 Carbon Valuation Approaches & Available Data

The economic value of reduced GHG is the value of avoiding damages caused by climate change, which is 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 many environmental and social impacts of climate change, and 4) the difficulty in expressing future costs in today's dollars (related to the discount rate chosen). Despite these uncertainties, SCC is the most appropriate metric to estimate the value of carbon sequestration and reduced GHG emissions because SCC represents the true economic value across the globe of reducing atmospheric GHG levels.

For several reasons, however, we also present alternative methods of assessing the value of carbon. These methods include: the market prices of carbon, the private and public values assigned to carbon by governments and private corporations, and the cost of carbon offsets, which represent the cost of replacing carbon sequestration. These alternative measures are important to consider for two reasons. First, given the significant uncertainties regarding the SCC, they provide a point of comparison to SCC values. The alternative measures are based on people's current willingness to pay to reduce carbon, and also the costs to reduce carbon emissions (or increase carbon sequestration); these measures are likely lower than the SCC true economic value of carbon, so provide a useful lower bound for the carbon value.[16] Second, the SCC represents the value of climate change mitigation to the global community. If we are assessing benefits to Oregonians, however, it may be more appropriate to focus on the current market rates in California/other regions for carbon as an indicator of willingness to pay for GHG reductions (these values also reflect the cost to Oregonians of investing in carbon mitigation through other mechanisms than agricultural conservation practices). As such, we present a discussion of the SCC, followed by an overview of the alternative market and policy methods that establish other values of carbon (market value of carbon, the private and public values assigned to carbon, and the cost of carbon offsets, which represent the cost of replacing carbon sequestration).

The various methodologies to measure carbon/GHG value, and what they represent are:

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[16] We expect these alternative measures to be lower than the true SCC as people's and government's current willingness to pay today for climate change mitigation is likely lower than the true value of climate change mitigation as people may not fully comprehend the costs of climate change and may not be fully taking into account the costs to future generations. Furthermore, while the replacement cost method (based on the cost of reducing carbon emissions or increasing carbon sequestration) is often taken to be a low bound estimate of value, this is not always the case. However, in the case of climate change replacement cost values are likely to be less than the true economic value of climate change mitigation as such projects can be achieved at a relatively low cost.

- **Social Cost of Carbon:** SCC represents the true economic costs of GHG emissions, which is equivalent to the value to global society of less GHGs in the atmosphere. This is the true benefit of reduced GHG emissions and increased carbon sequestration. Estimating the SCC is challenging, and there is wide variation in the available estimates. For example, a 2009 meta-analysis of nine studies identified estimates ranging from a *benefit* from GHG of \$120/tCO_2e to a cost of over \$13,800/tCO_2e (representing an extreme climate change scenario). The estimates had a mean value of \$636/ tCO_2e, and a median value of \$74/ tCO_2e. [17] The most common source used in the United States for SCC are values from the U.S. Interagency Working Group (IWG), which was formed to provide the US government with a SCC estimate (Interagency Working Group, 2016). Another frequent cited sources is a 2015 Stanford study that adapted one of the models used by IWG to incorporate additional costs to economic growth (Moore & Diaz, 2015). Here, are some of the most important sources of variability in SCC estimates:
  - <u>Our understanding of climate change is constantly evolving</u>, which causes SCC to change over time. As we better comprehend the climate's response to GHGs, researchers incorporate new insights and understanding into the SCC models, causing differences from previous SCC estimates. For example, recent model updates that affect the SCC include: an explicit representation and an updated damage function for sea level rise, updated adaptation assumptions, revised treatment of potentially abrupt shifts in climate damages, updates on impacts to the agricultural sector, and the inclusion of indirect effects of methane gases. In particular, the timing and magnitude of damages, which have a substantial impact on SCC estimates, are among the aspects that are steadily becoming clearer, and have led to differences between past SCC estimates (Tol, 2009). In general, improved understanding of climate change has resulted in SCC estimates rising over time. This highlights the importance of using SCC estimates that incorporate the latest climate change research. Also, as explained by the IWG, "the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change (Interagency Working Group, 2016)."
  - <u>Some damages from climate change are difficult to quantify and/or monetize</u>, causing some researchers to leave them out of SCC estimates. Climate change is expected to have detrimental impacts on ecological, social, and cultural resources, which are especially difficult to economically value. Examples include species extinction and geographic displacement of communities. For that reason, these values are often left out of SCC models, resulting in differences in SCC estimates (Ackerman & Stanton, 2010).
  - <u>Variability arises from social justice issues that are inherent in tallying climate change damages</u>. Depending on how impacts are calculated, climate change cost estimates can undervalue low-income populations and future generations. One problem arises when income losses are included as a cost of climate change. This naturally gives more weight to populations with higher incomes, despite the fact that climate change is expected to reduce

[17] Tol, Richard. 2009. "The economic effects of climate change". *Journal of Economic Perspectives*, Vol 23 No.2. Original estimates were converted from 1995\$/tC to 2015\$/tCO_2 using a conversion factor of 1 ton of C = 3.666 tons CO_2 and updated for inflation using the Implicit Price Deflator for Gross Domestic Product (IPD): Bureau of Economic Analysis (BEA), U.S. Department of Commerce. National Income and Product Accounts Tables, Table 1.1.9. October 29, 2015. Accessed online at http://www.bea.gov/iTable/index_nipa.cfm

the income of some impoverished areas by one-quarter (such as sub-Saharan Africa) (Tol, 2009). Even though the costs are dearer, income losses to poor populations do not carry as much weight as those with higher incomes. Similarly, some models equate the value of lives lost from climate change with the income produced during the victims' lifetimes (Ackerman & Stanton, 2010). The result is that victims in wealthy countries are counted as being more valuable than those in poorer countries. Some researchers employ methods that aim to reduce these inequities and make SCC estimates more socially just, which contributes to differences in SCC estimates.

- <u>Researchers disagree on the most appropriate discount rate to use when estimating SCC</u>. This can lead to wide variability in SCC estimates, even between studies that agree on the timing and magnitude of climate change damages. Discount rates are an accounting feature that incorporates people's time preference for goods. The natural effect of a discount rate is to place a higher value on costs and benefits that occur near the present time, and a smaller value on those occurring in the future. As result, the welfare of future generations is given less weight than current generations. The higher the discount rate, the less value is placed on future welfare. Naturally, this leads to issues of social justice between current and future generations, causing climate economists to disagree on the most appropriate discount rate.

- **Market Price of Carbon in Carbon Cap and Trade Markets (Cost of Abatement):** The market price of carbon is established through emissions trading systems (ETSs) designed to reduce GHG emissions. The general strategy of ETSs is to cap the amount of GHG emissions that can be released by limiting the number of permits to emit GHG. The emitters in regulated industries are allowed to buy and sell these permits to other market participants. The advantage of this system is that natural market mechanisms facilitate GHG emissions reduction at the lowest cost. In general, to meet their emissions cap, a GHG emitter that is subject to an ETS has a choice between reducing their GHG emissions or buying emission permits (also called "credits" or "allowances" depending on the market). Rationally, if buying credits is cheaper than reducing emissions, we expect an emitter to buy credits. Conversely, if emission reduction is cheaper than the credit price, we expect an emitter to sell credits. We thus can interpret the credit price as the approximate cost of GHG abatement or carbon sequestration offsets (which is likely very different from the *benefit* of GHG abatement or carbon sequestration).

  There are 28 ETS's in countries across the globe at various governmental levels (World Bank Group, 2019), with over 50 local, regional, and national jurisdictions participating (Environmental Defense Fund, 2019). Market prices are available from California, which began its own ETS in 2006 when it passed the California Global Warming Solutions Act of 2006, also called Assembly Bill 32 or AB 32. Market prices are also available from the Regional Greenhouse Gas Initiative (RGGI, which is a cooperative agreement between seven Northeastern and Mid-Atlantic states), which in 2005 became the first market-based regulatory system in the U.S. established to reduce GHG emissions. Both RGGI and AB 32 allow both reduced emissions as well as offset credits for sequestration of GHG.

- **Carbon Tax**: The price of carbon in a carbon tax set by governments and internally by some private companies is expected to at least partially reflect public preferences to mitigate climate change damage. However, the price for carbon established through a carbon tax does not necessarily equal the value of climate change mitigation. As damages are in the future and current voters may not expect to bear the brunt of climate change damages, the political process of setting the value of the carbon tax may result in a price that is significantly different (likely lower) than the actual value of avoided damages from emissions reductions. There are 29 carbon taxes, primarily applied at the national level, by such countries as Singapore, South Africa, Mexico, all the Nordic countries, France, and the United Kingdom (World Bank Group, 2019).

- **Carbon Offset Prices (Replacement Cost of Carbon)**: Several organizations implement projects, such as afforestation or methane capture, with the primary goal of sequestering carbon or other GHGs. Carbon offset prices represent the cost of implementing projects, such as afforestation or methane capture, with the primary goal of sequestering carbon or other GHGs. In the context of agricultural conservation projects, the cost of sequestration projects is important because it represents the price Oregonians would have to pay to sequester an equivalent amount of carbon through a different type of sequestration project. Thus, the cost of carbon sequestration is the "replacement cost" value of carbon sequestration through agricultural conservation practices. The Forest Trends Ecosystem Marketplace tracks voluntary carbon markets, including the prices and quantity of offset transactions by type and location (region and country) (Forest Trends Ecosystem Marketplace, 2017).

4.4 Fish and Wildlife Habitat

Much of the fish and wildlife habitat in our state is in privately owned working farms, ranches, and forests, and the health of our fish and wildlife species populations is heavily dependent on habitat conditions on these lands. As recognized in the NRCS Wildlife Habitat Component of the Conservation Effects Assessment Project, agricultural producers can effectively integrate fish and wildlife habitat conservation into their land management activities (Natural Resources Conservation Service, 2009).

From 2000 to 2007, working in partnership with NRCS and the Farm Service Agency, the Water Quality Information Center at the USDA National Agricultural Library and the Wildlife Society compiled literature reviews of the effects of conservation practices on fish and wildlife. These reviews in general concluded that a wide range of conservation practices can have fish and wildlife benefits. However, the review also highlights the limits of our knowledge of how practices affect fish and wildlife, noting that: a) little monitoring has been done, b) complexities of effects of various conservation practices coupled with landscape management diversity, "leaves many questions unanswered" c) that better information is needed on how broad practices "actually change habitat conditions and what benefits to individual species or species groups are achieved" and d)" Landscape effects (species-specific, spatial, and temporal) confound generalizations on the value of individual practices" and that "overall, effects of individual practices depends on many factors" (Natural Resources Conservation Service, 2009).

Regarding conservation practices with positive fish and wildlife effects, general findings from the reviews include (Natural Resources Conservation Service, 2009):

- Steam bank vegetation establishment has been documented to improve aquatic habitat.

- Fish passage, stream habitat restoration, livestock use exclusion practices, and conservation practices that reduce soil erosion and sediment delivery or that otherwise improve the quality of runoff water have been shown to improve aquatic habitat quality.
- Applying linear practices widely within an agricultural landscape could be expected to have positive wildlife benefits compared with continued intensive row cropping. Grassed waterways, riparian forest buffer, and other buffer practices designed to improve water quality have been shown to benefit aquatic habitat condition. Filter strips and field borders are shown to increase wildlife use of crop fields. However, the small area and high edge-area ratios of linear practices limit the usefulness of these practices for wildlife. Linear practices have high wildlife use but low reproductive success. Buffer width, vegetative composition and structure, and landscape context all affect wildlife communities. Positive effects are associated with longer and wider buffers, buffers associated with or connecting other habitat practices such as blocks of cover or food plots, and with practices that are grouped on the landscape.
- Wetland establishment practices are associated with substantial wildlife benefit. Wetland wildlife species richness varies based on wetland size, availability of nearby wetlands habitats, diversity of water depths and vegetation, wetland age, and maintenance and management.
- Soil and water conservation practices provide some habitat on cropland landscapes.
- Conservation tillage has been documented to benefit some species (beneficial insects, invertebrate food sources for birds and mammals). No-till provides greater wildlife benefit than more intensive tillage systems (nesting, winter food and cover).
- Change from cropland to grass land use has had a positive influence on grassland wildlife. Grassland bird benefits have been documented; effects on other wildlife are largely unknown. Wildlife response to grassland establishment is a multi-scale phenomenon dependent upon vegetation structure and composition within the planting, practice-level factors such as size and shape of the field, and its landscape context, as well as temporal factors such as season and succession.
- Rangeland conservation practices (prescribed grazing, prescribed burning, range planting, and restoration of declining habitats) can provide wildlife benefits, many practices produce both positive and negative responses by wildlife, but benefits generally outweigh detriments.

4.4.1 Biophysical Quantification

Due to the complex interactions among agricultural practices and fish and wildlife habitat, instead of aiming to quantify effects of specific practices on habitat, this review instead focuses on methodologies that quantify the extent and condition of habitat at a given point in time (regardless of which practices are being used). Recognizing that both habitat quality and habitat quantity are important, most of these methodologies incorporate both quality and quantity into a ‘functional habitat acre’ approach. In this approach, for example, two acres rated as providing 50% of potential habitat quality would be equivalent to one functional acre. These methodologies provide existing, clear, transparent guidance on the habitat conditions that are beneficial for fish and wildlife, and can serve as a starting point for a methodology for a statewide compensation program. However, rather than using a detailed, quantitative ranking system employed in many of the reviewed methodologies (and the level of expertise and time that entails), the general approach for habitat in a statewide compensation program may be to rate habitat at a coarser scale, such as using low, medium, and high functional quality ratings.

Given the diversity of habitats on agricultural lands throughout the state, **Table 4-8** summarizes habitat rating methodologies, many of them developed in coordination with Oregon agencies, including ones that relate to: oak woodland/savannahs, wetlands, streams, and sage-grouse. These capture most of the strategic habitats identified in the Oregon Conservation Strategy, with the exception of pine woodland and aspen woodland habitats and provide an excellent starting point for a statewide compensation program.

As noted above, water quality and water quantity both are factors in determining fish and wildlife habitat quality (and quantity). For example, wetlands provide groundwater recharge services, water quality services, and fish and wildlife habitat. We expect that all these benefits may best be captured through a per acre habitat valuation approach. On the other hand, for the value of water quantity/quality in flowing waters, the most feasible approach may be a combined approach to focus on 1) per acre or linear foot of riparian habitat values, and 2) value per acre foot of enhanced flow (water quantity benefit).

Table 4-8: Habitat Quantity Effect Quantification: Methodologies, Tools, and Data Sources

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Counting on the Environment	All	Fish passage removal	Fish habitat	Quality/ quantity of fish habitat made accessible	Excel, many inputs required	Medium	High	Functional acres	Willamette Partnership/TNC/ODOT; compensatory mitigation
Counting on the Environment	Willamette Valley	None explicitly	Oak Woodland/Savanna Habitat	Species presence, connectivity, etc.	GIS/Excel; 32 total data inputs	Medium expertise, 1 day site visit	High	Functional acres	Willamette Partnership; Defenders of Wildlife; Adamus Resource Assessment Inc.
Counting on the Environment	Upland Prairie	None explicitly	Upland prairie habitat	Species presence, connectivity, etc.	GIS/Excel; 25 total data inputs	Moderate, 1 day site visit	High	Functional acres	Institute for Applied Ecology; Willamette Partnership
Oregon Rapid Wetland Assessment	All	None explicitly	Wetland habitat	Connectivity, landscape setting	Excel/GIS, high data input requirements (83 to 95 inputs depending on type of wetland)	High expertise required, field data required	High	Functional Acres	Oregon Department of State Lands

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Wetland Plant Diversity Model	All	None explicitly	Wetland Habitat		3 indicators: 1) Native/Exotic/Invasive plant composition, b) Life-History Composition, c) Wetness Indicator (wetland/hydrophite/upland)	Onsite evaluation of overall plant diversity.	Medium	Plant diversity rating.	NRCS, Conservation Effects Assessment Project
Oregon Sage Grouse Habitat Quantification Tool	NE OR, SE OR, Central OR	None explicitly	Sage Grouse Habitat	Species presence, broader landscape setting, non-native species	Excel/GIS, 4 data inputs required, field data required	Moderate expertise	High	Functional Acres	OR Dept of Fish and Wildlife; compensatory mitigation
Salmon Safe Farm Certification	All	Riparian area management, fish passage, animal management, water conservation, water quality measures, IPM, on-farm biodiversity	Fish habitat	Connectivity	Map of property, pest management information, irrigation management information, annual water usage, fish screen location/condition, animal waste management practices, etc.	High. Onsite farm evaluation.	High	Binary: certified or not	Salmon Safe Inc.

METHODOLOGIES FOR VALUING AGRICULTURAL CONSERVATION MANAGEMENT ACTIONS

Method/Data/ Tool/Source	Applicable Agricultural Regions in Oregon	Conservation Practices Evaluated	Benefits Types Evaluated	Key Variables Determining Benefit Quantification	Data Inputs/Software Required	Type and Level of Effort/Expertise Required	Accuracy/ Certainty of Output	Output Provided (Metrics and Units)	Developer/ Notable Uses
Rangeland Health Assessment	Rangelands	None	Soil/Site Stability, Hydrologic Function, Biotic Integrity	Vegetation, Hydrology, Invasives	Soil type, ecological reference areas, complete evaluation matrix with 17 indicators	Medium.	Medium.	Functional Status of Soil/Site Stability, Hydrologic Function, and Biotic Integrity	NRCS
Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	All	None	Habitat quality.	Proximity to human land uses and intensity of land uses	Invest tool (downloadable) ; define land use types that provide habitat, provide a habitat suitability score for each land use type, define sensitivity of habitat to various threats, identify density of threats	Medium.	Low.	Habitat quality and rarity maps	Natural Capital Project, Stanford

Sources: (USDA, 2015) (Natural Capital Project, 2019) (Oregon Department of Fish and WIldlife, 2015)

4.4.2 Economic Valuation

Habitat and biodiversity support many social and economic values in Oregon, including:

2. **Subsistent/Recreational/Commercial Fisheries and Hunting**. People harvest shellfish, fish, deer, elk, and other species for personal and commercial use.
3. **Wildlife viewing.** Wildlife viewing is one of the most popular outdoor recreational activities, and is enjoyed in every ecosystem and area of Oregon.
4. **Aesthetics.** Open space and natural areas enhance view sheds and are aesthetically pleasing to people.
5. **Agricultural Productivity/Pollination.** Habitats for pollinators and other species can provide pollination and pest control services for agricultural production and for natural ecosystems.
6. **Cultural & spiritual values for habitat/species preservation**. As noted above, value for species and habitats includes the intrinsic value to people of biodiversity, including endangered species.

4.4.2.1 Locational Factors Affecting Value & Available Data

The factors affecting habitat enhancement and preservation value include the scarcity and connectivity of a given habitat, the species associated with a given habitat, and the potential type and level of human use (such as recreation) of a given habitat. As private lands may not allow public access, this review focuses the ways in which Oregon has documented species presence and potential distribution for several key species, and has also identified priority habitats as follows:

- Species distribution
    - *Data available: Oregon Conservation Strategy Species Distribution, fish distribution mapping,*
- Priority habitats
    - *Data available: Oregon Conservation Strategy Opportunity Areas, priority areas for streamflow restoration, Oregon significant native habitat areas*

Table 4-9: Data to Indicate Socioeconomic Value of Habitat Improvements

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Oregon Conservation Strategy Conservation Opportunity Areas (COAs)	Statewide	Identify priority habitat conservation areas	GIS	Define and map ecoregions, 206 priority habitat locations in Oregon, strategy habitats/species COAs were developed to guide voluntary conservation actions in Oregon. Land use or other activities within these areas will not be subject to any new regulations. COAs each provide recommended actions consistent with local priorities, and ongoing conservation efforts.	Oregon Department of Fish and Wildlife, Focusing investments in these prioritized areas.
Oregon Conservation Strategy: Species Distribution	All Oregon	Locations of economically important species	GIS, strategy reporting tool for a specific project area	Species of Concern & Species of Recreational/Economic Importance, species distribution models	Oregon Department of Fish and Wildlife
Oregon Conservation Strategy: Key Conservation Issues	All Oregon	Help identify conservation actions	GIS, strategy reporting tool for a specific project area	Key Conservation Issues	Oregon Department of Fish and Wildlife
Oregon statewide streams and fish presence	All Oregon	Indicate potential fish habitat benefits	GIS, web-interface, excel tables		Oregon Department of Forestry, identify uses of where riparian buffer rules apply
Oregon Fish Habitat Distribution Data and Fish Barrier Data	All Oregon	Indicate potential fish habitat benefits	GIS, web-viewer	Fish Habitat Distribution and Fish Barrier Data, including priority barriers. Fish species include: bull trout, fall/spring chinook, chum, coho, sockeye, summer/winter steelhead, green/white sturgeon lamprey, rainbow/ redband/ coastal cutthroat trout	Oregon Department of Fish and Wildlife

Data Source	Geographic Coverage	Potential Use	Data Format	Key Data Provided	Developer/ Notable Uses
Priority areas for Streamflow Restoration	Statewide	Indicate areas of high surface flow restoration need for salmonids	GIS, maps	River basins ranked for restoration need (for recovery of salmonids), flow restoration optimism, and State's priorities for restoration activities. Summer streamflow restoration priorities provided	OWRD and ODFW Natural Resources Information Management Program, used to fulfill Oregon Plan Measure IV.A.8, Identify Instream Flow Priorities
Oregon Watershed Restoration Inventory	Statewide	Identify potential overlap/connectivity with restoration projects	GIS, database format (MS Access and Excel), web user-interface	Database of restoration projects to improve aquatic habitat and water quality.	OWEB, originated with Oregon Plan for Salmon and Watersheds
Protected Areas Database	All Oregon	Connectivity / migration corridors potential	GIS	National inventory of US land and aquatic protected areas, land cover and species data	USGS-GAP
Oregon Significant Native Habitat	All Oregon	Help identify priority habitats	Maps, GIS?	Definition of native habitats on private lands that qualify for the Wildlife Habitat Conservation and Management Program	Oregon Department of Fish and Wildlife

Sources: (Oregon Department of Fish and Wildlife, n.d.; Oregon Department of Fish and Wildlife, n.d.; Oregon Department of Forestry, n.d.; Oregon Department of Fish and Wildlife, 2018; Oregon Department of Fish and Wildlife, 2004; Oregon Watershed Enhancement Board; Conservation Biology Institute, 2012)

4.4.2.2 Valuation Approaches & Available Data

Ideally, valuation of species and habitats would focus on the economic value associated with improved species populations, or changes in human use of habitats, or changes in the overall viability/resiliency/ecological functioning of a habitat type. These valuation techniques, however, are likely not feasible or appropriate for valuing changes at the farm-level. As such, this review of economic methodologies focuses on per acre costs and values that may be derived from conservation/mitigation bank markets, habitat conservation/enhancement programs, avoided water treatment costs from habitat preservation programs, and per acre habitat values from the economic literature (derived using a variety of valuation methodologies):

- **Conservation Bank/Mitigation Bank Markets:** Oregon has mitigation banks for a variety of ecosystems, including wetlands, rivers and streams, shrub and forestland, and estuaries (State of Oregon, 2019). Many mitigation banks are run by private entities, however, the State of Oregon also offers in-lieu-fee (ILF) mitigation for wetlands and stream restoration, whereby an entity can pay a fee in in-lieu of purchasing mitigation credits (assuming eligible in-lieu projects are available). To estimate the amount of ILF required to offset habitat impacts, the State provides a calculator that approximates the cost to offset or create one acre of new habitat (State of Oregon, 2019). The ILF, or restoration costs, differ by basin. Per acre habitat values from other mitigation banks in Oregon may be obtainable from private entities developing banks, as well as the entities such as the Willamette Partnership that manage habitat credit programs.

- **Habitat Conservation / Replacement Cost.** A measure of society's willingness-to-pay (or value) for habitat is the cost expended by organizations to create, restore, or enhance habitat areas. Non-profit organizations and governmental agencies such as the Oregon Watershed Enhancement Board, NRCS (including wetland and grassland reserve programs), The Nature Conservancy, Oregon Department of Fish and Wildlife, the US Fish and Wildlife Service, and the Freshwater Trust are funding and undertaking numerous restoration projects in Oregon. Through their investments, such organizations are revealing their willingness to pay for habitat; they must value habitat at least as much as the dollar value of their investments, so this provides a conservative estimate of the value of habitat to such organizations (it is conservative as they might be willing to pay even higher amounts to restore habitats). [18] In terms of replacement cost, the economic value provided by habitats on agricultural lands, is equivalent to the costs that would be necessary to create or restore habitat in other nearby areas to obtain the same level of ecological function.

  As such, for a proxy of the value of habitat, we can review information from past projects to estimate the per acre costs of conservation or enhancement. Data on the costs of conservation and enhancement projects is particularly available for wetland and stream restoration projects. As an example, in 2016 the USDA approved a $2.6-million grant to conserve 24,985 acres of wet meadow in the Southern Oregon-Northeastern California region. These wet meadows serve as important habitat for migratory birds, and are increasingly threatened by changing irrigation practices, aging water conveyance infrastructure, and fragmentation. In addition to protecting and enhancing migratory bird habitat, the money will help improve the drought resiliency of ranchlands (USDA NRCS, 2016). The value of the grant is roughly $110 per acre conserved (2019 dollars). The Oregon Department of Fish and Wildlife supports programs to protect and recover coastal and riverine habitats, which have included restoring the Siletz Bay National Wildlife Refuge, the Alsea River estuary, and the Coastal Strands (U.S. Fish and Wildlife Service, n.d.).

  However, other organizations have restored more diverse types of habitats. For example, in addition to restoring wetland habitats in the Willamette Valley, the Institute for Applied Ecology has restored multiple prairie habitats in the Oregon Coast Range mountains, oak and pine prairie habitat in the Cascade foothills, and grassland habitat at the Nestucca Bay National Wildlife Refuge in Tillamook County (in addition to others) (Institute for Applied Ecology, 2019). The West Multnomah Soil & Water Conservation District works to protect and enhance oak woodlands and savanna, meadow, wet prairie, upland forests in Multnomah County (West Multnomah Soil & Water Conservation District, 2019).

[18] Replacement cost may be higher than the economic value of the habitat if society would not actually choose to restore habitat in the absence of habitat provided on agricultural lands. Also, replacement cost may be higher than economic value if habitat conservation/enhancement projects are driven by regulatory requirements and are not voluntary projects.

- **Avoided Cost /Substitute Cost.** Particularly pertinent to wetland and riparian vegetation, water quality and flood control services provided by preservation of habitat can reduce 'built infrastructure' costs and flood damage costs. These values are most pertinent to regions looking to enhance water quality that can choose between investing in water treatment facilities or in riparian area restoration. Several examples highlight that wetland and riparian restoration investments can often achieve similar water quality outcomes at lower cost, *and* with other benefits related to aesthetics, recreation, and flood regulation.

  For example, to meet a temperature water quality requirement, Clean Water Services (a wastewater and stormwater utility) invested $17.6 million[19] in the restoration of 35 river miles of riparian habitat. Comparatively, installing and operating two water chillers would have cost $91.5 million, representing a savings $73.9 million[20] (Niemi, Lee, & Raterman, 2006). 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.

  Similarly, 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. Two meta-analyses indicate that the value of wetlands for water quality varies tremendously from study to study, with values in the range of $40 to $2,680 per acre per year, and average values of approximately $800 per acre per year (Brander, Raymond, Florax, & Vermaat, 2006; Woodward & Wui, 2001).[21]

- **Economic Literature: Per Acre Habitat Values.** Per acre habitat values are available from the economic literature, based on the wide variety of services provided by habitats. Wetlands and riparian areas are one of the most studied habitat types, but there are also studies available for grasslands and forests. No studies were found for sagebrush habitats. While this literature is very applicable and feasible to apply for valuing habitat enhancement/conservation in a statewide agricultural compensation program, it is important to note the high level of uncertainty in using per acre habitat values from the literature.

  For example, studies of wetlands value provide very different per acre values, ranging from a few dollars per acre up to hundreds of thousands of dollars per acre. Wetlands (and all other habitat types) differ in type and quality, and both ecological and economic benefits from their protection vary by location, even considerably. Values in the literature vary depending on type of wetland, types of services included, location, and study methodology. In general, the highest values provided by wetlands/riparian areas are those relating to provision of flood control and storm buffering, amenity and aesthetics, water quality, and biodiversity (particularly for birdwatching). In addition, habitat benefits are not constant for every acre, but vary depending on size and configuration. As noted by the authors of one review of wetland habitat values, "the use of

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[19] The source cited costs of $12 million in 2005 dollars; this study adjusted value to 2019 dollars.

[20] The source cited costs of $50.5 million in 2005 dollars; this study adjusted value to 2019 dollars.

[21] The $40 per acre per year value (in 2019 dollars) was from Brander et al, and presented in the original study as $26 in 2000 values. Woodward and Wui (2001) cited values of $1,378 and $417 in 1990 dollars for the upper limit and average values, respectively, which were adjusted to 2019 values.

benefits transfer to estimate wetland values faces substantial challenges. From our analysis it is clear that the prediction of a wetland's value based on previous studies is, at best, an imprecise science" (Woodward and Wui, 2001).

- **Economic Literature: Recreation Use Values. T**here is extensive literature on values for outdoor recreation that are dependent on ac**c**ess to natural areas, or related to fish/wildlife habitat presence (wildlife viewing, fishing, hunting, etc.). This literature typically presents value in terms of net benefit per person per day for a given activity type. The per person per day value of these uses varies widely depending on study methods, demographics of recreation users, and the characteristics of the site. As public recreation access to farmland and ranches is likely very limited, these values are generally not applicable. However, these are indirect recreation values of habitats derived from fishing/hunting/wildlife viewing of species at other natural areas that use habitats on agricultural lands. For example, a migratory bird that relies on habitat on a farm for part of the year may be viewed elsewhere in Oregon, or even in other states. Since the wildlife viewer indirectly benefits from the agricultural habitat used by the migratory bird, some portion of their use value is attributable to the agricultural lands. Quantitatively assessing this relationship would be challenging and likely highly uncertain, so using recreation values to assess value of habitats on agricultural lands may not be feasible.

- **Economic Literature: Species/Habitat Existence Values.** Habitat and species also have value to society, independent of their use (i.e., people value the existence of the habitat/species without expecting to ever view or directly engage with the species or habitat). Non-use, 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 the bald eagle or salmon, as well as for ecosystems that have received public attention and been the focus of public education, such as wetlands. Valuation studies often ask respondents to value an increase in abundance or increased survivability of a species, with such increases typically of at least 50 percent. As quantifying the population-level effect on a given species of conservation management actions, even at the landscape scale, is very challenging and not usually feasible, we do not expect this to be a feasible approach to estimating value of habitats on agricultural lands.

In summary, valuation of biodiversity and habitats provided on working agricultural lands is challenging. The most promising approach to valuing habitats is likely to review and adopt per acre values based on the values that are available from a variety of sources (e.g., mitigation markets, replacement costs, avoided costs, and the economic literature on total economic value/acre of habitat). These per acre values could then potentially be 'cross-checked' for reliability by using statewide values for recreation and total acreage of habitat estimate approximate per acre values for recreation or other key habitat uses/values.

5 Feasibility Determination

Based on the preceding discussion of the available methodologies for each key type of environmental benefit (water quality, water quantity, habitat, and carbon), this section provides an assessment of the feasibility of developing a valuation methodology that meets the OAHC criteria (fairness, certainty, transparency, and easy/inexpensive to use). We add the criteria of a reasonable level of accuracy such that the public will, with a reasonable level of certainty, receive benefits at least equal to the payments resulting from a fully developed valuation methodology. While we believe that developing a valuation methodology is feasible for nearly all of the conservation practice/significant benefit combinations indicated by bullet points in **Table 5-1**, the *relative* feasibility does vary substantially by practice and benefit type. **Table 5-1** summarizes the initial relative feasibility findings (as high, medium, or low) for each conservation practice and benefit type. The high, medium, or low feasibility rating is intended to convey the relative certainty and accuracy of valuation among the practice/benefit combinations that could be included in a valuation methodology. There are a few conservation practice/significant benefit combinations that are not feasible to value; we find for these that there are not sufficient data to quantify biophysical benefits (environmental outcomes) of the conservation practices. In our feasibility assessment we assume that a valuation methodology would be used to provide annual payments, and that there would be a corresponding annual farm site visit to visually review conservation practices and outcomes.

Overall, and as shown in **Table 5-1,** we rate feasibility of a valuation methodology for carbon as high across all key conservation practices (practice-based measurement focused on carbon storage and GHG outcomes). We rate feasibility as high for valuation of riparian and wetland habitats on a per acre basis, and medium to low for grassland, woodland, and sage grouse habitats (outcome-based measurement during annual site-visit). We rate feasibility high for water quantity benefits related to irrigation methods/scheduling, land leveling, and water made available for wildlife. We rate feasibility as medium for water quality across all key conservation practices (practice-based measurement focused on key pollutant outcomes).

More specifically, overall feasibility is a composite rating of three feasibility factors:

1. **Availability of transparent, accepted (by experts and regulatory agencies), and reasonably accurate tools/methods to quantify biophysical estimates in an easy to use and understand manner.** The standard for easy to use and understandable is that with a one or two-day training, a conservation planner would be able to implement and apply the methodology using one annual site visit and some follow-up desktop analysis/review. *We rate the available tools for water quality, water quantity, and carbon as having a high level of feasibility on this factor. We also rate the available tools that could be adapted for habitat evaluation at a high level of feasibility on this factor for wetland/riparian habitats, sagegrouse habitat, and Oakland prairie/savannah. Woodlands and grasslands are rated as medium level of feasibility on this factor due to less developed tools for habitat evaluation.*
    a. Water Quality. We expect water quality would be quantified (sediment, nitrogen, phosphorus) through use of the Nutrient Tracking Tool (NTT) developed by the NRCS to evaluate effects of agricultural conservation practices and approved for use by the Oregon Department of Environmental Quality for Oregon nutrient credit trading programs.

b. Water Quantity. We expect water quantity would likely be quantified through use of published data on changes crop water needs by region and published data on water use with various irrigation methods/schedules and land leveling. This approach could be supplemented with aerial imagery or metering as deemed appropriate and feasible.
c. Carbon. We expect carbon would be quantified through the use of the suite of NRCS COMET-Farm, COMET-Planner, and COMET-Energy tools specifically designed for use to evaluate carbon sequestration and GHG emissions on farms and ranches under a variety of management scenarios.
d. Habitat. We expect habitat would be quantified through the use of simplified versions of existing habitat assessment models developed by state agencies, or those developed in coordination with state agencies (such as the habitat assessment models developed through the Willamette Partnership's "Counting on the Environment" habitat credit accounting systems). We expect that developing a simplified version of these models would require several workshops of a panel of experts, preferably experts involved in developing the original assessment models, as well as representatives of the conservation planning community.

2. **The inclusion of a particular agricultural conservation practice by each biophysical quantification tool/method.** In other words, we reviewed the conservation practices evaluated in the NTT, COMET-Farm/COMET-Planner, and the availability of existing habitat assessment tools to determine if evaluating that particular practice is feasible with the available tools/methods. *The specific conservation practices listed in **Table 5-1** are based on the conservation practices included in these tools.*

3. **Availability of published (or derived) economic values for the environmental benefit type as quantified by biophysical tools.** We evaluated whether there are available published values, the degree to which these values may be representative/adjustable for the different agricultural regions of Oregon, and the degree to which these values actually represent economic benefits to Oregonians (as many published values are actually based on cost of implementation). We again expect that convening a panel of professional agricultural and natural resource economists, together with representatives from the conservation planning community, would be a good path forward to review and confirm selected values that would be applied in a valuation methodology. The goal would be to reach general agreement and confirmation of values that provide a reasonable estimate of value to the public of changes in biophysical conditions. *At this stage, we rate high feasibility on economic valuation for carbon, water quantity, and riparian/wetland habitat. We rate water quality and grassland/sagegrouse/woodland habitat valuation with low to medium feasibility due to limited economic studies that can be appropriately applied/adapted to diverse Oregon agricultural regions.*
   a. Water Quality. We expect water quality economic value would be quantified using existing literature on the value to society per unit of reduced pollutant entering waterways. There is available literature on sediment, and some available literature on nutrients; however due to the age of several key studies (dating back 20 to 30 years), and the site-specific nature of

benefit values, we rate the feasibility and accuracy of economic valuation of water quality as low to medium.

b. Water Quantity. We expect water quantity would likely be quantified through use of published data on crop water needs by region and published data on water use under various irrigation methods, irrigation schedules, and land leveling characteristics. We anticipate that these methods could be adapted to estimate the amount of water that is also made available to wildlife (as a habitat benefit). These methods could be supplemented with aerial imagery or metering as deemed appropriate and feasible. We expect valuation of water quantity to primarily be based on market transactions of water between agriculture and environmental uses, and rate water quantity valuation as highly feasible.
c. Carbon. We expect valuation of carbon to rely on prices from carbon market transactions and carbon offset program costs as conservative estimates of the economic value of climate mitigation (rather than relying on social cost of carbon estimates were are often much higher values). We rate carbon valuation as highly feasible.
d. Habitat. Habitat benefits are perhaps the most challenging to value economically. Wetland (and riparian areas as similar functioning to wetlands) have been studied the most, likely due to their actual, or perceived economic benefits being higher relative to other habitats. Establishing per acre habitat values for these habitats is highly feasible. Establishing per acre habitat values for other habitats has low to medium feasibility.

Table 5-1: Economically Quantifiable Benefits by Conservation Practice

Conservation Practice	Water Quality	Water Quantity	Habitat	Carbon
Vegetation (non-riparian)				
Vegetative Barrier/Shelterbelt		•		•
Filter strip/field border[1]	•		•	
Habitat Enhancement/ Preservation				
Flowing Water (flow improvement through water quantity method)			•	
Riparian Habitats[1]	•		•	•
Wetlands[1]	•		•	•
Woodlands *(water quality captured as buffer strip or riparian area)*			•	•
Grasslands *(water quality captured as buffer strip or riparian area)*			•	•
Sage-Grouse *(water quality captured as buffer strip or riparian area)*			•	•
Grazing/Animal Management				
Rotational/Prescribed grazing *(habitat benefits evaluated indirectly through grassland 'habitat' evaluation)*	•		•	
Compost application				•
Range/forage planting *(habitat benefits evaluated indirectly through grassland 'habitat' evaluation)*	•		•	•
Feed management				•
Animal Waste management *(water quality measured through crop nutrient management)*	•			•
Silvopasture				•
Crop Management				
Cover cropping	•			•
No Till/ Reduced Till	•			•
Nutrient management	•			•
Field Harvest Management *(habitat benefits evaluated indirectly through grassland/wetland 'habitat' evaluation)*			•	
Fertilizer Management	•			•
Irrigation/conveyance efficiency	•	•		
Land leveling	•	•		

1/Water quality add carbon benefits of these habits may be captured through the per acre habitat values. Care must be taken to ensure no double counting of value, depending on how the per acre habitat values are estimated and which services are included in the per acre habitat estimation methodology.

•	Conservation practice has potential significant impact on the benefit type
	Not feasible rating
	Low feasibility rating
	Medium feasibility rating
	High feasibility rating

5.1 Policy/Implementation Issues & Next Steps

A valuation methodology needs to explicitly address several policy issues. These include:

- **Determination of Baseline/Standard Practice.** How does OAHC envision that “standard practice” will be defined that will serve as the benchmark to estimate benefit, or ‘uplift’? Will it be measured based on regional average for all crops/farms? In relation to historic management on the farm in question? Average for a specific crop type? Where will the data come from to establish standard practice? How will the methodology account for changes over time in standard practice? Defining the baseline for measurement of benefits is particularly important if the program desires to include producers who are already implementing conservation management practices – if baseline is defined as current practice on a farm, such producers may be excluded from the benefits of the program.

- **Tradeoffs between Comprehensiveness of Program and Certainty of Economic Value.** To what degree does the OAHC want to comprehensively recognize and incentivize numerous types of environmental benefits, versus prioritizing environmental benefits with the highest level of certainty regarding economic value. This issue also relates to the question of separately valuing several services that may result in double counting of benefits (i.e., some per acre habitat values may implicitly include the value of the habitat for carbon sequestration or water quality). If emphasizing comprehensiveness, such services may be independently valued, if leading towards certainty that the economic value is conservative, then only the key service (i.e., per acre habitat value), may be applied.

In addition to addressing these issues, if funding is available to proceed to development of the valuation methodology, we recommend convening a set of panels to enhance public agency and stakeholder buy-in. These would include a scientific panel to develop specific procedures for biophysical quantification of habitat benefits, an economic/social panel of Oregon research economists (from private consulting, public agencies, and academia) to review and comment on recommended economic values, and key stakeholder/landowner panels to provide feedback on all elements of the proposed valuation methodology and its implementation, including how program design would affect their level of participation and the degree to which the program would meet their needs and challenges.

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