NON-MARKET ENVIRONMENTAL BENEFITS AND VALUES

EARTH ECONOMICS

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The authors are responsible for the content of this report.

Forward

TRUST LAND PERFORMANCE ASSESSMENT
Non-Market Environmental Benefits and Values

In March 2018, the Washington State legislature adopted Engrossed Substitute Senate Bill (ESSB) 6095, a supplemental capital budget. Section 7015 of the bill mandates the preparation of a study that became known as the Trust Land Performance Assessment (TLPA).

On February 19, 2019, Deloitte Transactions and Business Analytics LLP entered into a contract (Contract reference number 93-098343) with the State of Washington Department of Natural Resources (the "Client" or "Trust Manager") to conduct the TLPA.

A major component of the TLPA involves assessing the public interest value of asset classes across state trust lands and forestlands managed by the Client (the "study site"). This includes estimating the value of ecosystem services and recreational benefits for asset classes that produce these benefits.

To most effectively fulfill its obligations, Deloitte Transactions and Business Analytics LLP asked the Client if it could subcontract the public interest value component of the study to Earth Economics ("Earth Economics," "we," "our," or "us"), a nonprofit organization.

The Client approved this arrangement, and on May 13, 2019, Deloitte Transactions and Business Analytics LLP entered into a subcontractor agreement with Earth Economics whose principal office is located at 107 N. Tacoma Avenue, Tacoma, WA 98403.

This Earth Economics report fulfills this requirement of the TLPA.

Deloitte Transactions and Business Analytics LLP

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Non-Market Environmental Benefits and Values

INTRODUCTION

People rely on the abundance of goods and services provided by nature, often without realizing it. These benefits should be identified and quantified to ensure they are included in decision-making processes so communities can mitigate risk, increase resilience, and protect their natural capital wealth.

Because ecosystems are living systems, natural assets are often more resilient and less costly to maintain than built infrastructure. Without functional natural systems, many of the benefits that nature provides at no cost must be replaced by built infrastructure, which will incur construction and maintenance costs and eventually require replacement. Acknowledging the economic value of nature often shows nature-based solutions to be more cost effective than built infrastructure, while raising awareness of the long-term connections between people and these natural assets. When nature and its beneficial functions are not quantified, they are effectively valued at zero in the decision-making process. Understanding these values is critical to making informed land-use decisions.

This chapter presents an estimate of the total annual non-market economic value generated by the trust lands in Washington State. Non-market values describe benefits that are realized by communities, but which are not bought and sold in markets. These benefits do not have observable market prices and are often measured by revealed or stated preference methods. This differs from capital values presented elsewhere in this report that are defined by market prices for goods such as timber and food crops.

In order to describe these non-market values in dollar terms, this chapter focuses on economic values that are estimated using an ecosystem services framework. The following sections detail the steps involved in this valuation:

- The first section explains ecosystem service valuation by defining ecosystem services, outlining the history of the ecosystem service valuation discipline, providing recent evidence of ecosystem service valuation results that influence state and federal policies, and explaining how ecosystem service valuation estimates fit in with other values provided by the Trust Land Performance Assessment. The roles spatial data and the benefit transfer method play in connecting observed land cover to ecosystem services and monetary estimates are also highlighted.
- The second section presents methods and results specific to the estimation of all ecosystem services except recreation and carbon storage, which have their own source data and methods. Estimating these ecosystem service valuations is based on the transfer of select non-market data from other study sites to the subject state trust lands. Robust explanations of land cover classes, the groups of ecosystems within those classes, and the spatial attributes that differentiate them are central to this section.

- The third section focuses on recreation as an ecosystem service. Estimating its economic benefit requires a different method than the other ecosystem services, and so it is presented separately. This method is based on estimated recreational participation and the consumer surplus of each activity.
- The fourth section focuses on the carbon storage ecosystem service. Estimating the value of this service also requires a method that is distinct from other ecosystem services, as well as a different accounting framework, and so it is presented separately.

A Primer on Ecosystem Services

What are Ecosystem Services?

Forests, watersheds, mountains, and shorelines represent natural capital assets. These assets contain multiple ecosystems that perform a variety of ecosystem functions. These functions, in turn, provide beneficial services that enrich the human experience.

Ecosystem services—breathable air, drinkable water, fertile soils, recreational opportunities, disaster resilience—are critical to human survival and the basis of all other economic activity.

In recent decades, considerable progress has been made in systematically linking functioning ecosystems and the benefits they provide with human well-being. The framework used in this report is based on well-known typologies that identify 21 ecosystem services across four categories (see Table 1).[1,2,3,4] These ecosystem service categories, which are commonly used in the field of ecological economics, are defined as follows:

- *Provisioning goods and services* provide physical materials and energy that vary by the ecosystems that produce them. For example, mushrooms grow in forests, and it is common for people to gather wild foods and other materials for personal use rather than for sale in the marketplace.
- *Regulating services* affect the balance of material and energy cycles, as well as populations of plant and animal species. Functional ecosystems maintain water quality, limit soil erosion, regulate climate, and keep wildlife populations and diseases in check.
- *Supporting services* include the habitat and refugia for both plant and animal species. These services provide physical environments suitable for species to survive and thrive.
- *Information services* support meaningful human interactions with nature. These include spiritually significant places and species, environments for outdoor recreation, and opportunities for scientific research and education.

Table 1. Definition of Ecosystem Services Used in This Chapter

Category	Ecosystem Service	Economic Benefit to People
Provisioning	Energy and Raw Materials	Can include fuel, fiber, fertilizer, minerals, and energy
	Food	Can include livestock, crops, fish, game, and/or produce
	Medicinal Resources	Can include traditional medicines, pharmaceuticals, and/or assay organisms
	Ornamental Resources	Resources for clothing, jewelry, handicrafts, worship, and decoration
	Water Storage	Amount of surface or groundwater held and its capacity to reliably supply water
Regulating	Air Quality	Ability to create and maintain clean, breathable air
	Biological Control	Pest and/or disease control
	Climate Stability	Ability to support a stable climate at global and local levels
	Disaster Risk Reduction	Ability to prevent and mitigate natural disasters, including flood, fire, drought, etc.
	Genetic Transfer	Dispersal of genetic material via wind, insects, birds, etc.
	Soil Formation	Soil creation for agricultural and/or ecosystem integrity
	Soil Quality	Soil quality improvement due to decomposition and pollutant removal
	Soil Retention	Ability to retain arable land, slope stability, and coastal integrity
	Water Quality	Water quality improvement due to decomposition and pollutant removal
	Water Conveyance	Ability to provide natural irrigation, drainage, supply, flow, and use of water
	Navigation	Ability to maintain necessary water depth for recreational and commercial vessels
Supporting	Habitat	Ability to maintain genetic and biological diversity, and to promote species growth
Information	Aesthetic Information	Enjoyment and appreciation of nature through the senses (e.g., sight, sound)
	Cultural Value	Use of nature in art, symbols, architecture, and religious/spiritual purposes
	Science and Education	Use of natural systems for education and scientific research
	Recreation and Tourism	Can include hiking, boating, travel, camping, and more

History of Ecosystem Service Valuation

The concept of ecosystem services has appeared in published literature since the late 1970s. The concept began to gain traction with the 1997 publication of the book *Nature's Services: Societal Dependence on Natural Ecosystems*,[5] and a paper estimating the global contribution of ecosystem services published the following year in the journal *Nature*.[6] These two works sparked an explosion of research and interest in ecosystem services.[7]

Since then, considerable progress has been made in systematically linking functioning ecosystems with human well-being. The work of academics and global initiatives have marked key advancements in this task.**Error! Bookmark not defined.**,**Error! Bookmark not defined.**,**Error! Bookmark not defined.** These studies laid the groundwork for a conceptual framework for valuing natural capital and ecosystem goods and services.

Among the first to present a conceptual framework and typology for describing, classifying, and valuing ecosystem functions, goods, and services in a consistent manner were de Groot et al. in 2002.**Error! Bookmark not defined.** Recognizing the need for a standardized valuation framework, they began translating the complexity of ecological structures and processes into a limited set of ecosystem functions and subsequently identified how these functions provide people with valuable goods and services.

Around this time, an international coalition of more than 1,360 scientists and experts from the United Nations Environmental Program, the World Bank, and the World Resources Institute assessed the effects of ecosystem change on human well-being. Key goals were to better understand the interactions between ecological and social systems and develop a knowledge base of concepts and methods that would improve the ability to "…assess options that can enhance the contribution of ecosystems to human well- being."**Error! Bookmark not defined.** This study produced the landmark Millennium Ecosystem Assessment, which classified ecosystem services into four broad categories according to how they benefit humans: supporting, provisioning, regulating, and cultural services.

These conceptual frameworks provided the impetus for several subsequent initiatives and programs, most notably the Economics of Ecosystems and Biodiversity.**Error! Bookmark not defined.** This global initiative is characterized by a practical approach that helps shift the ecosystem service framework from the theoretical to the applied realm. The Economics of Ecosystems and Biodiversity targets practitioners and helps them recognize and incorporate ecosystems into decision making by offering a structured approach to valuation.

Methods Used in this Chapter

This chapter analyzes the economic value—measured in dollars—of the ecosystem of goods and services provided by state trust lands. The non-market value of the bulk of ecosystem services—except carbon storage and recreation[8]—are measured using a valuation approach that combines geospatial analysis with the benefit transfer method.

Identifying Ecosystems and Spatial Relationships

To value ecosystem services, it is first necessary to understand the types and extent of ecosystems present on state trust lands. Additional geographic context, such as spatial relationships between ecosystems and patterns of human use, also supports the valuation. Geographic information system (GIS) data is used throughout this assessment as an input for the valuation. If available, this report relied upon data sets from the Washington Department of Natural Resources (the "Trust Manager"), which were supplemented by publicly available data from other agencies within Washington State and the federal government when necessary.

Geospatial data enables the assessment of large study areas, with spatially referenced ecosystem extents used to understand various proximity metrics and relationships that refine valuation estimates. Additionally, GIS data conveys spatial patterns of human activities, particularly recreation, which demonstrates the distribution of outdoor recreational use within state trust lands and serves as an input for valuing recreation as an ecosystem service. Geospatial data supports each component of this assessment, as an understanding of the natural capital and human activities present within a landscape is essential in valuing its ecosystem services.

The Benefit Transfer Method

The benefit transfer method takes estimates from different study sites and applies them to the site of interest—in this case, the state trust lands. One familiar application of the benefit transfer method is a property assessment in which the estimated value of taxable property is determined by comparing the features of the property (e.g., number of bedrooms, lot size, view, recent remodel) with prices of similar properties in similar markets. As a means of indirectly estimating the value of ecological goods and services,[9] the benefit transfer method can generate a wide range of reasonable value estimates for a fraction of the time and money required to collect site-specific data in the field. This methodology is widely used in the field of ecosystem service valuation.

The search for transferable values focuses on primary studies with comparable land cover classifications (e.g., wetland, forest, grassland) within the study area. Any primary studies deemed to have incompatible assumptions or land cover types are excluded. Individual primary study values are adjusted and standardized for units of measure, inflation, and land cover classification to generate an "apples-to-apples" comparison.

How do Ecosystem Services Fit into the Trust Land Performance Assessment?

Ecosystem services are critical to human well-being, but investment and planning decisions that affect natural systems have not traditionally incorporated these benefits into their cost-benefit calculus. The language of budgets, costs, and return on investment is only beginning to incorporate these benefits into decision making, but the effect has been significant.

The values of ecosystem services have the power to change policy. The inclusion of these values in decision making is gaining significant traction at the federal policy level as the understanding of the value of natural capital—and how to measure it—improves. In 2013, the Federal Emergency Management Agency (FEMA) announced a landmark policy change that allows ecosystem services to be included in the formal benefit-cost analysis process for flood risk mitigation projects.[10] Incorporating the values of ecosystem services into FEMA benefit-cost calculations signals a fundamental shift in the way that FEMA understands the value of natural lands. This change unlocks a wide array of mitigation projects that qualify for FEMA funding, helping communities across the United States increase their resilience. FEMA is leading the way at the federal level by recognizing the non-market contributions of different land covers; these economic data speak loudly and have sparked a paradigm shift in federal disaster mitigation strategy.

Ecosystem services provide real economic value, but this value is rarely reflected in traditional markets. Estimating the economic value of ecosystem services in dollars allows such services to be included in benefit-cost analyses and provides decision makers with more complete information on the costs and benefits of a given project. Failing to account for these values means that high-dollar decisions are made using incomplete information, reducing the certainty that selected projects actually represent the most efficient use of public funds.

Public servants—whether at the local, state, or federal level—who are tasked with allocating taxpayer dollars to their highest and best use should want to make their decisions about which projects to invest in using the most complete information available. A decision that is made without accounting for the non-market values generated by natural lands can lead to inefficient investments.

The methods used in this chapter are limited by gaps in the valuation literature. Reliance on secondary data necessarily limits this effort to the published literature. This means this chapter does not estimate the value of every ecosystem service or recreational activity; only a subset of all benefits provided by the state trust lands are able to be quantified and monetized. Therefore, the values presented in this chapter should be treated as underestimates. Nevertheless, this exercise is an important starting point for including ecosystem goods and services in decision making.

ECOSYSTEM SERVICE VALUES ON STATE TRUST LANDS

Data and Methods

Asset Class Boundaries

This assessment summarizes the values of ecosystem services according to the trust land asset classes: Forested Asset Class, Cultivated Asset Class, Grazing Asset Class, and Other Asset Class. This delineation of state trust lands is used for two reasons. First, reporting ecosystem services values by asset class aligns with other chapters within this report. Additionally, the availability of baseline ecological data differs between asset classes, primarily due to the Trust Manager creating and maintaining an inventory for forested portions of the trust land portfolio.

The Forested Asset Class includes lands within the state trust lands portfolio that are managed at least in part for forestry (i.e., timber production) activities. The Cultivated Asset Class and Grazing Asset Class are defined by current trust leases. The Other Asset Class used in this assessment comprises all remaining trust land holdings, which may have a variety of uses from communication leases to commercial buildings to educational facilities. Appendix B details the data sources and processes used to assign state trust lands to their respective asset classes.

Base Land Cover

The ecosystem services valued in this section are assessed using a land cover-based approach. While the Trust Manager manages the trust lands according to their main use (e.g., Forested Asset Class, Cultivated Asset Class), most of these asset classes include land cover types that are not associated with these uses. For example, wetlands are found in all asset classes, but are not directly associated with a specific end use. The ecosystems present on state trust lands form the basis by which nature's services are understood. For example, wetlands efficiently remove sediment and pollutants from water and provide habitat that may differ from surrounding forest or grassland. The GIS data was used to calculate the area of each ecosystem—or land cover—type present within state trust lands, as on-the-ground data collection was neither feasible nor necessary for an assessment of this scale.

A combination of Trust Manager-supplied and publicly available data sets from state and federal government agencies create a detailed picture of ecosystems present within each asset class. As mentioned above, data quality and availability differ by asset class, resulting in varying levels of resolution, of which the coarsest data are derived from the National Land Cover Database at a 30-meter resolution. Data sources and aggregation methods are briefly described below for each asset class. All sources, data hierarchy, and modifications are detailed in Appendix B.

Forested Asset Class
For consistency across chapters of this report, spatial data provided by the Trust Manager is used to delineate land cover within the Forested Asset Class. Lands used for forestry are well-inventoried and monitored by the Trust Manager, and these findings are combined into a large forest inventory data layer. This inventory is used in conjunction with additional Trust Manager-supplied data specifying wetland, stream, and standing water extents on forestry land from both observed and modeled sources. The resulting aggregated land cover data details forest, wetland, freshwater, and barren land (e.g., roads) areas within the Forested Asset Class (see Appendix B for data set details).

Cultivated Asset Class
Land cover within the Cultivated Asset Class is primarily based on the Washington Department of Agriculture's 2018 crop layer, which is aggregated for annual and perennial crops. This represents a snapshot in time based on current lease and crop status. The coverage of cultivated land on state trust lands shifts from year to year and season to season as leases are issued or expire and leaseholders engage in crop rotation practices. Remaining areas within the Cultivated Asset Class boundary, but not under agricultural production, are characterized using the National Land Cover Database.

Grazing Asset Class
The National Land Cover Database categorizes land cover types within the Grazing Asset Class. These lands are not inventoried by the This inventory is used in conjunction with additional Trust Manager, making the data from the National Land Cover Database the best available spatial data for ecosystem types. This assessment assumes that grazing activities occur on pasture, grassland, and shrub/scrub ecosystems. To reflect the values of ecosystem services derived from active grazing lands, a rangelands ecosystem type is delineated, which comprises pasture, grassland, and shrub/scrub land cover types.

Other Asset Class
Other Asset Class encompasses a range of land uses and ecosystem types. As an inventory of ecosystems present is not currently performed by the This inventory is used in conjunction with additional Trust Manager, data from the National Land Cover Database is used to determine acreages of land cover types within this designation.

Spatial Attributes

Landscape-specific factors and relationships can affect the type and magnitude of ecosystem services produced by natural ecosystems. Applying spatial attributes to base ecosystem types (i.e., forests, grasses, wetlands, rangeland, and cultivated land) helps account for this variation in ecosystem service valuation.

This assessment considers a range of spatial attributes based on available valuation literature. The subset of attributes included in Table 2 represents characteristics found to differentiate the provision or value of ecosystem services produced by a particular ecosystem type, based on applicable valuation studies. The inclusion of spatial attributes generally increases accuracy, as each attribute narrows estimates to those that more directly reflect the extent of specific ecosystem services or their value.

Table 2. Descriptions of Spatial Attributes

Land Cover Type	Attribute	Asset Class	Data Source	Description
Forests	Evergreen	Forested	WA Dept. of Natural Resources Forest Inventory	Evergreen attribute from forest inventory data
Forests	Riparian	Forested	WA Dept. of Natural Resources Forest Inventory	Variable width buffers around wet areas defined by the Trust Manager
Forests	Upland	Forested	WA Dept. of Natural Resources Forest Inventory	Where riparian classification is available, upland are all forested areas not considered riparian
Forests	Adjacent to interstate highways	Forested Cultivated Grazing Other	WA DOT State Highways	Within a one acre buffer around interstates outside of urban growth boundaries
Wetlands	Proximity to major coastlines	Forested Cultivated Grazing Other	WA DOT Major Shorelines of Washington State	Within a one-mile buffer from the coast of the Pacific Ocean or Puget Sound
Forests Grasses Wetlands	Proximity to urban areas	Forested Cultivated Grazing Other	WA Dept. of Ecology Urban Growth Boundaries	Within a one-mile buffer of urban growth areas
Grasses Wetlands	Agriculture border	Forested Grazing Other	Land cover data	Within a one acre buffer of cultivated crops

Land cover types that provide *in situ* services (e.g., biological control, soil retention) are limited to a one-acre buffer (208.7 ft^2), based on research suggesting that the maximum effectiveness of these ecosystem functions is generally achieved within 200 feet.[11,12,13] Other ecosystem services (e.g., aesthetics, water capture) tend to be valued at somewhat greater distances. For these, one-mile buffers—an arbitrary (but arguably conservative) distance—are chosen to delimit these ecosystem services and their associated land cover types.

Other spatial attributes were defined based on the scope of the source valuation studies (e.g., wetlands near urban areas). For instance, while wetlands likely provide aesthetic value regardless of location, estimates of this value are currently only available for those wetlands proximate to urban areas.

Different spatial attributes are calculated for each asset class based on data availability, with the intention of maintaining consistency with the Trust Manager's spatial databases. Table 2 provides an overview of each attribute and the asset class and land cover combinations to which they are applied.

Benefit Transfer of Ecosystem Service Values

The benefit transfer method is used to estimate the ecosystem service values provided by the state trust lands. Values are derived from Earth Economics' proprietary Ecosystem Service Valuation Toolkit, an extensive repository of peer-reviewed primary studies, government reports, and gray literature that measure the non-market values of ecosystem services. To be accepted into the Ecosystem Service Valuation Toolkit, studies must use methods and techniques broadly accepted by environmental and natural resource economists, as well as pass an additional two-stage internal review for quality and logical consistency.

Earth Economics considers several criteria when selecting appropriate primary study values to apply to the state trust lands. In terms of land cover, studies specific to Washington State are prioritized. However, because that valuation literature is somewhat limited, studies for Oregon, northern California, and adjacent Canadian provinces are also included because of their relative geographic and climactic similarity to Washington. This results in a data set broadly representative of the state trust lands. Unfortunately, local valuation estimates for wetlands, which are highly valuable providers of ecosystem services, are not available. To ensure the contributions of wetlands are incorporated into the valuation, two global-scale meta-analyses of ecosystem services provided by wetlands are included. These global studies include Pacific Northwest wetlands, but regional values are not separately reported.

If multiple studies are identified that estimate the value of the same ecosystem service, these are reviewed once again for methodological quality. If the values are based on both revealed and stated preferences, the latter are rejected as these are sometimes considered less reliable. Finally, all outlying value estimates are reviewed for reasonableness.

As a final step, all ecosystem service values are then standardized to 2018 US dollars using inflation factors from the Bureau of Labor Statistics Consumer Price Index. Appendix C lists the studies used for benefit transfer estimates.

Table 3 summarizes the land cover, spatial attribute, and ecosystem service combinations for which valuation studies were identified. Recreation is valued separately (see the section titled "Recreation as an Ecosystem Service"), as is carbon storage (see the section titled "Carbon Storage as an Ecosystem Service"). Aside from these, the valuation literature supports valuation of one to four ecosystem services for each combination. Appropriate valuation studies were not found for six of the 21 ecosystem services. It is important to remember that the absence of any particular land cover ecosystem service value does not necessarily mean that these ecosystems do not produce these services, and it does not indicate that such services are not valuable. Many ecosystem services that clearly have economic value have not been valued in this chapter due to the lack of primary peer-reviewed data. For example, shrubland provides wildlife habitats, recreational opportunities, carbon sequestration, and other services; however, there are few valuation studies of ecosystem services in shrubland, so this analysis may show a lower total ecosystem service value for shrublands.

Readers should exercise caution when comparing total ecosystem service values across land cover types, as differences in value estimates could stem from missing information, rather than genuine differences in ecosystem service provisioning. This lack of available information underscores the need for investment in local primary valuations. See Appendix A for a detailed discussion on study limitations.

This chapter focuses on non-market ecosystem benefits. Although provisioning services such as food are often sold in markets, this chapter isolates the aspects of this service not captured by markets. This includes activities such as subsistence gathering (e.g. mushroom foraging) and producer surplus.

All ecosystem service values for each land cover and spatial attribute are summed to provide an estimated value of the total dollars per acre per year, which is then multiplied by the extent of the relevant land cover and spatial attribute combination. The result is a value that represents the annual flow of non-market ecosystem services provided for each land cover type in context. These values are then summed across all land cover types to produce the annual value of ecosystem services provided by the state trust lands.

Table 3. Valuation Literature of Land Cover Attributes and Ecosystem Service Combinations

Ecosystem Service	AG (ANNUALS)	AG (PERENNIALS)	FORESTS (RIPARIAN)	FORESTS (UPLAND)	FORESTS (RIPARIAN, EVERGREEN)	FORESTS (RIPARIAN, NON-EVERGREEN)	FORESTS (RURAL)	FORESTS (URBAN)	FORESTS (HWYS)	GRASSES (AG BORDER)	RANGELAND (ALL)	SHRUBS (URBAN)	WETLANDS (ALL)	WETLANDS (AG BORDER)	WETLANDS (COASTAL)	WETLANDS (NON-AG BORDER)	WETLANDS (NON-AG BORDER, NON-COASTAL)	WETLANDS (URBAN)
Food											•							
Medicinal Species																		
Ornamental Species																		
Energy and Raw Materials													•					
Water Storage													•					
Air Quality								•	•									
Biological Control	•									•								
Climate Stability																		
Disaster Risk Reduction										•		•		•		•		
Pollination and Seed Dispersal	•	•																
Soil Formation																		
Soil Quality																		
Soil Retention	•			•	•	•				•								
Water Quality				•										•		•		
Water Capture, Conveyance, Supply							•	•						•		•		
Navigation																		
Habitat and Refugia			•					•						•	•		•	
Aesthetic Information																		•
Cultural Value	•												•					
Recreation and Tourism																		
Science and Education																		

Key

•	Combination valued in data set

Black dots indicate at least one peer-reviewed article was identified that enumerates the financial value of the ecosystem service produced on each land cover type. Blanks cells indicate only the absence of appropriate valuation studies and should not be interpreted as an absence of actual value.

Results

To simplify, the land cover and spatial attributes in this section were combined into general land cover types—cultivated, forests, grasses, rangelands, and wetlands—and then broken out by asset class (see Table 4). The extents are not necessarily additive within asset classes (e.g., riparian forests include both riparian evergreen and non-evergreen forests). Each land cover type and attribute has been matched to either:

- Specific ecosystem services (e.g., air quality benefits adjacent to emitting sources, such as highways)
- Variations in the value of those services (e.g., water quality benefits are greater for wetlands adjacent to cultivated land)
- Specific characteristics identified in the original valuation study (e.g., there are studies of the aesthetic value of wetlands in urban areas, but not in rural areas)

The average total ecosystem service value by land cover type is presented in Table 5 and Table 6 (see Appendix C for more detailed results). Not surprisingly, the most substantial contribution within each asset class is associated with its primary purpose—forests provide the most value in the Forested Asset Class, annual and perennial crops provide the most value in the Cultivated Asset Class, and rangeland cover provides the most value in the Grazing Asset Class. As suggested earlier, wetlands are important within all asset classes. Overall, while forest lands represent 73 percent of all state trust lands, they provide 88 percent of the non-market ecosystem service value shown in Table 6. These benefits accrue each year, unless and until the reference ecosystems change, either through large environmental disruptions (e.g., climate change) or land use (e.g., urban development). These estimates represent the non-market benefits of the portion of ecosystem services for which acceptable studies could be identified. This means that these are conservative estimates of the true value of each ecosystem service. Moreover, these estimates do not include estimates for the value of recreation or climate stability (e.g., carbon storage), as these are each addressed separately in subsequent sections of this chapter.

Upon examining the individual ecosystem services within each asset class, nearly three-quarters of the non-market ecosystem service value for the Forested Asset Class (see Table 7) comes from water capture, conveyance, and supply. As might be expected, pollination services are most important in the Cultivated Asset Class, providing over half the annual non-market value produced within that asset class. Similarly, food—in the form of plants for grazing and browsing—provides the most value in the Grazing Asset Class, at nearly half the annual non-market contribution. For the Other Asset Class, disaster risk reduction; water quality; and water capture, conveyance, and supply all substantially contribute to the value produced within the asset class.

Again, due to gaps in the valuation literature, these estimates are necessarily lower than the estimate for the full range of ecosystem services provided by the state trust lands. For instance, woodpeckers and other birds are known to predate on mountain pine beetles (a concern in the Ponderosa pine forests of Eastern Washington), but no suitable study valuing this contribution could be found. Similarly, while scrubland (a component of the rangeland land cover) has substantial value as a habitat, its value could not be assessed based on the current literature. The relative paucity of Washington-specific primary valuation studies means that many ecosystem services known or predicted to be produced by land cover on state trust lands are not captured in this valuation.

Table 4. Spatial Extent of Land Cover Types and Attributes (Acres)

	Asset Class			
Land Cover	**Forested**	**Cultivated**	**Grazing**	**Other**
Ag (Annuals)	—	184,133	2,248	1,534
Ag (Perennials)	—	17,856	—	—
Forests (Riparian)	185,231	—	—	—
Forests (Upland)	1,882,635	—	—	—
Forests (Riparian, Evergreen)	136,214	—	—	—
Forests (Riparian, Non-Evergreen)	49,017	—	—	—
Forests (Rural)	2,045,108	2,982	16,864	20,265
Forests (Urban)	22,758	1	—	104
Forests (Adjacent to Highways)	90	227	269	264
Grasses (Bordering Cultivated Land)	—	3,804	893	464
Grasses (Urban)	—	447	306	779
Rangeland (All)	—	91,974	335,635	89,806
Wetlands (All)	13,293	755	2,991	4,533
Wetlands (Bordering Cultivated Land)	37	146	89	16
Wetlands (Coastal)	250	13	—	88
Wetlands (Not Bordering Cultivated Land)	13,256	609	2,902	4,517
Wetlands (Not Bordering Cultivated Land or Coasts)	13,006	596	2,902	4,429
Wetlands (Urban)	577	23	17	321

Table 5. Total Annual Average Value for all Ecosystem Services Included in this Analysis, by Land Cover and Attribute (2018 $)

Land Cover (Attribute)	Ecosystem Service Valued	Total $/acre/year
Agriculture (Annuals)	Cultural Value Biological Control Pollination and Seed Dispersal	$3
Agriculture (Perennials)	Pollination and Seed Dispersal	$2,821
Forests (Riparian, All)	Habitat	$0.08
Forests (Upland, All)	Soil Retention Water Quality	$138
Forests (Riparian, Evergreen)	Soil Retention	$3.09
Forests (Riparian, Non-Evergreen)	Soil Retention	$1
Forests (Evergreen)	Aesthetic Information Cultural Value Food (Mushrooms) Habitat Science and Education	$47
Forests (Rural)	Water Capture, Conveyance, Supply	$428
Forests (Urban)	Air Quality Habitat Water Capture, Conveyance, Supply	$1,721
Forests (Highways)	Air Quality	$523
Grasses (Agricultural Border)	Biological Control Disaster Risk Reduction Soil Retention	$5,229
Rangeland (All)	Food (Forage)	$61
Wetlands (All)	Cultural Value Energy and Raw Materials Water Storage	$124
Wetlands (Agricultural Border)	Disaster Risk Reduction Habitat Water Capture, Conveyance, Supply Water Quality	$29,206
Wetlands (Coastal)	Habitat	$423
Wetlands (Non-Agricultural Border)	Disaster Risk Reduction Water Capture, Conveyance, Supply Water Quality	$3,423
Wetlands (Non-Agricultural Border, Non-Coastal)	Habitat	$188
Wetlands (Urban)	Aesthetic Information	$10,595

Table 6. Annual Ecosystem Service Value, Average by Land Cover and Asset Class (2018 $ in thousands)

	Asset Class				
Land Cover	**Forested**	**Cultivated**	**Grazing**	**Other**	**Total**
Cultivated	—	$50,830	$6	$4	**$50,840**
Forests	$1,174,873	$1,397	$7,359	$8,991	**$1,192,620**
Grasses	—	$19,893	$4,670	$2,426	**$26,989**
Rangelands	—	$5,628	$20,538	$5,495	**$31,662**
Wetlands	$56,766	$6,803	$13,629	$20,761	**$97,960**
Total	**$1,231,639**	**$84,551**	**$46,202**	**$37,678**	**$1,400,071**
Acreage	2,170,070	301,807	366,240	124,969	**2,963,086**
% of State Trust Lands	73.2%	10.2%	12.4%	4.2%	
% of Annual Ecosystem Service Valuation	88.0%	6.0%	3.3%	2.7%	

Note: Totals may vary due to the effects of rounding.

Table 7. Annual Ecosystem Service Value, Average by Ecosystem Service and Asset Class (2018 $ in thousands)

	Asset Class			
Ecosystem Service	**Forested**	**Cultivated**	**Grazing**	**Other**
Food Provisioning	—	$5,628	$20,538	$5,495
Energy and Raw Materials	$810	$46	$182	$276
Water Storage	$335	$19	$75	$114
Air Quality	$11,942	$119	$141	$192
Biological Control	—	$1,860	$283	$148
Disaster Risk Reduction	$19,555	$16,807	$8,169	$8,557
Pollination and Genetic Dispersal	—	$51,020	$8	$5
Soil Retention	$10,677	$2,369	$760	$393
Water Quality	$273,499	$1,493	$5,458	$8,162
Water Capture, Conveyance, Supply	$890,774	$1,491	$7,752	$9,468
Habitat	$17,431	$3,390	$2,540	$1,293
Aesthetic Information	$6,113	$244	$180	$3,401
Cultural Value	$503	$65	$114	$172
Total	**$1,231,639**	**$84,551**	**$46,202**	**$37,678**

Note: Totals may vary due to the effects of rounding.

RECREATION AS AN ECOSYSTEM SERVICE

Outdoor recreation is one of the greatest ecosystem service benefits provided by natural lands. In this case, outdoor recreation as an ecosystem service is a measure of the value that participants receive from engaging in outdoor activities. The measure of this value is called consumer surplus, which is estimated through the value that recreationists place on their experiences above what they paid for those experiences. For instance, if an angler is willing to pay $90 for a day of fly fishing at Merrill Lake, but only incurred $35 in expenses, he will receive $55 in surplus benefits. No market transactions are required to gain consumer surplus. Consumer surplus is used as a measure of social welfare and can be useful in indicating the importance of community resources, such as a park.

It is important to note that economic benefits are different from economic contributions. Whereas economic benefits measure consumer surplus, the economic contributions of outdoor recreation measure the economic effects stemming from expenditures on outdoor recreation. The economic contributions of outdoor recreation begin when anglers, hunters, and backpackers head to the forests and spend money in local communities. These expenditures support salaries, businesses, and local and state tax revenue.

Economic contribution analyses can be useful in determining the relative size of an industry in comparison to the larger economy. In Washington, outdoor recreation is a powerful economic driver; in 2017, a report by the Outdoor Industry Association estimated that $26.2 billion was spent on outdoor recreation trips and equipment each year in the state.[14]

While reports show the spending effects associated with recreation on state trust lands are significant,[14] this analysis focuses on the public economic benefits provided by these lands.

Data and Methods

The annual economic benefit of recreation is calculated in several steps. First, the number of recreation days occurring on state trust lands is estimated for a set of activities, including hiking, mountain biking, hunting, and angling. Typically, this involves collecting use data from land managers; the Trust Manager does not consistently track recreational use on state trust lands. However, a small portion of recreation sites do collect primary use data through trail counters, garbage can collections, toilet pump-out frequencies, and road counters. This recreational use data was collected directly from regional recreation managers in the Department of Natural Resources.

Knowing that the data collected only represents a very small subset of all recreation occurring on state trust lands and that much of the data was collected only at high-use sites, an estimate was made based on the extent to which the given data reflects the true level of participation on state trust lands. These estimates are generated for each activity type and are used to extrapolate from the given data to generate an estimate of total recreational use. See Appendix D for details on how data coverage for each recreational activity is estimated.

For each of the recreational activities, consumer surplus values per recreation day are determined using the Recreational Use Values Database,[15] an extensive repository of consumer surplus values categorized by unique attributes such as activity, region, and land management type. The database is maintained by researchers at Oregon State University and is used by public agencies and non-profits around the country to assess the recreational benefits of public lands.

Finally, the total value of outdoor recreation was calculated by multiplying the total participants in each activity group by the average consumer surplus per day.

Results

Outdoor Recreation Participation on State Trust Lands

State trust lands receive millions of visitors every year, although no definitive estimate of total recreation participation has previously been generated. While this analysis is unable to precisely determine the total number of recreation days on these lands, the high-level estimates developed by extrapolating available data offer a path for the Trust Manager to better understand the recreational assets that exist on its lands and identify additional data collection needs that could aid in more refined participation estimates.

This analysis collects the available recreation participation data provided by the Trust Manager (see the column “Reported Recreation Days” in Table 8). To estimate the full extent of the use of state trust lands for recreation, Table 8 provides an estimate of the coverage of the data for each recreational activity. For instance, data from the Washington Department of Fish and Wildlife’s Harvest Reports was used to estimate the number of hunting days that occurred on state trust lands. Since all take in Washington must be reported, this data is assumed to represent 100 percent coverage for this recreational activity. A counterexample is seen for hiking. Only a small subset of the trust’s trails record trail counter data; therefore, the coverage of the data is relatively thin for this recreational activity. This data is assumed to represent only 15 percent of total hiking activity, while the remainder is left unaccounted for at recreation sites without trail counters.

To account for this gap in hiking data coverage, website traffic from DNR.WA.GOV specific to individual recreation sites (e.g., the Tiger Mountain State Forest webpage) was analyzed and paired with use estimates gathered from trail and car counters to determine the relative popularity of recreation sites. It is then possible to compare the website traffic to actual visitation, creating ratios that can be used as proxies and applied to other recreation sites that lack visitation data. Essentially, this approach scales the visitation estimates based on web traffic. Using these coverage estimates across the different recreational activity categories, a basic but defensible estimate of total recreation participation was calculated. A full accounting of the estimated data coverage for each activity is found in Appendix D.

Table 8. Estimated Recreational Use of State Trust Lands

Activity	Reported Recreation Days	Estimated Data Coverage	Estimated Total Recreation Days
Camping (Developed)	32,300	6.6%	489,394
Fishing	0	0%	1,000,000*
Hang Gliding and Paragliding	3,000	100%	3,000
Hiking	1,172,653	15%	7,817,687
Horseback Riding and Pack Stock	0	0%	286,368*
Hunting (Bighorn Sheep)	11	100%	11
Hunting (General Season)	456,147	100%	456,147
Hunting (Individual Hunts)	55,199	100%	55,199
Hunting (Moose)	354	100%	354
Hunting (Small Game)	173,044	100%	173,044
Hunting (Special Hunts)	56,142	100%	56,142
Mountain Biking	16,794	5.6%	299,893
OHV (4x4)	2,047	4%	51,175
OHV (ATV)	1,292	4%	32,300
OHV (Motorcycle)	3,437	4%	85,925
OHV (Other)	322	4%	8,050
Picnicking	13,800	1.75%	788,571
Rock Climbing	0	0%	81,486*
Shooting	19,500	10%	195,000
Snow Sports	0	0%	390,102*
Wildlife Watching	184,002	100%	184,002
Total	**2,190,044**		**12,453,850**

* See Appendix D for estimation methodology.

Economic Value of Outdoor Recreational Activities

Localized, activity-specific recreational use values were used to estimate the economic benefit (i.e., consumer surplus) provided by outdoor recreation. The values presented in Table 9 represent the average consumer surplus per person, per activity day. The range presented in the Recreational Use Values Database is large (e.g., hiking has a low value of $5 per day and a high value of $450 per day), but the collection of studies contained within the range "… include a mix of recreation sites with different qualities and characteristics, and the use of average values is typically most appropriate at this level of analysis."[15]

Economic Value of Outdoor Recreation on State Trust Lands

Using the participation estimates collected from regional recreation managers—2.1 million days—and the economic values from the Recreational Use Values Database, the estimated consumer surplus of outdoor recreation is $180 million per year. This value omits recreation that is known to occur, but not actively tracked. To more accurately estimate recreational participation, it is necessary to correct for the low coverage of these data. Using the previously generated data coverage estimates, it is possible to make this correction. Often, participation is tracked but data coverage is low, which is corrected by scaling the given participation estimates according to how well each data point captures true recreational participation. This is done by dividing the given estimate by the estimated percentage of data coverage.

Table 9. Average Economic Value (Consumer Surplus) of Recreation Benefits per Day (2018 $)

Activity	$/Day
Hiking	$87.89
Mountain Biking	$90.26
Camping (Developed)	$37.06
OHV	$52.19
Hunting	$80.55
Other Recreation (Flight, Horseback Riding, Climbing, Snow Sports)	$67.64
Picnicking	$49.17
Shooting	$67.25
Fishing	$74.42
Wildlife Watching	$62.57

Using this method to account for untracked recreation days, the estimated annual visits per year to state trust lands grows to 12.5 million visitations that provide nearly $1 billion in consumer surplus to recreational users. Comparing these estimates against those generated from existing data coverage reveals the importance of accounting for the gap in data coverage or risk undercounting both visitation and economic benefits. Focusing only on tracked recreation (i.e., 2.1 million visit days) captures less than 20 percent of the estimated total participation (i.e., 12.5 million visit days), which is calculated by scaling the data coverage gap using website traffic. The same is true for economic value: focusing only on tracked recreation yields a figure ($180 million) that is less than 20 percent of the economic value of recreation provided by state trust lands ($1 billion).

This analysis finds that a large portion of the recreational benefit generated by state trust lands is attributable to hiking, largely because the Trust Manager manages some of the state's most popular hiking locations, including Rattlesnake Ridge, Mount Si, and Capitol State Forest. Hiking is estimated to provide a benefit of $687 million annually. Hunting also drives a large share of total estimated value—nearly $60 million—which is tracked by the Washington Department of Fish and Wildlife. Finally, this analysis also finds that wildlife watching is a significant recreational activity, providing $11.5 million in annual economic benefits.

While hiking, hunting, and wildlife watching are tracked in some areas, many recreation activities have negligible data available. Fishing, for instance, could not be spatially tied to state trust lands, yet many anglers either pass through or choose to fish on water bodies located on these lands. As discussed in Appendix D, Washington has an estimated 11 million angler days per year, and it is known that 33 percent of anglers in Washington have reported fishing on state trust lands at least once in the past year, but the frequency is unknown. Attributing the 11 million days to the state trust lands is difficult, which makes an accurate estimation of these benefits a challenge. Due to the popularity of fishing in Washington and the wealth of opportunities for fishing on state trust lands, a placeholder estimate of 1 million user days was adopted until this estimate can be refined.

For some activities, no estimate for total recreation days was recorded by the Trust Manager, such as free-flight (e.g., hang gliding, paragliding), horseback riding, rock climbing, and snow sports. Millions of recreation days for these activities occur in Washington, and a portion of these are known to occur on state trust lands. This finding comes from analyzing the Statewide Comprehensive Outdoor Recreation Plan, which asks survey respondents if they participated in a given activity, and if so, what type of land management agency oversaw the recreation site (e.g., national forests, Washington State Department of Natural Resources, state parks).

This estimation underscores the importance of tracking the number of recreational user days to enable accurate estimates of economic benefits, an understanding of which can lead to more informed land management choices. Increasing the extent of the data coverage by tracking more recreation participation across activities would improve the accuracy of this estimate. Despite the uncertainties in the data, estimating a low value for the economic benefits of recreation on state trust lands is preferred to not estimating the value at all, for it is undoubtedly substantial.

Table 10. Economic Value of Outdoor Recreation on State Trust Lands (2018 $)

Activity	Reported Recreation Days	Estimated Data Coverage	Estimated Total Recreation Days	Consumer Surplus per Day	Estimated Value (in thousands)
Camping (Developed)	32,300	6.6%	489,394	$37.06	$18,137
Fishing	0	0%	1,000,000*	$74.42	$74,420
Hang Gliding and Paragliding	3,000	100%	3,000	$67.64	$203
Hiking	1,172,653	15%	7,817,687	$87.89	$687,097
Horseback Riding and Pack Stock	0	0%	286,368*	$67.64	$19,370
Hunting (Bighorn Sheep)	11	100%	11	$80.55	$1
Hunting (General Season)	456,147	100%	456,147	$80.55	$36,743
Hunting (Individual Hunts)	55,199	100%	55,199	$80.55	$4,446
Hunting (Moose)	354	100%	354	$80.55	$28
Hunting (Small Game)	173,044	100%	173,044	$80.55	$13,939
Hunting (Special Hunts)	56,142	100%	56,142	$80.55	$4,522
Mountain Biking	16,794	5.6%	299,893	$90.26	$27,068
OHV (4x4)	2,047	4%	51,175	$52.19	$2,671
OHV (ATV)	1,292	4%	32,300	$52.19	$1,686
OHV (Motorcycle)	3,437	4%	85,925	$52.19	$4,484
OHV (Other)	322	4%	8,050	$52.19	$420
Picnicking	13,800	1.75%	788,571	$49.17	$38,774
Rock Climbing	0	0%	81,486*	$67.64	$5,512
Shooting	19,500	10%	195,000	$67.25	$13,114
Snow Sports	0	0%	390,102*	$67.64	$26,386
Wildlife Watching	184,002	100%	184,002	$62.57	$11,513
Total	**2,190,044**		**12,453,850**		**$990,534**

* See Appendix D for estimation methodology. *Note: Totals may vary due to the effects of rounding.*

CARBON STORAGE AS AN ECOSYSTEM SERVICE

Increases in the proportion of heat-trapping gasses—primarily carbon dioxide and methane—within the Earth's atmosphere are affecting the climate and inflicting significant economic costs on communities around the world, including Washington State.[16,17] Severe precipitation, droughts, and temperature extremes—even wildfires—are growing in severity and frequency.[18] The cost of climate-related disasters in the United States from 1980 to 2017 totaled more than $1.1 trillion.[19] Climate impacts in Washington State are expected to increase in severity as the climate warms. The state already experiences multiple climate-related impacts, including damage to human health, industrial productivity, and property; reduced agricultural, seafood, and timber production; reduced hydropower generation; and increased shoreline erosion.[20] The importance of factors capable of limiting climate change are likely to grow over time.

Each growing season, trees, shrubs, grasses, and wetlands remove carbon from the atmosphere and sequester it as biomass, thus contributing to climate stability. In other words, sequestration is the ongoing conversion of atmospheric carbon to stored carbon, which may have benefits beyond contributing to climate stability (e.g., soil organic matter affects soil pH, moisture, and structure). While both sequestration rates and storage can be measured separately, the availability of primary carbon storage estimates for forests in the Forested Asset Class makes it possible to develop more focused storage valuation estimates for those lands. To maintain consistency across analyses, the climate stability ecosystem service of other land cover types—and forests outside of the Forested Asset Class—are also assessed in terms of carbon storage.

Calculating the value of stored or sequestered carbon is slightly different than a traditional benefit transfer. Instead of scaling per-area monetary values, the first step is to determine the carbon stored per acre. These storage estimates are then scaled by the extent of each land cover type, and the total carbon stored by a given land cover type within the study is assigned a carbon price.

There are many ways of assigning a price to carbon, including exchange values (e.g., market prices, emissions permit auctions) and Pigouvian taxes (e.g., carbon taxes). These mechanisms vary widely in their implementation depending on national and institutional context, but it is generally recognized that most tend to underestimate the marginal impact of emissions, which is the damage caused by each unit of carbon emitted. A more comprehensive approach—one adopted by the Washington State Department of Commerce—is to identify the full range of carbon impacts on society in the past, present, and future.[21] This "social cost of carbon" recognizes that deferring reductions in atmospheric carbon increases future impacts—in other words, the social cost of carbon grows over time. It increases because each additional unit of carbon emissions is expected to have higher and higher impacts, as ecosystems become increasingly stressed. Because of this, the value of interpreting carbon storage as an "annual social cost of carbon dividend" is problematic—the longer emission limits are delayed, the greater the social cost of carbon becomes.

This report uses the 2015 social cost of carbon estimate of $130.76 per metric ton of carbon (in 2018 US dollars).[22] While the source study for this estimate also concludes the real (i.e., inflation-neutral) social cost of carbon is expected to increase 3 percent each year through 2050, this 2015 estimate has only been adjusted for inflation, not the anticipated rise in real costs. It is thus a conservative estimate of the true social cost of carbon.

The Trust Manager provided the carbon storage estimates for forested land cover within the Forested Asset Class. The climate stability ecosystem service is valued directly from these estimates. Carbon storage on forested lands in other asset classes—and all other land cover types across all asset classes—is estimated based on generalized biophysical storage values found in the relevant literature (see Appendix C). All per-acre carbon storage values (including forested land cover within Forested Asset Class) are multiplied by the extent of each land cover type in acres, and again by the social cost of carbon.

Results

The average amount of carbon stored on each acre of forest within the Forested Asset Class is shown in Table 12. These averages by resource region include both above (i.e., standing trees) and below ground (i.e., root mass) carbon for both living and dead trees. Multiplying the sum of these per-acre averages by the extent of forest cover within each region of the Forested Asset Class reveals roughly similar carbon storage values across regions, although the greater extent of forest lands west of the Cascade Range means that most of this carbon storage value is found there.

For forests outside of the Forested Asset Class and all other land cover types across all asset classes, generalized carbon storage rates (in metric tons of carbon per acre) are applied (see Appendix E for sources). These are then scaled by the extent of each land cover type in each asset class and multiplied by the social cost of carbon for each metric ton of carbon (see Table 11). Because the climate stability benefits provided by forests within the Forested Asset Class have already been addressed, they were omitted here. However, both above- and below-ground carbon storage estimates for forested areas within other asset classes are included here.

Combining these estimates reveals that forests within the Forested Asset Class provide more than 90 percent of the climate stability ecosystem service value across all state trust lands; virtually all of that value across all forests, regardless of asset class. Annual and perennial crops provide the majority of climate stability value within the Cultivated Asset Class, and similarly, rangelands are a major factor in the Grazing Asset Class. Carbon storage in the Other Asset Class is evenly divided between forests and rangelands. Most of the climate stability provided by wetlands is found within the Forested Asset Class, and the largest climate stability value provided by grasses occurs within the Other Asset Class.

These are conservative estimates. The resolution of most land cover data is limited to 30 meters, meaning variations in land cover smaller than 30 x 30 meters may not be captured. Moreover, the social cost of carbon applied here is lower than other available social cost of carbon values and reflects the 2015 value, which has only been adjusted for inflation and does not account the expected 3 percent per year increase in the real social cost of carbon.

Table 11. Combined Social Cost of Carbon Storage (2018 $ in thousands)

	Asset Class				
Land Cover	**Forested**	**Cultivated**	**Grazing**	**Other**	**Total**
Cultivated	$0	$477,030	$5,309	$3,623	$485,962
Forests	$16,485,738	$28,056	$158,611	$191,577	$16,863,982
Grasses	$0	$1,097	$751	$1,911	$3,759
Rangelands	$0	$225,648	$823,443	$220,329	$1,269,421
Wetlands	$73,168	$4,156	$16,463	$24,951	$118,737
Total	**$16,558,906**	**$735,986**	**$1,004,577**	**$442,390**	**$18,741,860**

Note: Totals may vary due to the effects of rounding.

Table 12. Carbon Storage in Forests of the Forested Asset Class by Trust Manager Administrative Units (Average Metric Ton Carbon per Acre, Acreage, and Social Cost)

	West				East	
	Northwest	**Olympic**	**Pacific Cascades**	**South Puget Sound**	**Northeast**	**Southeast**
Live Trees						
Above Ground	54.29	67.44	57.88	59.54	19.97	27.81
Below Ground	11.26	13.79	12.33	12.87	3.84	5.52
Dead Trees						
Above Ground	2.99	5.15	3.57	2.04	2.20	1.88
Below Ground	0.88	1.55	1.02	0.60	0.53	0.49
Subtotal	**69.42**	**87.94**	**74.81**	**75.05**	**26.54**	**35.70**
Forested Asset Class Acres	316,814	349,070	397,668	287,831	387,202	329,310
Social Cost of Carbon (2018 $ in thousands)	$2,876,037	$4,013,928	$3,890,112	$2,824,800	$1,343,600	$1,537,251
Social Cost of Carbon Regional Subtotal ($ in thousands)	**$13,604,887**				**$2,880,851**	
Social Cost of Carbon Total ($ in thousands)	**$16,485,738**					

Note: Totals may vary due to the effects of rounding.

CONCLUSION

This chapter identified non-market ecosystem service benefits of state trust lands and provided conservative estimates for the economic value of these benefits. In total, these lands provide $1 billion per year of recreation value and $1.4 billion per year in other non-market ecosystem goods and services. Additionally, the current standing stock of carbon on state trust lands is worth $19 billion in carbon storage benefits, though this is not an annual benefit. These benefits accrue to users of state trust lands and to those in Washington State living upstream and downstream from them. The values presented in this report reveal the breadth and magnitude of the non-market economic benefits provided by state trust lands. Despite constraints due to gaps in the data, these results provide a broad sense of the economic importance of these lands.

Understanding the scale and importance of these non-market benefits—even in broad strokes—helps support shared goals, sustainable funding mechanisms for management, and better decision making. Natural lands provide goods and services that people need to survive. Without healthy natural capital, many of these ecosystem services that are provided at no cost by nature would cease to exist. Once lost, these services must be replaced with costly human-made capital, which is often less resilient and requires ongoing maintenance and replacement. When natural capital is lost, the economic goods and services it naturally provides also disappear.

Appendix A. Ecosystem Service Valuation Limitations

Valuation exercises have limitations, yet these limitations should not detract from the core finding that ecosystems produce significant economic value for society. Like any economic analysis, the benefit transfer method has strengths and weaknesses. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be of limited relevance to the ecosystems under analysis.
- Even within a single ecosystem, the value per acre depends on the size of the ecosystem. In most cases, as the size decreases, the per-acre value is expected to increase, and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
- Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not currently feasible. Therefore, the full value of all the open water, habitat, shrubland, grassland, etc., in a large geographic area cannot yet be ascertained. In technical terms, far too few data points are available to construct a realistic demand curve or estimate a demand function.
- The prior studies upon which calculations are based encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed too high or too low. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels: Even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
- The study by Costanza et al.23 of the value of all of the world's ecosystems has been criticized for estimating market values at a global scale. This critique is less persuasive if one recognizes the purpose of valuation at this scale, which is more analogous to national income accounting than to estimating exchange values.24

The chapter and supplementary appendices display study results in a way that allows one to appreciate the range of values and their distribution, and the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value or, alternatively, assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it would be better to be approximately right than precisely wrong.

Appendix B. Spatial Data Sources and Methods

ASSET CLASS GEOGRAPHIC BOUNDARIES

This section details the data sources and hierarchy used to define the spatial extent of the four asset classes used in this assessment.

Forested Asset Class

The Forested Asset Class comprises state trust lands where forestry activities are either the primary use or one of multiple uses. This encompasses both forest stands themselves as well as other already existing ecosystems (e.g., streams and wetlands) and human-created land covers (e.g., roads) necessary to manage these lands. A shape file supplied by the Trust Manager called "dnr_forested_land" was used to determine the Forested Asset Class boundary. This layer is located within the Trust Manager's geodatabase overlay_index, a working directory associated with the creation of temporary outputs in the process of aggregating water bodies within forested areas. This Asset Class boundary includes forested acres, wetlands, streams, and roads considered part of the body of land used for forestry.

Cultivated Asset Class

The Cultivated Asset Class denotes lands primarily designated for agricultural activities, as the Trust Manager leases a portion of state trust lands for agricultural production. The boundary of the Cultivated Asset Class was primarily determined by digitized leasehold boundaries supplied by the Trust Manager. These represent active agricultural leases that denote primary land use, not necessarily current land cover. Within these lease boundaries, leaseholders may manage a variety of land covers in addition to active crop production. As a result, and as seen within the other asset classes, a range of land covers are present within the Cultivated Asset Class boundary beyond simply annual and perennial crops.

There was some uncertainty as to whether the digitized lease boundaries supplied by the Trust Manager provided full coverage of agricultural lands, so the Washington Department of Agriculture 2018 crop distribution data layer was used to supplement lease boundaries and capture the full extent of the Cultivated Asset Class. Within the trust land boundary and excluding all land already identified in the Forested Asset Class, current agricultural areas (as defined using the 2018 crop distribution data layer) not already denoted by the agricultural lease boundaries were added to capture potential gaps in the digitized lease data and generate the final Cultivated Asset Class boundary.

Grazing Asset Class

Similar to the Cultivated Asset Class, the Grazing Asset Class was delineated based on current grazing lease boundaries within state trust lands. Priority was given to Forested Asset Class and Cultivated Asset Class, meaning that the Grazing Asset Class only encompasses land areas outside of the previously defined Forested Asset Class and Cultivated Asset Class. Any grazing leases that overlap with the Forested Asset Class were excluded from the definition of the Grazing Asset Class boundary.

Other Asset Class

After classifying the Forested Asset Class, Cultivated Asset Class, and Grazing Asset Class, the remaining areas within the trust land boundaries were combined into the Other Asset Class. This category comprises a number of different land uses and special permits.

LAND COVER AGGREGATION METHODS

Details of data and data processing required to aggregate ecosystem types for each asset class are presented below.

Forested Asset Class

Within the Forested Asset Class boundary, multiple data sets were used to categorize land cover, including data on forest inventory and two different water feature data sets that were provided by the Trust Manager. The Trust Manager-provided data was relied upon for consistency with other Trust Manager efforts.

First, water attributes including wetland types were found using two Trust Manager-supplied layers: wet_areas and synthetic streams. Wet_areas is characterized as a combination of: a layer based on the US Fish and Wildlife Service National Wetlands Inventory (fp_wet); a layer that captures assessed or known forested and non-forested wetlands on state trust lands (lk_slk_wetland); and a layer of water bodies that include features such as lakes, wet areas, reservoirs, impoundments, glaciers, islands, and dams (wbhydro). The US Fish and Wildlife Service National Wetlands Inventory is a public resource that provides information on the characteristics of US wetlands. For this study, data provided by lk_slk_wetlands layer was excluded because there is no current validation requirement for visually assessed wetlands and water bodies, meaning data can be entered but not reviewed for accuracy. For all other data within the wet_areas layer, features were classified as either herbaceous wetlands, woody wetlands, or freshwater.

Below is a list of attributes associated with each data layer included in wet_areas and how they were classified. Only water features within the trust land boundaries were used.

- wbhydro: marsh classified as herbaceous wetland and inundation classified as freshwater
- lk_slk_wetland: state land knowledge wetlands excluded from study
- fp_wet: Type A wetlands and Type B wetlands both classified as woody wetlands and non-forested wetlands were classified as herbaceous wetlands

These water and wetland data were further modified to include synthetic streams data, also provided by the Trust Manager. Using synthetic stream data provides more detail of the water features within the Forested Asset Class because the layers above focus on waterbodies and wetlands, not flowing surface water (e.g., rivers, streams). From the attributes of the synthetic stream layer, Type 3 streams were selected. Type 1-3 streams are considered fish bearing and are assumed to be used by a "significant number of fish species" as defined by the Trust Manager.[25] The synthetic streams layer did not include Type 1 or 2 streams. From these selected streams, a 10-foot buffer was created based on the average width of Type 3 streams as assessed, calculated, gauged, judged, and surveyed using imagery validation. Areas of overlap between the buffered streams classified as fresh water and the wet areas layer were determined. Fresh water features took priority and replaced the wet areas data if both existed. Finally, the two layers were combined to create one water feature layer that includes woody wetlands, herbaceous wetlands, and freshwater attributes.

The inventory layer, supplied by the Trust Manager, was used to determine the remaining land cover within the Forested Asset Class boundary. This layer included a forested and non-forested classification. Land that was classified as forested was further classified by conifer, hardwood, and mixed forest types. Non-forested land was classified as roads or barren land as defined by the Trust Manager (metadata: forest inventory).

To ensure each area of land was classified by only one land cover category (e.g., forest, wetland) the areas of overlap in the water features and forest inventory data sets were determined. Water features took priority and replaced the inventory data if both existed. Then the two layers were combined to create one layer that includes all Forested Asset Class land cover classifications. Acres of each land cover category were calculated using this layer.

Cultivated Asset Class

Land cover for land within the Cultivated Asset Class boundary was found using the National Land Cover Database and modified using the Washington Department of Agriculture crop distribution data layer. To ensure each area of land was classified by only one land cover category, the areas of overlap between the crop features and data sets from the National Land Cover Database were determined. Crop features took priority and replaced the data from the National Land Cover Database, if both existed. Then the two layers were combined. Attributes from the crop distribution data layer enable a more detailed view of the different types of crops within the boundary, and data from the National Land Cover Database categorized the remaining land within the Cultivated Asset Class boundary.

Grazing Asset Class

Land cover within the Grazing Asset Class boundary was categorized using data from the National Land Cover Database. Grazing is expected to occur on rangelands, grasslands, and shrublands within the Grazing Asset Class, which were combined to represent the extent of grazing lands. Acres of each land cover category were calculated within the Grazing Asset Class boundary.

Other Asset Class

Land cover within the Other Asset Class boundary was categorized using data from the National Land Cover Database. Acres of each land cover category were calculated within the Other Asset Class boundary.

Appendix C. Ecosystem Services Valuation Sources and Detailed Tables

The lowest and highest ecosystem service values reveal a range of values provided by estimates within one or more studies. Primary studies often provide a range of values that reflect statistical uncertainty or the breadth of features being studied. To recognize this variability and uncertainty, both high and low dollar per acre values are included in this appendix, if available, for each value provided in this report.

APPENDIX C-1. SOURCES FOR ECOSYSTEM SERVICE VALUES

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APPENDIX C-2. ECOSYSTEM SERVICE VALUE RANGES

Table 13. Value Ranges of Total Annual Ecosystem Services per Acre, by Land Cover and Attribute (2018 $)

Land Cover (Attribute)	Ecosystem Services Valued	Range
Agriculture (Annuals)	Cultural Value Biological Control Pollination and Seed Dispersal	$2.47 to $2.55
Agriculture (Perennials)	Pollination and Seed Dispersal	$2,302 to $3,340
Forests (Riparian, All)	Habitat	$0.04 to $0.12
Forests (Upland, All)	Soil Retention Water Quality	$138
Forests (Riparian, Evergreen)	Soil Retention	$0.76 to $5.43
Forests (Riparian, Non-Evergreen)	Soil Retention	$0.76
Forests (Evergreen)	Aesthetic Information Cultural Value Food (Mushrooms) Habitat Science and Education	$34 to $61
Forests (Rural)	Water Capture, Conveyance, Supply	$245 to $611
Forests (Urban)	Air Quality Habitat Water Capture, Conveyance, Supply	$1,052 to $2,488
Forests (Highways)	Air Quality	$32 to $1,112
Grasses (Agriculture Border)	Biological Control Disaster Risk Reduction Soil Retention	$4,587 to $5,872
Rangelands (All)	Food (Forage)	$15 to $107
Wetlands (All)	Cultural Value Energy and Raw Materials Water Storage	$43 to $266
Wetlands (Agricultural Border)	Disaster Risk Reduction Habitat Water Capture, Conveyance, Supply Water Quality	$28,510 to $30,002
Wetlands (Coastal)	Habitat	$283 to $491
Wetlands (Non-Agricultural Border)	Disaster Risk Reduction Water Capture, Conveyance, Supply Water Quality	$34 to $11,992
Wetlands (Non-Agricultural Border, Non-Coastal)	Habitat	$0.14 to $520
Wetlands (Urban)	Aesthetic Information	$10,595

Table 14. Annual Ecosystem Service Value, Range by Land Cover and Asset Class (2018 $ in thousands)

	Asset Class				
Land Cover	**Forested**	**Cultivated**	**Grazing**	**Other**	**Total**
Cultivated	—	$41,554 to $60,107	$5.5 to $5.7	$3.8 to $3.9	$41,563 to $60,117
Forests	$785,696 to $1,566,296	$740 to $2,076	$4,147 to $10,598	$5,090 to $12,928	$795,673 to $1,591,898
Grasses	—	$17,449 to $22,337	$4,096 to $5,244	$2,128 to $2,725	$23,673 to $30,306
Rangelands	—	$1,407 to $9,849	$5,135 to $35,941	$1,374 to $9,617	$7,916 to $55,407
Wetlands	$8,262 to $176,616	$4,463 to $12,445	$2,945 to $39,957	$4,231 to $61,603	$19,901 to $290,621
Total	$793,958 to $1,742,913	$65,612 to $106,813	$16,328 to $91,746	$12,827 to $86,877	$888,725 to $2,028,349
Acreage	2,170,070	301,807	366,240	124,969	2,963,086
% of State Trust Lands	73.2%	10.2%	12.4%	4.2%	
% of Annual Ecosystem Service Valuation	85.9% to 89.3%	5.3% to 7.4%	1.8% to 4.5%	1.4% to 4.3%	

Table 15. Annual Ecosystem Service Value, Range by Ecosystem Service and Asset Class (2018 $ in thousands)

	Asset Class			
Ecosystem Service	**Forested**	**Cultivated**	**Grazing**	**Other**
Food Provisioning	—	$1,407 to $9,849	$5,135 to $35,941	$1,374 to $9,617
Energy and Raw Materials	$162 to $2,268	$9 to $129	$36 to $510	$55 to $773
Water Storage	$335	$19	$75	$114
Air Quality	$735 to $25,396	$7 to $253	$9 to $299	$12 to $409
Biological Control	—	$1,860	$283	$148
Disaster Risk Reduction	$347 to $56,426	$15,924 to $18,501	$3,964 to $16,241	$2,012 to $21,121
Pollination and Genetic Dispersal	—	$41,751 to $60,289	$8	$5
Soil Retention	$10,359 to $10,995	($75) to $4,813	$186 to $1,334	$95 to $691
Water Quality	$249,901 to $342,644	$409 to $4,670	$292 to $20,596	$121 to $31,723
Water Capture, Conveyance, Supply	$510,994 to $1,276,027	$748 to $2,501	$4,148 to $12,563	$5,017 to $15,784
Habitat	$14,944 to $21,769	$3,276 to $3,589	$1,995 to $3,503	$448 to $2,768
Aesthetic Information	$6,113	$244	$180	$3,401
Cultural Value	$68 to $939	$33 to $98	$16 to $212	$23 to $321
Total	**$793,958 to $1,742,913**	**$65,612 to $106,813**	**$16,328 to $91,746**	**$12,827 to $86,877**

Note that some land cover types or land-use practices produce negative externalities (also known as disservices). This is clearly the case for erosion, especially when soils are regularly disturbed by cultivation. For lower value estimates, this results in a loss of $75,000 in the Cultivated Asset Class for soil retention (see Table 15).

Appendix D. Recreation Sources and Methods

This appendix details the data collection approach for each recreational activity and how the estimated data coverage was calculated.

Camping (Developed)

The Trust Manager manages 80 campgrounds across the state, including campgrounds that can only be accessed by boat, such as the Pelican Beach or Cypress Head campgrounds on Cypress Island. When monitoring campground use, many land managers track use through camping reservations and fees. However, because these campgrounds are available on a first come, first served basis, and there is no cost beyond the Discover Pass, monitoring campground use is difficult. In the data collection process, only Capitol State Forest was able to provide monitored data on campground use, at which recreation managers estimated 32,300 recreation days per year.

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 1.7 million developed camping participants in Washington.[26] This report found that 29 percent of camping participants visited a trust property at least once to participate in camping, resulting in a minimum of 490,017 days of camping at state trust lands. Therefore, Capitol State Forest accounts for approximately 7 percent of reported days per year.

Fishing

The 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation estimates that there were 13,449,000 days of fishing in Washington State.[27] National data from 2016 shows that while the total number of anglers in the United States has increased, the days of fishing have decreased.[28] This trend seems to follow fishing license sales data from the Washington Department of Fish and Wildlife, which shows annual permits decreasing from 2016 to 2018 (albeit an extremely small sample size), and single day permit sales increasing over this same time period.[29] This could indicate that while there are more anglers, the number of days fishing per angler is down. Assuming Washington State's participation in fishing is parallel to national rates, it is estimated there are 11,143,000 days of fishing in Washington State.

Due to lack of data, it was not possible to assign fishing days to state trust lands, although according to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, 32 percent of freshwater participants and 17 percent of saltwater participants visited state trust lands at least once to participate in fishing.[26] Because an unknown frequency of visitation is associated with these days, it is conservatively estimated that 1,000,000 fishing days occur on or are accessed through state trust lands per year.

Hang Gliding and Paragliding

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, 100,000 days of hang gliding, sky diving, or paragliding occur in Washington State every year.[26] The demand report also states that 3 percent of these days occur on state trust lands, such as Tiger Mountain State Forest's Poo Poo Point, Blanchard Forest's Samish Overlook, or the Chelan Butte Sky Park. It is therefore estimated that 3,000 hang gliding and paragliding activity days occur on state trust lands per year.

Hiking

The Trust Manager manages some of the most popular hiking trails in the United States, including Rattlesnake Ridge, Mailbox Peak, Mount Si, and Blanchard Forest's Oyster Dome, to name a few. Data on hiking days was available from the Snoqualmie Corridor and Capitol Forest, as well as limited data from the Olympic Peninsula Forest. Reported hiking days for these recreation areas totaled 1.17 million days. Website traffic provided by the Trust Manager showed that the webpages for the recreation sites that had data accounted for approximately 15 percent of all unique recreation-site webpage views.[30] This estimate is likely an underestimate of total use to these areas, and in total use to the state, due to the fact that these areas receive higher repeat visitors, who are less likely to revisit the webpage. Assuming data coverage of 15 percent, state trust lands provide 7.8 million days of hiking per year.

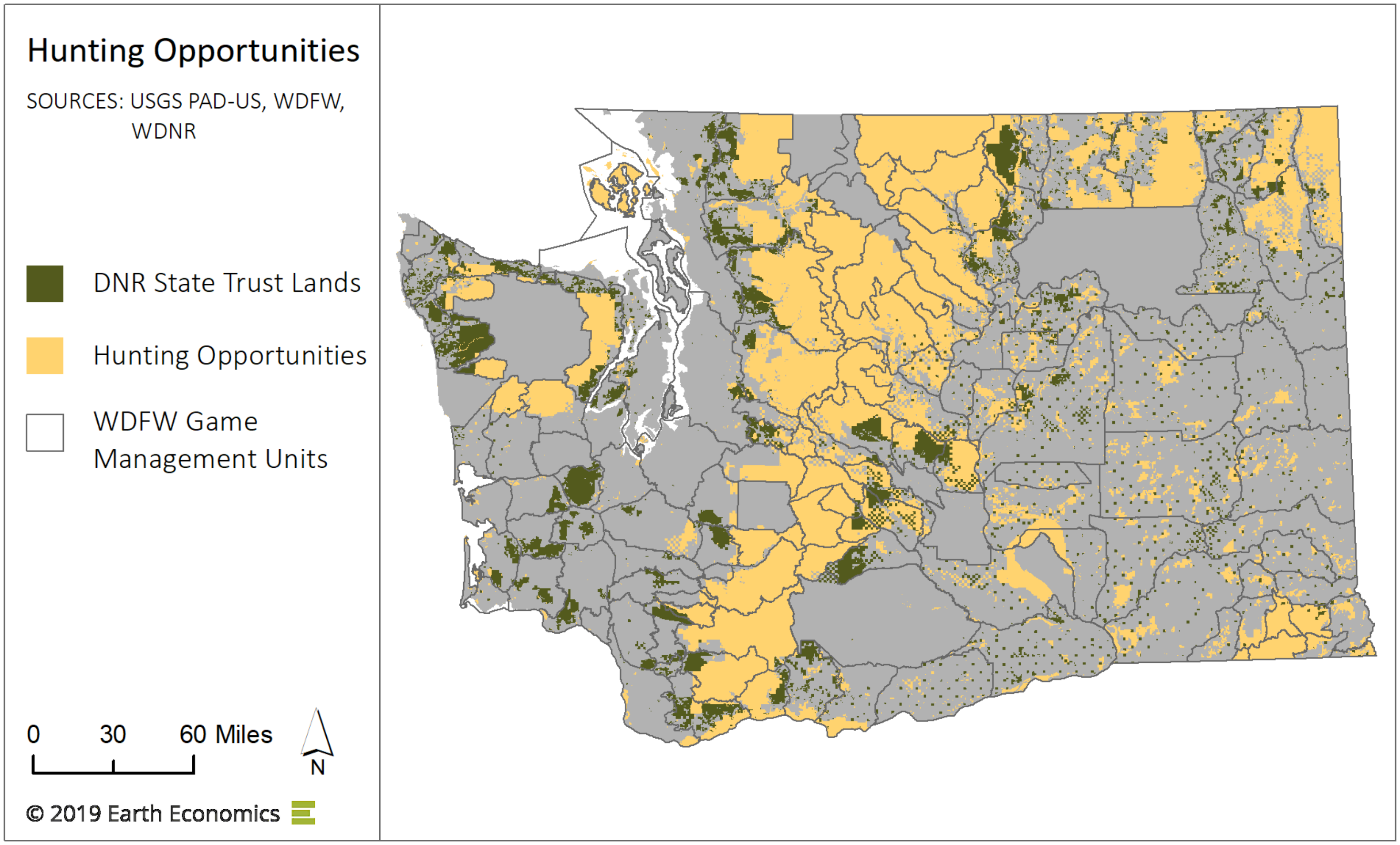
Horseback Riding and Pack Stock

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, approximately 4 percent of Washingtonians participated in horseback and stock activities on "Mountain or forest trails," with 15 mean user days per participant.[26] From this, it can be estimated that there were 4.3 million recreation days on forested trails. An unknown amount of these days occurred at Trust Manager-operated facilities, but 26 percent of surveyed participants did visit Trust Manager-operated facilities at least once for horseback and pack stock recreation. Therefore, at a minimum, there are 286,368 days of horseback riding and pack stock recreation occurring on state trust lands per year.

Hunting

Hunting data was collected from the Washington Department of Fish and Wildlife's Game Harvest Reports, which track all hunting harvests. Species recorded as hunted include elk, deer, turkey, cougar, black bear, small game, and furbearers. Each harvest is associated with a days per harvest metric and spatially assigned to a game management unit. To assign these to state trust lands, available hunting opportunities were identified in Washington State from the Bureau of Land Management, US Forest Service, Washington State Department of Fish and Wildlife, Washington Department of Natural Resources, and Private Lands Hunting Opportunities (Figure 1). Game management units were then overlaid. Next, the percentage of state trust lands out of all available hunting areas for each game management unit was calculated, as well as data from game allocated from Harvest Reports.[31] The analysis assumes a consistent harvest throughout the game management unit, and does not consider hot spots or unreachable areas within. The percentage of state trust lands within each game management unit's available hunting lands was then applied to the harvests for each game management unit to arrive at total hunting days for each game management unit. All game management units were then totaled to achieve a statewide total of 740,897 hunting days occurring on state trust lands per year.

FIGURE 1. HUNTING OPPORTUNITY AREAS IN WASHINGTON STATE AND ON STATE TRUST LANDS



Mountain Biking

Mountain biking occurs at many locations throughout state trust lands, but data was only collected for Capitol Forest and Reiter Foothills. Capitol Forest had an estimated 15,000 recreation days in 2018, based on vehicle counts at trail parking lots. Data for Reiter Foothills was estimated through an extrapolation of compliant and non-compliant Discover Pass reports from the parking lot, which were broken out by recreational activity. It was estimated that Reiter Foothills had 1,794 recreation days. A total of 16,794 mountain biking recreation days were reported for state trust lands.

Estimated coverage for this data is based on an analysis of the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, which found that 28 percent of Washingtonians participated in bicycling—a total of 2.1 million participants.[26] The survey found that 14 percent of respondents visited state trust lands at least once to participate in bicycling (assumed to be mountain biking). Therefore, it is estimated that there are at least 299,888 days of mountain biking occurring on state trust lands every year, and current data coverage is only 5.6 percent. This estimate is extremely conservative, as the survey reports Washingtonians who mountain biked on natural or dirt trails had a mean annual activity rate of 18 days per year; although it is not clear how many of these days occurred on state trust lands.

Off-Highway Vehicle (OHV)

OHV data was only available for Reiter Foothills Forest and was based on extrapolation of compliant and non-compliant Discover Pass reports from the parking lot, which were broken out by recreational activity. It was estimated that Reiter Foothills had 7,098 OHV recreation days.

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 500,000 OHV participants in Washington.[26] The demand report estimated that 35 percent of OHV respondents visited a trust property at least once to participate in OHV activities, resulting in a minimum of 177,450 days across all OHV categories. Therefore, Reiter Foothills accounted for only 1.75 percent of OHV days on state trust lands.

Picnicking

Picnicking data was only available for Capitol State Forest and was based on the use of day-use camping facilities. It was estimated that Capitol State Forest had 13,800 picnicking recreation days in 2018.

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 4.4 million leisure participants in Washington who are assumed to be picnickers.[26] This report estimated that 18 percent of leisure respondents visited a trust property at least once to participate in leisure activities in 2017, resulting in a minimum of 789,875 days of leisure activities on state trust lands in 2017.

Rock Climbing

No rock climbing data was recorded for state trust lands. However, according to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 281,000 rock climbing participants in Washington.[26] This report found that 29 percent of climbing and mountaineering respondents visited a trust property at least once to participate in climbing, resulting in a minimum of 81,486 days of climbing on state trust lands in 2017.

Shooting

Recreational target-shooting data was only available for Capitol State Forest, and was based on direct reports of participation. It was estimated that Capitol Forest had 19,500 recreation days in 2018.

According to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 1.4 million target-shooting participants in Washington.[26] The demand report found that 13 percent of target-shooting respondents visited a trust property at least once to participate in target shooting in 2017, resulting in a minimum of 185,932 days of target shooting on trust properties. Therefore, Capitol State Forest accounted for approximately 10.5 percent of all target shooting days on state trust lands in 2017.

Snow Sports

No snow activity data was recorded for state trust lands. However, according to the State of Washington 2017 Assessment of Outdoor Recreation Demand Report, there are approximately 2.3 million snow sports participants in Washington.[26] The demand report found that 17 percent of snow sports respondents visited a trust property at least once to participate in climbing in 2017, resulting in a minimum of 390,102 days of snow-based play on state trust lands in 2017.

Wildlife Watching

Wildlife watching is one of the most popular activities in Washington, accounting for an estimated 6.3 million away-from-home wildlife watching days. Wildlife watching is tracked through the US Census and spatially assigned through crowdsourced wildlife-watching data, which enables this value estimate.

To determine the number of wildlife watching days occurring on state trust lands, crowd-sourced wildlife watching data was downloaded from the US Geological Survey (USGS) BISON Database,[32] which maps species sightings across the United States and is a useful tool in spatially allocating wildlife viewing.

First, sightings on medium- and high-intensity developed lands were removed from the data set to limit the search to natural areas, as seen in Figure 2. The search was limited to natural areas to account for away-from-home wildlife watching only. Next, state trust lands were applied as a layer to the map (Figure 3).

Finally, the percentage of sightings that occurred on state trust lands versus the rest of the state was calculated (Figure 4). Using the USGS BISON Database, it was found that 2.9 percent of wildlife sightings occur on state trust lands in 2019. This percentage was then applied to all away-from-home wildlife watching days in Washington. In total, it was estimated that 184,002 wildlife watching days occurred on state trust lands in 2019.

FIGURE 2. AWAY-FROM-HOME WILDLIFE VIEWING AREAS

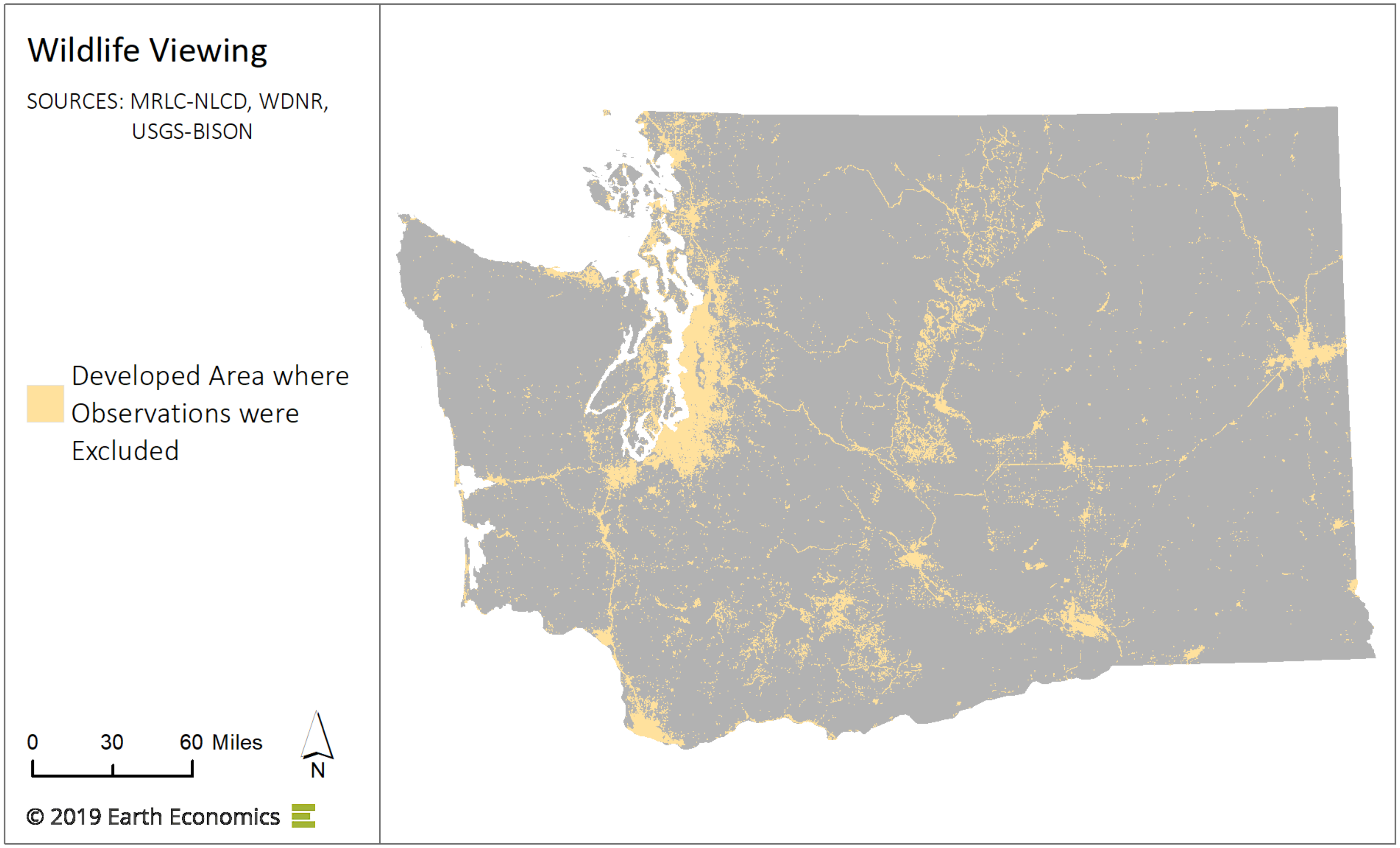


FIGURE 3. AWAY-FROM-HOME WILDLIFE VIEWING OPPORTUNITIES ON STATE TRUST LANDS

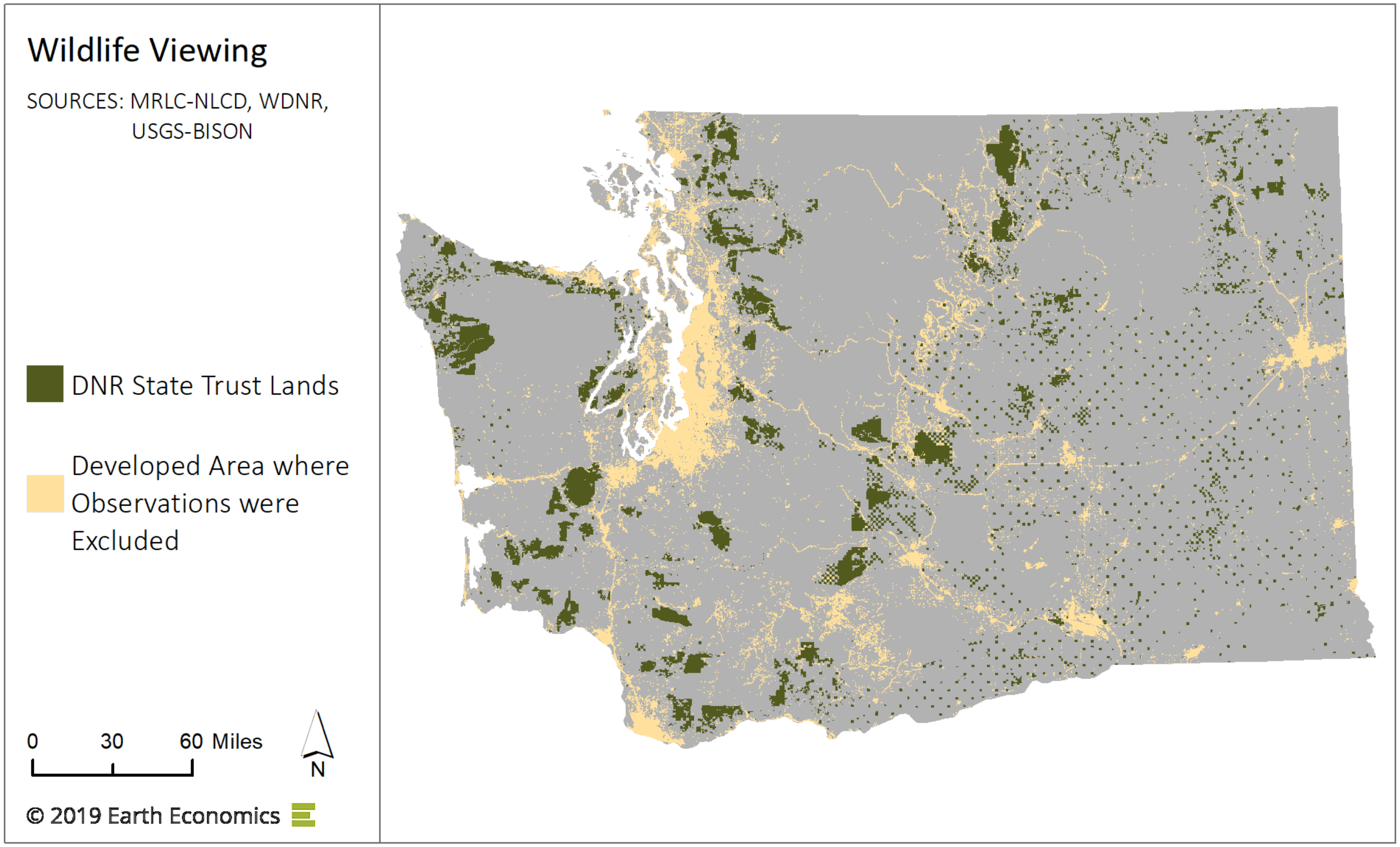
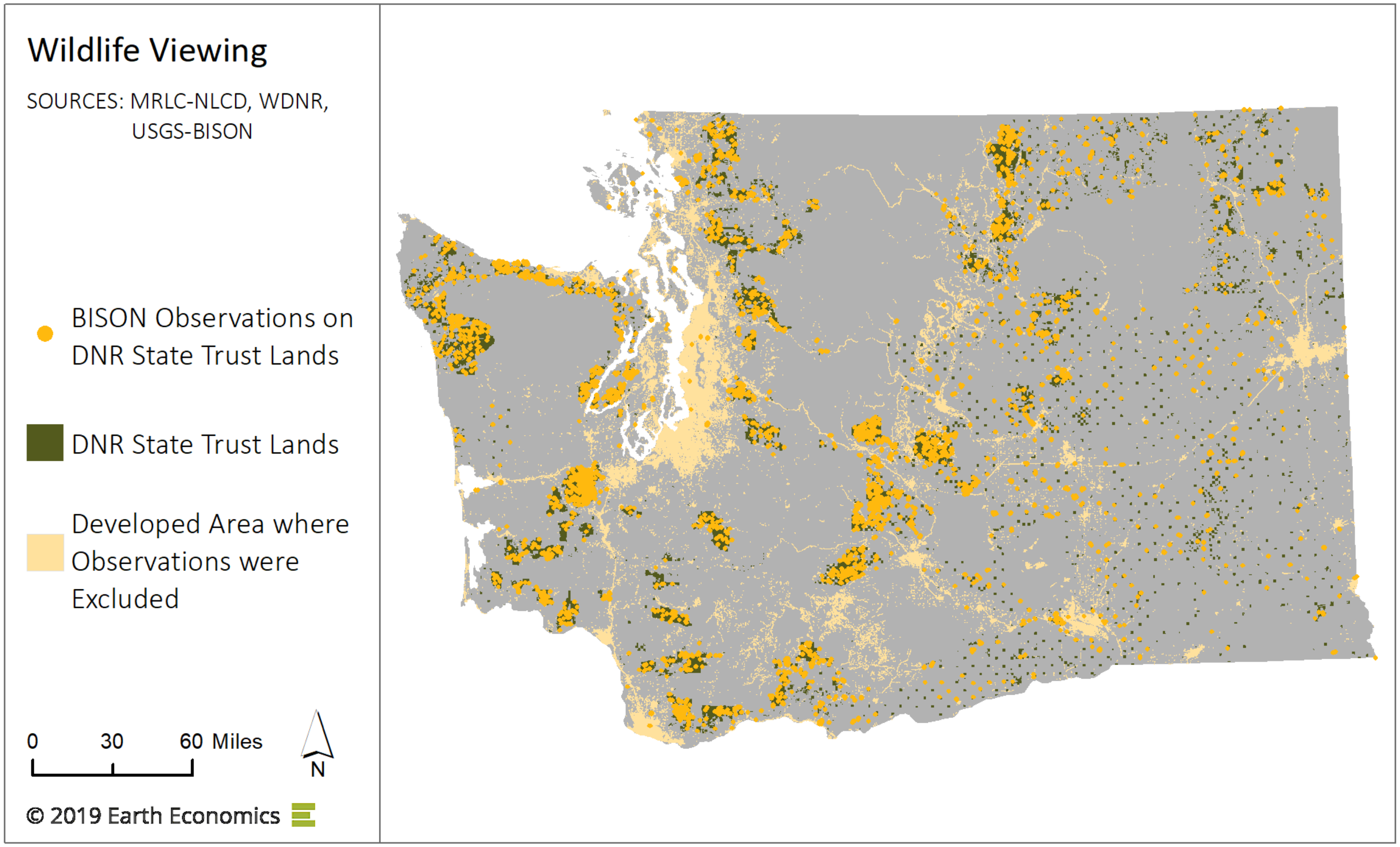


FIGURE 4. USGS BISON DATABASE SIGHTINGS ON TRUST LANDS



Appendix E. Carbon Valuation Sources

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