Idaho's Natural Capital Assessment: A Statewide Ecosystem Services Evaluation

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ACKNOWLEDGEMENTS

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GLOSSARY

ARRA – American Recovery and Reinvestment Act

Assessment – Analysis presented in this report.

Benefit Transfer Methodology (BTM) – BTM is an ecosystem service valuation method that uses values derived from published studies for application in similar ecosystems. It resembles a house or business appraisal that is based on comparable characteristics of similar houses or businesses.

Ecosystem – An interacting system of living organisms, soil, and climatic factors. Forests, wetlands, watersheds, ponds, prairies, and communities are ecosystems.

Ecosystem Services – Benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, air, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

Ecosystem Services Valuation (ESV) – Ecosystem service valuation: Ecosystem service valuation is the quantification of the benefits that people derive from ecosystems, generally expressed as non-market values or market value equivalents.

Ecosystem Service Value - Measure of the benefit provided by an ecosystem using market proxies to infer a dollar value equivalent.

Fire Mitigation – A project that reduces fire hazard.

Forest health – A measure of the robustness of forest ecosystems. Aspects of forest health include biological diversity; soil, air, and water productivity; natural disturbances; and the capacity of the forest to provide a sustained flow of goods and services for people.

Forest Management/Stewardship –a forest landowner plan that describes objectives, goals, current and desired future conditions for a forested area. Use Idaho's One Plan Template to develop plans. The One Plan is located on the Idaho Department of Lands website.

Geodatabase - A relational database that houses GIS data used to document grant funded activities.

Hazard Fuel Reduction – accounts for all methods of vegetation manipulation to meaningfully change expected fire behavior.

Natural Capital – The interconnected network of natural resources (also called green infrastructure) throughout Idaho that produces a variety of natural capital assets. These natural capital assets provide the people of Idaho with a wide range of ecosystem services, which contribute to the local economy, society, and environmental health.

Natural Capital Asset Map – Produced by the consultant team in collaboration with the project directors and stakeholder team, the Natural Capital Asset Map displays the distribution of natural capital assets throughout the State. This map incorporates over forty sources of data provided by the stakeholder team to represent the natural assets that are of greatest importance to the people and environment of the watershed

Shared Stewardship – an initiative, between states and the federal government, that aims to reduce wildfire risk, improve forest health, and support jobs through additional, coordinated active land management projects.

Thinning – a prescriptive treatment to reduce the stand density of trees to improve tree growth, enhance forest health, remove insect or disease, or recover potential mortality.

Valuation of Ecosystem Goods and Services Database (VEGS) – The VEGS is a computational engine and database developed and maintained by Equilibrium Economics for the application of "benefit transfer methodology" in "ecosystem service valuation". It houses the world's largest library of ecosystem goods and services valuation studies.

1. NATURAL CAPITAL AND THE IDAHO ECONOMY

Healthy landscapes: collectively referred to in this report as **Natural Capital**, build thriving economies. These landscapes are defined by unique natural features and a diversity of human-defined boundaries. Every farm, ranch, city, and town in Idaho resides alongside the state's rivers, valleys, and mountains. If the lands, rivers, rangelands, and forests are degraded, local economies are negatively impacted. Idaho is home to renowned recreation destinations such as the numerous peaks and lakes of the Sawtooth National Recreation Area. Or south of Sawtooth's, the Wood River Valley (Blaine County) offers summer and winter recreational opportunities (downhill and cross-country skiing, hiking, fishing, biking). The Wood River Valley is home to the Sun Valley Resort, which catalyzed $308 million in travel spending and $29.5M in county tax revenue in 2019 alone (Visit Sun Valley, 2020).

Working and natural landscapes provide tremendous benefits to the people of Idaho. The goods and services provided by natural and working landscapes are called ***ecosystem goods and services*** and provide a basis for recreation and economic development.

Forests and rangelands across Idaho's landscape, when healthy, can provide a wide range of ecosystem services for local communities. They shade and cool streams, improve water quality, deliver drinking water, provide places to recreate, support a forest-based wood products industry and enable economic development. When forests are degraded by pests, disease, and/or invasive species, among other threats (drought), they can pose a risk to neighboring communities through increased tree mortality and wildfire-risk. Poor forest health and burned area landscapes can damage communities across the state. Fortunately, investing in forest management activities can reduce tree mortality and fire risk and build health and resilience across valuable landscapes across Idaho.

To guide strategic investment in Idaho's Natural Capital, it is important to inform decision-makers, civic leaders, conservation organizations and forest, green and agriculture industry on the value of our state's natural resources and the importance of investing in their health and vitality. This assessment is a valuable tool to communicate the importance of investing in the state's natural resources. When local, state and federal leadership can effectively plan for and manage Idaho's forest resources using tools like Idaho's State Forest Action Plan and this Ecosystem Service Valuation of Idaho's Natural Capital, they will effectively build thriving and more resilient forests, agricultural lands and communities across the state.

1.1 HOW TO USE THIS REPORT

This assessment describes Idaho's natural capital assets (i.e. the goods and services provided by Idaho's natural resources, and the value of those goods and services). It provides the first-ever state-wide analysis of Idaho's Natural Capital, including identification of ecosystem services, valuation of individual ecosystem services, impacts of forests threats, and estimation of the asset value of the natural systems across the state. The conceptual framework described here, including definitions of Natural Capital and the estimation of economic value, are presented and available in the various data and tools developed as a part of this project. Together, these tools can be used in many practical applications, including:

- **Securing Pre- and Post-Disaster Funding:** The dollar values and analysis in this report can help in assessing the economic impacts of disasters in requesting pre- and post-disaster funding from a variety of agencies, including but not limited to: Federal Emergency Management Agency (FEMA), USDA Forest Service (USFS), USDA Natural Resource Conservation Service (NRCS); Idaho Department of Lands (IDL); Idaho Fish and Game (IDFG). The scale and cost of fires and floods in Idaho are growing, and so securing funding to mitigate disasters is crucial.
    - For example, FEMA uses Benefit-Cost Analysis (BCA) for allocating mitigation funding. *Following a flood, fire, landslide or drought disaster, Idaho and local officials can use the ecosystem service values provided in this study in place of the general (and lower) BCA values found in the FEMA BCA disaster mitigation toolkit and secure significantly more post-disaster flood mitigation funding.*
- **Estimate Return on Investment of Idaho's forest treatment programs**: The spatial data, economic values, and methods described in this report can be used to estimate a rate of return on investment for forest treatments and other mitigative activities (e.g., hazard fuel reduction, wetland creation etc.).
- **Scaling investments in natural capital to the size of the asset**: Understanding the scale of Natural Capital asset value in Idaho, combined with an understanding of the potential return on Natural Capital investment, can be used to inform future investments and determine the appropriate scale of investments in conservation and help secure more jobs and income from greater natural resource productivity and sustainability.
    - For example, the City of Snoqualmie in Washington State passed a 2020 ordinance to establish a portion of stormwater rate-payer fees to be allocated to support the city's urban forestry program. This funding mechanism was right sized for the local municipality, using a stormwater fee to maintain stormwater benefits provided by surrounding forests for the benefit of residents and visitors to Snoqualmie. Likewise, the From Forest to Faucet, a 2010 forest management partnership between Denver Water and the Rocky Mountain Region of the U.S. Forest Service, has resulted in over $66 million invested in forest management projects.

2. OVERVIEW OF ECOSYSTEM GOODS AND SERVICES IN IDAHO

Assessing the economic value of landscapes and ecosystem goods and services (the Natural Capital) is critically important to appropriately invest in sufficient funding to support healthy and resilient natural resources across the state, yet this is often challenging to accomplish. For example, every community and every Idahoan depend upon Idaho's Natural Capital. Most of the State's water originates in forests. Forest products have markets and monetary values. Many ecosystem services such as genetic diversity or place-based cultural significance have tremendous intrinsic value to society or specific communities but remain difficult or impossible to value monetarily. This assessment does not attempt to capture the intrinsic or symbolic values of landscapes and ecosystems. There are other approaches and non-monetary methods for describing and making decisions based on those values (Aldred and Jacobs, 2000; Gregory and Wellman, 2001; Wilson and Howarth, 2002). Additionally, this assessment is not focused on the market values of goods and services that are already monetized, traded, and regularly analyzed in traditional economic analyses such as agricultural goods, timber, and cattle. For example, the market values of commercial crops (wheat, onions etc.) represent the value of labor and capital inputs required to grow those crops, rather than the contribution of ecosystem services. ***The dollar values in this study measure the value of nature to people for the identified goods and services.***

3. Primer: What are Ecosystem Goods and Services?

In 2001, an international coalition of scientists, economists and policy makers assessed the effects of ecosystems on human well-being (MEA, 2005) The resulting Millennium Ecosystem Assessment classifies ecosystem services into four broad categories according to how they benefit humans:

- **Provisioning goods** provide physical materials and energy for society from natural systems. Forests produce lumber, agricultural lands supply food, and rivers and aquifers provide drinking water.
- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, improve water quality, control soil erosion or accumulation, reduce disaster damage, and regulate climate.
- **Supporting services** include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- **Information services** are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Each category above can be defined by several **ecosystem goods and services**, and contributions that ecosystem service make to human well-being. Table 1 identifies the ecosystem services valued in this analysis within these four categories and the economic benefits provided to people.

Table 1. Potential Ecosystem Services Values (Teal indicates ecosystem services valued in this report).

Service	Economic Benefits to People
Provisioning	
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
Water Storage	Providing long-term reserves of usable water via storage in lakes, ponds, aquifers, and soil moisture
Regulating	
Air Quality	Providing clean, breathable air.
Biological Control	Providing pest, weed, and disease control
Carbon Sequestration & Stock	Supporting a stable climate at global and local levels through carbon sequestration.
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts.
Pollination & Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
Soil Quality and Formation	Maintaining soil fertility and capacity to process waste inputs (bioremediation)
Soil Erosion Protection	Retaining arable land, slope stability, and coastal integrity.
Water Quality	Removing water pollutants via soil filtration and transformation by vegetation and microbial communities.
Water Supply	Regulating the rate of water flow through an environment and ensuring adequate water availability for all water users.
Temperature Regulation	Shade provided by forests can reduce local temperatures and provide energy savings
Supporting	
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity.
Nutrient Cycling	Movement of nutrients through an ecosystem by biotic and abiotic processes. Supports retention in the biosphere and the soil organic layer
Information	
Aesthetic Value	Enjoying and appreciating the scenery, sounds, and smells of nature.
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious, and historic importance
Science & Education	Using natural systems for education and scientific research
Recreation & Tourism	Experiencing the natural world and enjoying outdoor activities.
Artistic Inspiration	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media

4. Ecosystem Services and Economics: A Widely Accepted Federal Framework

The economic goods and services produced in a region can be quantified to provide a view of the region's economy. The value of these economic goods and services, including housing construction, industry, and services is typically estimated with market or appraisal values. Similarly, the value of the natural capital of Idaho's natural resources —and the ecosystem goods and services they provide—can be quantified with market and appraisal values. Each land cover type, from wetlands to forests to rangelands to agricultural lands, provides a suite of ecosystem goods and services. For example, **goods** provided by Payette National Forest include timber for construction, wild mushrooms for food; **services** include groundwater recharge (through interception and percolation of rainwater), carbon sequestration, recreational opportunities such as hiking and camping, and the removal of air pollutants such as sulfur dioxide and particulate matter. The identification and monetary valuation of these ecosystem goods and services provides insight into the economic importance of the State's natural capital.

The value of ecosystem goods and services (referred to hence fourth as just ecosystem services) is recognized in federal policy. FEMA, among other U.S. federal agencies, has incorporated these values into disaster risk planning and mitigation efforts with a series of policies (FEMA, 2013, 2016, 2020a). In 2013, FEMA adopted ecosystem services values in FEMA Mitigation Policy FP 108-024-01 to include the monetary value of environmental benefits in flood and hurricane mitigation programs for all 50 U.S. states. Having found the inclusion of ecosystem services highly effective for saving taxpayer money and reducing the cost of repetitive disasters, FEMA subsequently added to the policy in May 2016, adding ecosystem services to fire, drought, and landslide mitigation as well (FEMA, 2016). In 2020, FEMA removed previous restrictions and limitations on when ecosystem services could be included in benefit-cost analysis. The new policy makes it easier to incorporate ecosystem services into risk-based mitigation projects.

The federal government in 2015 issued memorandum M-16-01 on "Incorporating Ecosystem Services into Federal Decision Making" (OMB et al., 2015). The 2015 memorandum expanded the incorporation of ecosystem services in decision-making to all federal programs, including USDA Forest Service, USDI Bureau of Land Management, among other federal agencies US Fish and Wildlife Service and the US Army Corps of Engineers, among other federal agencies (National Ecosystem Services Partnership, n.d.; Schaefer et al., 2015)).

4.1 Idaho Department of Lands and State & Private Forestry Programs – An economic context

Idaho Department of Lands (IDL) has a multitude of roles in managing forest lands, agricultural lands, rangelands, and commercial lands across the state. IDL is a large and diverse agency with a multitude of mandates, including:

- State Trust Land Management,
- State and Private Forest Management,

- Forest Practices,
- Shared Stewardship,
- Mining and Minerals,
- Management of Navigable Waterways.

This report assesses the Ecosystem Service Values of lands across diverse landscapes including forest lands and rangelands. The report also takes a deeper dive into Idaho Department of Lands Programs within State and Private Forestry, funded in large part by the USDA Forest Service (Forest Stewardship; Forest Health; Urban and Community Forestry; Forest Legacy; Conservation Education; State Fire Assistance, and Rural Fire Capacity.).

5. Using an Ecosystem Service Framework to Inform Idaho's State Forest Action Plan

Idaho's State Forest Action Plan (FAP) is an all-lands resource plan. Although its name includes "Forest," and much of the focus of the plan is on forests, FAP priorities and strategies identified are designed to promote sound management of all natural resources within the State of Idaho. Idaho's Forest Action Plan (FAP) has a ten-year planning and action horizon through the Idaho Lands Resource Coordinating Council (ILRCC) which advises Idaho Department of Lands on delivery of USDA State and Private Forest Programs.

In Idaho, the Idaho Department of Lands (IDL) administers the USDA Forest Service State & Private Forestry (S&PF) programs, a key federal funding resource for investing in the health of Idaho's state and private forested lands. S&PF programs include:

- Forest Stewardship,
- Forest Health,
- Urban and Community Forestry,
- Forest Legacy,
- Conservation Education,
- State Fire Assistance, and Rural Fire Capacity.

In 2020, Idaho Department of Lands led the effort to develop a comprehensive resource assessment – Idaho's State Forest Action Plan (FAP) through a collaborative process involving representatives from federal and state agencies, counties, non-governmental organizations, S&PF program advisory groups, tribes, forest stakeholders, and private citizens.

The FAP's purpose is to ensure that state and federal resources focus on landscape areas with the greatest opportunity to address shared priorities and achieve measurable physical and economic outcomes. A parallel purpose is to help landowners and land managers in Idaho better recognize and support opportunities for leveraging resources to address critical issues in-order to have the greatest positive impact on Idaho's forest resources and communities. The FAP provides a framework for stakeholders to receive technical and funding support to address resource issues of greatest concern to the State of Idaho. By focusing forest and resource management activities in areas of greatest priority, the State can leverage funds and coordination across land ownerships as an effective way to address the most critical natural resource issues across Idaho, at a scale where significant, positive changes can be realized. This Idaho Natural Capital Assessment offers the FAP a statewide Ecosystem Service Valuation analyses, which is another layer of information to assist the State with meeting its resource management objectives.

5.1 FAP Identified Threats

Idaho's State Forest Action Plan defines key threats to the state's natural capital. These resource threats are identified and prioritized in the FAP and are used in this Natural Capital Assessment to estimate their economic impact.

- **Relative Threats to Forest Health**: The primary threats to natural resource health include insects, diseases, noxious weeds, increased drought and fire. These have ecological, social, and economic consequences. The major impacts include damage to wildlife habitat, timber and agricultural markets and recreation. Threats to resource health also increase the risk of catastrophic wildland fire and harm to human health from smoke inhalation. Natural resource threats include:

   - **Insects**: Insect threats are modeled using data on bark beetles, the balsam wooly adelgid (BWA), and the Douglas-fir tussock moth (DFTM). While bark beetles and the DFTM are native to Idaho, BWA is non-native and causes significant mortality of true fir trees. This creates significant canopy loss which negatively impacts water quality and fish habitat. Bark beetles cause tree mortality by actively feeding and reproducing beneath the bark. The FAP estimates the risk of bark beetle-caused mortality by examining four major species of bark beetles in Idaho: mountain pine beetle (MPB), spruce beetle (SB), western pine beetle (WPB), and Douglas-fir beetle (DFB). The DFTM is a native defoliator which can cause tree mortality during periodic, cyclical outbreaks.
   - **Diseases:** Root diseases and white pine blister rust (WPBR) both cause significant tree mortality. There are four root diseases: fungi, Armillaria, laminated, and annosus root disease and the Schweinitzii root and butt rot, that are the primary root diseases that impact forest health. Root disease, though slow acting, is estimated to be the number one tree killer in Idaho. The WPBR is an introduced fungus that impacts western white pine and other five-needled pines throughout Idaho.
   - **Noxious weeds:** Noxious weeds alter natural resource vegetation. The Idaho State Department of Agriculture lists 51 noxious weeds that are present in the state of Idaho. The Idaho FAP measured weed threats using weed presence using data obtained from the University of Idaho.
   - **Climate change**: Climate change includes increasing temperatures, changes in precipitation and decreasing snowpack. This is driving greater drought and wildfire threats and shifting where forests grow. Measured in frequency and magnitude of predicted land cover changes, climate change may shift current forest ranges and increase stress to existing forest ecosystems.

- **Relative Fire Risk to Communities and Ecosystems:** The risk of fire is widespread and has significant impacts throughout Idaho. Identifying the communities and landscapes that are at the greatest risk of damage from wildfires is critical to implementing strategies to minimize wildfire risk and the associated impacts. Vegetation and fire history are important factors when considering fire risk. Wildfire risk has increased due to changes in climate, increased tree mortality from insects and disease, population increases and associated development, fuel accumulation due to fire suppression, and resource management practices. Much of Idaho's development is within the wildland-urban interface (WUI), which increases fire risk to communities and landscapes.
- **Potential Loss of Canopy to Development and Urbanization:** Increases in the human population and the associated development in Idaho pose a significant risk due to conversion of forest, shrub, and grassland to other uses. Communities across Idaho are

faced with increasing development encroachment into in the WUI, which is often directly linked to conversion of forestland and loss of canopy cover. In addition, this conversion also means a loss in productive natural habitats, increased wildfire risk, and reduced management on adjacent lands.

5.2 FAP Identified Benefits

Natural resource ecosystem services provide a range of benefits to communities across Idaho. Natural resources promote biodiversity, provide clean air and water, and make sustainable wood and agricultural products and markets possible. Considering the increasing resource threats, further funding of the proper management of Idaho's natural resources helps ensure these benefits are realized now and into the future. The benefits from Idaho's natural resources are identified and prioritized in the FAP and are used in this study to estimate their economic impact.

- **Benefits to Wildlife and Biodiversity:** Forest and rangelands are critical for wildlife habitat and biodiversity. Natural resource management practices can enhance habitat and increase biodiversity. This helps support threatened, endangered, and rare fish and wildlife species and ecologically important plant communities. Highlighting critical habitat and range is important for prioritizing actions that enhance fish, wildlife, and plant species and communities. Natural resource management can be used to improve and expand existing habitat while promoting biodiversity.
    - **Migratory Species:** Fences, roads, and development in and along migration routes are major threats to the long-term health of Idaho's migratory animals. In April 2022, the U.S. Geological Survey released Ungulate Migrations of the Western United States, Volume 2 (USGS, 2022). The report showcases 65 deer, elk, and pronghorn migrations mapped with 9 western states and tribal lands.
- **Benefit to Water Quality and Quantity from forests, rangelands and community tree canopy:** Intact landscapes provide immense value toward ensuring water quality, aquifer recharge, stormwater mitigation and erosion control. Forests, community trees and rangelands are critical to water provisioning in the West, particularly for Idaho. Natural landscapes capture, regulate, and convey water, recharging surface and groundwaters. Tree canopy shades and cools streams, improving fish habitat, and intercepts rainfall, reducing stormwater impacts. Root systems reduce soil compaction, erosion, and stormwater runoff (which reduces contamination in local water resources) while increasing soil stabilization and groundwater recharge.
- **Benefit to Air Quality from forests, rangelands and community tree canopy:** Natural resources can both improve and degrade air quality. Wildfires are a significant source of air quality concerns. Communities affected by wildfires are damaged by the smoke, degraded air quality and the associated health effects. In addition, biogenic volatile organic compounds (BVOCs) are released from certain tree species. This increases ozone production, and these effects are more significant in urban areas. Healthy forests can absorb and filter particulates and pollutants from the air, improving air quality. Similarly, trees sequester and store carbon and produce oxygen. This can mitigate climate change impacts and improve air quality. Volatile organic compound (VOC) production increases with increasing temperatures. A healthy forest canopy can also mitigate urban-heat island

effects, cooling nearby buildings and reducing VOC production. Natural resource management practices can increase forest and rangeland health and fire resiliency, reducing the negative impacts on public health, while reducing air pollution and particulate matter and mitigating climate change impacts.

- **Benefit to Sustainable Forest-Based Wood Products Markets & Agriculturally Based Markets:** Forests and rangelands provide timber, biomass, recreation, water, hunting and fishing opportunities, and other ecosystem services. The forest-based wood products market provides jobs and income to communities and helps fund continued forest management. When markets for forest-based products decline or are lost, forest management becomes further underfunded. This can lead to increased insect and disease problems, fire risk, and a decline in overall forest health, and further lost jobs and income.

5.3 IDL Forest and Rangeland Treatment Impacts on Ecosystem Services

The Idaho Department of Lands (IDL) developed goals and strategies intended to effectively reduce threats and/or protect, conserve, and enhance the benefits of the State's natural resources. Among IDL's many goals are a desire to better administer and implement forest and rangeland treatments on a landscape scale to increase and maintain vegetation diversity and resiliency over time. Forest and rangeland treatments are activities that occur on the landscape and are performed to impact vegetation (e.g., hazardous fuel), address an insect and disease issue (e.g., herbicide), or install vegetation (e.g., tree planting). These treatments aim to reduce the intensity and size of wildfires, increase species diversity, and restore forests to a more resilient condition. While forest treatments have a short-term mixed impact on ecosystem services, this assessment shows how the reduced risk of high severity wildfire and pest infestation creates a net positive impact on ecosystem service value over time.

All grant-funded forest treatments in Idaho have been carefully recorded, but this information has not been catalogued in a way that facilitates analysis. This report is part of a larger Landscape Scale Restoration (LSR) Grant funded research project, which includes the creation of the Idaho Forest Economics Geodatabase (aka the Geodatabase). The Geodatabase houses Geographic Information Systems (GIS) data related to on-the-ground forest treatment actions that were funded by grants secured through IDL's State and Private Forestry programs. The data housed in the Geodatabase catalogs all IDL grant funded forest treatments from 2008 – 2016. The Idaho Forest Economics Geodatabase supplements IDL's Federal Grant Databases, which are designed to capture current and ongoing Service Forestry (Forestry) and Fire Risk Mitigation (FRM) activities. The forestry and FRM databases are online, allowing grantees to record their fire mitigation (e.g., hazardous fuel removal) and Landscape Scale Restoration grant activities occurring throughout the state. The Forest Economics Geodatabase, which houses historic activities, coupled with IDL's online geodatabases give the agency a long-term (2008 to current) view of forestry and fire mitigation work performed in the State. Such information is vital as the State continues its efforts to protect, conserve and enhance its natural resources.

The geodatabases mentioned above contain Geographic Information Systems (GIS) data (Points, Polygons, Lines and Tables) related to on-the-ground actions (hazardous fuel treatments, forest health actions etc.) that were funded by grants secured through IDL's State and Private Forestry programs. Grant funded actions occurred throughout the state, with some work extending into surrounding states (cross-boundary). The GIS data documents the location and pertinent information (type of action, acres treated, etc.) of grant funded activities from 2008 to present.

IDL has a deep understanding of the benefits of resource treatments to improve health and resilience of Idaho's natural resources. Idaho's Natural Capital Assessment, in combination with the FAP, Idaho Forest Economics Geodatabase, and additional deliverables created through this USDA Forest Service Landscape Scale Restoration Project will provide the data and tools to improve strategic delivery of IDL's State and Private Forestry Programs to improve health and resilience of Idaho's natural landscapes.

6. USING AN ECOSYSTEM SERVICE APPROACH TO VALUE NATURAL CAPITAL IN THE STATE OF IDAHO

This chapter details the methodology used to value the ecosystem services of Idaho's natural capital. Multiple data sources were used for this analysis, including multiple databases of scientific peer-reviewed literature, geospatial data (e.g. Geographic Information System data [GIS]), and economic data provided from the FAP, IDL, and other sources statewide (e.g., IDFG).

Overall, to arrive at a baseline economic value in this report, the annual dollar value of each ecosystem service is estimated for each acre of natural capital across the state of Idaho. In other words, across the landscape of Idaho, ecosystem goods and service values are estimated in units of $/acre/yr. This is done in two steps. First, collecting biophysical (spatial) data to identify natural capital land cover and related condition on the ground and characteristics associated with the land cover, such as riparian areas, contiguousness, or habitat type. Second, economic data is derived using biophysical data inputs and used to estimate the annual dollar value per acre.

Figure 1 below outlines the steps taken to calculate ecosystem service value of Idaho natural capital and lists the data sources used at each step. The remainder of this section follows the steps in Figure 1.

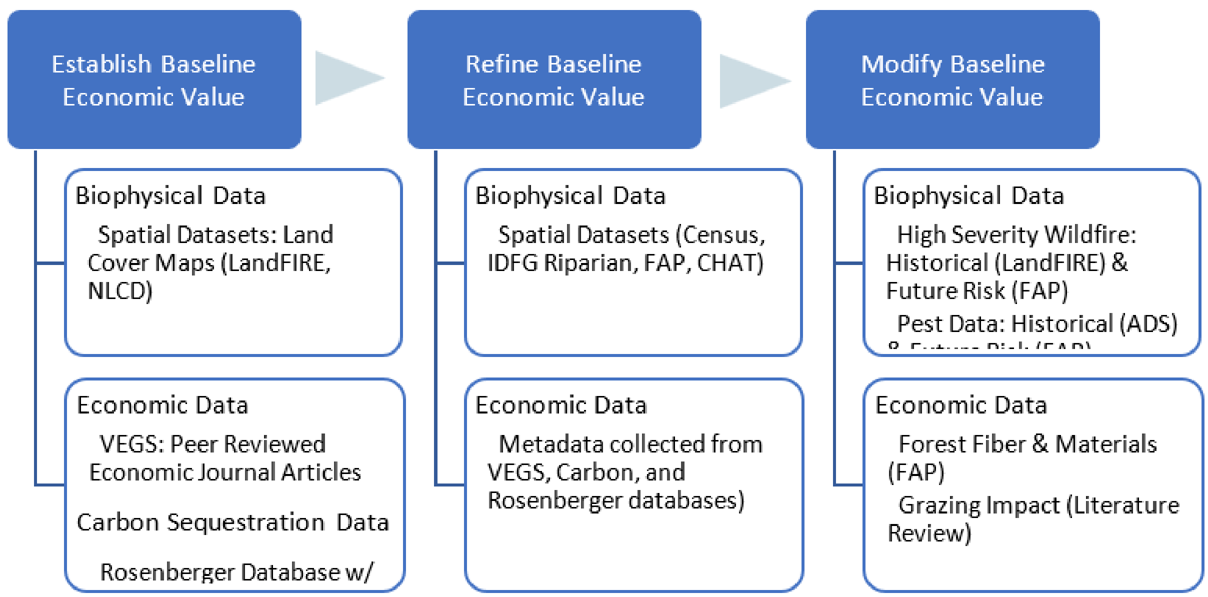


Figure 1. ESV Methodological Overview.

Each section (blue boxes) in Figure 1 above shows the use of both biophysical data and economic data to calculate ecosystem service value. Section 6.1 outlines the biophysical data used to inform the ecosystem service valuation. Section 6.2 provides an overview of the economic data and the benefit transfer method employed in this report, and how spatial data outlined in Section 6.1 are combined with the economic data.

6.1 Biophysical Data Model Overview

Each subsection below follows the biophysical spatial data categories shown in Figure 1. Collectively, this data is referenced in the remainder of this document as the "biophysical data model," simply representing the selection and composition of data related to land cover, land cover features, and other data sources representing conditions on the ground. All biophysical data is spatial and collected in GIS files and processed in ESRI ArcGIS Professional.

6.1.1 Baseline ESV Biophysical Model: LandFIRE and Other Vegetation Landcover Data

The primary GIS layer used to estimate the number of acres of natural capital across the state of Idaho is the LANDFIRE 2018 from the US Department of Agriculture and US Department of Interior LANDFIRE Program. The dataset reflects a snapshot of landcover from 2018 satellite photos and landscape indicators. Figure 2 depicts a rasterization of the derived land cover for the state (30m pixel resolution).

While LANDFIRE maps provide one of the most comprehensive and up-to-date land covers maps for the broader region, there are some data gaps. For example, wetland types are consolidated land cover types. Additionally, other spatial data sources provide more updated information on rapidly changing regions due to development. To address these challenges, additional datasets were used to supplement LANDFIRE data to provide further specificity and updated information. Table 2 provides of list of these data sources.

Table 2. GIS Data Enhancements to LandFIRE Landcover Dataset.

GIS Data Layer Name	Source	Use Description
Landfire - Existing Vegetation Type	Multiple organizations	Base vegetation type (aka Land Cover) for the project
NLCD Dataset	USGS	Crosswalk Landfire classes to NLCD to assist in ESV analyses
NHDPlus Waterbody	ESGS	Add further detail to "Open Water," enabling the separation of rivers and lakes. Determine lakes greater than 1 acre in size.

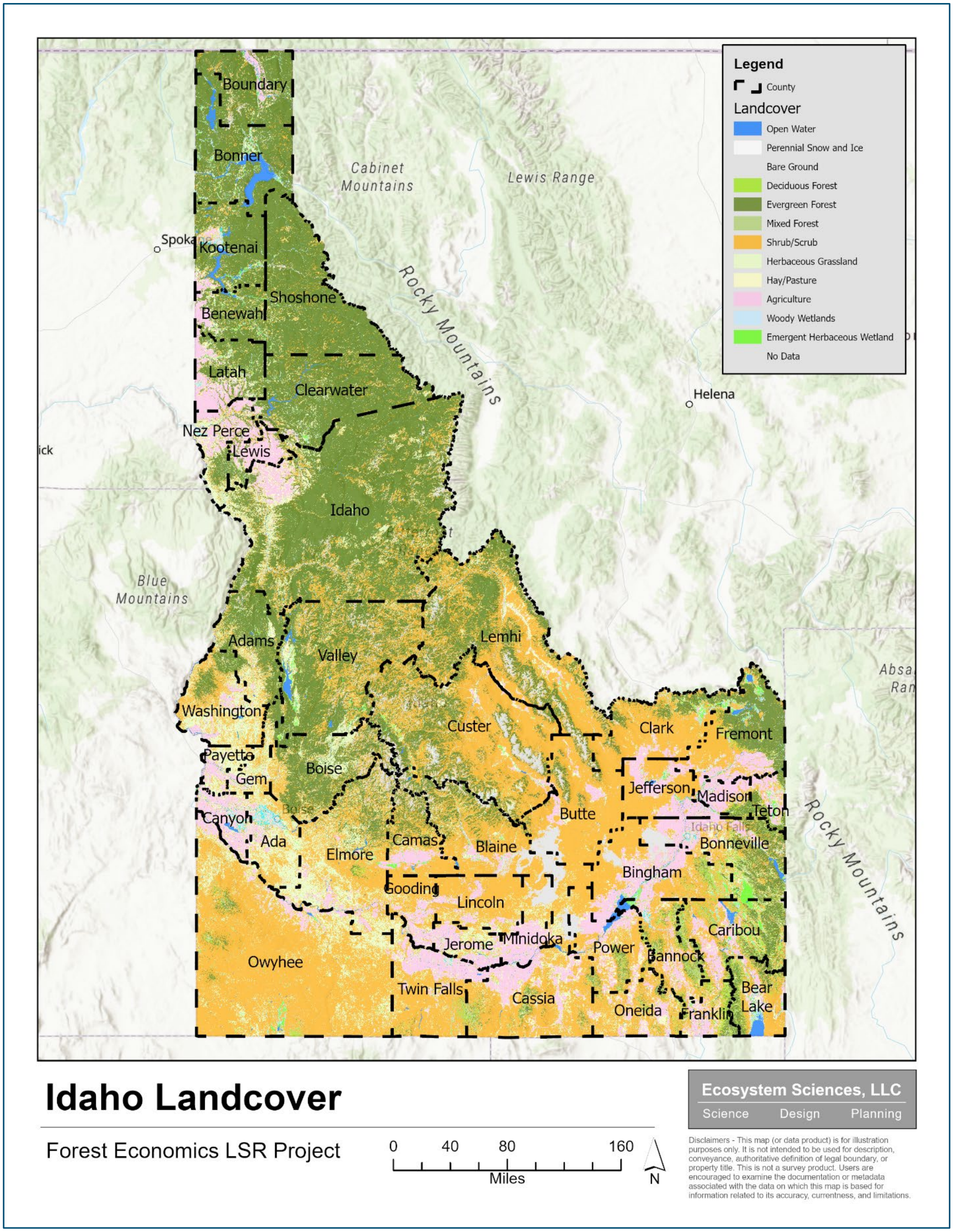


Figure 2. Combined Landcover Map of Idaho.

Table 3 below shows the final land cover list using all the sources listed in Table 2 above. All non-herbaceous land covers were removed from the list below, including barren land, ice, and urban categorizations.

Table 3. Final Land Cover Type.

Land Cover Type	Acres	Percent
Lake	445,605	0.9%
River	166,363	0.3%
Deciduous Forest	660,779	1.3%
Evergreen (Coniferous) Forest	16,153,882	31.7%
Mixed Forest	297,926	0.6%
Shrub/Scrub	20,445,441	40.1%
Herbaceous/Grassland	5,643,455	11.1%
Hay/Pasture	998,122	2.0%
Agriculture (Cultivated Crops)	4,818,643	9.5%
Woody Wetlands	826,639	1.6%
Emergent Herbaceous Wetlands	490,565	1.0%
Total	**50,947,420**	**100%**

6.1.2 Refining ESV Biophysical Model: Landscape Characteristic (Attribute) Data

Adding particular characteristics to landcover can significantly improve ecosystem goods and services analysis, reducing margins of error. Several landscape characteristics or ways of defining the landscape, such as riparian corridor, proximity to urban areas, or contiguous forest, can influence economic value to beneficiaries of natural capital. For example, a national forest is, on average, of more recreational value when closer in proximity to an urban area (e.g., Boise), than a different national forest land further from population centers because visitation is greater at the former. Economic studies have shown, total consumer surplus is highest with more users and at a lower travel cost. Similarly, property value decreases if adjacent or near a recent high severity fire, which is a temporary economic effect, where property values recover as the forest within visual range recovers from the fire.

This study uses the best available data to address as many landscape characteristics as possible. Table 4 below lists each of these characteristics (called attributes) and GIS data sources used to spatially represent them. Section 6.2 outlines how economic data is used to incorporate these attribute maps.

Table 4. List of Attributes.

GIS Data Layer Name	Source	Attribute Definition
Potential Riparian and Wetland	IDFG 2017	Identifies potential riparian and wetland ecosystems often in and near waterways. This GIS model is composed of twelve existing land cover maps layered together and compared to known wetland sites using aerial imagery.
Urban and Suburban Boundaries	US Census Bureau, 2021	Cities with populations over 50,000, or metro areas, were identified as urban. All other cities and all census blocks with greater than one house per acre were identified as suburban.
Public Drinking Water	FAP, 2020	This layer identifies the physical area around wells or surface water intake including the boundaries of surface and subsurface areas that contribute to those water sources.
Contiguous Acreage	WAFWA, 2019	Large intact blocks or other dataset that identifies large areas of native habitat that are relatively intact or have low levels of anthropogenic impact.
Terrestrial Species of Economic Importance	WAFWA, 2019	Identifies terrestrial game species especially if habitat needs are not already covered by "Species of Concern" mapping.
Aquatic Species of Economic Importance	WAFWA, 2019	Identifies sportfish, especially if habitat needs are not already covered by "Species of Concern" mapping.

6.1.3 Modifier ESV Biophysical Model: Forest Threats, Benefits and Treatments Data

Section 5.2 provided an overview of forest threats and benefits outlined in the FAP. Many of the datasets outlined in the FAP demonstrate the magnitude of forest threats and risks, as well as the location density of forest benefits. For example, sections of the southern portion of the Nez Perce-Clearwater National Forests provide crucial habitat for species of concern that overlap with areas of high risk to forest health from insects and diseases, thus deemed a high threat and high benefit area. While many of the forest benefits reflect real on-the-ground conditions, forest threats represent risk, or potential impact, and do not reflect current conditions. Therefore, multiple datasets in addition to the FAP will be needed to estimate both the impact of historic threats to existing conditions and the potential impact of at-risk areas. Collectively, these datasets are called "threat/benefit modifier" datasets for the remainder of this report. This section outlines modifier data sources used in both historic impact and potential impact cases that influence economic value of Idaho's natural capital today and in the future.

Among many of the modifier datasets included in the FAP, the forest threat categories of focus in this study are limited to forest health and fire risk. The FAP defines forest health to include insects, diseases, noxious weeds, and climate change data; however, due to data limitations, this study will estimate the economic impact only of insects, while the other forest health indicators were used to define the Section 7.2 Case Studies. Insect data from the FAP was used to understand relative risk (potential future impact) to forest health, while other GIS data sources were collected to estimate recent insect impacts. Each is outlined in Table 5 below.

The FAP defines forest fire risk where communities, their infrastructure, and associated landscapes are at relative risk from wildfires due to existing conditions. While this data was used to estimate future impact, recent high severity forest fires data sources were collected and used. Each is outlined in Table 5 below.

Another relevant dataset used in this study as a multiplier dataset is forest treatments. While forest fire risk and forest health measure conditions deemed threats, forest treatments also measure on-the-ground conditions, however they are recognized as beneficial, mitigating or reducing the risk of wildfire and negative forest health impacts. To measure forest treatments, this study has limited its scope to *forest thinning*, an activity that accounts for most forest treatments. Forest thinning is the cutting or removal of some trees, often those in poorer or less suitable conditions, to allow remaining trees to grow faster, provide more timber, increase resilience, and reduce fire risk. Table 5 outlines this data, its use, and sources.

Table 5. Biophysical Model GIS Sources for Modifier Datasets.

GIS Data Layer Name	Source	Use Description
Forest Health – Bark Beetle (MPB)	USFS, 2021	Historical: Uses recent GIS snapshots of forests in areas impacted by bark beetle, mountain pine beetle specifically (other beetles not included). "TPA / Percent Affected" field filtered for "severe outbreaks" only.
Forest Health - Balsam Wooly Adelgid	USFS, 2021	Historical: Uses recent GIS snapshots in areas impacted by BWA.
Composite Relative Risk to Forest Health (Insects, pathogens, invasive species, climate change)	FAP 2020	Risk (Potential): Combines seven data sources to create a weighted scale risk categorization
Forest Fire History	FAP 2020	Historical: Identifies high severity wildfires that occurred over the last 10 years.
Relative Fire Risk to Communities and Ecosystems	FAP 2020	Risk (Potential): Identifies location of communities, their infrastructure, and landscapes at risk of fire.
Forest Treatment: Thinning	IDL Forestry and Fire Mitigation Databases (IDL, 2021a)	Historical: Location and extent of forest thinning activities since 2008

As Table 5 above shows, the FAP provides spatial data on multiple forest health and fire risk categories. However, not all FAP data sources were used. Appendix E outlines data limitations, including forest health and other spatial datasets included in the FAP.

6.2 Ecosystem Service Valuation Model Overview

Figure 1 (page 20) above generally shows how economic data is derived using biophysical data inputs and used to estimate the annual dollar value per acre. The remainder of section 6.2 describes the process following the steps outlined in Figure 1.

6.2.1 Baseline ESV Economic Model: Benefit Transfer Methodology and Biophysical Model

Biophysical data is used in conjunction with economic valuation studies to derive the dollar values for forests and other Idaho landscapes. To value ecosystem services in the state of Idaho, the Benefit Transfer Methodology (BTM) was used. Like house or business appraisals, BTM calculates the economic value of ecological goods and services by using economic data and transferring quantitative estimates, in this case monetary values, from the existing literature (often referred to as the study site or sites) to a comparable study area of interest (often referred to as the policy site). Economists often refer to the degree of similarity between the study site and policy site as correspondence. The greater the degree of correspondence, the lower uncertainty and error in transfer of economic values. As in a house or business appraisal, BTM accounts for the value of various attributes (number of rooms in a house, or different assets in a business) and establishes the value based on closely related comparable valuations. The correspondence between the study site and policy site refers to the degree of uncertainty, to which All valuation appraisals include a degree of uncertainty. A house appraisal will have several "comparables" that range in value, though a single value is often chosen. The greater the similarities are between the study site and the policy site, the lower the error is when transferring values between sites. Both socio-economic and biophysical characteristics can be used to assess the correspondence between sites.

Figure 3 below is taken from a study published in the journal Ecosystem Services (Hill et al., 2014), where many study data points were taken within the State of Idaho. This study focuses on the ecosystem service of water quality (nitrogen and phosphorus removal) and values this service provided by forests in upstream water catchment basins. These values will be used in this study where similar conditions are matched. The next section details how these conditions, called landscape characteristics, are pulled from each study.

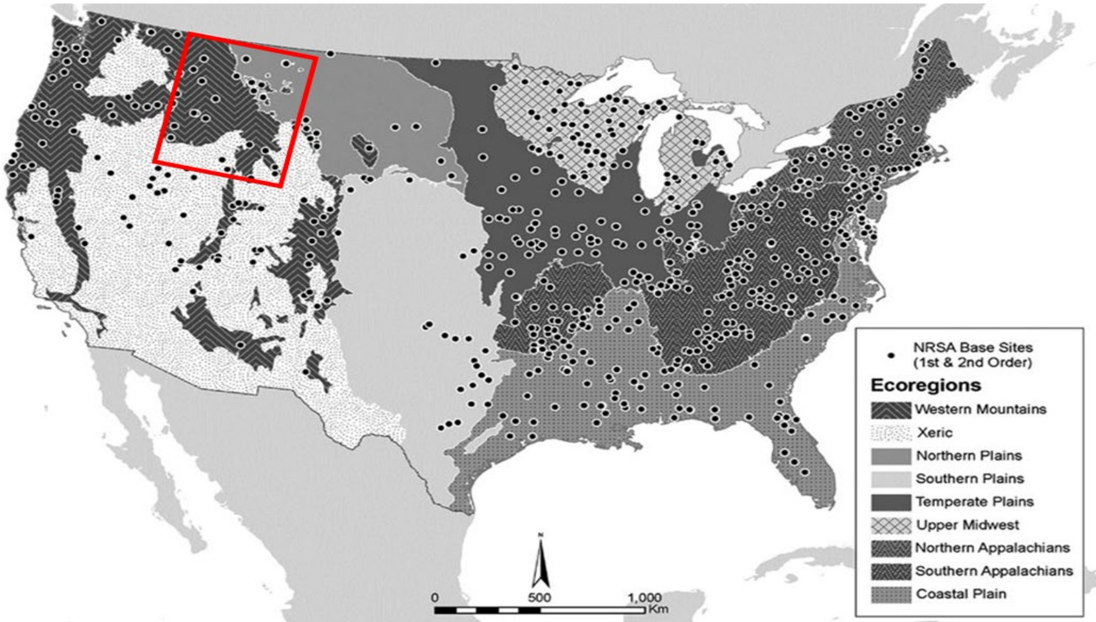


Figure 3. Study data overview taken from Hill et al. 2014.

BTM is an accepted and commonly applied methodology in economics, particularly for ecosystem service valuation. It has been accepted by academics, private industry, federal, state and local governments. In the 1960s, the U.S. Water Resources Council developed "Unit Day Values" (UDV) for recreation (Loomis, 2015). The U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation utilized these values to estimate the benefits of recreation from the development of reservoirs. The USDA Natural Resources Conservation Service updates and provides these values for other state and federal agencies on their website, including a database of existing studies that can be used for benefit transfer. The U.S. Forest Service utilizes BTM for their Resource Planning Act values for recreation. These values include UDVs for hunting, fishing, and wildlife viewing. In June of 2013, FEMA approved Mitigation Policy FP-108-024-01 (FEMA, 2013), based on values developed using this methodology, for use in all hurricane and flood disaster mitigation across all 50 states. BTM has become the go-to approach for valuation delivering for decision-makers a timely and cost-effective way to value ecosystem services across large landscapes (Wilson and Hoehn, 2006).

To integrate the biophysical model described above with the BTM economic analysis, this study utilized the Valuation of Ecosystem Goods and Services (VEGS) database. VEGS is the largest and most comprehensive database of published peer-reviewed primary valuation studies for BTM use in the world. VEGS is a collection of ecosystem service valuation studies mapped across vegetation types around the country and world. This database was developed and vetted within environmental and natural resource economics communities over the last four decades and contains many primary studies with valuations applicable to the State of Idaho. Appendix A1 provides more information on VEGS and its use in this study.

Using VEGS, many Idaho-specific data points from the economic literature were mapped to the data in the biophysical model described in Section 3.1. This is done in multiple steps. First, each study provided by VEGS reviewed to understand which ecosystem service is of focus, is then converted to US$ per acre per year and is categorized by land cover type. This allows each study to be mapped to the land cover from Table 3 presented in Section 6.1.1 to value a suite of ecosystem services listed in Table 1 above. Appendix A2 provides further detail on application BTM, including details on best practices used in this study. Appendix A3 also outlines the ecosystem service valuation literature found in VEGS.

Subsequent steps to map the economic model (studies from VEGS) to the biophysical model are detailed in the remaining sections. Section 6.2.2. shows how attribute GIS data are incorporated, and where data collected in each study from VEGS allows for economic values to be applied with greater specificity than just based on land cover type (e.g., evergreen forest, open water etc.).

6.2.2 Refining ESV Economic Model: Integrating Attribute GIS Data with BTM

The ecosystem service value of natural capital is dependent on several characteristics, including location and proximity to beneficiaries (humans), presence of habitat, or other ecosystem features. For example, the ecosystem service value of recreation for a small city park is often more economically valuable (per-acre) than a similar rural park due to higher use and demand. The city park has a higher number of residents and greater person/days of use. Boise Parks and Recreation maintains over 90 parks throughout the city (City of Boise, n.d.), many of which provide recreational value to more people than similar parks in smaller neighboring towns. This does not mean that rural and small-town parks are unimportant. It simply recognizes higher use. To account for the economic effects of physical location and proximity to beneficiaries, data from the GIS and biophysical model was used to reflect proximity to urban populations as well as other natural capital characteristics.

For each study in its database, VEGS collects over 200 fields of metadata from each study using spatially dependent characteristics (called "attributes" in the remainder of this study). These attributes reflect this reality and refine the accounting methodology. For example, VEGS can provide information on an individual ecosystem service valuation study, such as whether it was conducted in a riparian zone, and how the riparian zone was defined. All VEGS studies relevant to Idaho were matched to the attribute data described in the biophysical model (Section 6.1.2.). Appendix G lists all studies extracted from VEGS, associated with the employed attributes.

Table 6. lists each attribute and data deployed in Section 6.1.2., describing how each dataset was utilized in the economic model, and which ecosystems services are influenced by the attribute.

Table 6. Economic Study Description by Attribute.

Attribute Name (Biophysical Model GIS Data)	Description of GIS Data Use in Economic Model: *Criteria for ecosystem service valuation (ESV) for all VEGS studies in order to have attribute associated with value.*	Relevant Ecosystem Service
Riparian Buffer	ESV applicable when VEGS study is within a defined riparian boundary. The data indicator is binary, indicating whether a pixel is in the buffer zone.	All
Urban and Suburban Boundaries	ESV applicable when VEGS study is within the defined urban boundaries. The data indicator is ternary (3 options), indicating whether a pixel is located with one of two buffer zones.	All
Public Drinking Water	ESV applicable when VEGS study is a supporting service (water quality or water supply) to surface or underground drinking water supply. The data indicator is binary, indicating whether a pixel falls within the drinking water boundary.	Water Supply, Water Quality
Contiguous Acreage	ESV applicable when VEGS study is of forest ecosystems that are defined as contiguous, matching the criteria of contiguousness defined in the GIS data. This data indicator is binary, indicating whether a pixel a part of a contiguous system.	All
Terrestrial Species of Economic Importance	ESV applicable when VEGS study includes one or more species including Bighorn Sheep, Elk, and Mule Deer. This data indicator is quaternary (4 options), indicating whether a pixel falls in habitat areas as defined in the GIS data.	Recreation, Habitat
Aquatic Species of Economic Importance	ESV applicable when VEGS study includes one or more of multiple species including catfish, bass, trout, and salmon. This data indicator is trinary, indicating whether a pixel falls in habitat areas as defined in the GIS data.	Recreation, Habitat

6.2.3 Refining ESV Economic Model: Integrating Threat/Benefit Modifier GIS Data with BTM

Idaho's forests are rapidly changing given increasing threats to wildfire and health, as well as increasing use of forest with population growth in the region. The section above outlined changes in ecosystem service value based on attributes of natural capital, using land cover maps and other spatial data such as proximity to beneficiaries or presence of habitat. The most recent land cover maps will not reflect the impacts of the most recent fire or pest infestations on natural capital, nor will any attribute data account for this effect. To account for the economic effects of landscaping disturbance events like fires and pest infestations, additional modifier data was collected. Unlike attribute data, threat/benefit modifier data reflects recent disturbances or changes to on-the-ground conditions or highlights the risk of such a change, which is outlined in Table 7 below. Appendix B provides detailed calculations on use of modifier data shown below. Appendix E discusses data limitations on accounting for fire and pest impacts, including the use of most recent data available.

Modifier data is not integrated directly with VEGS study metadata and does not inform valuation study selection and application. Rather, the literature that accompanies threat/benefit modifier data adjusts economic value of the preexisting natural capital. A collection of datasets quantifies the magnitude of impact of each ecosystem service and land cover combination, *modifying* their value due to the disturbance event. Table 7 lists each modifier dataset used in this study. The table provides a description of how threat/benefit modifier datasets were utilized in the economic analysis, and which ecosystem services are impacted by the threat/benefit modifier event type.

Table 7. Descriptions of Modifier Datasets used in Economics Datasets.

<table>
<tr><th colspan="2">Modifier Name (GIS Data)</th><th>Description of Modifier Data Use in Economic Model</th></tr>
<tr><td rowspan="4">Historic</td><td>Forest Health - Mountain Pine Beetle</td><td rowspan="2">ADS data (1997-2020) was filtered for high severity impacts of MPB and BWA. Overlayed with land cover data, the ADS data was converted to a binary value showing if (yes/no) there was a high severity impact at any given point. Economic value of ecosystem services was reduced where high severity infestations were shown, combining the binary GIS pixel with the economic value.</td></tr>
<tr><td>Forest Health - Balsam Woolly Adelgid</td></tr>
<tr><td>Historic Wildfire</td><td>Across all historic wildfires, high severity burn areas by land cover were identified. Economic value of ecosystem services was reduced, showing impact, for only high severity burns, treating the GIS pixel as binary.</td></tr>
<tr><td>Forest Thinning</td><td>Forest thinning activities were drawn as polygons, allowing for the estimation of acreage of such treatments. For each acre of thinning, both ecosystem service impacts (positive and negative) and wildfire risk reduction were measured. Appendix E discusses study limitations with data related to forest thinning.</td></tr>
<tr><td rowspan="2">Risk</td><td>Relative Wildfire Risk</td><td rowspan="2">The FAP collected several datasets, including recent landscape conditions and model data. Relative risk of wildfire and forest health was mapped across the state, identifying the highest risk areas. These high-risk areas were used in the economics analysis.</td></tr>
<tr><td>Relative Forest Health Risk</td></tr>
</table>

In addition to the BTM methods described above, recreation and carbon analysis provided additional values and those models/methods follow.

6.3 Public Lands Recreational Model

The BTM model describes a method for valuing recreation, and this can be improved with the availability of recreational visitation data. Alternative models can be used to allow for a more accurate recreation evaluation. Recreational economics is rich in the consumer surplus value of natural areas, particularly public spaces. This study was able to utilize public visitation data and consumer surplus economic models to arrive at an annual dollar value of recreation in public recreation areas. Figure 4 below outlines how this information was calculated.

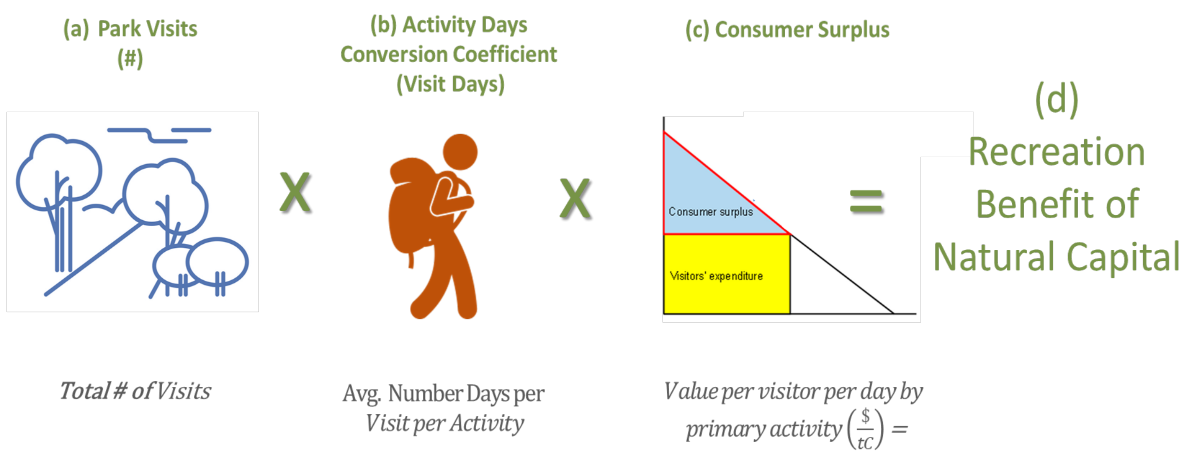


Figure 4. Calculating Recreation Benefits of Natural Infrastructure.

- Four primary public lands were of focus in the use of the consumer surplus model, namely US National Forests, US National Parks (and other park systems maintained by USNPS), Bureau of Lands Management Lands, and Idaho State Parks. While other local park systems were considered, limited visitation data was available to include them in this scope (e.g., Boise Parks and Recs managed properties). Appendix C provides visitation by each public land system.
- Park surveys and visitor data collection has shown that visitors enjoy parks for many reasons and activities, but visitors often have a *primary* activity, or the activity considered the highest priority to the visitor, and thus the primary reason to recreate in the park (Rosenberger et al., 2017). All primary activities (i.e. hiking, camping, sight-seeing, bicycling) do not account for the same time. Calculating "visitor days" normalizes this data, allowing comparability between shorter activities like visiting a nature center (average 1.1 visitor days) and longer visitor days like backpacking (average 2.7 visitor days) (ibid).
- Consumer surplus, or net willingness to pay, is a measure of the welfare an individual gains by participating in an activity or purchasing a good. This measure is commonly used for benefit-cost analysis by federal agencies such as the US Army Corps of Engineers, Bureau of Reclamation, US Environmental Protection Agency, and the Forest Service (ibid). In the context of recreation, consumer surplus is the economic value of a recreational activity above what must be paid by the recreationist to enjoy the activity. In US dollar units, ample research is available for deriving consumer surplus from specific recreational activities in regions all over the United States. Appendix C provides a full list of these activities and how these values were derived.

Appendix E discusses the data limitations of this recreation model. Results from the public lands recreation model are presented in Section 4, outlining visitation for each public lands system statewide.

6.4 Carbon Model

Data on how much carbon is in Idaho forests is available. Thus, carbon sequestration values can be calculated from Idaho data.

Sequestered carbon biomass provides economic value by contributing to climate stability. Each year, trees, shrubs, and grasslands through photosynthesis remove carbon dioxide from the atmosphere and sequester carbon. To arrive at an annual dollar value per acre of carbon sequestration, total carbon biomass was combined with dollar values for each ton of carbon sequestered. Figure 5 summarizes what each component includes.

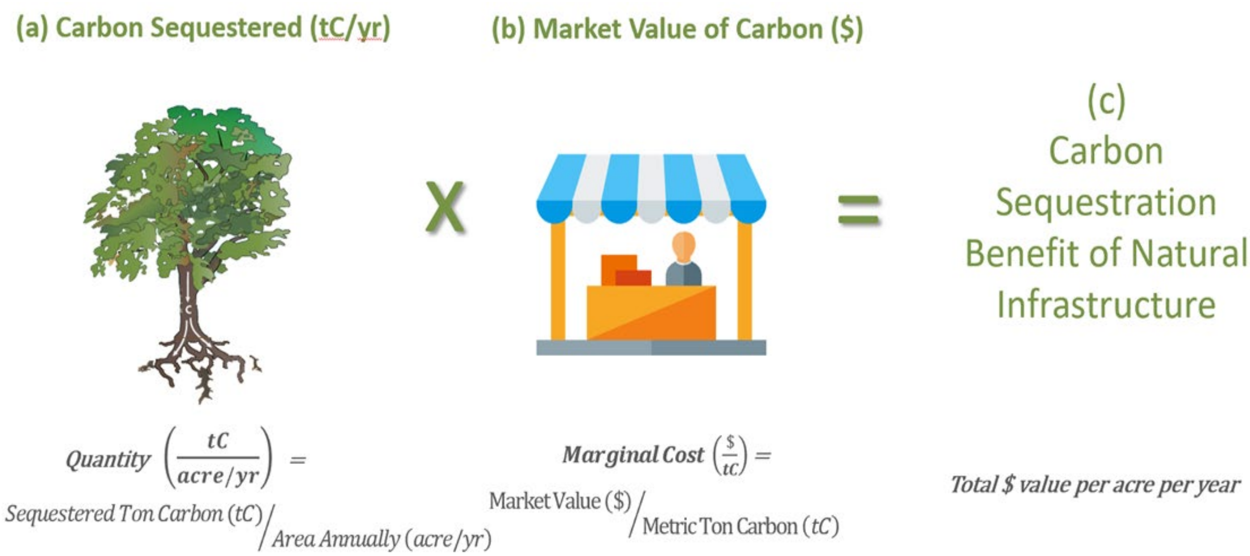


Figure 5. Calculating Carbon Sequestration Benefits of Natural Infrastructure.

- Data on tons of carbon sequestered by natural capital is well documented and published globally, especially for forests. Equilibrium Economics maintains a carbon database complete with 73 studies and 3800 values. This database was used to measure the carbon sequestered by vegetation types each year, as well as stored in mature forests. Appendix C provides the list of studies and values used to arrive at these calculations.
- Carbon prices are determined in markets where people, firms or governments pay for carbon sequestration. The social cost of carbon calculates the dollar benefits of carbon sequestration. Markets determine what a company pays to purchase a factory. The revenue benefits to the company from using the factory to manufactured products should be larger than the cost of the factory.
- Dozens of carbon values exist today in US markets alone. For example, as of mid-2022, the California Carbon Auctions market trading at $29.15 per ton of carbon (California Air Resources Board, 2022). In addition to carbon market values, other carbon values have been established, including estimates for the social cost of carbon. The social cost of carbon (SCC) is defined as a more comprehensive estimate of climate change damages from carbon emissions, or benefits from carbon sequestration and includes, among other

things, changes in net agricultural productivity (agricultural damage with drought or productivity with greater climate stability), human health (larger disease ranges, such as dengue fever), property damages from increased disasters such as fires and floods and changes in energy costs, such as reduced costs for heating and increased costs for air conditioning (EPA, 2016). The Interagency Working Group on Social Cost of Greenhouse Gases, representing multiple federal US agencies, published in 2021 interim results on the SCC in their Technical Support Document under Executive Order 13990 (IWGSCGG, 2021). The technical report published several SCC values. For this study, the SCC value selected from the report represented the 2020 value using a 2.5% discount rate, with a $76.00 cost per metric ton of carbon.

Appendix E discusses the data limitations of this carbon model. Results from the carbon model are presented in Section 4, including carbon stored and sequestered statewide, as well as carbon impacts of forest threats in three separate case studies.

6.5 Asset Value and Time

Forests are assets that can produce value indefinitely. Like other assets, forests both produce an annual set of benefits, such as water production, and are standing assets, like a house. If healthy, forests can be self-maintaining, unlike cars, buildings, factories, and other built assets. Over the last 40 years, this long-term value of natural capital has been increasingly understood, analyzed, and appreciated as critically important.

When the benefits of natural infrastructure are valued as assets and brought into the light of economic decision-making, they can be seen as cost-effective systems producing goods and services. Simply laying out the dollars and cents of natural capital allows for better decision-making. Investments in natural capital often have very high rates of return, and so better understanding the asset value of forests, provides a bottom-line understanding of why forests should be retained, restored to health, and enhanced to continue to provide real returns to citizens, private companies, and government.

A forest produces ecosystem goods and services with a flow of value each year, just like traditional capital assets, such as a car factory. Economists calculate natural asset value with net present value calculations of the future flows of ecosystem services, in the same way that the asset value of a built capital asset (such as an apartment, power plant or bridge) can be calculated as the net present value of its expected future benefits. Though land is bought and sold, many of the monetarily valuable services, such as drinking water production and flood risk reduction are not exchanged in markets. Thus, this calculation is an estimate of asset value which incorporates benefits provided, but not always the sale of those benefits.

The net present value of the Idaho's forest ecosystem services was calculated using two discount rates over 50 years: 2.25%, used by the U.S. Army Corps of Engineers (USACE, 2021) and 0% percent discount rate. A discount rate is used to maximize "present value," and so treats future generations (or the same generation in five years) as less valuable. A gallon of water worth $1 today is worth 0.9775 next year. The discount rate of 0% percent provides decision-makers with a view of value unbiased to the present by valuing the gallon of water that someone drinks next year the same as a gallon of water someone drinks this year. Discount rates also generally reflect the fact that build capital depreciates (falls apart), whereas the reality of healthy natural capital is that it appreciates into the future, rather than depreciates (as a forest grows it is worth more as opposed to a car that is generally worth less. Federal agencies like the Army Corps of Engineers use a 2.25% percent discount rate for water resource projects (Ibid).

6.5.1 Implications of Discount Rate Selection

Discounting has limitations that may result in under- or overestimates when applied to natural infrastructure. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations, or even to this generation in just a few years into the future. The use of a 2.25% discount rate as cited above, for example, renders first year benefits of up to $1 billion to near $0 by 50 years. In other words, what may be worth $1 billion today is suggested to be worth nothing in 50 years' time if discounted accordingly. Discounting the future more heavily tilts investment decisions toward the present, making it less likely that society will undertake actions to mitigate climate change, conserve biodiversity, or prevent other forms of environmental degradation.

Evidence from behavioral economics and psychology shows that human behavior is inconsistent and sometimes at odds with the standard economic approach that assumes a constant discount rate (Polasky and Dampha, 2021). Uncertainty about future states of environmental goods and services have created demands for alternative discounting approaches in environmental economics. Some policy makers have argued for the use of a dual-rate discount, simply applying a different discount rate to environmental benefits versus financial values. Hyperbolic discounting has been used to discount according to a hyperbolic function that generates a declining rate of discount as the time horizon grows longer (ibid). Some have even argued for the use of a negative discount rate in environmental economics, which appreciates value over time (Bleurbaey and Zuber, 2012). Each case argues that global environmental change has long-lasting impacts that raise difficult intergenerational equity issues.

Appendix D provides further detail on the use of discount rates and total ecosystem service value over 50 and 100 years. Appendix B outlines research and data used to estimate the rate of recovery of natural capital following disturbances from severe wildfire, severe beetle infestation, and other impacts, as well as the data limitations of using discount rates to monetize value over time.

7. Economic Impact of Idaho's State and Private Forestry Programs

Idaho's natural capital provides between $15.6 and $27.3 billion in state-wide benefits to people each year — significant annual economic benefits. These economic values are extremely important to the health and vitality of Idaho's economy, environment and residents and visitors to the state. Additionally, investments in forest conservation, enhancement, and protection from threats can provide vast and long-term benefits. Financially, investment in natural capital can yield tremendous return on investment due to both the low cost of investment and the productive suite of ecosystem services and benefits it produces. Forest investments are multiple, not single benefit investments.

State officials and land managers make choices today that affect the current and future state of Idaho's natural capital. This economic analysis is designed to be a pragmatic, accurate, and dynamic tool for decision-makers. The baseline ESV is informed by landscape threats can be split and categorized at any scale from an acre to a million acres. Furthermore, this economic analysis can show value changes in the landscape due to historic forest restoration and treatment activities. The results provide a first view of the actual benefits that treatments provided in the form of a rate of return on investments (e.g., forests) and long-term benefits provided to the taxpayers (e.g., ecosystem services $).

The remainder of this section breaks down the ecosystem service valuation across Idaho and Landscape Priority Areas. In Section 7.2., case studies are used to assess the impact of disturbances such as wildfire and pest infestation.

7.1 Breakdown of Ecosystem Service Valuation of Idaho's Natural Capital

Table 8 presents the total annual ecosystem service values provided by Idaho's Natural Capital. All values are standardized to 2021 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. These tables provide insight into the annual flow of benefits provided by the ecosystems of the state. This represents the annual flow of value for the specific ecosystem services examined.

Table 8. Total Annual Ecosystem Service Value of Idaho Natural Capital.

Ecosystem Service	All Ecosystem Services	
	Low	High
Aesthetic Value	$1,118,352,685	$1,959,619,549
Air Quality	$56,720,797	$93,225,766
Carbon Sequestration	$879,385,544	$2,179,529,579
Disaster Risk Reduction	$5,722,094,646	$9,474,628,372
Habitat	$3,293,085,017	$4,156,498,762
Recreation & Tourism (Private Lands)	$524,253,877	$1,248,705,654
Recreation & Tourism (Public Lands)	$1,974,702,675	$2,280,999,254
Soil Erosion Protection	$111,828,542	$1,089,390,798
Water Quality	$1,358,953,656	$2,486,428,692
Water Supply	$602,394,482	$2,332,066,968
Total	**$15,641,771,921**	**$27,301,093,394**

Figure 6 represents the average of each annual low and high value derived for each pixel (30m x 30m) in the State. Showing an individual number was necessary for spatial representation of ecosystem service value across the state, but inherently places specificity in a value that is better represented by a range (i.e., low and high values). Appendix E discusses why value ranges were calculated in Table 8, and why assigning a single value to ecosystems services can be fraught with interpretation issues.

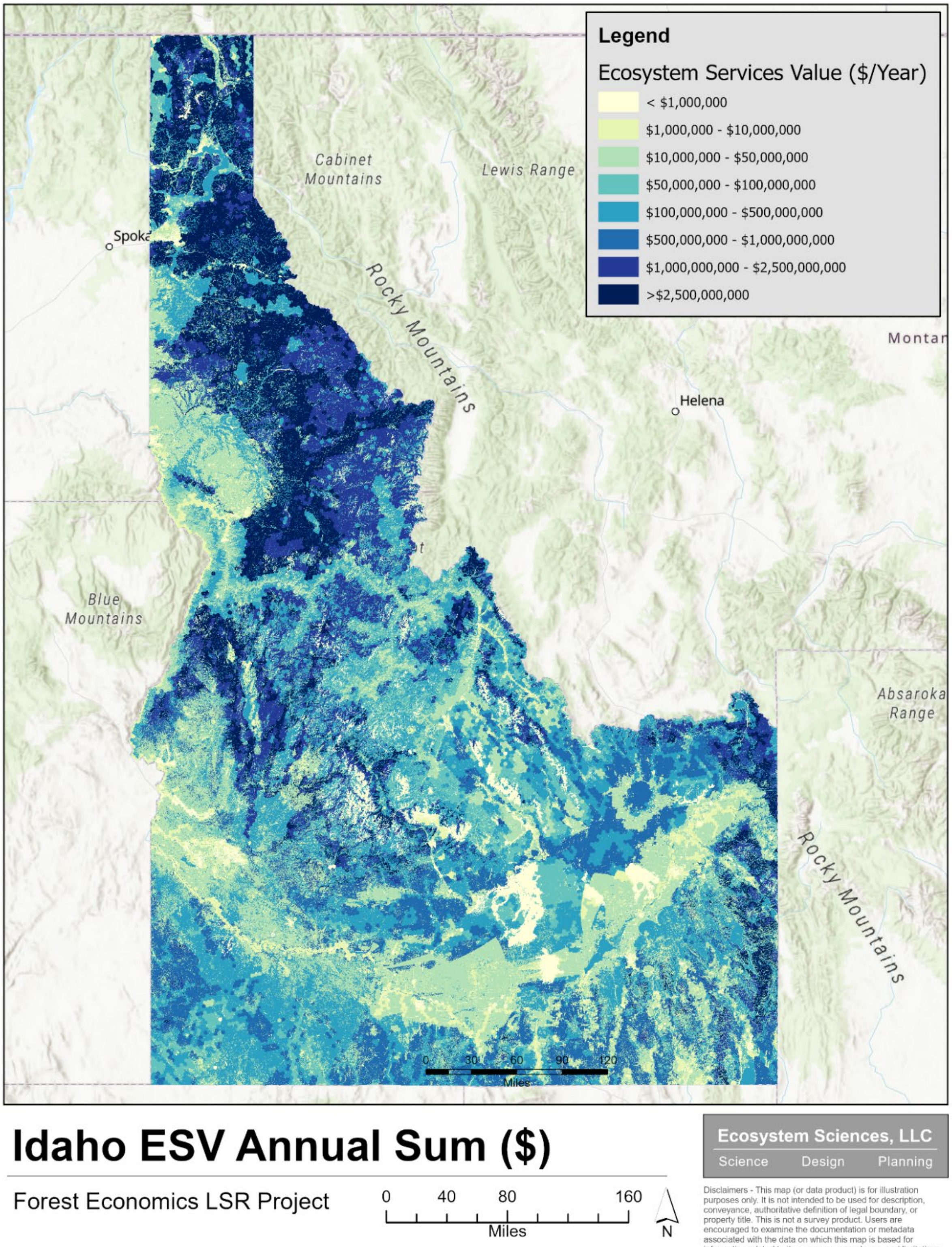


Figure 6. Sum Annual Ecosystem Service Values.

These "big numbers" displayed in Table 8 and Figure 6 are important. They indicate that investments in Idaho's Natural Infrastructure (e.g., forests) can provide vast and long-term benefits if these assets are protected and restored. Moreover, investment in natural capital can yield tremendous return on investment due to both the low cost of investment (relative to building new assets) and because it supports a suite of ecosystem services and benefits (not just a single benefit). In addition to the annual flow of ecosystem service benefits detailed above, these economic data can be used to calculate a general asset value for the County's natural capital. The asset value is calculated in Section 7.1.3 below.

7.1.1 Carbon Sequestration and Stock Breakdown

Each year, trees, shrubs, and grasslands sequester carbon from the atmosphere into living plants and soils. Table 9 provides more detail on what each component includes. As shown in Section 3.3, carbon sequestered each year was multiplied with market values to arrive at a total annual value of carbon sequestration across Idaho. Table 9 summarizes this value by acres of Idaho land cover types.

Table 9. Carbon Sequestration by Land Cover Type.

Land Cover	Carbon Sequestration				
	Acreage	Tons Low	Tons High	Benefits Low	Benefits High
Agricultural	4,818,555	0.10	0.15	$35,450,358	$54,759,846
Deciduous	660,777	0.48	1.13	$24,257,490	$56,768,812
Emergent Herbaceous Wetlands	490,546	0.07	0.08	$2,561,998	$2,873,775
Evergreen	16,153,802	0.48	0.78	$587,847,914	$958,283,516
Grasslands	5,643,415	0.11	0.11	$45,082,601	$45,082,601
Lakes	445,605				
Mixed Forest	297,923	0.48	1.13	$10,841,606	$25,595,183
Pasture	997,873	0.04	0.24	$3,069,074	$18,414,446
Rivers	166,364				
Shrubland	20,444,367	0.11	0.62	$163,320,491	$969,073,317
Woody Wetlands	826,627	0.11	0.77	$6,954,012	$48,678,083
Total				**$879,385,543.65**	**$2,179,529,578.71**

Carbon stock refers to stored carbon in soils and plants which has been sequestered over time. In forests, carbon is typically stored in the biomass, as well as surrounding dead wood, humous, and soils. The ability to store carbon depends on the condition of the forest (age and health) and the management practice. Poorly managed or unhealthy forests can rerelease carbon back into the atmosphere and/or have lower storage ability compared to healthy and well managed forests. Like carbon sequestration, ample research exists on the carbon stock of an existing forest stands based on species, age, site value and climactic zone. Table 10 below presents the total carbon stored in Idaho's natural capital.

Table 10. Carbon Storage by Land Cover Type.

Land Cover	Carbon Storage				
	Acreage	Tons Low	Tons High	Benefits Low	Benefits High
Agricultural	4,818,555	5.42	17.57	$1,984,400,973	$6,434,239,994
Deciduous	660,777	49.23	98.62	$2,472,149,498	$4,952,706,285
Emergent Herbaceous Wetlands	490,546	18.34	79.55	$683,567,845	$2,965,714,269
Evergreen	16,153,802	79.20	115.38	$97,229,408,974	$141,645,909,548
Grasslands	5,643,415	6.89	15.87	$2,957,116,624	$6,808,518,077
Lakes	445,605				
Mixed Forest	297,923	49.23	115.38	$1,114,610,569	$2,612,357,971
Pasture	997,873	6.89	10.39	$522,879,792	$788,038,470
Rivers	166,364				
Shrubland	20,444,367	13.03	31.48	$20,247,042,618	$48,919,873,158
Woody Wetlands	826,627	25.68	66.15	$1,613,330,756	$4,155,824,483
Total				**$128,824,507,648**	**$219,283,182,256**

Carbon stocks represent historic carbon capture and therefore it will not be used in the calculations of future asset value presented in this report. However, this is because total carbon biomass would help guide development and management decisions to help minimize the amount of carbon released into the atmosphere. Development of land resulting in the cutting of forest stands and disposal of the timber releases carbon into the atmosphere, imposing a cost on society through increased GHG emissions. For both carbon sequestration and storage, Appendix C provides details on the dollar values and sequestration rates used to calculate the total economic value in Table 9 and 10. Appendix E outlines data limitations on this carbon model.

7.1.2 Public Recreation Breakdown

Public recreation areas provide economic value to residents as well as seasonal travelers and tourists from all over the world. Each year, half a billion recreation days are enjoyed in the state. As shown in Section 3.4 above, recreational value in public lands was derived by combining visitation data and consumer surplus value by activity. Even the high value could be an underestimate of recreation values as recreation, as a sector is not tracked in national economic data. Table 11 summarizes this visitation and value by recreational area. Table 12 summarizes the same value by primary activity.

Table 11. Visits by Recreation Area.

Recreation Area	Total Visits	Low	Avg	High
BLM	30,978,000	$48,317,475	$60,158,763	$71,627,473
National Monument	5,797,305	$47,168,841	$158,550,726	$269,932,611
State Parks	256,423,126	$45,021,421	$150,787,047	$256,470,416
USFS	160,870,668	$91,713,924	$558,859,222	$2,514,228,405
Total	**454,069,099**	**$232,221,661**	**$928,355,759**	**$3,112,258,905**

Table 12. Visits by Primary Recreation Activity and associated Value.

Activities	Total Visits	Low	Avg	High
Backpacking	10,577,922	$990,154	$4,322,823	$14,086,464
Big Game Hunting	17,493,941	$3,355,837	$20,424,222	$88,240,494
Camping	15,778,368	$10,080,419	$33,966,791	$137,773,742
Cross-country Skiing	42,863,161	$4,932,813	$18,694,002	$58,534,306
Downhill Skiing	12,633,292	$11,391,015	$112,811,929	$383,660,125
Freshwater Fishing	37,065,856	$9,211,583	$34,957,407	$124,352,851
Gathering Forest Products	11,696,636	$3,012,132	$17,432,905	$69,710,085
General Recreation	66,364,634	$67,010,744	$211,146,226	$423,082,256
Hiking	11,696,636	$12,360,176	$67,203,526	$302,759,810
Horseback Riding	5,899,331	$323,621	$1,736,296	$8,237,285
Jogging/Running	5,797,305	$1,282,763	$4,311,809	$7,340,855
Motorized Boating	13,876,636	$3,085,702	$10,509,921	$34,636,249
Mountain Biking	11,696,636	$2,735,898	$14,616,360	$63,071,638
Nature Study	17,595,967	$5,570,328	$25,497,214	$99,066,278
Nonmotorized Boating	7,977,305	$3,450,744	$7,378,322	$11,305,901
Off-Highway Vehicle	18,365,231	$8,824,595	$24,021,609	$88,257,205
Picnicking	5,899,331	$2,920,577	$13,324,889	$61,892,689
Rock and Ice Climbing	5,797,305	$334,337	$1,123,823	$1,913,308
Sightseeing	32,724,018	$30,153,911	$108,347,306	$415,044,328
Small Game Hunting	2,180,000	$2,456,497	$3,039,437	$3,622,378
Snowmobiling	14,159,211	$1,136,891	$6,428,098	$27,982,909
Swimming	25,471,246	$6,325,308	$21,226,226	$55,147,963
Visiting Historic Sites	17,493,941	$4,266,831	$16,994,791	$53,472,682
Wildlife Viewing	42,965,187	$37,008,786	$148,839,826	$579,067,103
Total	**454,069,099**	**$232,221,661**	**$928,355,759**	**$3,112,258,905**

Results from the public recreational model above show that, on average, recreation from public lands amounts to over three billion dollars annually. This does not account for recreation on private and other lands not included in this data. Appendix E discusses these limitations.

7.1.3 Asset Value of Idaho's Natural Capital

Degradation of these natural capital assets will be at great cost to people living today and in the future. If these assets are enhanced, they can be a basis for clean air, clean water, vibrant agriculture and industry, employment, rising real wages, and a high quality of life for present and future generations. Thus, the use of a discount rate better reflects the asset value of Idaho's natural capital. The net present value of Idaho's natural capital was calculated over 100 years using two discount rates: 2.25%, and zero, as discussed in Section 6.5 above. Table 13 presents the total value of Idaho's natural capital over this 100-year period.

Table 13. Total Asset Value of Idaho's Natural Capital.

Discount Rate: 2.25%			Discount Rate: 0%	
Low	High		Low	High
$131,790,119,455	$230,026,008,431		$1,564,177,192,058	$2,730,109,339,421

Treated with a 2.25% discount rate like a built capital bridge or factory, the value of natural capital in Idaho is $132 to $230 billion. Treated as an asset that persistently provides the same value across time, using a zero-discount rate for only 100 years yields a natural capital asset value range of $1.6 to 2.7 trillion. Because this valuation does not include all ecosystem goods and services, it is an underestimate, yet even this conservative estimation demonstrates the sizeable asset value of the natural capital of the State.

Currently, the value of economic assets is generally not considered beyond 100 years, and this study follows that tradition. With no cut-off date for valuation and a zero-discount rate, any renewable resource would register an infinite value. Clearly, even far greater value exists for the many generations who will benefit from Idaho's natural capital well beyond the 100-year point, assuming it is adequately protected.

7.2 Case Study Analysis

Section 7.2 highlights the diverse geographic regions of the State of Idaho using three case studies. The case studies presented below provide a more in-depth analysis of how natural capital provides benefits to the local populous (Figure 7). Each case study examines the ecosystem service values that local forests, lakes, rivers, and other natural capital provide to communities.

When considering the benefits of natural capital, it is also important to assess threats to its value. These case studies also cover the potential economic losses that could occur due to key ecological threats present in each case study area. Using threats and benefits defined by Idaho's Forest Action Plan (FAP) this section samples the diversity of the state and tells three unique stories of wildfire threat, forest health threats, and impacts from growing populations. Table 14 identifies each FAP threat and benefit addressed in the case studies below. While each case study focuses on an individual threat, each contains some instance of all FAP threats. The maps associated with each case study are at a scale that demonstrates high-value landscapes, at-risk landscapes, or areas in need of management (e.g., ecosystem restoration, fire-risk abatement, or forest health improvements).

Table 14. FAP Topics Addressed in Three Case Studies Overview.

Case Study	FAP Threats			FAP Benefits			
	Forest Health	Fire Risk	Canopy Loss	Wildlife-Biodiversity	Water Quality-Quantity	Air Quality	Forest-Based Products
1. Pend Oreille Lake/ Priest River	X			x	x		x
2. Treasure Valley/ Lower Boise River			x			x	
3. Portneuf Mountains/ Pocatello		x		x			x

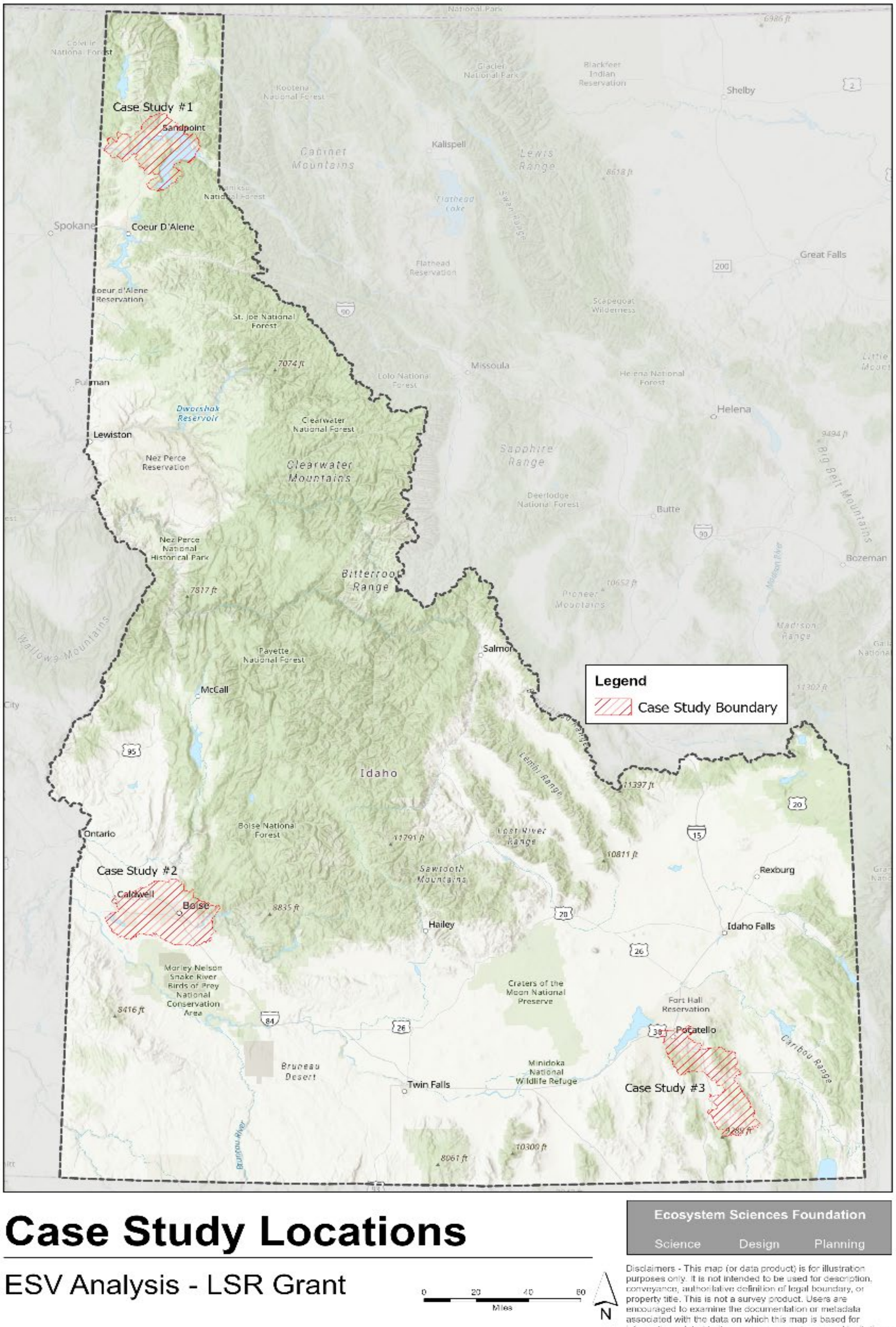


Figure 7. State of Idaho and three Case Study Locations.

7.2.1 Case Study 1: Valuing the Panhandle's Diverse Forest Resources

The Pend Oreille Lake/Priest River case study area is primarily located in Bonner County and is home to nearly 20 communities and a population of over 23,000. Lake Pend Oreille is one of the largest and deepest natural lakes in the western United States at 43 miles long with 111 miles of shoreline. Albeni Falls Dam sits on the Pend Oreille River. Behind the dam, the waters of the Pend Oreille stretch 65 miles through a glacially carved valley that separates three mountain ranges.

Case Study 1 at-a-Glance	
Total Area	380, 314 Acres
Population	23, 027 (2019 ACS)
Landcover	
Coniferous Forest	57%
Open Water	24%
Drinking Water	177, 697 acres
Riparian	120,157 acres
Lake / Reservoir	93, 324 acres
Land Ownership	
Private	55%
BLM	2%
USFS	14%
State	5%

Recreation Impact

More than half of Lake Pend Oreille in its southern reaches is encompassed in the Idaho Panhandle National Forest. A substantial portion of all recreation in the National Forest take place on the lake or its shores. The area also contains two Idaho State Parks: Round Lake State Park and Farragut State Park. Both State Parks, as well as the Panhandle National Forest areas, have the highest rates of camping and backpacking visitation relative to the entire state. In 2021 alone, both State Parks hosted nearly 170,000 campers. Visits to the State Parks create an economic impact of $148.8M to $253.5M each year. The region's trails, water, and campsites have attracted a resort community and retirement destination in Bonner County. The amenities that bring tourists also attract entrepreneurs and small business owners and help those business owners to recruit and retain skilled employees.

Public Recreation Impact: $148.8M to $253.5M each year

Water Quality and Habitat

Lake Pend Oreille and its river provide habitat for many migratory and threatened species. Waterfowl numbers have been as high as 60,000 ducks, 15,000 Canada geese and 2,000 tundra swans (IDFG, 2019). The watershed supports a wide diversity of catchable species such as whitefish, cutthroat and brown trout, mackinaw or lake trout, large and smallmouth bass, crappie, pumpkinseed sunfish, northern pike, walleye, perch and bullhead (catfish), all of which support the local fishing economy. The lake also provides a source of clean water for drinking and irrigation. Clean water is the basis of support for all habitat along the Pend Oreille River and the downstream lake.

Section 6 summarized the methods used to calculate ecosystem service value of water quality across the state. **Natural capital in the Pend Oreille case study region provides $22.6M to $43.3m in water quality benefits and $398.8M to $472.6M in habitat benefits, each over a 50-year period.**

Multiple impacts to water quality and habitat threaten case study region. In 1954, the Albeni Falls Dam was constructed with the intent to generate power and serve as a flood control mechanism. The dam produces over 200 million kilowatt hours of electrical energy each year. However, the dam changed the natural cycle of the Pend Orielle River and its downstream habitat. Areas that were historically flooded for a short period are now inundated for longer time periods, reducing critical waterfowl habitat. Additionally, according to an Idaho Department of Environmental Quality (DEQ) report, 52% of those assessed Idaho waterways are impaired to the point of harming aquatic species and/or threatening recreational opportunities (Idaho Conservation League, 2018).

Forest Products Economy

The forest products economy is an important economic driver in Idaho, particularly in the Panhandle. Idaho has 17.7 million acres of forests spanning from the Canadian border to the southern edge of the state, with over 215,000 acres of within the Pend Oreille Lake watershed. Statewide, the forest products economy supports over $2 billion in gross product, and 31,000 jobs in 2021.

Multiple data sources were used to estimate the value of working forests in the case study region, including data from Bonner County (Bonner County, 2022), the State of Idaho, and BLM (BLM, 2020). According to this data, approximately 130,960 acres of the case study area are "productivity lands," or lands with potentially merchantable forests. Market research shows that an average harvestable acre of Douglas fir, the predominant species in the case study area, produces between 10,000 and 15,000 board ft (Jacobson, 2008). Finally, as of August 2022, one thousand board-feet (MBF) of Douglas-fir fetched approximately $450-$555 in Pacific-Northwest markets (Wolcott, 2022). **This data shows that potential harvestable value ranges from $589M to $1.09B.**

Economic Impact of Threats to Forest Health from Pests

Section 5.2 of this assessment described how threats to forest health came from multiple causes, the most significant being insects and diseases that result in tree mortality, among several other threats. Tree mortality at large scales is a real threat in Idaho and will likely modify current ranges of forest species and contribute significant additional stress to forests. These factors alter forests ecologically and can have very negative social and economic impacts as well. They alter wildlife habitat, timber markets, recreation, and can sometimes exacerbate wildfire.

This section models forest loss of high-risk forests of the Panhandle case study area according to the 2020 Forest Action Plan (FAP), and the potential economic impact to forest health of this forest loss. The analysis below focuses only on impacts from Mountain Pine Beetle (MPB) and Balsam Woolly Adelgid (BWA) threats. MPB causes tree mortality by actively feeding on mature ponderosa and lodgepole pine and reproducing beneath the bark, while the BWA feeds on sap impacting all sizes of subalpine fir, Pacific silver fir, and grand fir trees. The impact of forest loss from their effects is detailed below. Each section outlines data sources, methods, and results of simulating severe threat of stands of high-risk forests in the Pend Oreille Lake region.

Summary Results: This analysis shows that, due to MPB and BWA threat, high-risk forests in the Pend Oreille Lake region face an economic loss between $111M and $160M over 50 years. Findings show that these threats would impact 18,703 acres of forest, focused primarily on recreation areas on the northern sections of Pend Oreille Lake.

Case Study 1 Approach

The FAP describes MPB and BWA and the risk to existing forests and provides spatial data to understand where this risk exists. The map below shows a composite map of high-risk forest health stands from MPB and BWA. In the Pend Oreille Lake region, 18,703 acres of forest were identified as high-risk.

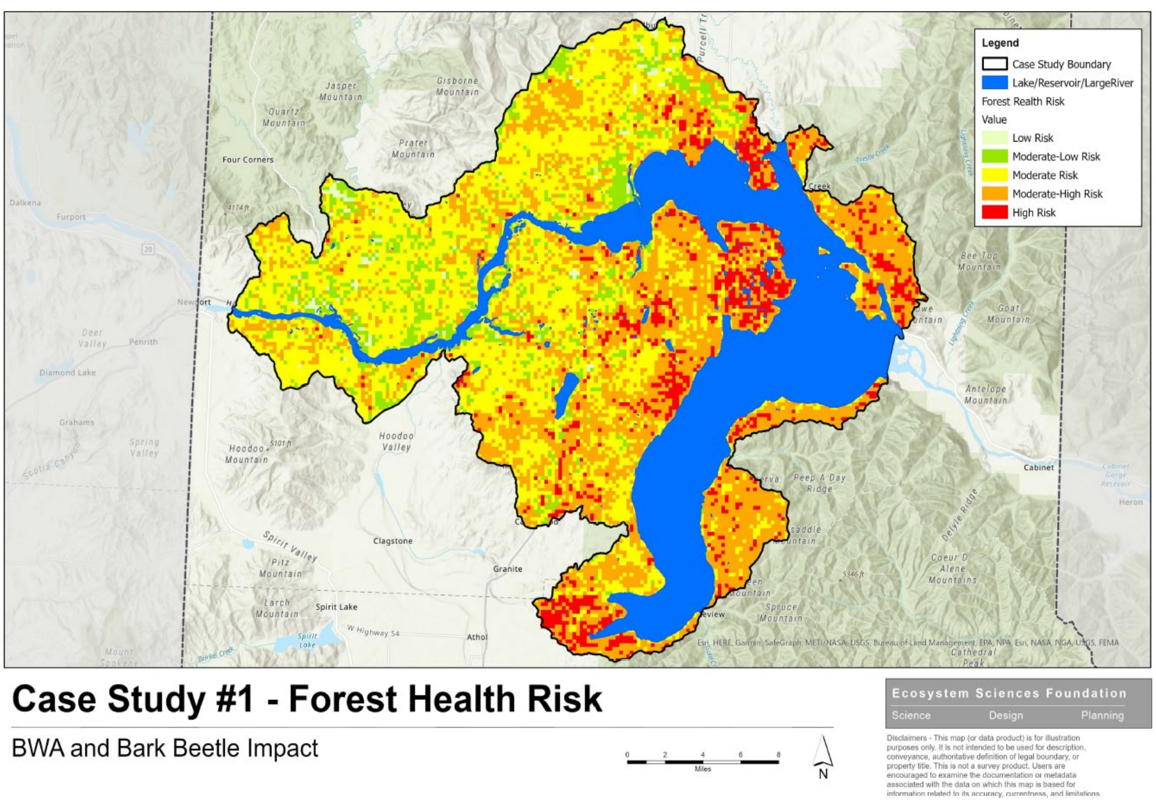


Figure 8. High Risk Pest Infestation Areas for MPB and BWA in the Panhandle Case Region.

Using impact assessment methods described in Section 6, the impact to forest health was estimated from high-risk areas shown in Figure 8. Economic impact was estimated for four ecosystem services: Aesthetic information (property value), carbon sequestration and stock, recreation, and stormwater retention.

Due to spatial and economic data limitations described in Appendix E, only threats from MPB and BWA were analyzed. Appendix E describes at length the assumptions and limitations of the various approaches used to estimate ecosystem service value, consumer surplus, and impacts to these benefits.

Case Study 1 Results

Ecosystem service loss occurs because of tree mortality. Under the high-risk impact scenario, ecosystem service loss from 18,703 acres of forest accounts for $83.5M to $121M in just the first year. Much of this accounts for carbon stock due to tree mortality. Carbon also ceases to be sequestered in the first year and into the future for dead trees. Section 6.4 provides an overview of the calculation method.

Table 15. First Year Ecosystem Service Impact of Realized High Risk Infestation.

Land Cover	First Year Ecosystem Service Impact	
	Low	High
Aesthetic Value	$16,887	$32,830
Carbon Sequestration	$490,037	$798,837
Carbon Stock	$81,051,627	$118,077,766
Stormwater Retention	$1,900,567	$1,960,690
Recreation & Tourism (Private Lands)	$82,121	$90,860
Total	**$83,541,239**	**$120,960,983**

Recreationalists who visit Round Lake State Park and Farragut State Park, both are in this case study region, would experience an impact with the loss of forests. Consumer surplus value loss, an economic model detailed in Section 6.3, is calculated to be between $5.7M and $8.1M in just the first year. Section

Table 16. First Year Recreation Impact of Realized High Risk Pest Infestation.

State Park	First Year Consumer Surplus Impact		
	2021 Visitors	Low	High
Round Lake State Park	115,153	$950,737	$1,345,695
Farragut State Park	576,544	$4,760,118	$6,737,580
Total	**691,697**	**$5,710,855**	**$8,083,276**

Asset value accounts for total annual ecosystem service value lost over a 50-year period, discount future years. Section 6.5 provides details on calculations of asset value.

Table 17. 50 Year Asset Value of Realized High Risk Pest Infestation.

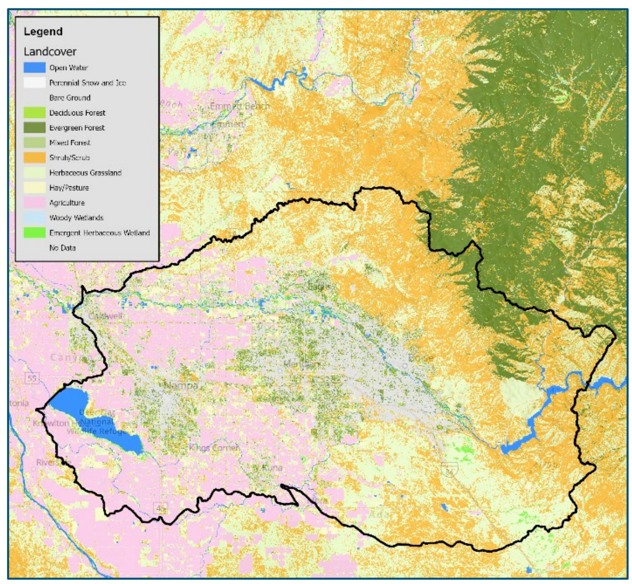
50 Year Asset Value	
Low	High
$110,868,127	$159,530,913

The results above exclude multiple ecosystem services and forest threats identified in the FAP. Risk from the Douglas-fir tussock moth, root disease, white pine blister rust, and other climate change induced threats were not included due to spatial or economic data limitations. Additionally, the impacts to soil erosion control, water quality, water supply, and other ecosystems were also not included. The estimates above measure the risk of impact and represent an underestimate to high-risk areas.

7.2.2 CASE STUDY 2: BUILDING FOREST AND COMMUNITY RESILIENCE IN IDAHO'S STATE CAPITAL

Idaho's Treasure Valley is the State's most populous area and home to Idaho's Capitol City of Boise. The boundary of Case Study #2 follows much of the Lower Boise River Watershed. The small amount of public land (BLM 8%, USFS 4%) and State (IDFG 4%, State Land 2%) is very important and valuable to the local communities, as these areas provide important recreation opportunities. Case Study 2's climate is considered Cold Semi-Arid (Koppen Climate Type), and thus is dominated by grassland (57%) and shrub/scrub (24%). Trees provide a respite from the summer heat within the cities, while beautifying streets and neighborhoods.

Case Study 2 at-a-Glance	
Total Area	513,401 Acres
Population	616,141 (2019 ACS)
Landcover	
Grassland	57%
Shrub/ Scrub	24%
Agriculture	17%
Drinking Water	152,607 acres
Riparian	22,192 acres
Lake/ Reservoir	11,286 acres
Land Ownership	
Private	79%
BLM	8%
USFS	4%
State	2%
IDFG	4%



RECREATION IMPACT

The Treasure Valley region's forest service lands, state parks, and other protected areas provide essential habitat, corridors, and migratory refuges amidst a region largely developed. These protected areas attract millions of visitations each year from the city of Boise, residents of Idaho, and out-of-state visitors.

Lucky Peak State Park and adjacent Boise National Forest surround the nearly 4.5 mi^2 Lucky Peak Lake, home to many species including the area's keynote species the Double-crested Cormorant. Eagle Island State Park is situated on an island between the north and south channels of the Boise River with access to rainbow trout and mountain whitefish. Both State Parks offer ample fish and other water recreation opportunities on lakes, rivers, and ponds. Visits to the State Parks create an economic impact of $136.2M to $218.5M each year.

The region experiences the State's highest rates of day-use visitors seeking hiking, wildlife viewing, and site seeing. Multiple BLM recreation access points start just outside of Boise proper, including Ridge to Rivers, Miller Gulch Trailhead, and Hull's Gulch Trailhead. Lucky Peak State Park and Eagle Island State Park alone see approximately 1.2 million day-visitors each year.

Public Recreation Impact: $136.2M to $218.5M each year

Impact of Heat Island

Boise is also one of the fastest growing areas of the country. The Treasure Valley gained 25,000 residents in 2021 (Carmel, 2022). The region is also among the fastest warming areas of the country, where over the past five decades the average summer temp has increased by 5.6 degrees Fahrenheit. Urban development is a major contributor to the increase in heat due to a phenomenon known as "Urban Heat Island." Buildings, roads and other infrastructure absorb, hold and re-emit the sun's heat back into the surrounding air way more than natural environments.

Urban heat is linked with tree canopy density, but the solution is not always as simple as "Planting more trees in hot areas". Many times, the areas of cities that have a "Heat Island" effect do not have room or growing conditions to support trees. The City of Boise is working to combat this by planting 100,000 trees by 2030, having planted over 13,000 urban trees since Jan 2022.

The tree canopy in the Treasure Valley is not uniform and neither is the ability of residents to plant and support trees. Affluent neighborhoods tend to have denser canopies. This is due to many factors including age of development, percent of households that rent and population density. Through partnerships with Boise's Climate Action Division and American Forests, the Challenge is using equity focused mapping tools to strategically target tree planting efforts in neighborhoods of greatest need.

Impact on Air Quality

In the early 2000's, the Treasure Valley regularly experienced poor air quality, the worst readings in the state, due to winter inversions trapping smog (IDEQ, 2021). The last decade's increased wildfire frequency has further contributed to poor air quality in the region. Treasure Valley's limited tree canopy amidst mostly shrub and grassland play a crucial role in abating the worst air quality conditions. Protecting these assets and increasing tree canopy will sustain and improve the Valley's air quality and the value it provides to Idahoans. Today, t**he Valley's natural capital provides $3.7M to $4.6M in air quality benefits, accounting for particulate matter and other pollutant removal, as well as avoided health costs from poor quality, amortized over a 50-year period.** Section 6.1 summarized the method used to calculate ecosystem service value of air quality across the state.

Case Study 2 Economic Impact of Canopy Loss Scenario from FAP

The Treasure Valley area which includes Ada and Canyon Counties has seen expansive growth, 26% and 23% respectively, which has put a substantial strain on the local housing markets. Rapidly rising rents and appreciating home values have forced city and county leadership to address housing issues with new housing policies, programs, developments, projects, and partnerships. This trend is pushing new developments into the outskirts of the city, with rows of units going up rapidly and often with limited consideration for canopy preservation.

To understand development trends on Idaho's tree canopy, the 2020 FAP identified the areas at greatest risk of conversion from forestland to other uses, specifically development. With this conversion comes a loss of productive forests, increased wildfire risk to property as more homes are "in the woods", and pressure to reduce or eliminate management on adjacent lands. Also important are those areas that may be converted from one housing density to a significantly higher density within developed areas as this may also lead to loss of canopy and the benefits it provides. The Case Study 2 analysis estimates the economic impact of potential forest canopy loss, identified as high risk through 2030, according to the FAP assessment (Figure 9). These findings show high-risk areas account for 10,733 acres of tree canopy (64% of all tree canopy), focused primarily in the foothills of Boise. The threat facing the Treasure Valley's tree canopy from development will result in an ecosystems service impact between $55M and $73M through 2030, if that canopy is lost. Acreage loss was assumed to occur relative to housing density with a linear relationship year-over-year, described further below.

Case Study 2 Methodology

The FAP describes risk to existing forests as the possibility of development through 2030, based on research from the publication Watersheds at Risk to Increased Impervious Surface Cover in the Conterminous United States (Theobald et al., 2009). The methods used by Theobald *et al*. (2009) are described in the 2020 FAP and shown in Figure 9. This map was overlayed with Treasure Valley Canopy Network canopy data that maps tree canopy cover in the Treasure Valley from 2011 (TVCN, 2013). When filtering the map from Theobald *et al*. by high risk of development areas, the result is 10,733 acres of tree canopy cover loss at high-risk of development.

The FAP also defines high development pressure as the conversion of forest canopy from one category of housing density to another *higher* density category. The average housing density in Treasure Valley is below approximately two units per acre (U.S. Census Bureau, 2021), making half of the housing density categories in the FAP applicable to the region. For this analysis, each housing density conversion category was converted to percentage of impervious surface, based on the estimated number of housing units per acre (taken from the FAP), average lot size by density (City of Boise, 2022; MOGREENSTATS, 2013; US Census Bureau, 2022), and impervious surface estimates by lot size (Table 18).

Table 18. Canopy Percentage Loss by Housing Density Category taken from the FAP.

Category	Description	% Impervious Surface
5	1.7-10 acres per unit (rural 2)	1.8%
6	0.6-1.7 acres per unit (exurban/urban)	7.6%
7	<0.6 acres per unit (exurban/urban)	34.9%
8	Urban/built up (commercial, industrial, transportation)	95.0%

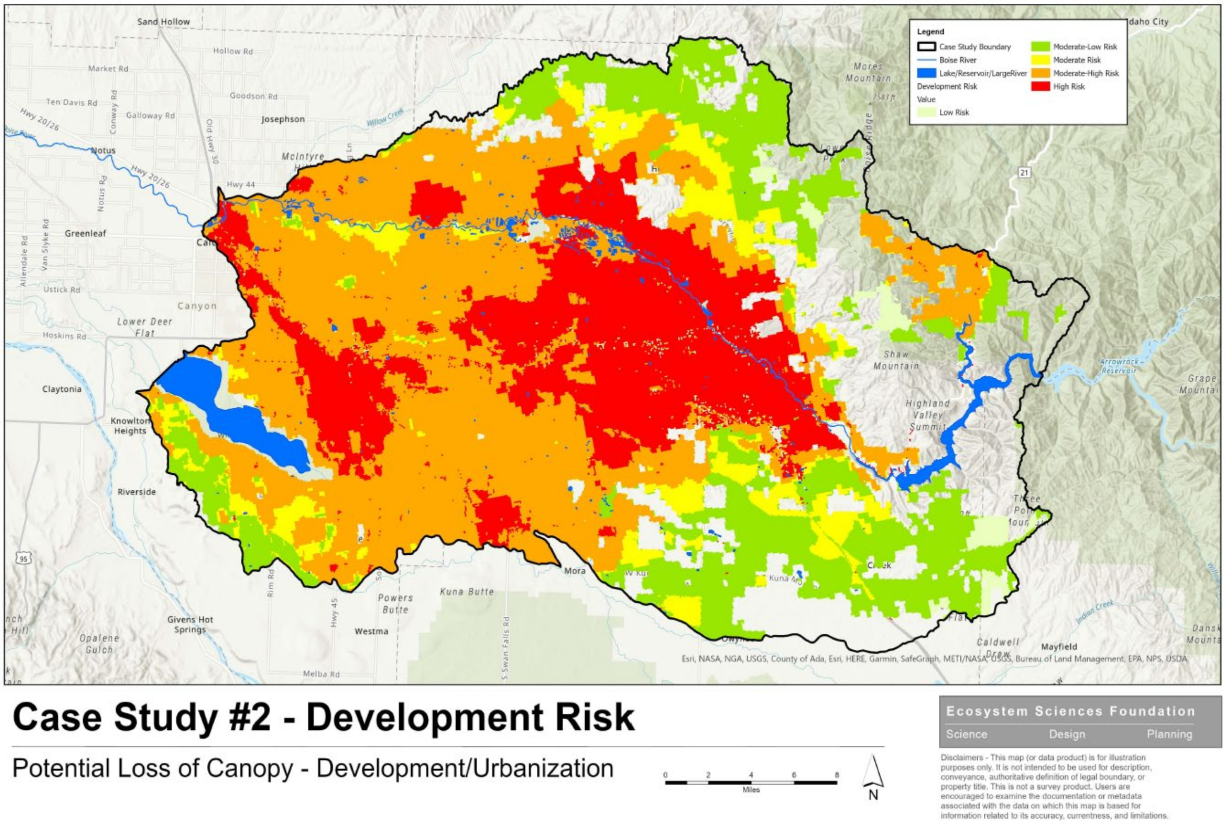


Figure 9. High Risk Areas for Potential Loss of Forests and Canopy from Development in the Treasure Valley Case Region.

Section 7 of this report estimated the ecosystem service value of forests statewide, using geospatial data to adjust value based on population demographics, riparian corridors, proximity to drinking water resources, connectivity of forests, and other habitat indicators. As discussed above, conversion of forest or other vegetation to impervious surface effectively removes all ecosystem service benefits. Using the percentage impervious surface factors in Table 18 above, ecosystem service value in the high development pressure areas was reduced according to housing density category through 2030. With no annual development information from the canopy threat data introduced above, annual development was assumed to be linear.

The approach above is based on impervious surface calculations related to the development of a home and the surrounding assets typically associated with a home (driveway, walk paths, buffer around home, etc.). This analysis did not incorporate assumptions related to clearcutting for large lot installments, where immature seedlings trees are replanted. It also did not account for road networks and other development activities associated with large development projects that often results in tree removal and installment of other impervious surfaces. The estimate above should be considered an underestimate with the exclusion of these factors.

Case Study 2 Results

Ecosystem service loss occurs as a result of tree canopy converted to impervious surface. Under the high-risk development scenario, ecosystem service loss from development occurs in plots within 10,733 acres of forest, accounting for $2.9M to $4.3M in just the first year.

Table 19. Ecosystem Service Loss after First Year of Canopy Development.

Ecosystem Service	First Year Ecosystem Service Impact	
	Low	High
Aesthetic Value	$359,992	$364,701
Air Quality	$27,450	$35,614
Carbon Sequestration	$15,234	$28,874
Carbon Stock	$2,159,986	$3,482,415
Stormwater Retention	$322,412	$358,505
Habitat	$4,205	$5,294
Recreation & Tourism (Private Lands)	$9,309	$12,579
Soil Erosion Protection	$452	$462
Water Quality	$12,532	$21,251
Water Supply	$11,336	$11,336
Total	**$2,922,908**	**$4,321,030**

Much of this lost ecosystem service value is from carbon stock due to tree removal and processing. Property value is also impacted in homes near developments. Stormwater and soil erosion benefits are lost. Habitat and recreation are lost. Section 6 of this report describes the methods used to arrive at this value.

Asset value accounts for total annual ecosystem service value lost over a 9-year period (through 2030), with future years discounted by 2.5%. Section 6.5 provides details on calculations of asset value.

Table 20. Asset Value of Ecosystem Service Loss from High-Risk Development Scenario.

9- Year Asset Value	
Low	High
$110,868,127	$159,530,913

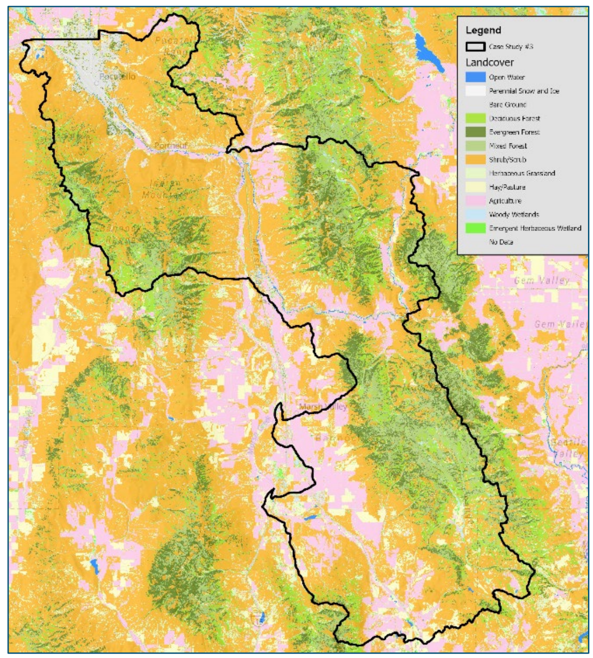
7.2.3 Case Study 3: From Grazing to Recreation – Assessing the Value of Rural Idaho

Southeast Idaho is a beautiful part of the State. Home to several mountain ranges that provide impressive scenery as well as recreational opportunities for locals and non-residents. Case Study 3 examines a portion of Southeast Idaho that includes the Portneuf Range and Bannock Range as well as the City of Pocatello. Pocatello is the fifth largest city in Idaho, boasting a population greater than 50,000. In total, Case Study 3 is home to over 78,000 residents.

With significant forested area coupled with public land, recreation is a vital industry in Case Study 3. The mountains of the area are home to OHV trails, hiking trails, and mountain bike trails. In fact, the City of Pocatello's website boasts that, "there are over 1,000 miles of recreational maintained trails and pathways around Pocatello for hikers, bikers, horse and ATV riders, and explorers of all ages and abilities. Numerous trailheads around town are portholes to the vast, rolling foothills of the Rockies and backcountry this area is famous for. Snowshoers, snowmobilers and XC Ski buffs know *their* patience pays off big-time when these trails turn white" (Visit Idaho, n.d.).

Another important aspect of Case Study 3 is its abundance of grazing area. There are over 212,000 acres of allotments just on Public Land in Case Study 3 (BLM and USFS). These areas provide ample forage for cattle, sheep and other ungulate grazing. Thus, the cattle industry is a major economic driver for the residents of Case Study 3.

Case Study 3 at-a-Glance	
Total Area	421, 641 Acres
Population	78, 129 (2019 ACS)
Landcover	
Shrub/ Scrub	44%
Coniferous Forest	10%
Deciduous Forest	10%
Agriculture	10%
Drinking Water	30,906 acres
Riparian	33,270 acres
Lake/ Reservoir	353 acres
Land Ownership	
Private	54%
BLM	13%
USFS	21%
State	11%



Recreation Impact

Blackrock Canyon Recreation Area is managed by the Bureau of Reclamation (BLM) and in Bannock County, Idaho (South of the City of Pocatello). The Blackrock Canyon Recreation Area is associated with the Blackrock Rock Trail System, providing non-motorized and motorized users over 40 miles of trails to utilize for OHV, equestrian, mountain biking and hiking. According to the BLM's Recreation Management Information System, the Blackrock Canyon Recreation Area received 48,116 visits from recreationists from October 1, 2017, to September 30, 2018, resulting in 59,390 visitor days spent on outdoor recreational activities (BLM Pocatello Field Office, 2020). Using consumer surplus model value estimations outlined in the full report, visits to the region create an **economic impact of $11.3M to $18.2M each year.**

Eastern Idaho is the state's mecca for Off-Highway Vehicle (OHV) recreation. Statewide, OHV enthusiasts take nearly 1 million recreation trips each year and spend over $150 million on OHV recreation trips and nearly $250 million on OHV capital expenditures such as the vehicles themselves. The outdoor recreation industry is among the state's largest economic sectors from the smallest rural town to the largest city.

Recreation Impact: $11.3M to $18.2M each year

IMPACT OF GRAZING

BLM Idaho authorizes livestock grazing for domestic horses, sheep, and cattle on over 11.5M acres of public land, including 2,100 grazing allotments, over 1,600 livestock operators, and over 1,800 grazing permits (BLM, n.d.). When conducted under multiple management regimes that incorporate rotations, holistic planned grazing, and/or selective conservation, livestock grazing can minimize ecological impacts. Research shows that unregulated livestock grazing has negative ecological consequences through land clearing, habitat loss, overgrazing, and greenhouse gas emissions (Asner et al., 2004).

This section demonstrates measurable impact of unregulated grazing on Idaho BLM lands. Using the ecosystem service framework introduced in the full report, Table 21 outlines research on ecosystem service impacts due to unregulated grazing.

In each case above, heavy or "unregulated grazing" is compared to "no grazing." In many cases, sustainable grazing, or some other best-management-practice (BMP) acted as a proxy to "no grazing" because of the minimal impacts BMP render in practice.

Table 21. Impact Magnitude of Unregulated Grazing by Ecosystem Service.

Ecosystem Service	Magnitude of Impact	Description & Source
Soil Carbon	-18%	A literature review of research found an average 18% reduction in soil organic carbon of heavy grazing relative to medium grazing (Conant and Paustian, 2002)
Above Ground Carbon	-75%	A literature review of research found an average 75% reduction in above ground carbon of heavy grazing relative to light/medium grazing (Conant and Paustian, 2002)
Stormwater Retention	-39%	Impact from reduced vegetation and bulk soil density (Jones, 2000)
Soil Erosion	-45%	Impact from reduced vegetation and bulk soil density (Jones, 2000)
Shrub Cover	-13%	Impact from soil compactedness and overgrazing (Jones, 2000)
Grassland Cover	-20%	Impact from soil compactedness and overgrazing (Jones, 2000)
Spread of Noxious Weeds	Negative	Yellow starthistle is an invasive plant that rapidly reproduces to form dense monocultures, inhibiting the growth of nearby plants. The invasive opportunistically inhabits disturbed lands, especially in overgrazed rangelands and pastures (ISDA, n.d.).
Water Quality	Negative	Occurrence of fecal coliforms was directly related to the presence of cattle on summer range and winter pastures in a 3yr case study on 233 km2 rangeland in SW ID (Roche et al., 2013)
Recreation	Negative	The study showed a negative association with recreational consumer surplus values and insight cattle and sheep grazing (Shonkwiler and Englin, 2005)
Soil Health	Negative	Rotational grazing was found to have greater soil organic carbon than continuous grazing. Impacts: Increased soil compactedness and reduced bulk density (Byrnes et al., 2018)
Fire Suppression	Positive	Non-grazed rangelands had over twofold more herbaceous standing crop than grazed rangelands (P,0.01). Fuel accumulations on perennial bunchgrasses were approximately threefold greater in non-grazed than grazed treatments (Davies et al., 2010)

SAGE GROUSE

No other bird better symbolizes Idaho's high desert country than the greater sage-grouse. Sage-grouse (*Centrocercus urophasianus*) once were abundant in sagebrush habitats of the western United States and Canada, having since declined 80% range-wide since 1965 (Coates *et al.*, 2021). In 2021, multiple federal agencies and universities compiled information and created a range-wide database of greater sage-grouse breeding grounds, used to assess past and current sage-grouse population trends. The USFWS findings indicated that the major threats to sage-grouse are habitat loss and the lack of regulatory mechanisms to prevent loss and fragmentation of habitat.

Grazing is the most extensive land use within sage-grouse habitat and the effects of livestock grazing on sage-grouse are often debated (Conway et al., 2020). A 2012 scientific research project examined the effects of cattle grazing on: 1) demographic traits of greater sage-grouse; and 2) sage-grouse habitat characteristics, fuel loads and wildfire behavior. The 10-year study occurs on six sites across Idaho, including Sheep Creek in the Owyhee Mountains, Brown's Bench near Twin Falls, and the foothills of Jim

Sage Mountains (ibid). Studies have shown that successful sage-grouse nests tend to have taller grass in the immediate vicinity compared to unsuccessful sage-grouse nests.

Case Study 3 Economic Impact of Wildfire Threats

The risk of fire is widespread and has significant impacts throughout Idaho. As a recent example, the Moose Fire in central Idaho has burned 82,874 acres, much of it high severity (U.S. Forest Service, 2022). The Moose Fire is on track to surpassing the 2013 Beaver Creek Fire, second in size to only the 635,000-acre Murphy Complex Fire among fires that burned in the 21st Century in Idaho. Identifying the communities and landscapes that are at the greatest risk of damage from wildfires is critical to implementing strategies to minimize wildfire risk and the associated impacts. Vegetation and fire history are important factors when considering fire risk.

Section 5.1 described how threats from wildfire are exacerbated by multiple factors, including changes in climate, increased tree mortality from insects and disease, population increases and associated development, among others. These factors damage forests ecologically and have very negative social and economic impacts as well. They damage wildlife habitat, timber markets, recreation, and can exacerbate wildfire.

This section models forest and other natural capital losses of all high-risk wildfire areas in the Portneuf Range and Bannock Range case study area. The economic analysis assumes high severity burn of all high-risk areas, omitting impacts from medium and lower severity burn areas.

This analysis shows that high-risk forests in the area face an economic loss between $117.9M and $245.1M over 50 years from high severity fire. Findings show that high-severity burns would impact 36,208 acres of forest, focused primarily in areas south of Pocatello and the west side of Caribou National Forest.

Case Study 3 Approach

The FAP describes wildfire risk to existing forests and provides modeled spatial data to understand where this risk exists. The map below this model data of all high-risk forests based on slope, aspect, vegetation type, fire history, and Wildland-Urban Interface (Figure 10). In the Portneuf Range and Bannock Range region, 36,208 acres of forest were identified as high-risk.

Using wildfire impact estimation methods described in Section 3.1, the economic impact was estimated for five ecosystem services: Aesthetic information (property value), carbon sequestration and stock, recreation, soil erosion, and stormwater retention. Section 6 and the appendices describe at length this approach, including the assumptions and limitations of the various models used to estimate ecosystem service value, consumer surplus, and impacts to these benefits.

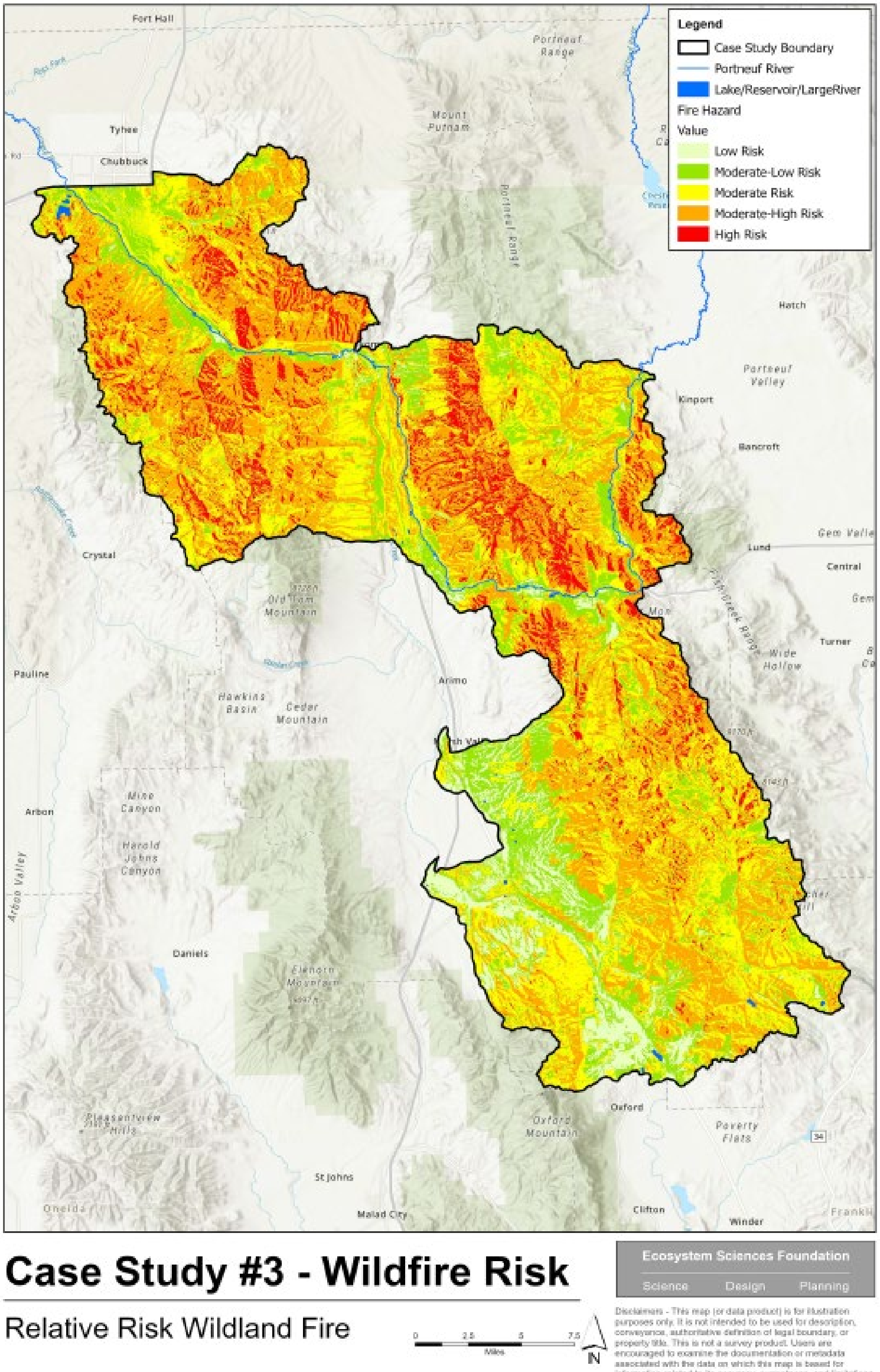


Figure 10. High Risk from Wildland Fire in Portneuf Range Case Region.

Case Study 3 Results

Ecosystem service loss occurs because of tree mortality. Under the high-risk wildfire scenario, ecosystem service loss from high-severity fire occurs to 36,208 acres of forest, accounting for $96.7M to $182.2M in just the first year.

Table 22. First Year Ecosystem Service Impact from High-Risk Fire.

Land Cover	First Year Ecosystem Service Impact	
	Low	High
Aesthetic Value	$44,402	$66,670
Carbon Sequestration	$690,307	$2,011,267
Carbon Stock	$90,454,551	$172,833,268
Stormwater Retention	$723,170	$1,566,745
Recreation & Tourism (Private Lands)	$335,123	$381,171
Soil Erosion Protection	$110,556	$947,548
Total	**$96,693,826**	**$182,197,787**

Much of the value accounts for carbon stock due to the burned tree and soil biomass. Carbon also ceases to be sequestered in the first year and into the future for dead trees until regeneration occurs. Section 6.4 provides further detail on how this was calculated.

State parks that experience severe wildfires are often closed the first year for safety concerns. As Section 6.3, immediately after the park reopens, post-burn lands often attract more people, particularly hikers, bikers, and off-highway vehicles due to the change in landscape. After approximately 5 years, the park experiences a decrease in average visitation due to the loss in appeal of modified landscapes. Full details on recreational value over time are provided in Section 363.

Table 23. First Year Recreation Value Loss from High-Risk Fire.

State Park	First Year Consumer Surplus Impact		
	2021 Visitors	Low	High
Blackrock Canyon Recreation Area	59,390	$4,335,718	$4,391,119

Asset value accounts for total annual ecosystem service value lost summed over a 50-year period, discounting future years. Recovery of ecosystem service value loss varies between ecosystem services with different recovery times and rates. Section 6.5 provides details on calculations of asset value.

Table 24. Asset Value Ecosystem Service Loss from High-Risk Fire.

Asset Value	
Low	High
$117,857,909	$245,136,339

The results above exclude multiple ecosystem services and burn severity categories identified in the FAP. Medium and lower risk wildfire threats were not included. Additionally, the impacts to water quality, water supply, and other ecosystems were also not included. The estimates above measure the risk of impact and represent an underestimate to high-risk areas.

8. Policy Discussion and Opportunities for Application

The Idaho Natural Capital Assessment and tools created through this project reveal the value of Idaho's natural resources. This view opens a range of opportunities for the State of Idaho to inform resource management that: improves the health of Idaho's landscapes, spurs economic development in communities, supports workforce development and more. The path forward will be multi-faceted and will be supported by federal state and local programs, some currently in-place, others in the pipeline, and innovations in early development. There is a myriad of opportunities currently available to support resource management activities, including Federal funding and program support through the Inflation Reduction Act and Infrastructure Bill; State funding; program support through the Idaho Workforce Development Fund and local initiatives. By using the Idaho Natural Capital Assessment to inform management decisions and future policy development, Idaho can build a more resilient future for all Idahoans by implementing strategic, ecologically sustainable, and economically beneficial policies and practices. Through this concluding section of the assessment, we explore opportunities for application of this assessment through a variety of strategies and examples from cities and states across the US.

8.1 Benefits for Citizens of Idaho

8.1.1 Resource Management and Job Creation

Conservation, restoration, and active management of Idaho's natural resources benefits the environment and creates jobs in Idaho communities. Increasing the pace and scale of active resource management is critically needed to address a variety of threats – including wildfire, bark beetle infestation, and climate change impact such as drought – and improve the health of our natural ecosystems, watersheds, and resource-dependent communities. For example, an Arizona community study discovered that 12,000 acres of mechanically thinned forests reduced fire threat and created more than 900 full-time jobs in the region, accounting more than $50 million in regional labor income (Hjerpe et al., 2021). Active forest and resource management has and will continue to provide steady employment in Idaho communities.

A range of skills are needed to manage the risks facing Idaho's natural resources, from skilled laborers to transportation engineers, foresters, fish and wildlife professionals, rangeland managers and many more. Economic recovery spending could support the expansion of resource and restoration workforce development programs, creating better education opportunities that lead to high-skill resource management jobs. Economic recovery spending could support forestry and agriculture industry training for high school and college students – for example, by expanding access to training camps for low-income students or offering more scholarships for natural resource degrees. When paired with workforce development programs like the Idaho Conservation Corps, these investments would create a ladder to higher paying resource management positions while restoring healthy forests.

8.1.2 Opportunities for Small Municipalities to Support Active Management of Riparian Areas and Roads

Currently, local government funding for rapid wildfire response typically comes from general budget allocations for all fire-related activities, including wildfire recovery and risk prevention. Sometimes these funds are consolidated into general emergency response, whether for flood, drought, or fire. However, there are no funds allocated specifically to short-term, post-fire restoration. Active resource management will allow watershed vegetation to recover faster than if left un-managed.

Resource management activities will reduce erosion and sedimentation in nearby creeks. Existing programs have shown to be successful in erosion reduction. In 1967, the State of Colorado established the Emergency Fire Fund, a voluntary system in which resources are pooled between 43 (of 64) counties throughout the state (DFPC, 2017). Although most of these funds are used to control active fire, the fund has also contributed to short-term restoration and active management of high-priority areas.

8.2 Funding Resource Management Activities at the Right Scale

Wise investment in Idaho forests and rangelands ensure that all residents have access to the full basket of resource generated goods and services including timber, agricultural crops, safe drinking water, beauty, wildlife, and recreation. Critically, the scale of funding needs to be at the scale of the resource. Case study 3 in Section 7.2 shows that 36,208 rural acres of forest are at high risk of being lost from the threats posed by severe wildfire. If all high-risk areas came under severe wildfire, ecosystem service impacts would amount to $117.9M and $245.1M over 50 years. This loss is staggering considering southeast Idaho is not heavily forested compared to Idaho's panhandle which faces the same risk of severe wildfire. As discussed throughout this assessment, active resource management reduces the risk of catastrophic wildfire improves overall resilience and health (Barnes et al., 2017). To address the scale of risk throughout the state, strategic funding of active resource management is critical to build more healthy and resilient natural systems and in-turn more resilient resource -based economies across the state.

8.2.1 Collaborative Governance to Fund Recovery in Rural Communities

Collaboration and funding are critical to securing the value of ecosystem services over the long run. Rural communities are the provisioning areas of ecosystem goods and services. Urban communities benefit from water provisioning, disaster risk reduction, wildlife, recreation, and other benefits provided by rural landscapes. Local governments are often obligated to take on the responsibility of disaster recovery and the mitigation of risks associated with wildfire. With limited resources available to invest in recovery and future mitigation, rural communities are left with limited capacity to implement such measures. With county and state collaboration, local governments can work with non-governmental organizations (NGOs) to create community programs that cost-share disaster risk mitigation or reduce insurance premiums with implementation of preparedness plans.

For instance, in Utah the State Division of Forestry, Fire and State Lands (FFSL) attempted to establish cooperative agreements with county governments to assist with the cost of wildfire suppression in the form of insurance premiums (Hansen, 2017). Although this system worked in some circumstances, wildfires in the last two decades have exposed the missing link: Municipal governments that own vast areas of incorporated wildlands were not able to participate in the wildfire suppression cost assistance system. After three years of collaborative efforts with county partners and municipal service providers, FFSL helped ensure that Utah's 2016 legislature unanimously passed a comprehensive wildland fire policy. Today, all communities participating in the State's cooperative are required to develop a Community Wildfire Preparedness Plan (CWPP). A CWPP is a plan that communities create, in collaboration with 39 emergency management and land management agencies, allowing them to be proactive in managing their wildfire risk.

Coordination of local governments through interlocal agreements can save hundreds of millions of dollars and provide better services. For example, in the Green River watershed of King County, WA, 16 cities have interlocal agreements whereby funds largely collected from downstream urban areas can be invested into areas higher in the watershed to provide better water quality and greater flood risk reduction. The interlocal agreements help invest in forests and floodplain restoration reducing infrastructure conflict, for example storm water investments that pipe water faster into rivers, damaging downstream levees and causing increased flooding. Investments in forests, floodplains, and infiltrating storm water into groundwater benefit salmon habitat, reduce flooding, and extend the life of built infrastructure like levees.

Washington State and Oregon are significant downstream beneficiaries of water originating in Idaho forests and conducted down the Snake River. Currently, some federal funding through the Bonneville Power Administration returns to Idaho for salmon restoration projects, but this downstream payment for ecosystem services in upstream Idaho could be significantly expanded.

The value of Idaho's forests and natural resources has been explored extensively in this assessment. The next step could examine the downstream beneficiaries and potential funding mechanisms for investment back into Idaho's natural resources.

8.3 Leveraging Federal Funding

Natural capital provides an outstanding investment opportunity. Investing in and protecting natural capital avoids future costs and produces clear economic returns in the present and future. Revealing the full returns of these investments requires that we go beyond traditional analyses that measure only built capital and include also the value of natural capital and its ecosystem services. Natural capital can have clear, fair, and high-return funding mechanisms paid for by its beneficiaries. For example, at least six US water utilities include on their water bills natural capital charges that support investment in watershed restoration and easement purchases, and many more utilities allocate part of their budget to watershed protection. The City of Bellingham, Washington has raised more than $28 million since 2001, which has allowed it to purchase and steward nearly 1,800 acres of open space surrounding its water source (City of Bellingham Public Works Department, 2013).

8.4 Infrastructure Investment & Jobs Act and NEPA Rules

The Infrastructure Investment and Jobs Act (IIJA) was signed into law on November 15, 2021 (Pollack and Fite, 2021) opening the door for access to new funding for fire related restoration in Idaho. The IIJA includes funding commitments to suppress fires over the past. The law also includes policy changes that could affect millions of people whose business, recreation, and enjoyment depend on healthy forests.

The IIJA established a new statutory categorical exclusion (CE) under NEPA for fuelbreaks. A fuelbreak is a modified strip of vegetation or other combustible material that creates a barrier to slow or stop the progress of a wildfire. The IIJA fuelbreak CE applies to fuelbreak projects up to 1000 feet wide and encompassing up to 3000 acres. A statutory CE is a type of NEPA compliance where a full environmental impact statement is not required because Congress has determined projects within the scope of the CE grants a category of projects with automatic NEPA compliance if they meet the statutory CE's requirements. Projects that meet the statutory CE's specific elements will not be subject to additional regulatory processes.

8.4.1 FEMA Benefit Cost Analysis

In 2013, the Beaver Creek fire was started by lighting close to Fairfield and Hailey, in the Sawtooth National Forest. The fire raged for most of August 2013 and burned more than 114,000 acres, coating the Sun Valley resort area in a thick layer of ash. The fire incurred an estimated cost of over $25 million, destroying and damaging homes, bridges, culverts, and roads (Murri, 2020). While cleanup costs were included in the FEMA disaster declaration resulting from the fire, damages not assessed included ecological costs, such as lost recreation, continued erosion, and short-term flooding costs among other ecosystem service impacts. Approximately 9,439 acres of vegetation and soil experienced high severity burn (Burned Area Emergency Response, n.d.), resulting in further damages that were not accounted for.

The inclusion of environmental benefit valuations is becoming more common and accepted in addressing significant, complex policy issues. On May 13, 2016, FEMA expanded the application of ecosystem services to all FEMA mitigation project types, including fire and drought (FEMA, 2016). FEMA now allows restoration of streams and floodplains that mitigate the effects of drought and wildfire. Actions such as reforestation, soil stabilization, and flood diversion and storage are now eligible. These wildfire and drought related mitigation activities are applicable to both the Hazard Mitigation Grant Program (following disaster declaration), as well as the Pre-Disaster Mitigation program. While competitive at varying degrees, states and counties are able to apply for both funding sources. This policy advancement represents an important acknowledgement of the importance of ecosystem services loss in the event of wildfire.

Federal disaster assistance is organized in three categories: Individual Assistance, Public Assistance, and Hazard Mitigation Assistance (FEMA, 2020b). Individual Assistance eligibility is verified by FEMA or the providing agency. The program can provide financial assistance for housing, small business loans (through the SBA), unemployment assistance, legal services, counseling, and special tax considerations. Public Assistance eligibility is based on the Project Formulation which documents work and costs associated with the claim (Ibid). These projects are categorized as debris removal, emergency protective measures, road systems and bridges, water control facilities, public buildings and contents, public utilities, and parks, recreational, and other. The Hazard Mitigation Assistance Program has separate eligibility requirements. According to FEMA, "All mitigation projects must be cost-effective, technically feasible and effective, and compliant with the National Environmental Policy Act (NEPA) and any other applicable requirements outlined in federal, state, territorial, federally recognized tribal and local laws," (FEMA, 2021). The primary difference between mitigation assistance and other disaster assistance is that mitigation projects must comply with NEPA requirements.

This report did not provide a benefit-cost analysis (BCA) of purchasing property in the highest risk areas and returning the area to open space. However, multiple benefits would be experienced in a buyout scenario, including the avoided damages and casualties with repeated fires and improved water quality. Further research is needed to understand the details.

FEMA provides funding through the Hazard Mitigation Grant Program (HMGP), which includes acquisition projects, used to support long-term solutions to the cost of natural disaster. A BCA of future firefighting costs, such as avoided response and public infrastructure damage, may demonstrate the cost effectiveness of home acquisitions.

8.4.2 The Infrastructure Reduction Act

The Inflation Reduction Act (IRA) was signed into law by President Biden on August 16, 2022. The IRA provides billions of dollars in incentives, grants, and loans to support new infrastructure investments in the areas of clean energy, transportation and the environment. The funding mechanisms provided through this act have immense opportunity to support various programs in Idaho to build community resilience through investment in strategic resource management activities. For example, IRA provides $1.5 billion in funding to support urban and community forestry programs, of which Idaho is poised to greatly enhance funding resources to support its Idaho Urban and Community Forestry Program. This assessment can be used to justify funding investments and strategically invest funding into the communities and landscapes across Idaho of greatest need to improve long-term resilience.

8.5 Leveraging State and Local Funding

Local governments, private industry and state agencies are investing in Idaho every day. Idaho Department of Lands has been working together successfully with industry, communities, and the Idaho State Legislature to enhance funding investments for expanding wildfire response and workforce development. These strategic and mutually beneficial partnerships can continue to grow and expand into resource and workforce investment activities for the benefit of the environment and regional economy. This natural capital assessment is a valuable tool to support and enhance all these strategies by providing sound data through an economic discussion of the value of investments to benefit Idahoans and long-term resilience.

9. CONCLUSION

Idaho is a resource rich state with highly diverse landscapes. Leaders and policymakers at the state and federal level have a rich history of public and private partnerships that invest in resource conservation and resource dependent industries that drive the state's economy. This natural capital assessment is a first of its kind look at the value of the state's natural resources to support policy development and strategic resource management. While the future of Idaho's valuable natural resources may be uncertain with changing political, societal and climate conditions; there is a great opportunity to frame a more resilient future through a deeper understanding of the economic benefits of the state's natural resources for air quality, water quality, carbon sequestration, recreation, tourism and much more.

10. Appendix A: Benefit Transfer Methodology Detail

A1: Overview of VEGS

Equilibrium Economics maintains the Valuation of Ecosystem Goods and Services (VEGS) database, the largest and most comprehensive databases of published, peer-reviewed primary valuation studies for BTM use in the world. This database has been compiled over years of research identifying appropriate primary ecosystem goods and services valuation studies for benefit transfer. Each study is reviewed multiple times and approved by internal staff for use in value transfer. The database includes well over 4,000 values from nearly 1,000 published sources. The database includes valuations from around the world, with most values based in North America.

VEGS contains many primary studies with valuations applicable to the State of Idaho. The valuation techniques employed in these studies include market pricing, replacement cost, avoided cost, production approaches, travel cost, hedonic pricing, and contingent valuation. These techniques have been developed and vetted within environmental and natural resource economics communities over the last four decades. Equilibrium Economics used several criteria to select appropriate primary study values for Idaho, including geographic location, demographic characteristics, and ecological characteristics of the primary study site. This appendix provides descriptions of primary valuation techniques, examples of how specific studies have employed them, and how Equilibrium Economics applied them to this valuation.

A2. Further Discussions in Benefit Transfer Methodology

Benefit transfer is a widely accepted valuation method that has been used for many decades in the ecosystem service valuation field. Authors such as Freeman (1984) have been conducting benefit transfer since the 1980s, and in the early 1990s benefit transfer was broadly recognized as a distinct area of research (Rosenberger and Loomis, 2001). Currently, the use of benefit transfer values is used by several federal agencies. The EPA utilizes benefit transfer in benefit-cost analyses related to proposed air and water quality regulations and is specifically discussed in the EPA's Guidelines for Preparing Economic Analyses (EPA, 2014). The U.S. Forest Service and U.S. Army Corps of Engineers both utilize benefit transfer for estimating the economic value of recreation related to project activities and impacts (Johnston et al., 2015). FEMA allows the use of benefit transfer values in their Hazard Mitigation Assistance Program and all other mitigation projects (FEMA, 2016).

The benefit transfer method allows for the estimation of ecosystem service values at large scales when analysis of primary data is unavailable. This is achieved by transferring values estimated in a previous study (i.e., study site) in a different location, to the area of interest, or target location (i.e., policy site). There are two primary forms of Benefit Transfer: unit value transfers and function transfers.

Unit value transfer offer several approaches that transfer a single value per unit (e.g.., per acre, per trip) from the study site to the policy site. One approach can be to directly transfer the value obtained from a single study site and apply it to the policy site. Function transfer uses a value function estimated for an individual study site in conjunction with information on policy site characteristics to calculate the unit value of an ecosystem service at the policy site. The latter may provide a more accurate estimate of value for the policy site with the available of on-the-ground data and particularly if limited studies exist which meet the criteria for a valid value for transfer. If few cases, a third technique can be used, which involves the use of administratively approved values in often government jurisdictions. Some examples of administratively approved values include the U.S. Forest Service Resources Planning Act for recreation and other ecosystem services or the U.S. Water Resources Council's values for recreation (Richardson et al., 2015; Rosenberger et al., 2017).

Currently, multiple academic articles and federal agencies publish criteria and best practices to ensure valid benefit transfer. Criteria were first recommended by Boyle and Bergstrom (1992) which states that, under ideal conditions, the source and target sites, populations, and welfare measures are matched as closely as possible. Since then, guidelines have been proposed to ensure appropriate value transfer when variation in study and policy site is present. Rolfe et al. (2015) summarize the set of criteria suggested by Bennett in 2006 under five requirements:

- **Condition:** The biophysical conditions in the source case must be like those in the target case.
- **Scale:** The scale of environmental change considered in the source must approximate the target.
- **Socioeconomics:** The socioeconomic characteristics of the population impacted by the change investigated in the source must approach those of the target population.
- **Framing**: The frame or setting in which the valuation was made at the source must be close to that of the target.
- **Rigor**: The source study must have been conducted in a technically satisfactory fashion.

This report meets these requirements in several ways.

- Each study extracted from VEGS is a peer-reviewed academic journal article, government agency report, or technical report. Each value associated with VEGS has undergone a double-blind review process by one or more economist(s) affiliated with Ecological Economics. This ensures that the source study has utilized appropriate valuation methodology (#5).
- 26 different GIS data sources were collected for this study related to ecological and socioeconomic conditions (#1, #3). This local data is matched to regionally relevant values extracted from VEGS (#4).
- Values extracted from VEGS and transferred from primary studies are ecosystem specific and are only applied to the same ecosystem and/or land cover type (#1, #2).
- Combining ecosystem-specific values with relevant attribute features (proximity to other land cover types, contiguous acres, riparian, etc.) ensures that biophysical conditions (#1), the scale of the landscape (#2), and the surrounding area or setting (#4) being valued closely matches that of the primary valuation.
- Function transfer is used where data is available (carbon analysis, public recreation analysis) at state-scale to ensure that local socioeconomic characteristics and data are incorporated into the value transfer (#5).

A3. Description of Primary Study Valuation Techniques

All values extracted from VEGS and included in this analysis were sourced from studies conducted in temperate ecosystems and biomes consistent with the state of Idaho. Through this filtering process, Equilibrium Economics ensured that estimates from areas with considerably different ecologies or demographics to Idaho were excluded.

A3.1: Revealed-Preference Approaches

Market pricing: Valuations are directly obtained from what people are willing to pay for the service or good on a private market. Example: timber, agricultural products, and water are sold in markets, the price times quantity sold provides a value.

The total timber production from Idaho forest lands could be used in this analysis. As noted in Section 2, this value is not included as part of our Benefit Transfer because 1) It is already counted in the market economy; and 2) The market price of food includes significant human inputs in addition to natural capital (e.g. labor, machinery) and would therefore overstate the value contributed by nature alone.

Travel cost: Based on the cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service. Example: Recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.

Hedonic pricing: The value of a service can be estimated by comparing the prices of similar, but non-identical goods under the assumption that the price of a good can be broken down into its attributes. A house along the coastline will be more expensive than an identical inland house because of the aesthetic value provided by a view or proximity to the coast. This added value, "hedonic value," is measurable. It is only a partial estimate of aesthetic value, however, because many people who do not own "view" property still enjoy the view and that aesthetic value remains unmeasured.

Mahan (1997) prepared for the U.S. Army Corps of Engineers, values several wetland types and their effect on residential property values in east Oregon, using the hedonic pricing method. Their findings show that wetlands have a significant influence on nearby residential property values; different types of wetlands have significantly different marginal implicit prices; and wetlands and non-wetland greenspaces (e.g. public parks, lakes, or rivers) have significantly different marginal implicit prices. The first step is to calculate a price function that relates the price of a property to several variables including distance to four wetland types. The authors then can estimate a willingness-to-pay function for different wetland types and sizes. Using their results, we calculate an annual per acre value by taking the average willingness to pay per acre of wetland and multiplying it by the number of property sales per year in the study area.

Production approaches: Service values are assigned from the impacts of those services on economic outputs. Example: Improvement in watershed health leads to an increase in commercial and recreational salmon catch.

Knowler et al. (2003), utilizes a production function approach by specifying a full bio-economic model of a coho fishery in eastern British Columbia. They estimate the economic value of changing the quality of fish habitat by using empirical analyses to link fish population dynamics with indices of land use in surrounding watersheds. This allows the authors to estimate habitat ecosystem service values at different levels of degradation, which they express as a net present value per kilometer of stream length at a 5% discount rate. This length-based value (i.e. $/km of stream) was then converted to an annual area-based value ($/acre/year).

A3.2: Cost-based approaches

Replacement cost: Cost of replacing ecosystem services with man-made systems. Example: The cost of replacing a watershed's natural filtration services with a man-made water filtration plant.

Avoidance cost: Value of costs avoided or mitigated by ecosystem services that would have been incurred in the absence of those services. Example: If wetlands (and their associated hurricane buffering services) are lost, additional costs are incurred during storms as coastal property is damaged. Rein (1999) investigates the economics of implementing vegetative buffer strips (VBS) as a tool to protect water quality from nonpoint pollution, based on avoided costs to the grower and to society as a whole the costs of installing a VBS include the loss of potential agriculture profits, and VBS installation and maintenance. Benefits include reduction of herbicide use, reduced farm damage from soil erosion, and avoided cost of road clearing due to sediment capture. Results indicate a net economic benefit to the grower for installing vegetative buffer strips within the first year. Benefits are expressed annually for a 1-acre VBS. Therefore, the only conversion necessary for benefit transfer is to adjust for inflation.

A3.3: Stated-preference approaches

Contingent valuation: People are asked to state directly what they would pay for a specific environmental service. Example: People are asked their willingness to pay to preserve a local wilderness area for aesthetic reasons.

11. Appendix B: Attribute and Modifier Data Detail

The content breaks down each threat by ecosystem service and provides a summary of the numerical value taken from each study and attributed to each ecosystem service. Much like the benefit transfer methodology, the threat impact is understood from each study listed below and attributed to threats found in Idaho.

B1: Threat to Forest Health: Mountain Pine Beetle

Native bark beetles attack and kill trees by feeding and reproducing in the conductive tissue beneath the bark, resulting in eventual tree mortality. The literature research and cited below reflects the effect of tree mortality on individual ecosystem services due to severe infestation/impact of bark beetles. Due to a desire to focus on the most significantly damaging and well-researched species, mountain pine beetle was the only bark beetle included in this analysis. Appendix E discusses these and other study limitations.

Impact: Carbon Sequestration
Data Source: Hawbaker, 2010
Study Description & GIS Data Use Description: Field sampling and LIDAR data collected through the northern Rocky Mountain Range indicated that the MPB outbreak caused a 72% decrease in aboveground live biomass. Data tables also show standing live carbon recovery rates to pre-outbreak conditions.

Impact: Aesthetic Value
Data Source: Price et al., 2010
Study Description & GIS Data Use Description: The study uses implicit prices for MPB damage calculated using GIS data showing a 0.1, 0.5, and 1.0-kilometer buffers of property with severe infestations and resulting dead trees. Predominant species studied: Lodgepole pine.

Impact: Stormwater Retention
Data Source: 1) Schnorbus et al., 2010 2) Knight et al., 1991
Study Description & GIS Data Use Description: 1) The study models in S and SE British Columbia how loss of forest cover due to MPB induced pine death (w/ salvage harvesting) results in higher snow accumulation over the winter and higher melt rates during the spring. This effect, combined with a loss of transpiration was shown to result in more runoff, increasing magnitude and frequency of peak-discharge events. Multiple data points show anywhere from 6% to 40% increase in runoff volumes.
2) The study developed a stand-level simulation model to calculate outflow and soil-water volume in lodgepole pine dominant forests in the Medicine Bow Mountains of Wyoming. The study showed a 92% increase in water outflow in thinned forests followed mortality of trees stands (60% death rate).

Impact: Recreation
Data Source: 1) Michalson, 1975 2) Walsh and Olienyk, 1981
Study Description & GIS Data Use Description: 1) The study conducted a survey of visitors to and locals in proximity to Idaho's Targhee National Forest, estimating visitor days (VD), expenditure (EX), and

consumer surplus (CS). The study compared campgrounds with MPB infestations to those without infestations, finding that VD declined by 13.4%, EX by 8.1%, and CS 13.5%. 2) The study estimated the average arc elasticities for aggregate recreation demand in a 1- to 15-percent decrease from the predicted level of the indicator variable with a mean number of 178 trees per acre.

B2: Threat to Forest Health: Balsam Woolly Adelgid

The balsam woolly adelgid (Adelges piceae) (BWA) is a non-native, invasive sucking insect that infests grand fir (Abies grandis) and subalpine fir (Abies lasiocarpa) in Idaho, causing serious mortality of the latter and loss of tree canopy. Loss of canopy in these areas can impact water quality and fish populations downstream, as well as snowpack. The literature research and cited below reflects the effect of tree mortality and canopy loss on individual ecosystem services due to severe infestation/impact of BWA. Due to limited research on BWA, research on the impact of Hemlock Woolly Adelgid acted as a proxy for the impact of BWA. In other cases, research from bark beetle infestations was also used. Appendix E discusses the similarities of both pests and their impacts on their host species, as well as other study limitations.

Impact: Aesthetic Value
Data Source: 1) Holmes et al., 2006 2) Huggett et al., 2008
Study Description & GIS Data Use Description: 1) The study estimates economic damages to homes due to outbreaks of hemlock woolly adelgid in rural New Jersey. Hedonic property values were estimated to measure the effect severely defoliated and/or dead trees. The study found an average 2.26% reduction in housing price.
2) The study estimates economic damages to homes due to outbreaks of HWA in another region in New Jersey, more urban than the example above. Hedonic property values were estimated to measure the effect. The study found an average 8.3% reduction in value.

Impact: Carbon Sequestration/Stock
Data Source: Nuckolls et al., 2009
Study Description & GIS Data Use Description: The study estimates fine root biomass and above ground biomass reduction as a result of HWA adelgid outbreaks in south Appalachian hemlocks in North Carolina. The study found that Hemlock trees had 80% crown loss by the third year of the infestation, and an average 22% reduction in fine root biomass.

B3: Threat to Communities: Severe Wildfire

Impact: Aesthetic Value
Data Source: 1) Stetler et al., 2010 2) Loomis, 2004
Study Description & GIS Data Use Description: 1) The study estimated the change in home sale prices in western Montana of homes within 5, 10, and 20km from a high severity fire. Findings showed a 3% to 15% reduction in home sells, depending on the distance to the fire, and whether there was a view of the fire. Some of these results were not significant at the 95% threshold but were at the 90% threshold. The study found that over 7 years we needed, on average, for housing prices to recovery. 2) As a comparison study, Loomis found that, 5 years and large wildfire, home in proximity to a fire in Pine CO were 15% to 16% less in price.

Impact: Stormwater Retention

Data Source: 1) Robichaud et al., 2016 2) Abramson et al., 2009

Study Description & GIS Data Use Description: 1) A study of the 2000 Valley Complex wildfire conducted a rainfall simulation in burned and non-burned areas. Months after the fire, burn area runoff yields increased by 10-20% in the first two years compared to non-burned areas. By the fifth year, water yields performed better than unburned areas. All results were statistically significant.
2) The comparison study from Santa Barbara CA found that estimated flood discharge associated with the FEMA 100-year storm is four to 20 times more likely one year after high severity fire. In "small" fire conditions, flood discharge with the same storm increased by only 25%.

Impact: Soil Erosion

Data Source: 1) Robichaud et al., 2016 2) Abramson et al., 2009

Study Description & GIS Data Use Description: 1) A study of the 2000 Valley Complex wildfire conducted a rainfall simulation in burned and non-burned areas. Sediment yields increased by more than tenfold directly after and one years after the fire, with rates recovering in the second year and sedimentation recovered by the fifth year. All results were statistically significant.
2) The comparison study found that erosion rates increase up to 385% for a 2-yr storm and by three orders of magnitude for a 100-yr storm.

Impact: Recreation (Hiking & Biking)

Data Source: Loomis, 2004

Study Description & GIS Data Use Description: The study surveyed visitors of National Forests across the state of Colorado. It found that recreational value increased shortly after a severe crown fire, at diminishing returns, for the first five years following the fire. Estimated demand functions then showed a negative relative value about 8 years after the fire, not returning to normal levels until approximately 50 years following the fire.

Impact: Carbon Sequestration/Stock

Data Source: 1) Crooks et al., 2014 2) Liu et al., 2014 3) Smith et al., 2006

Study Description & GIS Data Use Description: All three studies provide carbon sequestration rates of dozens of forest types following a disturbance (wildfire, clearcut, etc.). Sequestration rates can be extracted at five-year increments.

The table below shows a summary of the factors, or multipliers, pulled from the literature cited in Section 3 above. These are used to reflect modified ecosystem service value due to the characteristics and threats. All values below are assumed to reflect time period "0" (today), or the effect of the identified threats at the time period reflected in collect GIS data.

B4: Temporal Considerations

Each multiplier dataset will have a corresponding temporal factor, or recovery rate, that will differ between each multiplier dataset and each ecosystem service. To match the underlying recovery-rate research associated with each multiplier and ecosystem service, and to retain simplicity in the economic model, this will be done on an annual basis. The following sections outline recovery rates of each ecosystem service grouped by multiplier (threat) datasets. Appendix E summarizes the research and assumptions used in this report to show how each multiplier changes over time.

B4.1: Mountain Pine Beetle Temporal Factors

One study in southeast British Columbia sampled 22 sites in a watershed that fed Flathead Lake in Montana (Amoroso et al., 2013). The study focused on the effect of MPB outbreaks in predominately ponderosa pine forest, finding that severe outbreaks killed an average of 70.7% pine in the Flathead Valley, consistent with Hawbaker (2010) finding of carbon loss of approximately 72%. Amoroso et al. (2013) found that the occurrence of the MPB epidemic resulted in more structurally and compositionally diverse stands leading to multiple successional pathways different from those of even-age pine dominated stands. The authors also found that the ingress of natural regeneration was slow in the first few years after MPB attack followed with a strong pulse of recruitment 10–20 years post disturbance which then slowed considerably by 30 years post-MPB attack. Lodgepole pine retained clear dominance in 41% of the stands but other species, such as interior spruce, western larch and Douglas-fir, increased their relative dominance and had become dominant almost 30 years after the attack in 23% of the stands.

Table 25. Summary of Modifier Threat Data Reduction Factors.

Multiplier	Ecosystem Service	Modifier Reduction Factor	Study Description & GIS Data Use Description
Forest Health: MPB	Carbon Sequestration	72%	Based on 72% biomass reduction factor cited in literature
	Aesthetic Value	N/A	The study cited is most appropriately applied in suburban boundaries. This scenario did not include acreage with an urban attribute
	Stormwater Retention	23%	Calculation of multiple data points: (.40+.06)/2 Taking a conservative approach, the lower cited values were averaged.
	Recreation	13.50%	The Targhee National Forest Consumer Surplus value was used.
Forest Health: BWA	Carbon Sequestration	80%	Based on 80% biomass reduction factor cited in literature. Does not account for ground and root biomass.
	Aesthetic Value	2.26% to 8.3%	The studies referenced are relevant to rural and suburban contexts. This scenario did not include acreage with an urban attribute.
	Recreation	13.50%	MPB was used as a proxy for recreation impact of dead trees. The Targhee National Forest Consumer Surplus value was used.
Historic Wildfire	Recreation	*Activity specific	Hiking experiences short-long term increase in ES value following a fire, while biking experiences short-term decreases. More research required.
	Aesthetic Value	3.50%	Multiple values could be considered from the Stetler et al., (2010) paper with attributes related to proximity and severity of the fire. The value selected represented in the statistical model a large fire (>405ha) but between 10km and 20km away from the large fire.
	Stormwater Retention	20.70%	Values were taken from Robichaud et al. 2016 representing the PF0 time period (months after fire) runoff percent difference between control and burned area sampled runoff volumes.
	Soil Erosion	100%	Robichaud et al. show substantial sediment yield following large and small fires across 59 samples. Soil erosion benefits are assumed lost in the first year following a fire.
	Carbon Sequestration	100%	Following high-severity fires, all above ground biomass is assumed burned, providing no carbon sequestration benefit immediately after the fire. In years following the event, this factor decreases.

The data from this study suggests that ponderosa pine recovery from a severe outbreak of MPB is sigmoidal (S-curve), reaching steady state growth rates by approximately 30 years. Species variability shifts, reducing presence of the pine. As the most robust study on MPB recovery, factors introduced above are used in this study. Throughout the state of Idaho where high-severity infestations of MPB have been detected, data cited in the above report will be used to estimate the mortality rate, recovery rate, and post-infestation recovery period. This data will be used to make assumptions about the recovery rate of the monetary value of specific ecosystem services provided by the landscape. This information is summarized in Table 26 below.

B4.2: Balsam Wooly Adelgid Temporal Factors

One study sampled 1,337 plots in five peaks in the Great Smoky Mountain National Park, focusing on mortality rate and recovery of BWA infestations in spruce-fir forests (Smith and Nicholas, 1998). The authors found that Fraser fir was most severely impacted, with an average 72.3% mortality rate, compared to 10.6% and 21.2% mortality rate of spruce and hardwoods respectively. Compared to MPB outbreaks, recovery is much slower given the influence of multiple waves of infestations. Smith and Nicholas found mortality rates, at peak, hold for nearly eight years after the first infestation, with rates declining by the 20th year to approximately 47%. The authors referenced outside literature, citing a wide range of time to full recovery estimated between 35 and 60 years. A more recent study in Boise and Payette National Forests found that mortality rates of all size classes were observed up to 60% ten years post-invasion (Lowrey, 2015).

The best available data on the effects of BWA infestation impacts comes from the southeast US. This research is used to estimate the impact of the BWA impact on Idaho's forests. Compared to MPB, outbreak recovery post-BWA infestations are longer, but mortality rates are similar. For the report, the rate of recovery will be assumed to have a sigmoidal curve, like the MPB, over a longer time frame. As with the MPB, this data will be used to make assumptions about the recovery rate of the monetary value of specific ecosystem services provided by the landscape, which is summarized in Table 26 below.

B4.3: High Severity Wildfire Temporal Factors

Recovery from wildfire varies drastically based on fire intensity and severity, tree species, and existing conditions. The degree of damage to roots, stems, and the crown determines whether trees will survive a fire. For example, mature ponderosa pines develop very thick bark that insulates the cambium from damaging heat (Moench, 2002). Even if the bark is considerably scorched, the cambium can remain undamaged. Their roots run deep thus providing further protection where other species may be more susceptible to slow hot fires. Trees beyond the pole stage are very resistant to fire damage if they are not too crowded. Douglas-fir shares similar bark characteristics with ponderosa pine. As a result, this study focuses solely on high-severity fires that threaten all forest types, leaving the landscape barren in the aftermath of a large fire. An abundance of research exists on the long-term effects of forest fire by different ecosystem services. Table 26 below outlines each source used and the factors used to reduce ecosystems service value as a result of a high-severity fire, and the associated recovery rate. Data limitations related to attribute and modifier spatial and economic data is discussed in Appendix E.

Table 26. Temporal Effect of Multiplier Data.

Multiplier	Ecosystem Service	Reduction Factor (Year 0)	Estimate Recovery Time	Curve Type	Description of Assumptions
MPB	Carbon Sequestration	72%	55-66 years	Sigmoidal	From Hawbaker, 2010
	Aesthetic Value	Varied	7-15 years	Straight line	Year 0 impacts vary by property proximity. The impact to property value is driven by "unsightly" effects of dead trees. Less like the effects of high severity wildfire, a dead tree stand may exist for several years following mortality post-infestation. Straight line value recovery assumed
	Stormwater Retention	23%	5 years	Sigmoidal	Following tree death and defoliation, first succession vegetation is quickly established and recovers lost water retention provided by prior tree stands
	Recreation	13.50%	7-15 years	Straight line	Like the impact to aesthetic value, recreation is impacted by "unsightly" effects of deads trees. However, this value is reflected in consumer surplus rather than property value, but recovers once vegetation, whether the same or other species, establishes in place
BWA	Carbon Sequestration	72%	55-66 years	Quadratic	From Hawbaker, 2010
	Aesthetic Value	Varied	See MPB		
	Stormwater Retention	23%			
	Recreation	13.50%			
Historic Wildfire	Recreation	Varied	50 Years	Varied	Impact varies by recreational activity. Loomis et al. demonstrate the varied demand function by recreational activity, with an approximate but not consistent recovery time of approximately 50 years.
	Aesthetic Value	3.50%	7-10 years	Straight line	Straight line assumed. Literature Stetler et al. (2010) suggest >7 years, with others (Loomis, 2004) showing up to 10 years.
	Stormwater Retention	20.70%	5 years	Sigmoidal	Both based only on four temporal time stamps, but with 59 field observation data collections. Using a nonlinear regression, the curve appears to be quadratic with an R^2 between .55-.75 depending on the approach.
	Soil Erosion	100%			
	Carbon Sequestration	100%	55-115 years	Dual-phased	Species specific (time range would narrow with species specificity). Two phases: Near flat, even decreasing trend until ~15 years. Then positive slope until maturity. Based on Smith et al. (2006)

12. Appendix C: Using Function Transfer to Value Carbon Sequestration and Public (Consumer Surplus) Recreation Value

This section details how the annual value of sequestered and stored carbon was derived for natural capital in Idaho. The function transfer was used to combine carbon estimates with market values. The following sections provide data summaries and references for carbon sequestration rates by forest land cover types, as well as stored carbon estimates by forest types. This section does not calculate the values presented in Section 4. The methodology and market values used in this study were summarized in Section 3.3.

C1: Annual Carbon Sequestration and Total Carbon Storage Estimates

Multiple studies are available to estimate carbon sequestered by forest types found in Idaho. Table 27 below lists the taxonomy of forest type groups along with their annual carbon biomass sequestration rates. For each study, carbon biomass sequestered was converted to annual metric tons of carbon sequestered per acre for each forest type group.

Table 27. Forest Type Acreage.

Land Cover	LC Sub-specific	Full Reference	Low Estimate	High Estimate
Evergreen Forest	Douglas-fir	Heath et al. 2003 Smith et al. 2006	0.78	0.78
	fir-spruce-mountain hemlock		0.72	0.77
	lodgepole pine		0.52	0.54
	ponderosa pine		0.48	0.52
Agriculture	Average	Liu et al. 2012 Manley et al. 2005	0.10	0.15
Deciduous Forest	Aspen-birch	Heath et al. 2003 Smith et al. 2006	0.60	1.13
	elm-ash-cottonwood		0.77	0.77
	maple-beech-birch		0.63	0.63
	oak-hickory		0.48	0.48
Emergent Herbaceous Wetlands	Freshwater mineral soil	Bridgham et al. 2006	0.07	0.07
	Non-permafrost peatlands		0.08	0.08
Grasslands		Liu et al. 2012	0.11	0.11
Rangelands		Schuman et al. 2002	0.04	0.24
Shrublands	Shrublands	Liu et al. 2012	0.11	0.24
	Multiple Juniper Types	Heath et al. 2003	0.62	0.62
Woody Wetlands		Liu et al. 2012	0.11	0.77

Multiple studies are available to estimate carbon storage by forest types found in Idaho. Table 28 below lists the taxonomy of forest type groups along with their total carbon biomass stored rates. For each study, carbon biomass stored was converted to metric tons of carbon storage per acre for each forest type group.

Table 28. Carbon Storage by Land Cover Type.

Land Cover	LC Sub-specific	Full Reference	Low Estimate	High Estimate
Evergreen Forest	Douglas-fir	Smith et al. 2006	113.27	113.27
	fir-spruce-mountain hemlock		114.49	115.38
	lodgepole pine		82.35	86.08
	Ponderosa pine		79.20	80.37
Cultivated		Liu et al. 2012 Manley et al. 2005	5.42	17.57
Deciduous Forest	aspen-birch	Heath et al. 2003 Smith et al. 2006	98.62	98.62
	Multiple		49.23	55.96
Emergent Herbaceous Wetlands		Bridgham et al. 2006	18.34	24.36
Grasslands		Liu et al. 2012	6.89	15.87
Rangelands		Schuman et al. 2002	6.89	10.39
Shrublands	Multiple	Liu et al. 2012	18.94	20.32
	Juniper	Heath et al. 2003	24.44	31.48
Woody Wetlands		Liu et al. 2012	25.68	31.88

C2: Annual Consumer Surplus Value of Public Recreation

The following section provides data overviews used in the economic evaluation of public recreation. The subsections below follow the format of Figure 5 in Section 3.4.

C2.1: Recreational Visits

Section 4.1.1. provides a breakdown of visitation by public recreation area and activity. A dataset for each public recreation area is available at the corresponding agency's website.

Table 29. Public Lands Visitation Data Source.

Public Recreation Area	List of Parks/Areas	Data Year	Source of Data
US Forest Service	Idaho Panhandle NF Nez Perce-Clearwater NF Payette NF Salmon-Challis NF Boise NF Sawtooth NF Caribou-Targhee NF	2016 through 2020	National Visitor Use Monitoring Program Results Application Web Tool.
Idaho State Parks	34 State Parks	2019	(State of Idaho Department of Parks and Recreation Visitation Dataset)
National Park Managed Recreation Areas	Craters of the Moon National Monument Nez Perce National Historic Park Big Hole National Battlefield Hagerman Fossil Beds National Monument Minidoka National Historic Site City of Rocks National Reserve	2021	National Park Service Visitor Use Statistics Web Tool (National Park Service, 2022)
Bureau of Land Management		FY2020	Public Land Statistics 2020 FY2020 Report

Recreational activities varied between each agency. To create a comparable list of recreational activities, each agency's recreational activities list was best matched to the Recreation Use Values Database (RUVD). This database was used to extract consumer surplus economic values and is described below.

C2.2: Active Days Conversion Coefficient

Calculating "visitor days" normalizes visitation, allowing comparability between shorter activities like visiting a nature center (average 1.1 visitor days) and longer visitor days like backpacking (average 2.7 visitor days). Table 30 below shows the full conversion table.

Table 30. Active Days Conversion Coefficient Table (Rosenberger et al. 2017).

Primary activity	R1	R2	R3	R4	R5	R6	R8	R9	R10
National Backpacking	2.4	2.5	2.1	2.7	2.8	2.6	2.4	2.5	2.7
Bicycling	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.1	1.1
Cross-country skiing	1	1	1	1	1.1	1.1	1	1	2
Developed camping	2.7	2.7	2.6	2.5	2.8	2.8	2.8	2.9	2.5
Downhill skiing	1	1	1	1	1.1	1.1	1	1	1.1
Driving for pleasure	1.1	1.1	1.1	1.1	1.1	1.1	1	1	1
Fishing	1.3	1.2	1.3	1.5	1.3	1.3	1.1	1.3	1.3
Gathering forest products	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1
Hiking, walking	1.1	1.1	1	1.1	1.1	1.1	1.1	1.1	1.1
Horseback riding	1.3	1.3	1.1	1.4	1.2	1.4	1.6	1.4	1
Hunting	1.3	1.3	1.6	1.6	1.5	1.5	1.2	1.2	1.5
Motorized trail activities	1.3	1.3	1.2	1.4	1.3	1.3	1.1	1.1	1
Motorized water activities	1.3	1.1	1.1	1.2	1.3	1.4	1.2	1.1	1.1
Nature center activities	1	1	1	1	1.1	1.1	1	1	1
Nonmotorized water activities	1.7	1.1	1.2	1.7	1.4	1.3	1.2	1.3	1.1
Off-highway vehicle use	1.2	1.2	1.2	1.5	1.2	1.3	1.2	1.2	1
Other motorized activities	1.5	1.2	1.1	1	1.2	1.2	1.1	1.1	1.1
Other nonmotorized	1.1	1.2	1	1.2	1.2	1.1	1.1	1.1	1.1
Picnicking	1.2	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.2
Primitive camping	2.8	2.4	2.4	2.5	2.3	2.6	2.3	2.7	2
Relaxing	1.6	1.5	1.4	1.5	1.5	1.5	1.3	1.4	1.4
Resort use	2.5	2.1	2.6	2.5	3.2	2.3	3.1	2.2	3.1
Snowmobiling	1	1.2	1	1.1	1.2	1.2	1	1.1	1.1
Viewing natural features	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1	1.1
Viewing wildlife	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.1	1.1
Visiting historic sites	1.1	1.1	1.1	1.1	1.1	1.1	1	1	2.9
Other activities	1.1	1.2	1.1	1.2	1.1	1.1	1	1.2	1.1
No activity reported	1	1	1	1	1	1	1	1	1
Weighted activity average	1.2	1.1	1.2	1.3	1.2	1.2	1.2	1.2	1.2

C2.3: Consumer Surplus Values Data

The RUVD (2016 update) currently contains 421 documents of economic valuation studies that estimated the use value of recreation activities in the U.S. and Canada, totaling 3,192 estimates in per person per activity day units, 21 primary activity types, and associated metadata including activity mode, resource type, primary species sought, etc. (Rosenberger, 2016). The database is available for public download.

Over 1,000 values were found relevant to recreation in Idaho, specific to activities conducted in National Forests, BLM lands, and elsewhere. Table 31 below provides a summary of this data.

Table 31. RUVD Database Extract Summary Results.

Activity	Number of Studies	Minimum $ Value	Avg $ Value	Max $ Value
Backpacking	43	$2.19	$16.41	$60.16
Beach	29	$4.79	$50.67	$149.46
Big Game Hunting	152	$9.11	$96.13	$342.31
Camping	71	$0.97	$21.02	$166.11
Freshwater Fishing	211	$3.04	$71.95	$372.27
General Recreation	72	$3.44	$54.72	$258.79
Hiking	87	$3.11	$67.70	$350.00
Leisure Bicycling	1	$27.96	$27.96	$27.96
Motorized Boating	17	$3.64	$28.90	$59.77
Mountain Biking	9	$16.63	$126.42	$222.72
Nonmotorized Boating	40	$6.58	$59.06	$351.70
Off-Highway Vehicle	34	$9.92	$50.56	$140.29
Other Recreation	82	$1.29	$43.04	$346.93
Picnicking	19	$5.03	$21.54	$75.99
Rock and Ice Climbing	23	$10.48	$65.85	$268.11
Saltwater Fishing	15	$10.88	$74.59	$140.43
Sightseeing	26	$12.40	$66.83	$557.37
Small Game Hunting	29	$20.96	$110.72	$363.87
Swimming	6	$12.64	$26.21	$49.31
Waterfowl Hunting	26	$18.67	$90.93	$298.07
Wildlife Viewing	64	$3.33	$48.46	$228.95

13. Appendix D: Asset Value

When the value of natural systems is brought to light, it shows that investments in restoration and conservation have the capacity to provide good rates of return. Benefit/cost analysis and rate of return calculations were initiated after the 1940s to examine investments in built capital assets which were expected to be productive for a few decades until they required replacement. Built capital does fall apart and depreciate without maintenance.

Natural systems do not depreciate or fall apart like built capital assets. In fact, natural systems can even appreciate in value over time, being composed of living and growing organisms. Of course, natural systems are only renewable if they are protected against degradation, development, unsustainable extraction, and other impacts. As long as the natural infrastructure of Idaho is not degraded or depleted below its ability to renew itself, this flow of value will continue into the future.

Discounting can be adjusted for different types of assets and is designed to reflect the following:

- **Time preference of money.** This is the value that people put on something for use now, as opposed to the value they assign for that use or income at a later date.
- **Opportunity cost of investment.** A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a positive return in one year.
- **Depreciation.** Built assets such as roads, bridges and levees deteriorate and lose value due to wear and tear. Eventually, they must be replaced.

Discounting has limitations that may result in under- or overestimates when applied to natural infrastructure. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations, or even to this generation in just a few years into the future. Natural infrastructure assets should be treated with lower discount rates than built capital assets because they tend to appreciate over time, rather than depreciate.

The US Army Corps of Engineers recognizes this and provides a lower discount rate for natural capital and long-lived built water structure capital assets such as dams and levees.

Today, Idaho's forested watersheds are providing more water, to more people, for a greater total value than provided 50 or 100 years ago. Unlike a factory that is 50 years old, a protected watershed will appreciate in value if it remains mostly intact and experiences an increase in demand for its services. Additionally, most of the benefits that a natural asset such as forests provides reside in the distant future, whereas most of the benefits of built capital reside in the near-term, with few or no benefits provided into the distant future when the asset has deteriorated. Both built and natural assets are important to maintain a high quality of life, but each operates on a different time scale. It would be unwise to treat human time preference for a forest like it were a building, or that of a building as if it were a disposable coffee cup. Thus, a low discount rate better reflects the asset value of Idaho's natural assets.

The net present value of the state's forest ecosystem services was calculated using two discount rates over 50 years: 2.25% (used by the U.S. Army Corps of Engineers) and 0% percent. The discount rate of 0% percent reflects the fact that human population and future development will degrade Idaho ecosystems and reduce their ability to provide ecosystem services if they are not adequately protected. This process is analogous to depreciation of a built capital asset. Federal agencies like the Army Corps of Engineers historically have used a 3.5% percent discount rate for water resource projects (USACE, 2021).

The cut-off date is arbitrary. Clearly, far greater value yet resides for the many generations who should benefit from the watershed well beyond 50- or 100-year periods, assuming the watershed is adequately protected. Currently, the value of economic assets is generally not considered beyond 50 years. This study follows that tradition. With no cut-off for value, any renewable resource would register an infinite value. However, the value of watersheds does extend far beyond a 50-year period, and better tools for capturing that value are being developed by economists.

Calculating the net present value of an asset implies the use of a discount rate. The range of values used as discount rates varies greatly across federal agencies and applications. There is no standard across the board. The current rate for federal water projects is 2.25% (USACE, 2021). This rate was chosen and used for this analysis based on federal acceptance for water projects.

Another advantage of Idaho's natural asset and investments in forests is the fact that they cannot be "outsourced." Idaho's forest factory cannot pick up and leave the state. Idaho's forests are rooted in Idaho. These assets are here and benefit the people of Idaho today, as they will, if healthy, in 50 or 100 years.

14. Appendix E: GIS and Economic Analysis Study Limitations

The results of the first attempt to assign monetary value to the ecosystem services rendered by the state of Idaho have important and significant implications on the restoration and management of natural capital. Like any economic analysis, this study has strengths and weaknesses. While these limitations must be noted, they should not detract from the core finding that ecosystems produce a significant economic value to society. The following outlines study and data limitations of both the spatial and economic analysis.

E1: GIS Data Limitations

E1.1: Standard Land Cover GIS Data Limitations

- **Spatial analysis:** Land cover GIS data limitations include accuracy, ecosystem health, and spatial effects. GIS layers sourced for this analysis have varying degrees of accuracy. For instance, Landfire GIS data provides results of land cover mapping at a 30-meter resolution. This means that smaller tracts (<30m) of ecosystems may not be accurately represented in the GIS data.
- C**ategorical precision:** Many vegetation types were consolidated to create broad categories of vegetation, to facilitate one-to-one comparison to the VEGS database studies. For example, Landfire provided 4 cover classes that were dominated by deciduous trees. These 4-cover classed crosswalked to the GAP land cover class "Deciduous Forest."
- **Temporal sensitivities**: Some inaccuracies may be due to land cover changes after the date in which data was published and any errors associated with remote sensing classification. The source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use changes done after the data was sourced, inaccurate satellite readings, and other factors. Such inaccuracies can be attributed development, disturbance (e.g., fire) or land conversion (e.g., shrubland converted to agriculture).
- **Ecosystem Health**: Many factors reflect ecosystem health, making conditions difficult to be accurately reflected in GIS data. Differences in ecosystem health could lead to both over- or underestimates of current values. Attribute data can help mitigate those effects related to varying ecosystem health.

E1.2: Spatial Attribute Data

Each spatial attribute dataset has the same limitations described above. Some limitations are unique to each dataset, described below:

- **Terrestrial Species of Economic Importance**: The raw dataset provided six different species categories, three of which were consolidated. This was done to best match the economic studies paired with associated species. As a result, low priority categories encompassed a large portion of the state. This species-specific analysis still reflects best practices of BTM as described in Appendix A.

- **Aquatic Species of Economic Importance**: The raw dataset provided four different species categories, two of which were consolidated. This was done to best match the economic studies paired with associated species.

E1.3: Spatial Modifier Data

- **Historic vs Risk Definitions**: Spatial data related to fire has both a historic and future (risk) lens. While the former is defined by mapped high severity burn areas, the latter is hypothetical, and is referenced spatially to risk of human structures, rather than risk to vegetation or habitat. Both datasets reflect the best available data and science and are carefully defined to avoid conflation of two different spatial datasets.
- Several forest health related insects and diseases were scoped out of the economic analysis due to limited spatial data. This includes all beetles (except for MPB), all root disease, and all blight. Alternatively, Spruce budworm was not included in the economic analysis due to limited research despite the availability of spatial data. All forest health threats were described in Sections 1 and 2 above.

E2: Economic Analysis Data Limitations

This study displays results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not as precise as a single value. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

E2.1: Benefit Transfer Method

- **Incomplete Coverage**: As Section 2 shows, not all ecosystems and their distinct services to people have been quantified. Some of the ecosystem services shown in Section 2.1.1 are inherently difficult to value or in some cases impossible (nutrient cycling, cultural value). These limitations likely result in an underestimate of value for total ecosystem service value.
- **Transfer Study and Value Limitations**: As in any appraisal methodology, the selection of comparable values for benefit transfer can influence the results. The following are considerations of limitations of the database of studies, or the transferred studies/values themselves:
  - **Limited Data**: When studies and/or data are limited for some ecosystem services and land cover combinations, the value can be biased to the conditions and socioeconomics of the limited number of studies, rather than being based on an average of several relevant studies. To address such study limitations, values ranges are presented, where these ranges may become more exaggerated with more data uncertainty.
  - **Willingness-to-pay Limitations**: Many estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously known.

- **Price Distortions**: Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values
- **Non-linear/Threshold Effects**. The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher or lower levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg et al., 2002). Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing
- **Sustainable Use Levels**: The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

- **Omissions of Economic Model**: The approach and models used in this study do not attempt to reflect the full comprehensive ecosystem service value of Idaho's natural capital. The items below reflect some of many features of natural capital that were not valued in this study.
  - **Increases in Scarcity**: The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al., 2002). If Idaho's ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.
  - **Existence Value**: The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.
  - **Other Non-Economic Values**. Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns (de Montis et al., 2004)(Janssen and Munda, 2002). Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns
  - **Predictive model**: The comprehensive analysis outlined in this report, including the BTM, recreation, and carbon models, do not provide statistical best-of-fit outputs such as R-squared or z results. Each of these models has embedded in them multiple references to peer-reviewed academic journals that contain statistical models and results, and the references selected for this analysis were only those that passed with statistical significance. The accuracy of the models and economics outputs presented in this report are demonstrated by following benefit transfer and function transfer best practices, which is outlined in Appendix A2 above. Furthermore, all results are

presented in value ranges, acting as a form of confidence interval, and relaxing the necessity of statistical significance. All value ranges presented throughout this report were calculated from transferred data results selected by conservative criteria, likely resulting in an underestimate of a particular ecosystem service value. The intent of this study was not to calculate exhaustive exact value across all ecosystem services, but to measure value proxies in the absence of monetary data otherwise.

E2.2: Function Transfer: Carbon and Public Recreation Model

- **Carbon Model**: While function transfer utilized more accurate and plentiful data, existing carbon literature infrequently provides information that can be paired with attribute data. For example, few carbon studies have associated metadata such as riparian indicators or contiguous systems. As a result, the same attributes used in the BTM process were not used in the carbon model.
- **Public Recreation Model**: This economic model is as accurate as the data related to activity valuation (consumer surplus) and visitation data. The former has as rich dataset for the continental US. In the latter case, visitation data was only available for US Forest, US Parks managed lands, BLM lands, and State Parks. Additionally, several USFS datasets are only as recent as the sample surveys conducted by the USDA Forest Service National Visitor Use Monitoring program. In some cases (Sawtooth NF, Caribou-Targhee NF), the latest dataset available was 2020. For others, data was collected for 2016 and later. To reflect recent surges in recreational visitors in 2021, a statistical model was used to estimate visitation in each recreation area described in Appendix C.

E2.3: Economic Model Using Attribute and Modifier Data

- **BTM and Attribute Combinations**: Section 3.1 and Appendix B outline all GIS datasets used for each attribute. Given each datasets indicates if a pixel falls within two or more categories for one of six GIS datasets, this suggests that any individual pixel can represent multiple combinations of categories from these GIS datasets. When accounting for all 11 unique land covers (Section 3.1.1.) with all categories from each attribute GIS dataset, 1,703-pixel combinations become possible. The BTM model cannot account for every possible combination with an existing economic value. Due to this limitation, if a given land cover / attribute (LC/A) combination was not matched to an existing study and value from VEGS, then the next most relevant study was selected, often omitting one of the attribute combinations. A hierarchy of options was developed to account for when a LC/A was not accounted for in the economic model, where fallback options represent a lower more conservative economic value. This process is based on BTM practices discussed in Appendix A, where best practices suggest that the best possible matching criteria be used to transfer an economic value from study site to policy site (best matching Criteria 1 through 4).
- **Omission of Spruce Beetle**: As mentioned in the GIS limitations section above, several bark beetles were excluded due to spatial data limitations. Likewise, Spruce Beetle was not included in this analysis due to limited available of economic impact research.
- Economic Impact, Forest Health and Fire Threat Severity: As shown above, historical spatial data for both for forest health and fire threats describe high severity infestation or burn areas respectively. The definition for high severity burns or pest infestations likely differs

methodologically from research on economic impact used in this study. The research used and described in Appendix B was the best attempt at matching severity descriptions, and filtering for only high severity impacts. It follows that only high severity impacts of fire and pest infestation were included in this analysis, suggesting that moderate impacts were excluded from the analysis, and therefore rendering total economic impact as an underestimate.

- To estimate the economic impact of Balsam Woolly Adelgid (BWA), research for *Hemlock* Woolly Adelgid (HWA) was used as a proxy due to the ample research published on the latter. Host species for each pest are much different, namely that the physical location of the host species is on near opposite ends of the country. The recommendation was that use of HWA impact research was only relevant as a proxy for impacts related to recreation and aesthetic information ecosystem services. The justification: The biological impact of HWA on its host species related to other regulating ecosystem services (air stormwater retention, water quality, and carbon sequestration) is fundamentally different to inform BWA impact, resulting in incomparable impacts, especially over time. However, for recreation and aesthetic information, severe infestations of both pests result in tree mortality. It follows that the impacts measured for these two ecosystems services is conducted via surveys recreationalists or real estate appraisals, both of which done in the context of deceased trees. The fundamental difference in a stand of deceased trees, whether from BWA or HWA on their respective host species, was arguably negligible.

15. APPENDIX F: REFERENCES

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