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Ecosystem Service Valuation of Wyoming's Forests

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List of Acronyms

AF: Acre Foot

BTM: Benefit Transfer Method

CV: Contingent Valuation

ESV: Ecosystem Service Valuation

EVT: Existing Vegetation Type

IUCN: International Union for Conservation of Nature

LF: LANDFIRE

NLCD: National Land Cover Database

TNC: The Nature Conservancy

UN SEEA-SEA: United Nations System of Environmental-Economic Accounting − Experimental Ecosystem Accounting

USGS: U.S. Geological Survey

USDOI: U.S. Department of the Interior

USDA: U.S. Department of Agriculture

WTP: Willingness to Pay

MEA: Millennium Ecosystem Assessment

Executive Summary

Background and Purpose

Covering more than 9.2 million acres, Wyoming's forests are a world-renowned asset. These forests provide a wide range of benefits including accessible recreational opportunities, water capture and delivery, water quality enhancement, and wildlife habitat. These benefits are called ecosystem services and they are enjoyed by not only Wyoming's residents but also by those living downstream from Wyoming's headwaters, by millions of visitors that come to experiencethese unique ecosystems every year as well as many other people far beyond the state.

In order to manage these assets well into the future, it is important to better understand their full value. Since conservation requires investment and often competes with other economic development options, estimating the economic value provided by healthy forests can help make better economic decisions. When costs and benefits from different land use options are evaluated with the same metrics (i.e., dollars or dollar equivalents), the full value of conservation can become more evident. Thereby, estimating the economic value currently provided by Wyoming's forests can help our natural resource management agencies, the private sector, communities, and other stakeholder groups make more informed decisions about investments in forest health.

To help address the challenges of long-term and large-scale forest management, The Nature Conservancy in Wyoming (TNC) aims to leverage the full value of Wyoming's forests to bring more funding, innovation, and climate-informed science. In this context, TNC and Wyoming State Forestry Division contracted this study to estimate the monetary value of ecosystem services, or benefits, provided by Wyoming's forests to people. The study includes both current financial flows to industries and people as well as the more intangible benefits, which translate into quality-of-life enhancements but that may not have formal markets associated with their provision and are hence provided for free by nature.

This high-level valuation study is best suited for communication purposes, raising awareness, identifying stakeholders, and prioritizing further research. The results and recommendations will be used to highlight the potential economic impact of investments in forest health in Wyoming with the long-term goal of developing new sources of private and public capital for forest management.

For example, at the state level, economic data can be used by the Wyoming State Legislature and Governor's Office to support their work in enhancing and protecting local communities. At the federal level, these findings can assist Congressional representatives and other elected officials in local districts in making informed decisions about forest management policies to understand how they could contribute to local economic development. Additionally, agencies such as the US Forest Service can use the results of this report as an example of the economic impact of investments into national forests and to inform upcoming Forest Plan revisions. In fact, this guidance is included in the Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies, announced in April 2022 (Exec. Order No. 14072, 2022). Data provided by this report is relevant to the Executive Order's "Economic Opportunities in Outdoor Recreation and Sustainable Forest Products" focus, which aims to support forest-related economic opportunities on local and regional levels. This effort will bring together various sectors and levels of government in advancing community-led opportunities. Wyoming forest managers and policymakers can build on the information included in this analysis to bolster support for activities and services identified here as significant economic tools and identify opportunities for forest services that could provide greater economic benefits. In addition, the Executive Order aims to streamline "Guidance on Valuing Nature"; this report can serve as a baseline for future forest economic valuation studies.

Key Findings

The study valued 15 ecosystem services provided by 9.2 million acres of forests on public and private land in Wyoming that have not traditionally been monetized: aesthetic information, air quality, biological control, cultural value, energy and raw materials, flood risk reduction, food, global climate stability, local climate regulation, recreation and tourism, science and education, soil retention, water supply and storage, water quality, and wildlife habitat. Some of these ecosystem services were studied more in-depth because of their particular relevance and importance in Wyoming. These included water supply and storage, recreation and tourism, climate regulation, and wildlife habitat.

Recreation and Tourism

The analysis showed that forest recreation is greatly valued, not only locally but also nationally and internationally. It is also a significant revenue generator for the state, responsible for about $1.5 billion in spending per year, fueling local businesses and economies. Forest recreation also generates important quality of life benefits that amount to at least $770 million per year (in consumer surplus). These only account for some of the many recreational activities that happen in Wyoming's forests and do not consider important benefits such as the health benefits of recreating in forests.

Wildlife Habitat

Wildlife habitat was the most valued service by Wyoming residents. There are many iconic species that depend on the vast forest land of Wyoming, such as elk and mule deer, which are not only valuable for wildlife viewing and hunting, but also for the ecological roles they play in maintaining healthy forests. Forests also maintain cool water temperatures, important for fish populations and other riparian wildlife. This study valued fish, bird, and iconic species habitat as well as biodiversity and the increased value obtained by having large, contiguous forest space. Wildlife habitat values ranged from $1.09 per acre (for non-riparian, non-contiguous forests) to $2,829 per acre for more critical forest habitat. The overall wildlife habitat value was between $813 million to $5.2 billion in benefits provided every year.

Water Supply and Storage

Forests play an important role in water cycles. They regulate water flows, clean water, store it, and even affect local rain cycles. As Wyoming becomes increasingly vulnerable to droughts and changes in water availability, understanding the role of local forests in providing and cleaning water will be important. In this study, we looked at water quality, water supply, and water storage. These benefits accrue to households, industry, recreational activities, water utilities and millions of users downstream (from Colorado to Louisiana) who depend on the headwaters of Wyoming. The overall value for all water-related services provided by the different types of forests in Wyoming amount to about $1.4 billion to $2.1 billion in benefits provided every year.

Climate Regulation

Climate regulation is also an important ecosystem service, given the capacity of trees to store and sequester carbon. Climate change is also one of the biggest challenges of the current century and having an integrated forest management strategy that includes climate change mitigation and adaptation is a must. Our estimates showed yearly average values for carbon sequestration of about $6.30 to $22.95 for an acre of forest, which amount to between $58 million to $211 million in benefits every year. Carbon storage, which was not calculated as a yearly value but as a stock of stored value, amounted to between $19 billion to $70.9 billion in benefits.

Overall

- As a system, Wyoming's 9.2 million acres of **forests provide between $22.3 billion to $28.8 billion of benefits** every year. These values represent both market revenues and non-market benefits provided to both Wyoming residents and businesses as well as benefits provided beyond state lines.
- If their benefits are protected and harnessed, **the asset value of Wyoming forests, over the next 100 years, is between $983 billion and $1.3 trillion**.
- The ecosystem service valuation analysts that conducted this study believe these overall values to be conservative and under-estimates.
- The beneficiaries of Wyoming's forest ecosystems are many and diverse, and a coordinated effort is needed to protect and grow this vast wealth encapsulated in

Wyoming's rich natural lands.

- Conserving healthy forests as a critical asset should be a clear priority for stakeholders and forest land managers in Wyoming.
- Increased and more targeted investments in forest conservation and restoration treatments give us our best chance to reduce the worst risks of climate change, and create healthier air, lands, and waters. Realizing those benefits will require a whole-of-society approach to reducing risk and restoring resilience − one with input and efforts from all levels of government, the private sector, communities, and other stakeholders.

Key Assumptions

This study describes the value of 9.2 million acres of forests on public and private land in Wyoming, making up 15% of the total land cover of the state, while other trusted sources such as the Rocky Mountain Research Station often note that Wyoming's forests cover approximately 10.5 million acres (17% of the State's land area). The difference can be explained by exclusion of certain tree species from the scope of the study: Pinyon-Juniper woodlands, Limber Pine-Juniper woodlands, and Great Plains floodplain species (e.g., Cottonwoods). It was determined these exclusions better achieve an economic valuation of the specific ecosystem services provided by large and connected tracts of forest ecosystems.

Key Limitations

While Wyoming's forests have long-supported important industries like ranching agriculture and timber harvesting, this analysis was used to highlight ecosystem services that have not been traditionally monetized. Nevertheless, these industries are inextricably linked to the benefits provided by Wyoming's forest ecosystems.

Agriculture

Agriculture plays an important role in the Wyoming economy, generating $2.1 billion of gross revenue in 2014. This production generates total economic activity of $4.2 billion in the state's economy, which supports more than 33,000 total jobs and nearly $950 million of total labor earnings (Taylor et al., 2017). Forested rangeland plays a critical role for many Wyoming ranching operations, supplying a main source of forage during certain seasons of the year. Wyoming ranches hold approximately 1,982 federal grazing permits, representing 2.4 million Animal Unit Month (AUMs) of grazing, many of which are associated with forested lands (Taylor et al., 2022).

This study required defining forests as areas with tree cover, which resulted in the omission of most grazable "rangelands" located adjacent to forested lands. Deriving a tenable value for the contribution that forest cover makes to cattle/sheep weight gain in Wyoming would require a different methodology outside the scope of this project.

Timber

Wyoming's forest product industry is also a significant component of Wyoming's economic and employment picture. A 2018 analysis reported that primary and secondary wood products manufacturers, and forestry, logging, and forestry support firms directly contributed approximately 952 jobs and $41.4 million in labor income to the State. In total, 30 primary wood-processing facilities were in operation across 15 Wyoming counties in 2018. These facilities included a wide variety of wood-processing capabilities – 12 sawmills, 12 post and pole producers, 2 log home manufacturers, 1 log furniture manufacturer, and 3 other wood products facilities (Marcille et al., 2021). Many of these facilities have been able to increase efficiencies with technological investments in recent years, enabling them to utilize more wood, by-products, and mill residue than ever before. Noteworthy, also, is the economic commerce that takes place between Wyoming and its neighboring states, driven by the wood products provided by forest ecosystems.

This high-level valuation study required analysts to make multiple assumptions, simplifications, and generalizations. Additionally, the best available data was limited. More primary data would make the study more detailed and robust. More in-depth analyses for individual services would also improve the accuracy of value estimates for those services.

1. Introduction

Wyoming's forests are essential ecosystems that regulate and supply water, provide wildlife habitat for valued species, sequester and store carbon, and provide recreational opportunities, among many other important benefits. They are diverse, ranging from dry ponderosa pine woodlands, lodgepole pine monocultures, and mixed conifer montane forests dominated by firs and spruce, to stands of whitebark pine in the far reaches of the subalpine and alpine. Throughout the state's history, forests have shaped communities and industries. They also support a deep cultural heritage, livelihoods such as ranching and timber, and key aspects of public health. And beyond Wyoming, the state's forests store and provide water to four major river basins in North America.

Nonetheless, our forests are increasingly vulnerable in a drying and warming climate, and it is critical that we help them adapt. A warmer, drier climate and decades of under-funded forest management have made forests susceptible to increased wildfire and vulnerable to disease and insect damage. Investing in forest conservation and restoration is critical for retaining the benefits provided by our forests well into the future.

An important step in accelerating investments in forest health is understanding the economic value of "ecosystem services" provided by forests – benefits that are essential to our quality of life, but which we generally take for granted. Better understanding our forests' full value is especially important because conservation investments often compete with other economic development priorities. To facilitate more clear economic comparison, The Nature Conservancy in Wyoming (TNC) and Wyoming State Forestry Division commissioned this study to estimate the monetary value of the benefits provided by Wyoming's forest ecosystems. When costs and benefits from different land use options are evaluated with the same metrics (i.e., dollars or dollar equivalents), the comparative value of conservation can become more evident.

Forests provide both market and non-market benefits to communities throughout Wyoming and across the United States. Market benefits include revenue from outdoor recreation and forest-based tourism (e.g., visitor fees, equipment purchases, hunting licenses, etc.). These are monetary benefits in which markets exist. Non-market benefits include wildlife habitat, water supply, soil retention, and aesthetic value. Millions of people nationwide depend on Wyoming's headwaters. Forests regulate rainfall patterns, serve as catchment areas, and filter water along riverbanks to increase water quality not only in the state but far beyond. Each year 16.3 million acre-feet of surface water is produced through precipitation alone across Wyoming and is spread across the Mississippi, Colorado, Snake, and Columbia Rivers (Jacobs & Brosz, 1993).

Americans from Los Angeles to New Orleans drink water that originates in Wyoming forests. Yet unlike timber products or coal, they pay nothing back to Wyoming for it. Moreover, as droughts become more frequent and long-lasting, forests and watershed protection will be even more important to ensure reliable water supplies.

This ecosystem service valuation study includes 15 ecosystem services provided by 9.2 million acres of forests on public and private land in Wyoming that have not traditionally been monetized. The value of these can be used to better understand the benefits of conservation and treat forests as natural capital. This valuation includes both current financial flows of money to industries dependent on the ecosystem services provided by forests, as well as the more intangible benefits, which translate into quality-of-life enhancements. These non-market benefits often do not have formal markets and are hence provided for free by Wyoming's forests. For example, clean air and water are services provided by forests' ecological functions which we do not pay for but greatly value.

Understanding the value of forest ecological functions, the way that these become benefits to people, and how we value these benefits is at the core of this valuation. This study aims to provide better understanding of the economic value provided by Wyoming's forests so that our natural resource management agencies, the private sector, governments, communities, and other stakeholder groups can make more informed decisions about investments in forest health.

1.1 Understanding Nature's Value

Clean air, clean water, healthy food, flood risk reduction, waste treatment, timber, and a stable climate are all examples of ecosystem goods and services. These are defined as the benefits people derive from nature. Ecosystems, such as forests, are a type of capital (natural capital) that produce ecosystem services through their ecological functions (Figure 1.1). Like financial capital, if we do not use it wisely, we can run the risk of losing value and productive potential now and in the future. Without ecosystems (forests, wetlands, rangelands, farmlands), we would not have the benefit of nature's services, which are in fact the basis of most economic activity. In Wyoming, forests are critical natural capital that can produce goods and services into the indefinite future. The health of Wyoming's forests affects people, industries, and communities.

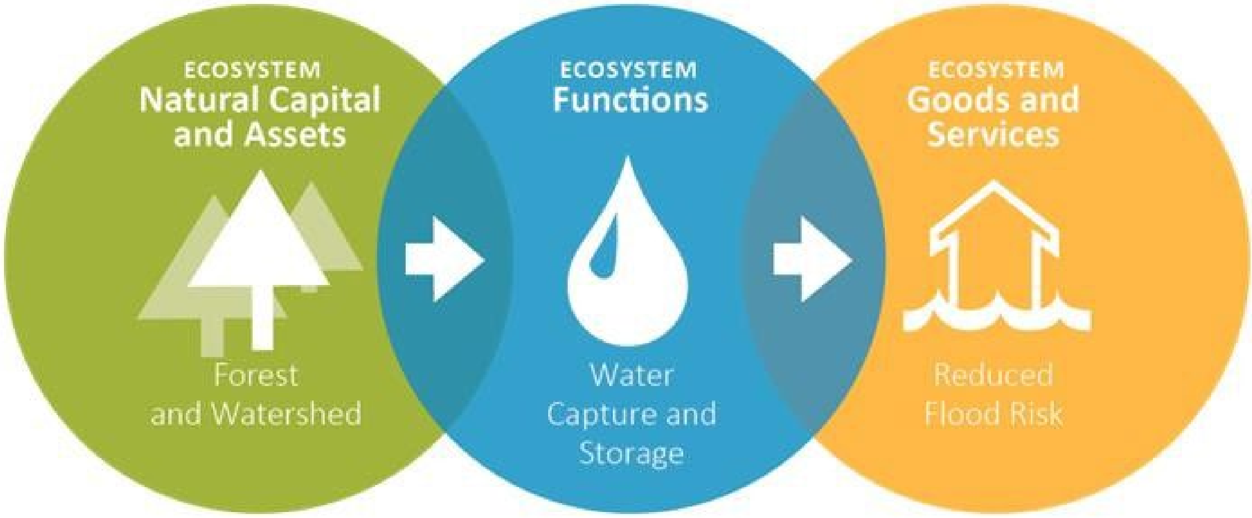

Figure 1.1 The relationship between ecosystems, functions and services.

In 2001, an international coalition of over 1,360 scientists and experts from the United Nations Environmental Program, the World Bank, and the World Resources Institute assessed the effects of ecosystem change on human well-being. A key goal of the assessment was to develop a better understanding of the interactions between ecological and social systems, and in turn to develop a knowledge base of concepts and methods that would improve our ability to "…assess options that can enhance the contribution of ecosystems to human well-being" (MEA, 2005). This study produced the landmark Millennium Ecosystem Assessment, which classifies ecosystem services into four broad categories according to how they benefit humans. These categories are as follows:

- **Provisioning goods** provide physical materials and energy for society from natural systems. Forests produce lumber and fruits, which can be directly consumed and sold in markets.
- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact forests 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 named above includes a suite of different services and contributions. Table 1.1 identifies the ecosystem services valued in this analysis within these four categories and the economic benefits provided to people.

Table 1.1 List of ecosystem services provided by natural capital.

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
Global Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and carbon stock storage.
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 Retention/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.
Local Climate Regulation	Shade provided by forests can reduce local temperatures and provide energy savings
Supporting	
Wildlife 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

Some of these services are provided within markets (such as timber sales or recreational expenditures), however many are provided free of charge, outside markets. Regulating and provisioning services are often provided outside market settings, often resulting in a lack of incentives for their conservation and in potential inefficient management of the forests. By calculating their economic value, they can be put in the same playing field as many other market goods and services, which benefit from economic incentives for their protection and efficient use. Moreover, by treating forests like a form of capital, and an asset, we can make better economic decisions that will benefit us now and in the future.

This study dives into some of these critical ecosystem services to better understand their importance and the economic value associated with each of them.

2. Methods

2.1. Overview of the Methodology

This study analyzes the provision of ecosystem services by forests in Wyoming to better understand their importance and their economic value. To do this, we first conducted a spatial analysis to characterize forest types across the state as well as biophysical attributes that are likely to influence ecosystem service production. To prioritize ecosystem services for valuation and to guide the framing of the study, we conducted a survey distributed to Wyoming residents on their preferences and values. The core ecosystem service valuation is then done through a Benefit Transfer Method (BTM) which involves distilling data and values obtained from existing valuation studies conducted in Wyoming or in comparable ecosystems. We complement and refine many of these values with local data regarding prices, wildlife population counts, or consumer behavior. Five ecosystem services are studied in more detail, including recreation, wildlife habitat, global climate stability, water supply and storage as well as water quality.

Values for an additional 10 ecosystem services are also estimated through the BTM approach and translated into per acre values for different forest types. Using forest type acreage and their respective ecosystem service values, an overall value is derived for all of Wyoming's forests.

2.2. GIS Characterization of Wyoming's Forests

2.2.1. Forest Distribution by Type and Density

The first step to this valuation was to establish the total forest acreage in the state. The National Land Cover Database (NLCD) produced by the Dewitz and the U.S. Geological Survey (2021) was first used to distinguish forests from other land cover types. The NLCD forest categorization classes include deciduous, evergreen, and mixed forests. Each of these forest types are presented in Table 2.1. The total NLCD Wyoming forest area adds up to 7,192,162 acres (Dewitz, J & USGS, 2021), which is lower than what the 2016 LANDFIRE data shows (U.S. Department of Agriculture et al., 2020). LANDFIRE is a suite of data products published by the USDA, USDOI, and USGS. According to McKerrow et al. (2016), these discrepancies can arise because the "NLCD shrub definition is based solely on height and includes true forest types that are regenerating, while the LANDFIRE definition is primarily based upon species."

Table 2.1 and Figure 2.1 show the extracted land cover types based on NLCD for the year of 2019 in Wyoming:

Table 2.1 National Land Cover Database acreage by land cover type.

NLCD Class	Acres
Open Water	444,923
Perennial Ice/Snow	12,792
Barren Land (Rock/Sand/Clay)	765,126
Deciduous Forest	247,375
Evergreen Forest	6,898,072
Mixed Forest	46,715
Shrub/Scrub	35,392,600
Grassland/Herbaceous	15,113,060
Sedge/Herbaceous	911,012
Woody Wetlands	458,037
Emergent Herbaceous Wetlands	772,241

Source: Dewitz, J & USGS, (2021), CSF Elaboration.

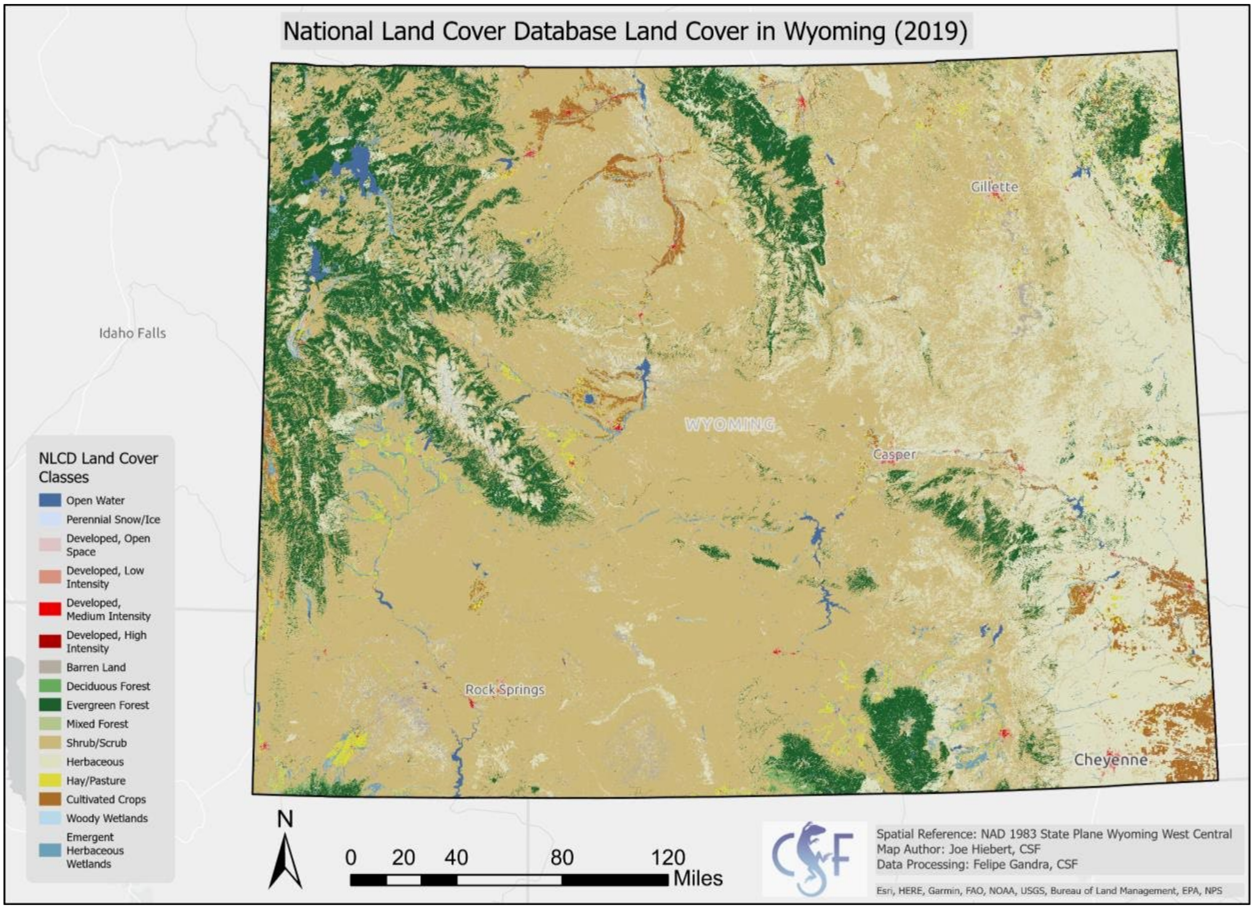

Figure 2.1 National Land Cover Database land cover in Wyoming.
Source: Dewitz, J & USGS (2021), CSF Elaboration.

Given the different possibilities, LANDFIRE's Existing Vegetation Type (EVT) Database was subsequently used to further identify forest types to be included and determine their distribution across the state. This data source is more detailed and granular, particularly with respect to forests.[1] The EVT data represents "the current distribution of the terrestrial ecological systems classification, developed by NatureServe for the western hemisphere (…) and defined as a group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients" (U.S. Department of Agriculture et al., 2020). Certain forest types were excluded in this valuation to ensure consistency with other TNC Forest strategies in the state. LANDFIRE provides a depiction of forest types by tree species.

[1] LANDFIRE EVT is mapped using decision tree models, field data, Landsat imagery, elevation, and biophysical gradient data.

Table 2.2 summarizes the EVT vegetation types chosen for exclusion and subtracted from the total forest acreage found for the state.

Table 2.2 LANDFIRE Existing Vegetation Type categories chosen for exclusion.

Value	EVT Name	EVT Sub-Class
7016	Colorado Plateau Pinyon-Juniper Woodland	Evergreen open tree canopy
7049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	Evergreen open tree canopy
9014	Northwestern Great Plains Floodplain Forest and Woodland	Deciduous open tree canopy
9015	Northwestern Great Plains Riparian Forest	Deciduous open tree canopy
9026	Western Great Plains Floodplain Forest and Woodland	Deciduous open tree canopy
9028	Western Great Plains Riparian Woodland	Deciduous open tree canopy

Source: U.S. Department of Agriculture et al., (2020), CSF Elaboration.

Forest types were also classified into "sparse tree canopy" (10-25% canopy crown closure), "open tree canopy" (25-60% canopy crown closure) and "closed tree canopy" (60-100% canopy crown closure), to illustrate tree density.[2] Figure 2.2 displays this additional forest layer according to the LANDFIRE EVT typology, and Table 2.3 summarizes the acreage for each forest class.

Using this system, the total forest area calculated for Wyoming was 9,207,068 acres, which excludes 109,068 acres as shown in Table 2.3. Without these exclusions, total forest would be 9,316,136 acres.

[2] A re-classification table (.csv format) was employed to re-code the EVT 2016 raster in QGIS, excluding the aforementioned classes and aggregating entries according to the "EVT_CLASS" LANDFIRE attribute, based on FGDC classes from the USDA National Vegetation Classification Standard (Brohman et al., 2005).

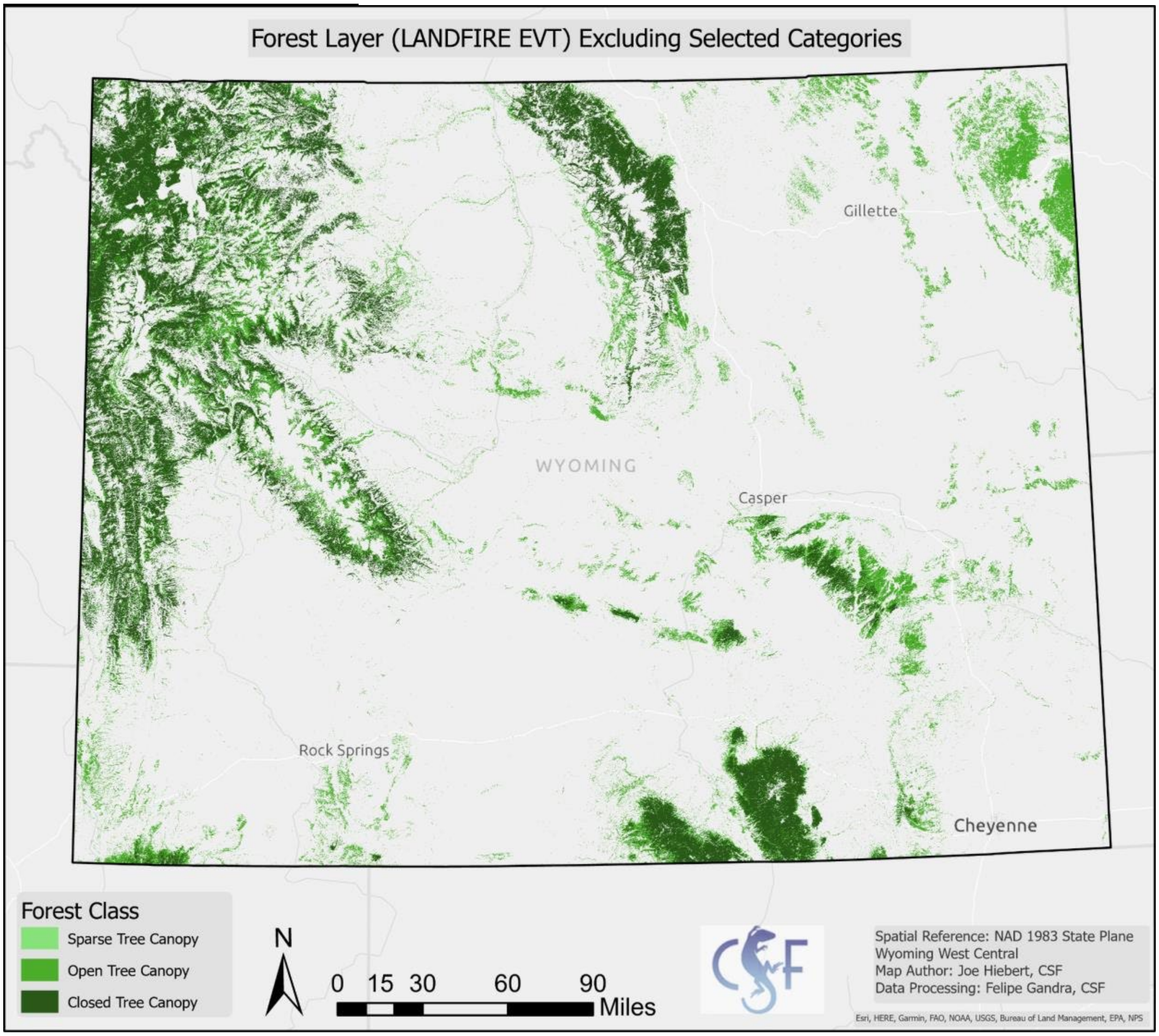

Figure 2.2 Forest layer (LANDFIRE EVT) excluding selected categories. Source: U.S. Department of Agriculture et al., (2020), *CSF Elaboration.*

Table 2.3 Forest acreage (with TNC-excluded areas) for the state of Wyoming.

Forest Classes	Acres
Sparse tree canopy	11,319
Open tree canopy	3,926,534
Closed tree canopy	5,269,215
Total forest acreage	9,207,068
Acreage excluded	109,068

Source: U.S. Department of Agriculture et al., (2020), CSF Elaboration.

To further understand ecosystem functionality, the IUCN Global Ecosystem Typology 2.0 was also used to characterize forest ecosystems. The IUCN typology represents both ecosystem function and biodiversity and is often used to value natural capital (Keith et al., 2020; United Nations, 2021). The typology is based on a consistent hierarchical classification system that, in its upper levels, defines ecosystems by their convergent ecological functions − providing "a framework for understanding and comparing key ecological traits of functionally different ecosystems and their drivers." The top level divides the biosphere into five global realms, the second comprises 25 subcomponent biomes, and the third level, which was used here to further characterize forests in Wyoming, specifies 108 Ecosystem Functional Groups portraying ecosystems that share common ecological dependencies and convergent biotic traits.

Two Ecosystem Functional Groups (EFGs) were found to characterize Wyoming forests: Boreal and Temperate Montane Forests and Woodlands (T2.1) and Temperate Woodlands (T4.4). The key ecological drivers and traits in each of these functional groups are presented in Figure 2.3 and Figure 2.4. Boreal and Temperate Montane Forests (Figure 2.3) are distributed across Eurasia and North America, extending to temperate latitudes on mountains, whilst Temperate Woodlands (Figure 2.4) occur in temperate southeast and southwest Australia, southern areas of South America, the Mediterranean region and temperate Eurasia (Keith et al., 2020).

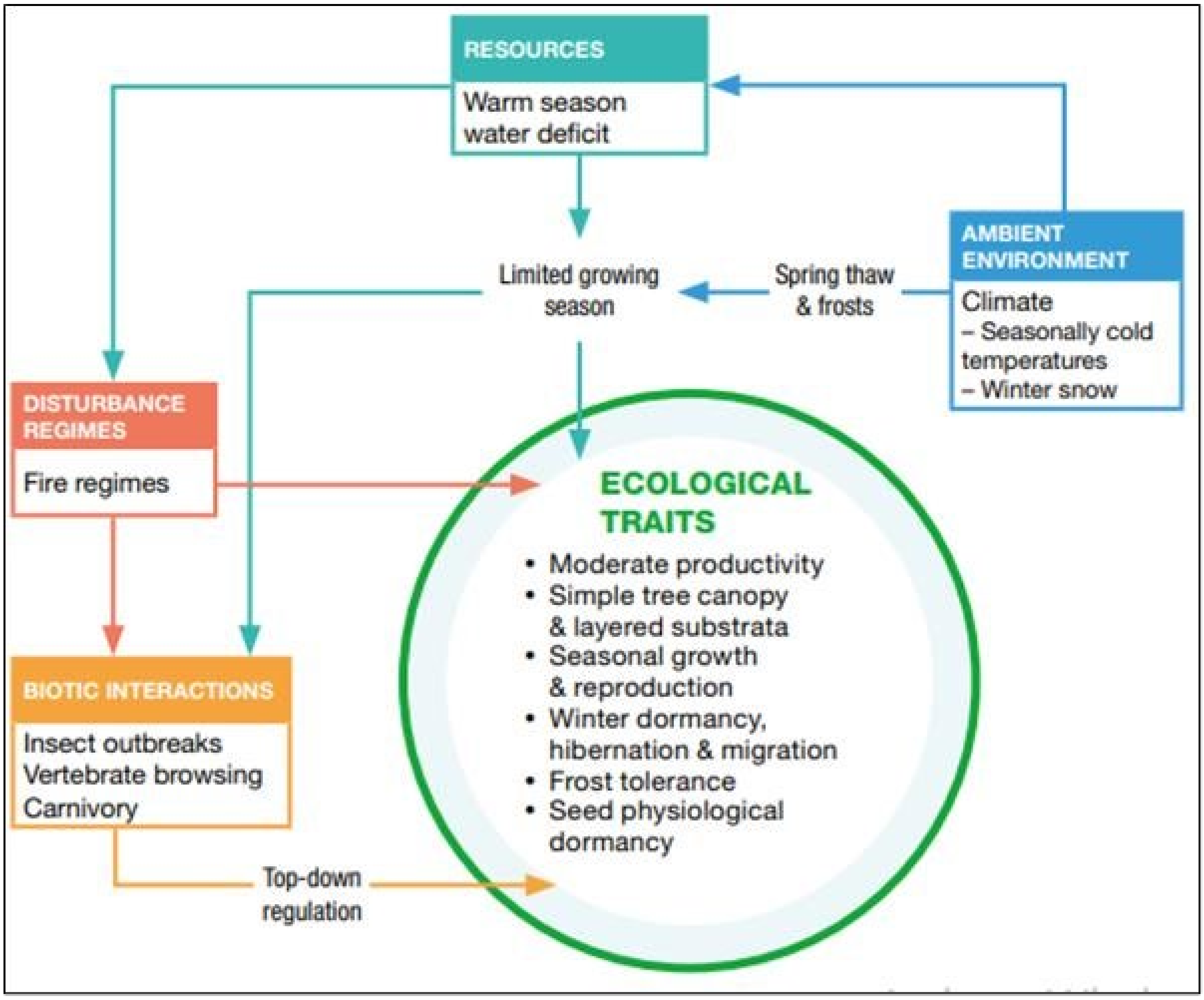

Figure 2.3 Key ecological traits and drivers for T2.1 ("Boreal and Temperate Montane Forests and Woodlands").
Source: Keith et al., (2020)

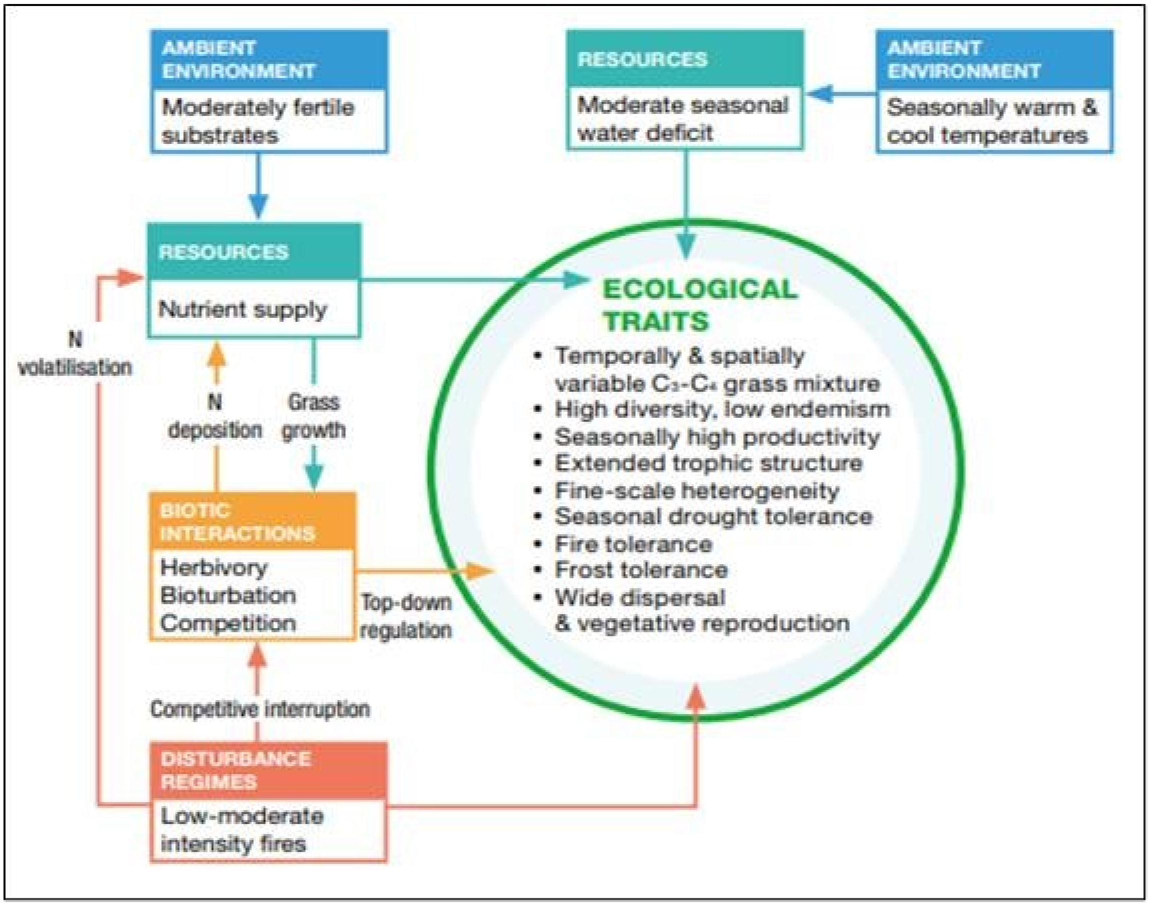

Figure 2.4 Key ecological traits and drivers for T4.4 ("Temperate Woodlands"). Source: Keith et al., (2020)

Each of these groups has a respective shapefile (GeoJSON format) available for download (Keith et al., 2021) and they were clipped to the extent of WY and overlaid with the forest layer developed in the previous step, which created two separate forest functional groups. A visual illustration of this step is presented in Figure 2.5, showing how forest areas in Wyoming were defined according to the IUCN functional group “Temperate Woodlands”.

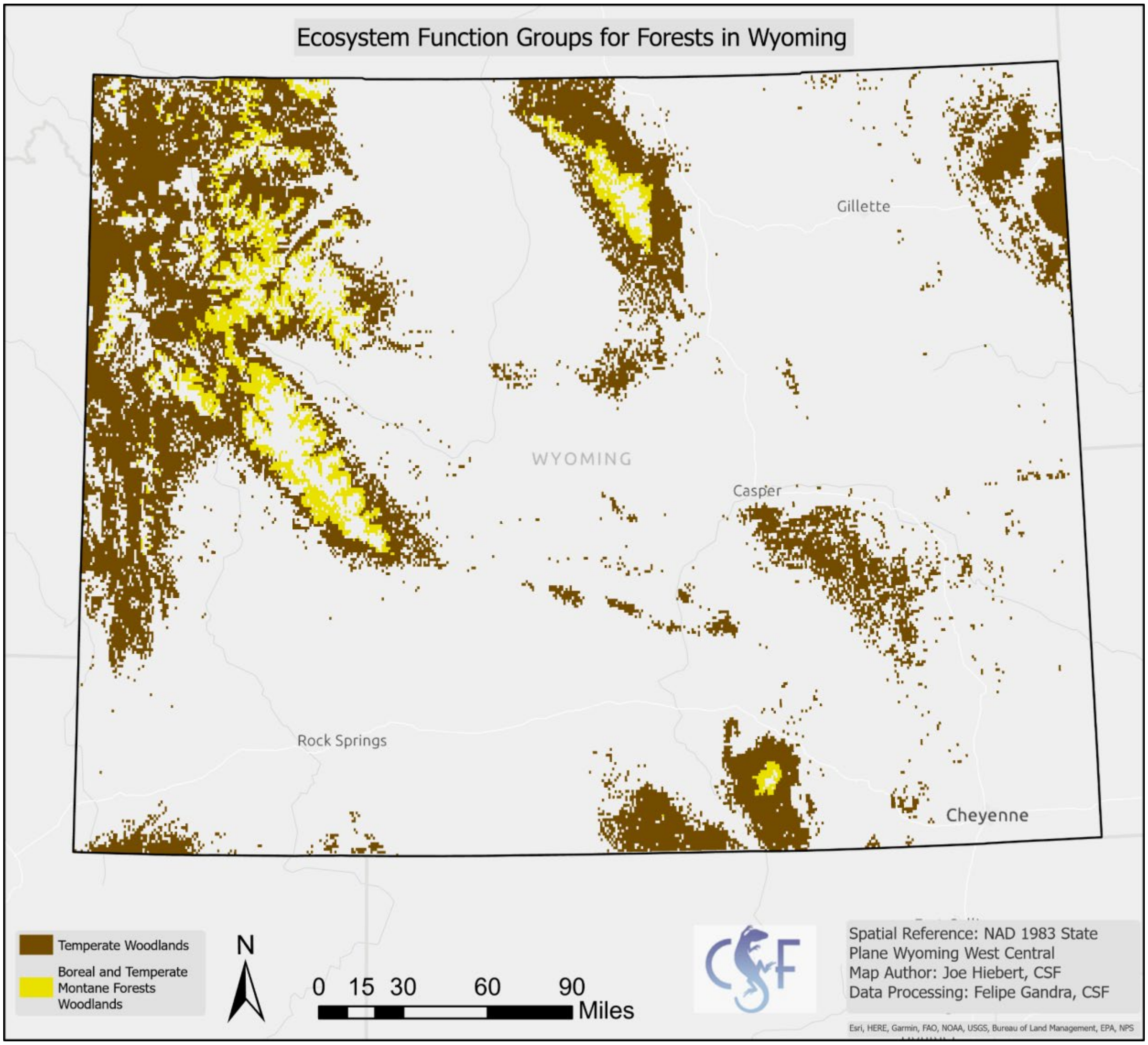

Figure 2.5 Ecosystem function groups for forests in Wyoming.
Source: Keith et al., (2020); U.S. Department of Agriculture et al., (2020); CSF Elaboration.

Acreage by forest type for these IUCN Ecosystem Function Group Classification is presented in Table 2.4.[3]

[3] Forest pixels outside of the boundaries were considered "boreal and temperate montane forests and woodlands," until further GIS refinement.

Table 2.4 Forest cover by IUCN ecosystem functional group.

IUCN Ecosystem Functional Group	Acres	Percent
Temperate Woodlands	7,605,529	86.9%
Boreal and Temperate Montane Forests and Woodlands	1,601,539	13.1%
Total forest cover (excluding TNC selected areas)	9,207,068	100.00%

All the different classification systems can be used to better understand the types of forest found in Wyoming from a biophysical perspective. Ultimately, the LANDFIRE classification system was retained for estimating acreage in the study.

2.2.2. Further Attributes of Wyoming's Forests

There are many ecological and socio-economic attributes that influence ecological functions and their ability to provide ecosystem services. For example, proximity to people or to other land uses can impact their value. Forests adjacent to rivers can improve water quality and prevent erosion. Recreational activities may also depend on access to the forests and permitted uses. To better characterize the forests of Wyoming and to guide the selection of applicable values, additional GIS data was collected to identify key ecological, social and economic attributes. More in particular, these three attributes were spatially depicted for this analysis:

Riparian Corridors

Riparian corridors refer to areas alongside or adjacent to streams, rivers, lakes and other water bodies. They are particularly important because some kinds of wildlife habitat or water-based recreational activities are only possible in riparian zones. For this study, riparian buffer areas for Wyoming were extracted from EnviroAtlas' Watershed Index Online Riparian Zone layer (EPA, 2020), which uses data created by the U.S. Geological Survey. They produce a 108 meter buffer around surface water features such as rivers, streams, lakes, reservoirs, oceans, estuaries and wetlands. These features are drawn from a 2011 National Land Cover Database (NLCD) hybrid map and a 2011 Cropland Data Layer (CDL). The data is combined with flowline and waterbody features from the National Hydrography Dataset (NHD) Plus (version 2.1), after which the distance from surface water features is calculated (EPA, 2020).

In order to derive the amount of forest acres within this riparian buffer network, the EnviroAtlas riparian zone map was overlaid with the forest layer depicted in Figure 2.2, leading to the output in Figure 2.6. The total riparian forest acreage was calculated at 1,749,589 acres, or roughly 19% of the forest acreage in Wyoming. This information was later applied to the valuation estimates in order to distinguish the additional benefits provided by riparian forests in the state.

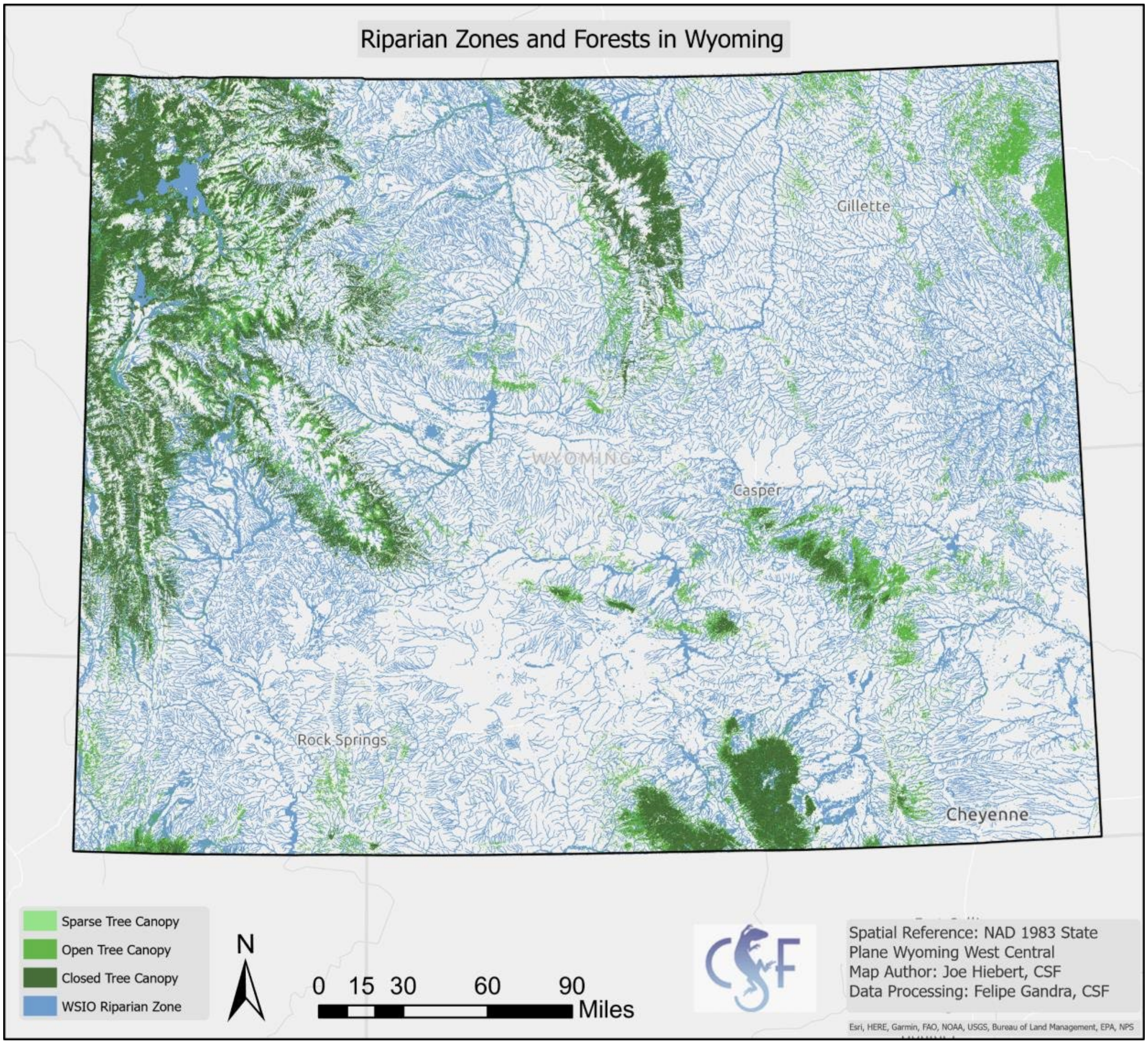

Figure 2.6 Riparian forest buffer considered in this study.

Forest Contiguity

A contiguous tract of a single land cover type can provide greater ecosystem services due to its size and continuity. Wyoming's forests in the Greater Yellowstone ecosystem, for example, provide greater and more crucial wildlife habitat because of its size and continuity. For this study, a simplified assumption was made for contiguous forest areas based on outputs from LANDFIRE EVT. After clipping forested areas and excluding vegetation categories described above, the variable “EVT_CLASS” was used to classify forest cover according to “sparse tree canopy” (10-25% crown closure), “open tree canopy” (25-60% crown closure) and “closed tree canopy” (60-100% crown closure). The latter category (“closed tree canopy”) was assumed to represent contiguous tracts of forest, while the other two were not. This led to a total contiguous forest area of about 5,269,215 acres, or close to 57% of the total forest acreage of the state. This definition is particularly important since habitat values are directly impacted by this characteristic, as can be read in the appropriate section further in the report.

Forest Ownership

Information on land ownership was used to understand forest management regimes, protected area designation, permitted activities and the frequency of use of forests for recreational activities. This information comes from the Protected Areas Database (PAD-US), managed by USGS (USGS Gaps Analysis Project (GAP), 2022). For the 9.2 million acres of forest considered in this project, we identified 17 different land managers, including federal agencies, state and local governments as well as private and tribal lands (Figure 2.7). Apart from private lands, the Forest Service and the National Park Service were identified as the largest land managers. This information was used to identify recreational activities and uses and estimate values for this service (recreation and tourism).

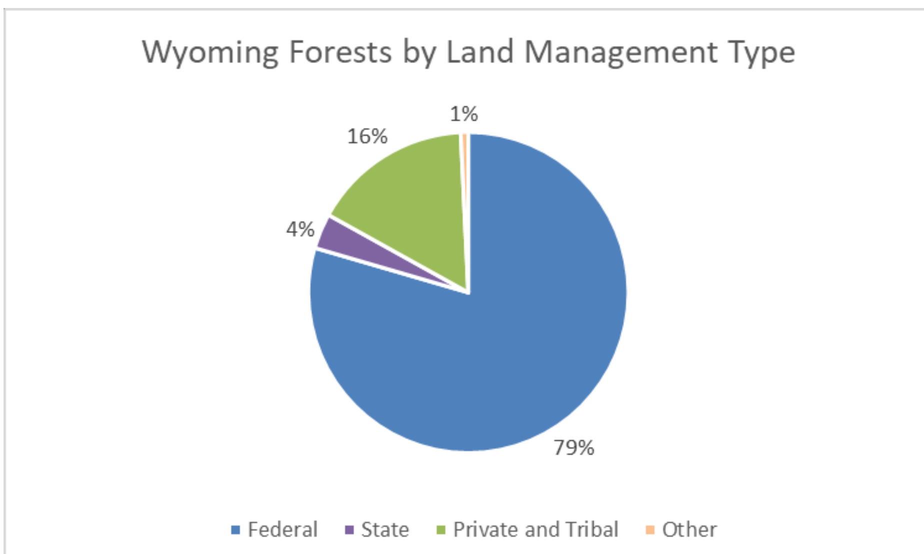

Figure 2.7 Wyoming forest acreage classified by land management type.

2.3. Ecosystem Service Valuation of Wyoming's Forests

There are a variety of methods for valuing the different ecosystem services provided by forests. The physical nature of ecosystem services determines the correct method for valuation. Lumber sold in markets can be valued with a market method. Recreational benefits can be valued with travel cost methods (the amount of money people spend to have a recreational experience). Disaster risk reduction and flood control value, like the valuation of dams, is based on an avoided cost approach (the avoided cost of flood damage).

Economics uses different valuation methods to value different things. Values are assigned to each income flow (e.g., ecosystem service) and asset (e.g., forest type) based on their condition and market factors such as frequency of use or willingness to pay. The sum of all the ecosystem service values represents an estimate of the total value. For example, a building may be valued based on the rent received from all the different units that make up the building. Similarly, each ecosystem service value may be added to estimate the value of the forest. In turn, the expected flow of value over the lifetime of the forest (or building) can be used to estimate an asset value.

In this valuation, each ecosystem service is valued separately and when added together at the end, to represent an overall value for Wyoming's forests. The value of providing clean water is separate and additive to the value of forests for hunting or erosion control. Each value pertains to a different beneficiary and amount of value. Table 2.5 below shows common and well accepted ecosystem service valuation methods that were used in the values selected for this valuation.

Table 2.5 Ecosystem service valuation methods.

Direct Market Methods: Observable markets with direct market prices
Where well-functioning markets exist (e.g., they satisfactorily capture consumer values and costs), prices can be used to represent the ecosystem service value. For example, fees paid to landowners for hunting leases reflect the value placed directly on the ecosystem's production of habitat for recreation (hunting). But most ecosystem services are not provided through markets. Also, if markets exist, they may misestimate the true value of the ecosystem service due to subsidies, externalities, or market distortions. Also, given that certain goods and services are often provided by public institutions or are highly regulated (e.g., water supply), the prices for these services will be artificially distorted. If the price paid embodies other significant factors of production (e.g., inputs, labor, technology), an indirect market price method should be considered, such as residual value estimates.
Indirect Market Methods: Prices in related markets are used as proxies.

Given that ecosystem service values include the contribution of nature to economic activity, prices from existing markets can be used to distill the specific contribution from nature by looking at substitute goods that are traded in market to get a proxy value or complementary goods that are used in combination with ecosystem services to create economic value. Within this category of valuation methods one can use referential markets (markets for similar or substitute goods), residual values (subtracting the costs of other factors of production from gross market values), production functions (valuing ecosystem services as factors of production).
Revealed Preference Methods: Uses consumer purchasing decisions and/or behavior to infer ecosystem service values.
When there are no suitable direct or indirect markets to dissect to extract ecosystem service values, consumer behavior is used to infer the values placed on ecosystem services relative to other goods and services. These methods include hedonic valuations (extracting premiums placed on property values for environmental amenities), averting behavior (expenditures to prevent or mitigate negative environmental impacts), travel costs (uses costs and time spent going to natural lands).
Cost Based Methods: The cost of damages that would be incurred by communities in the absence of ecosystem services.
When demand-based approaches are not possible or suitable, ecosystem service values can be valued based on provisioning costs. These methods assume that people would be willing to pay at least as much as it costs to provide these services. Specific methods include replacement costs (approximating value with what it would cost to replace these with market substitutes), avoided costs (estimated damages that would be incurred by communities in the absence of ecosystem services) or mitigation or restoration costs.
Stated Preference Methods: These methods are based on surveys asking respondents' willingness to pay or willingness to accept for the provision of different ecosystem services.

These surveys are also used in marketing studies and are rigorously conducted to infer realistic willingness to pay or accept values for the provision of different levels of ecosystem services, which allows for the creation of a demand curve. These surveys are also often the only way to estimate non-use values. Specific methods include contingent valuation surveys or choice modeling or conjoint analysis.

The benefit transfer method uses existing data from published valuation studies.

The benefit transfer method uses secondary data to estimate the value of an asset or benefit stream. Like a house or business appraisal, this method estimates value by applying "comparable" sales or primary valuation data already completed in similar locations or contexts.

2.3.1. Benefit Transfer Method Employed in this Report

For this valuation, the Benefit Transfer Method (BTM) was used. In this method, the biophysical characterization of Wyoming's forests was used in conjunction with economic valuation studies (employing one of the methods above) to derive the dollar values for forests in Wyoming. Like a house or business appraisal, BTM calculates the economic value by using economic data from similar or comparable study areas and applying them to the target site (i.e., Wyoming's forests). Many of the studies used in this valuation were from Wyoming itself while others were from similar ecosystems and demographic areas.

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 uses various attributes (number of rooms in a house, or different assets in a business) to establish the similarity between places. In this valuation geography, population density, and ecosystem size were considered as attributes to ensure comparability.

An in-house database of more than 4,000 ecosystem service values dissected from existing studies was used to identify comparable ecosystem service values. All categories of ecosystem goods and services listed below are present and valuable in Wyoming forests. However, not all clearly valuable forest goods and services have dollar values as there are yet many gaps in forest ecosystem services valuations. Therefore, this valuation is still an underestimate of the total value of forests in Wyoming.

A total of 19 studies were selected for the benefit transfer, with 79 distinct values for 15 different Wyoming forest ecosystem goods and services (See Appendix E. General Benefit Transfer Valuation Studies). The list of ecosystem services valued in this study is presented below:

- Aesthetic information
- Air quality
- Biological control
- Cultural value
- Energy and raw materials
- Flood risk reduction
- Food
- Global climate stability
- Local climate regulation
- Recreation and tourism
- Science and education
- Soil retention
- Water supply and storage
- Water quality
- Wildlife habitat

Some of these ecosystem services were studied more in-depth because of their particular relevance and importance in Wyoming. These included water supply and storage, recreation and tourism, global climate stability, and wildlife habitat.

All values are presented in a per acre per year unit. Even if studies do not originally publish their results in this unit, data provided within the study or easily accessible public data is used to translate results into a per acre annual value to ensure consistency within the results and to be able to sum across categories. References for every value are presented in Appendix E. General Benefit Transfer Valuation Studies.

Given that there are limitations on the precision of the ecosystem service values that are estimated through a BTM approach, a range of possible values is often provided for every ecosystem service. The inclusion of a range of values reflects the availability of multiple studies for a given ecosystem service and the variance that can be found across forest types. For example, if there are two studies of comparable quality and transferability for estimating the value of recreational hunting in Wyoming's forests, both results will be presented in the form of a range from the lower available value per acre to the higher available value per acre.

2.3.2 Contingent Valuation

In addition to the BTM described in the previous section, a rapid contingent valuation (CV) was carried out to better understand local preferences and ecosystem service relevance as well as values associated with Wyoming's forests. CVs are one of the most common valuation tools, involving a survey on the willingness to pay (WTP) for a change in ecosystem quality or ecosystem service provision. The survey conducted in this study focused on understanding the relative importance of the different forest related ecosystem services being provided in Wyoming and deriving a WTP to ensure continued forest health in the state. This information helped to guide the overall valuation and prioritize ecosystem services for valuation.

The CV survey consisted of a total of 7 questions (see Appendix B. Contingent Valuation Survey) and was intentionally kept short to maximize response rates. It was an online survey distributed through posts on reddit and Facebook groups as well as via professional networks of both The Nature Conservancy and the Conservation Strategy Fund. A QR code was also created and distributed via posters and handouts at various social spots (restaurants, supermarkets, hardware stores, retail shops) throughout Wyoming, including Lander, Riverton, Jackson, Sheridan, and Cody during the months of May, June and July 2022. Given the distribution channels, the sample collected cannot be considered random nor completely representative of Wyoming's population, but it does provide various perspectives from residents in the places where it was distributed. Moreover, due to time and distribution constraints, the number of responses remained relatively low which could also affect the representativeness of the sample.

A total number of 77 responses were collected but of these, only 75 were retained due to the exclusion of outliers (extreme numbers that are deemed unrealistic). Most respondents (77.3%) considered almost all ecosystem services "important" or "extremely important". In terms of specific ES types, the categories with the highest levels of importance[4] were "Wildlife habitat" followed by "Water supply and storage", "Water quality" and "Recreation". Less important ecosystem services were "Wood/timber" and "Climate change impact reduction". The word cloud in Figure 2.8 visually demonstrates those ecosystem services considered more important (bigger font) and less important "smaller font".

[4] Attributed levels of importance by ES type were converted to values of -2,-1,0,1,2 and then multiplied by number of responses and added up to provide total "word values'' which were then divided by 10 as the software used (wordclouds.com) could only go up to a frequency of 99. The values were then rounded off to the nearest number (the program only accepts whole numbers) to be used as "weights'' to generate a word cloud using wordclouds.com.

Figure 2.8 Relative importance of ecosystem services according to the survey conducted.

Those ecosystem services considered most important were prioritized for a more in-depth analysis. Climate change impact reduction (global climate stability) was also studied in-depth as it is an integral part of the forest management strategies led by the Nature Conservancy.

Regarding the value results, the lowest amount respondents were willing to contribute towards Wyoming's forests was zero and the highest was $10,000 per year. The average (mean) WTP was $350 with a midpoint (median) WTP of $50 per year as shown in Table 2.6.

Table 2.6 Summary of responses for contingent valuation survey.

What is the maximum amount you would be willing to pay as an annual contribution?	
WTP	Value (US$)
Minimum	0
Median	50
Mean	350
Maximum	10,000
No. of obs.	75

The CV survey seeks to elicit a monetary value based on a hypothetical scenario where the respondent can choose to pay to keep the ecosystem service or not pay and lose it. However, being a hypothetical scenario can result in biased responses, particularly if the scenario is perceived as being lacking in credibility. Also, respondents may misunderstand or not fully understand the hypothetical scenario they are being asked to pay for or they may elicit protest responses. The simplicity of the survey may not have provided a clear enough picture or been sufficiently convincing to obtain thorough responses. Nevertheless, the survey was useful to the project to guide and contextualize the analysis conducted.

2.3.3 Structure of the report

The following sections present the in-depth analyses conducted for recreation, wildlife habitat, global climate stability, and water ecosystem services. These are all translated to a per acre value and are added to the other ten ecosystem service values that were derived through a pure benefit transfer method. These overall results are presented in section 7 as both a yearly flow of values as well as an asset value estimate for all of Wyoming's forests. The results obtained are discussed and compared with some of the findings from the survey in Section 8 (Discussion and Recommendations).

3. Recreation Values

3.1. Introduction to Recreation

One of the critical ways that forests provide value to individuals, communities and economies is through recreation opportunities. Recreation to experience the natural and unique lands of Wyoming is very valuable to both residents and tourists, as it creates jobs and boosts local economies through opportunities to engage in activities such as fishing, hunting, hiking and wildlife watching. Outdoor recreation is an important part of Wyoming's economy, driving 3.4% of the state's GDP in 2020 (Bureau of Economic Analysis (BEA), 2021). Recreation experiences in Wyoming are accessible mainly in the state's protected areas and public lands, which contain most of Wyoming's forests and preserve its impressive mountain ranges and diverse flora and fauna. In fact, Wyoming contains Yellowstone National Park, the world's first national park, making Wyoming the location of a significant recreation landmark for local residents and visitors alike.

Recreation in Wyoming's forests creates economic value in two ways. First, recreational activities provide individual benefits to participants. By engaging in enjoyable activities such as fishing, hiking, hunting, and wildlife viewing, participants experience a gain in quality of life, which can be measured through their willingness to pay for such experiences. This benefit is known in economics as consumer surplus. In addition, individuals participating in recreation activities pay for travel expenses such as hotels, restaurants and gas, purchase recreation-related items such as fishing gear, and pay fees for entrance and licenses. These expenditures support local industries and jobs and contribute to state and local tax revenue. This part of the analysis estimates the value of recreational activities in Wyoming's forests. We found that annually, recreation in forests in Wyoming generates almost $1.5 billion in expenditures and over $770 million in consumer surplus.

3.2. Methods for Recreation

This analysis involved first identifying landowners and or managers to better understand recreational activities throughout the different forests found in Wyoming. Forested land within each land manager was identified as well as the recreational activities that are provided by forest managers. Local data was collected on the frequency of each activity as well as the expenditures made. In addition, the benefit transfer method was used to estimate value beyond expenditures (consumer surplus) or to fill data gaps in places where local data was not available. Figure 3.1 below represents the various components of this analysis.

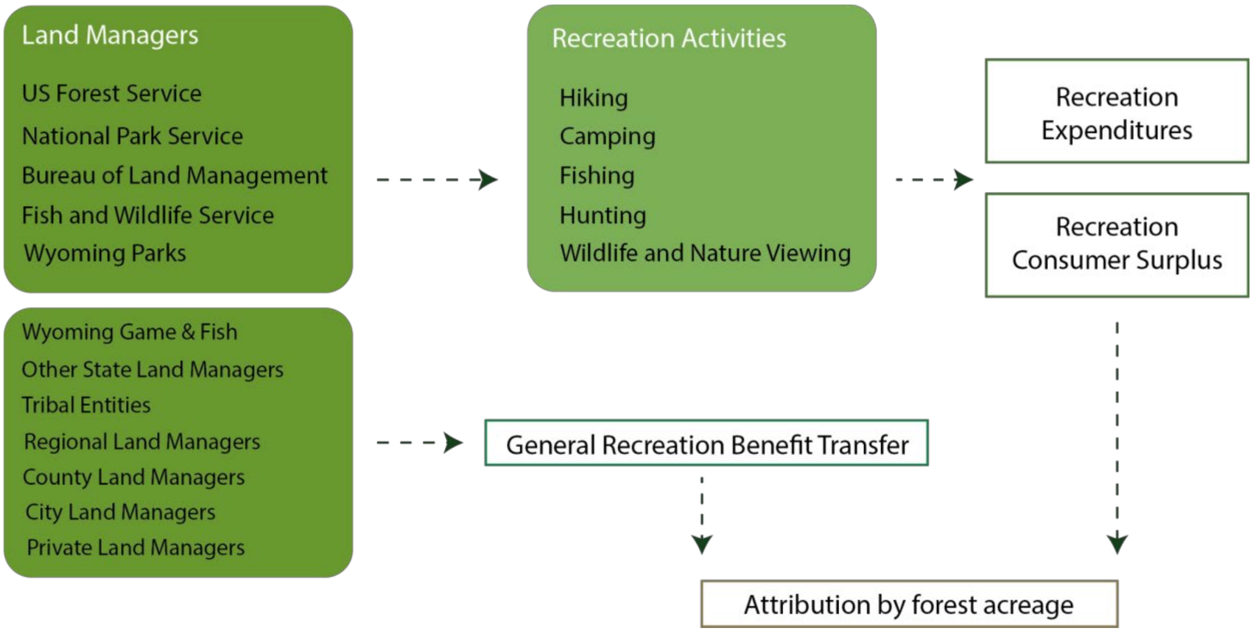

Figure 3.1 Recreation analysis methodology, indicating the land managers, activities, and types of economic values used for the analysis.

The level of recreation activity (and availability of recreation data) in forests is mainly based on the accessibility of forests, which is in part determined by land managers. For example, forests in national parks are more likely to have higher levels of recreation than private lands. There are also different activities allowed in different forest lands. To identify landowners and managers, we used data provided in the Protected Areas Database (PAD-US), which is a comprehensive database of all protected lands in the United States and includes information such as the agencies or organizations that manage protected areas and how they are managed (USGS GAP, 2022). We identified 17 different land managers for the 9.2 million acres of forest in Wyoming, including federal, state and local government agencies as well as tribal and private landowners. Of the 9.2 million acres identified as forest, 7.9 million acres were accounted for in PAD-US (ibid). The remaining 1.3 million acres were attributed to private lands. Besides private lands, the largest areas of forest in Wyoming are managed by the Forest Service and the National Park Service.

The Wyoming forest extent was overlaid with the PAD-US map for Wyoming to identify land managers as shown in Figure 3.2.

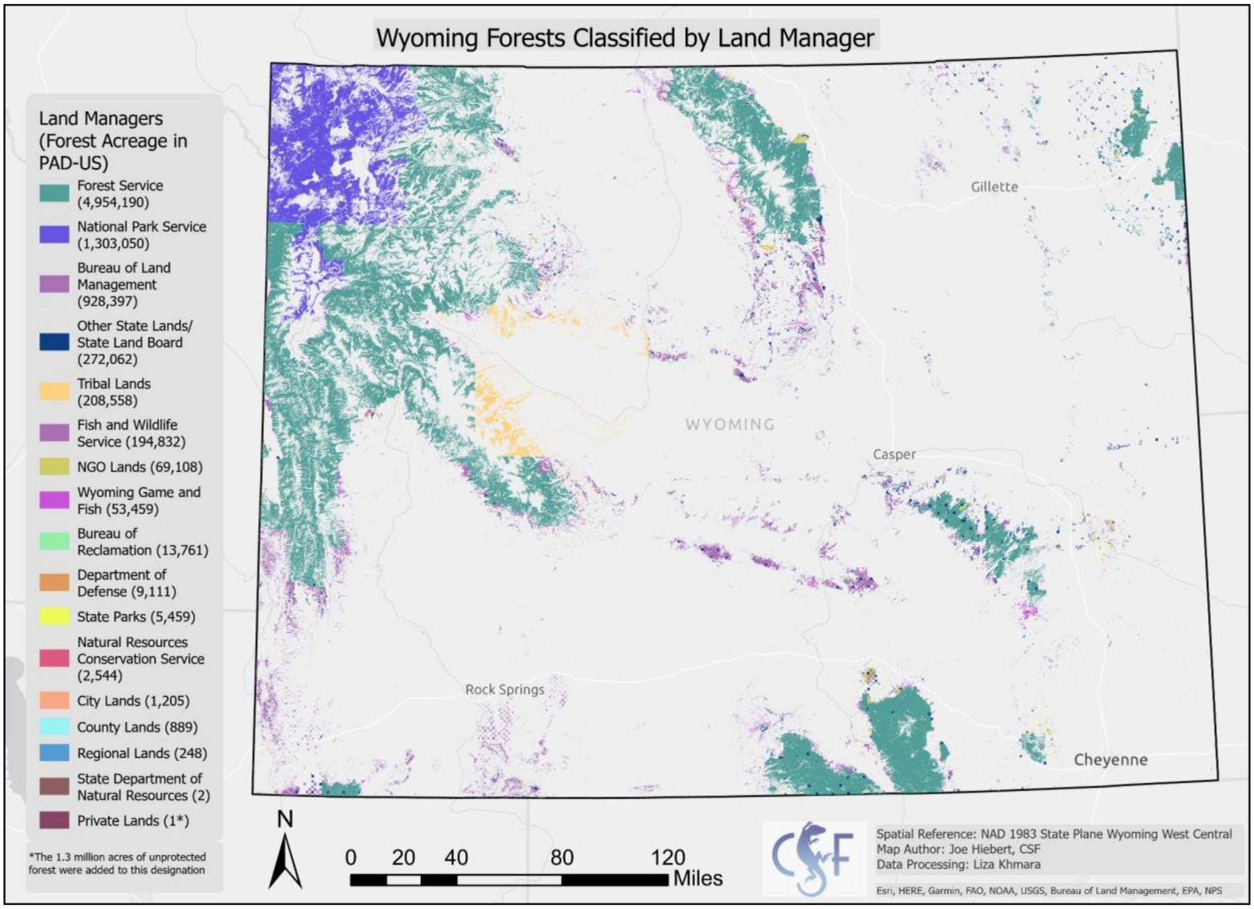

Figure 3.2 Map of Wyoming forests classified by land manager.

Since this valuation is focused on forests, we carved out the forest areas and calculated the percentage of forest in each land manager's areas (Table 3.1). We also examined each land manager's accessibility for recreation (either open access, which has no special requirements for access, or restricted access, which requires a permit) as part of the initial inclusion/exclusion process for Wyoming forests relevant to recreation. We excluded forests from land managers with percentages of forest cover and public access under 5%, such as forests managed by the Department of Defense. This resulted in 11 different land manager types accounted for, as shown in Table 3.1.

Table 3.1 Forest visits and attribution by land manager.

Land Manager	Total Visits	Forest Acreage (% of manager total)	Visits in Forests
US Forest Service	18,290,423	4,954,190 (21)	3,840,989
National Park Service	9,296,184	1,303,050 (20)	1,859,237
Private Land		1,493,278 (9)***	
Bureau of Land Management	1,148,839*	928,397 (5)	57,442
Other State Lands		272,062 (8)	
Fish and Wildlife Service	7,974,000**	194,832 (18)	1,435,320
Wyoming Game & Fish		53,459 (12)	
Wyoming State Parks	5,369,863	5,459 (6)	3,221,918
City Land		1,205 (10)	
County Land		889 (11)	
Regional Land		248 (13)	

* This value is total activity days for hiking, fishing, camping, hunting and wildlife viewing
** This value is total activity days for fishing, hunting, and wildlife viewing
*** Includes tribal land

Next, we sought out data on recreational visits. This was done through a review of publicly available data and when that data was not available, we contacted land managers to request the data. Visitation days per activity were recorded for a limited number of activities (hiking, camping, fishing, hunting, wildlife viewing)[5] as shown in Table 3.2. Considering that these were activities that took place in the entire area managed by each land manager, activities that took

[5] Activity days were either provided directly in the data sources or were calculated by multiplying total visitation in Wyoming for each land manager by the percentage participation for each activity as reported in visitor use surveys. All visitation types (e.g., overnight) were classified as one visitation day per person.

place within forests were conservatively estimated to be proportional to the amount of forest acreage. It is likely that forests are areas of greater recreational visits than other land cover types, however, this assumption was adopted due to the lack of better data on the relationship between visitation and land cover type. The resulting number of visits to the forests managed by each land manager is shown in Table 3.1. The Forest Service and National Park Service receive the highest visitation and have the most forest area, both in absolute area and in proportion to the total area of land owned by the manager. The Bureau of Land Management sustains the lowest relative levels of visitation, likely because the agency mainly focuses on other land uses than recreation such as cattle grazing, mining and coal leases and its forest cover made up only 5% of the agency's land, further reducing the estimated number of visitation days, with the adopted methodology. State parks receive high visitation, indicating that they play a significant role in Wyoming outdoor recreation. Some land management agencies in Table 3.1 do not include visitation because that data is not recorded or published; in these cases, we measure recreation value through a per acre benefit transfer approach. In this analysis we estimated that there are over 10 million annual visits to Wyoming forests, demonstrating the importance of forests to recreation and cultural experiences for residents and visitors.

As noted earlier, the economic value of recreation was considered through the expenditures made as well as through the quality-of-life value obtained from these activities outside markets (consumer surplus). This information was obtained for each activity and for each land manager, when possible.[6] Appendix D. Recreation Studies for Valuation lists the economic valuation studies used to obtain these values. As noted in Table 3.2, recreation in Wyoming results in both boosts to local economies and benefits to visitors - on average, recreation participants spend between $99 (for hiking visits) and $157 (for camping visits) per day, depending on the recreation activities. These include expenditures in transportation, lodging, and entrance fees, among others. Consumer surplus benefits range from $42.42 (camping) to $102.34 (fishing) per day. These are approximations to the value received freely by having recreational activities in these forests.

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[6] Consumer surplus values were mainly derived from the Recreation Use Values Database (Rosenberger, 2016). Expenditure values were obtained from land management agencies (e.g., FWS expenditure values) or from a literature search. When land managers did not have specific values, the next most similar value was adopted.

Table 3.2 Recreation values by activity based on average expenditures and consumer surplus.

Activity	Total Forest Activity Days	Average Expenditure/Activity Day	Average CS/Activity Day
Hiking*	2,760,092	$99.45	$71.40
Fishing	1,102,384	$130.08	$102.34
Camping*	942,797	$157	$42.42
Hunting**	439,661	$145	$88.30
Wildlife Viewing	3,613,016	$121.16	$57.70
Total	**8,857,950**		

*does not include FWS values

**does not include NPS values

Table 3.3 shows total economic values by activity, where per-day consumer surplus and expenditure values were multiplied by the number of activity days for each activity for each land manager and summed to find total expenditures and consumer surplus per activity for all managers. In this method, we could not account for many of the forest acres where activity-specific visitation data was not available. It, therefore, only accounted for five land management agencies (Forest Service, National Park Service, Bureau of Land Management, Fish and Wildlife Service and Wyoming Parks), which together would account for over $1 billion in spending annually and over $600 million in annual consumer surplus. These estimates are lower than the totals calculated for forest recreation, as we excluded land managers that did not report activity data or do not provide recreation opportunities for the activities being studied.

By looking at activity specific results, hiking and wildlife viewing result in the largest expenditures and consumer surplus, followed by camping, fishing, and hunting. As activity values are based on visitation, the activities with the highest total visitation numbers generate the most value (e.g., wildlife viewing, hiking).

Not all activities take place everywhere evenly. For example, Yellowstone National Park, which makes up the majority of National Park Service forests in Wyoming, restricts any hunting activity. In addition, the Fish and Wildlife Service does not report hiking and camping data.

Expenditures made in the market and the value obtained beyond market expenditures (consumer surplus) can also be added to represent the total value obtained from each activity. Expenditure and consumer surplus values for all land managers, including those calculated with the benefit transfer method, are included in Table 3.5. The addition of these values increases the total economic benefit of Wyoming forests.

Table 3.3 Total expenditures and consumer surplus by recreation activity.

Activity	Forest Activity Days	Forest Expenditures by Activity	Forest Consumer Surplus by Activity
Hiking*	2,760,092	$301,266,990	$242,781,321
Fishing	1,102,384	$156,502,779	$115,711,359
Camping*	942,797	$164,734,797	$44,077,857
Hunting**	439,661	$57,656,787	$43,558,457
Wildlife Viewing	3,613,016	$586,702,122	$227,269,499
Total	**8,857,950**	**$1,266,863,474**	**$673,398,492**

*does not include FWS values

**does not include NPS values

3.3. Recreation Results

Since this valuation is being done from a spatial perspective, we also translated these values to a per acre value. To do so, we divided the total values for consumer surplus and expenditures by the amount of forest acreage for each manager. For the land managers that we did not obtain activity data for, we obtained a generic per acre value for general recreation from a literature search (Joshi et al., 2017) for a benefit transfer to calculate consumer surplus (and total forest benefits) included in Table 3.5. Table 3.4 shows the value per acre per activity for each type of value (expenditure or consumer surplus) as well as a total value (expenditures plus consumer surplus). We identified per acre values by dividing values in Table 3.3 (total expenditures and consumer surplus) by the 9.2 million acres of forest in Wyoming. Values range from about $11 per acre for hunting to $88 per acre for wildlife viewing. This range can be mainly attributed to the low participation in hunting relative to wildlife viewing (439,661 activity days for hunting versus 3,613,016 for wildlife viewing). Adding up the values for these selected activities results in a total value per acre of about $214 per acre per year.

Table 3.4 Per acre values by recreation activity.

Activity	Expenditure/Acre	CS/Acre	Total/Acre
Hiking	$32.72	$26.37	$59.09
Fishing	$17	$12.57	$29.57
Camping	$17.89	$4.79	$25.68
Hunting	$6.26	$4.73	$10.99
Wildlife Viewing	$63.72	$24.68	$88.20
Total	**$137.59**	**$73.14**	**$213.53**

We also calculated total forest values (expenditures, consumer surplus, and their sum) by land managers, to illustrate the economic output generated by the actors involved in Wyoming forest management. Our results show that forests under the management of entities such as the Forest Service, National Park Service, Fish and Wildlife Service, and Wyoming State Parks provide recreation opportunities that result in significant gains for recreation participants and the state economy; these three agencies individually generate expenditures ranging between

$185 million to $880 million and consumer surplus between $97 million to $433 million (Table 3.5). Other types of land, such as private and tribal, also generate impressive economic contributions. Lower values are generally due to less participation or visitation in recreation activities; for example, the Bureau of Land Management generates relatively low value because it has the lowest visitation and low forest acreage (Table 3.1). In our estimates, we obtained separate expenditures and consumer surplus values for the land managers that provided visitation data and used the benefit transfer method to calculate the values for the remaining land managers. Individual contributions to recreation activities by land managers providing recreation data are shown in Appendix C. Recreation results by land manager.

Table 3.5 Total recreation value by land manager.

Land Manager	Total Forest Expenditures	Total Forest Consumer Surplus	Total Forest Benefits
US Forest Service	$881,277,820	$433,155,510	$1,314,433,330
National Park Service	$392,437,514	$199,334,927	$591,772,441
Private Land* **		$11,705,179	$11,705,179
Bureau of Land Management	$10,388,829	$2,801,397	$13,190,226
Other State Land*		$1,887,602	$1,887,602
Fish and Wildlife Service	$184,277,342	$97,902,110	$282,179,453
Wyoming Game & Fish*		$599,019	$599,019
Wyoming State Parks	$12,181,157	$24,272,433	$36,453,590
City Land*		$10,998	$10,998
County Land*		$8,777	$8,777
Regional Land*		$2,948	$2,948
Total	**$1,480,562,662**	**$771,680,901**	**$2,252,243,562**

*benefit transfer method

**includes tribal land

We examined the economic value of recreation activities in forests in Wyoming, finding that they contribute, in total, almost $1.5 billion in spending annually and over $770 million in consumer surplus. These findings are consistent with the Outdoor Industry Association/Bureau of Economic Analysis account for outdoor recreation which found that outdoor recreation resulted in approximately $1.25 billion in state GDP contributions and $625 million of income revenue in 2020. Federal, state, private and tribal actors play particularly important roles in supporting the recreation economy in Wyoming's forests. In particular, values derived from the benefit transfer method (land managers that did not provide visitation data) provide an additional $14 million annually in consumer surplus. On a per acre basis, the recreation value is approximately $213 per year, adding up hiking, fishing, camping, hunting and wildlife viewing activities (Table 3.4). These results demonstrate the importance of supporting Wyoming's forests to continue to provide meaningful and enjoyable recreation opportunities to local residents and visitors to support local economies and industries. They are additive in the overall economic value of Wyoming forests (Table 7.1).

4. Wildlife Habitat Values

4.1. Introduction to Wildlife Habitat

Wyoming is among the most valuable places for wildlife habitat in North America, with more than 62.7 million acres in size and an average of one person per every 111 acres. The region's forests and grasslands are home to more than 100 mammal species and 400 species of birds, many of which are protected species within national parks, wilderness areas and wildlife refuges. Wyoming's iconic wildlife include bison, mountain lions, wolves, bald eagles, grizzly bears, black bears, elk, moose, mule deer, bighorn sheep, pronghorn antelope and wild horses, among many others. As demonstrated in the Recreation Section, Wyoming's wildlife and natural beauty attract millions of visitors each year. Meanwhile the region's habitat provides value to scientists, educators, and people all over world, many of whom have never and may never visit the region to experience it in person. It also provides refuge to migratory species. This section explores the value habitat provides beyond the scope of recreational opportunities to people.

Several efforts have been made to map species and their migratory patterns across the state. The Western Association of Fish and Wildlife Agencies developed the Crucial Habitat Assessment Tool, identifying crucial big game ranges (pronghorn, bighorn sheep, elk, moose, mule deer, mountain goat and white-tailed deer), as well as sage-grouse core habitat areas and connectivity areas. A basic layout of this map can be seen in Appendix F.

Other interesting resources are the Species Richness and Range-Size Rarity spatial datasets created by the International Union for Conservation of Nature (IUCN). These 2021 maps are based on raw species range maps for amphibians, birds and mammals and contain information from all red list categories, as well as threatened species identified by IUCN.[7] A basic depiction of these maps can be seen in Appendix F.

To estimate the value provided by habitat, we identified areas of wildlife habitat value in the state. We then found valuation studies for the value attributed to these habitat types. We also conducted a separate analysis on two key species that depend on forests in Wyoming (mule deer and elk) to illustrate a value per animal and hence the importance of animal abundance.

The following section outlines the spatial data and research utilized to estimate wildlife habitat values.

4.2. Wildlife Habitat Methods

[7] They have a resolution of 900 km2, which means that each pixel or square in the map represents an area of 30 by 30 km (IUCN, 2021). It should be stated that the species ranges have not been refined to consider particularly relevant altitude and land cover variations, and that the data is biased towards vertebrates, which are the most thoroughly analyzed taxonomic group in the literature currently.

People place value in habitat for simply knowing it is protected and exists, whether they intend to visit it or not (existence value). They also value its continued existence for future generations to come, knowing that it will be there for others to enjoy (bequest value). Hundreds of studies estimating the bequest and existence ecosystem service value have been conducted over the last several decades. This report uses species specific data and research from Wyoming to estimate annual habitat value.

The first part of this research involved a BTM valuation, using local valuation studies asking people for their willingness to pay to preserve waterfowl habitat, fish habitat, wildlife habitat in general, as well as local biodiversity in areas that share geographical and climatic characteristics with Wyoming. Table 4.1 below lists the habitat valuation studies and their corresponding values. These range from about $1/acre to as much as $2,780 per acre per year. The values reported by each study were adjusted to better match the context of Wyoming's forests, then corrected for inflation and transformed into per acre values.

For example, the study used for bird habitat (Haefele et al., 2019) consisted of a multi-country willingness to pay for transborder migratory waterfowl species − specifically, the Northern Pintail, whose territorial extent includes the state of Wyoming. To adjust the WTP values reported by the primary study, which refer generally to households in the U.S., the number was multiplied by the number of households in the state − 233,231 (U.S. Census Bureau, 2020e) − and divided by the forest acreage for Wyoming, rendering per-acre values for this particular species.

The fish habitat valuation followed a similar process, based on the willingness to pay for protecting critical habitat for threatened and endangered fish (Ekstrand & Loomis, 1998). The original study consists of a habitat valuation appraisal for 9 species of fish covering 2,456 river miles of habitat in the states of Colorado, Utah, Arizona and New Mexico. Our research indicated that only four of these species were present in Wyoming: namely, the bonytail chub, the Colorado squawfish, the humpback chub and the silvery minnow. Therefore, we adjusted the valuation estimate per household reported in the study by multiplying it with a ratio of 0.44. The number of households in the four corner states, estimated at 6,576,932 (U.S. Census Bureau, 2020d, 2020b, 2020c, 2020a), was then multiplied by this WTP per household. For acreage conversion, the spatial unit used by the authors (river miles) was multiplied by the maximum natural width of the Colorado river. This was the most consistently reported width metric in the literature for the four corner states, but likely overstates the obtained fish habitat area, which came up to a total of 297,299 acres. This figure was used to generate per-acre estimates contained in Table 4.1. These values were only applied to the riparian forest range of Wyoming (close to 19% of the total forest acreage).

Table 4.1 Values per acre for wildlife habitat.

Habitat Value	Value range (2021 USD) acre/year	Source
Waterfowl habitat	$0.83 - $0.95	Haefele et al., 2019
Fish habitat	$421.29 - $2,780.54	Ekstrand and Loomis, 1998
Contiguous habitat	$11.41	Beyers, 2002
Biodiversity in contiguous habitat	$1.19 - $8.17	Haener and Adamowicz, 2000

4.2.1. Iconic species valuation

In addition, we looked at two species of interest − mule deer and elk − which rely heavily on forests for their habitat and are iconic to the state. The stability of these populations is vital, since they form an important part of the food web that make up the larger ecosystems of Wyoming's forests. Figure 4.1 demonstrates how these species' ranges are closely correlated with forested areas.

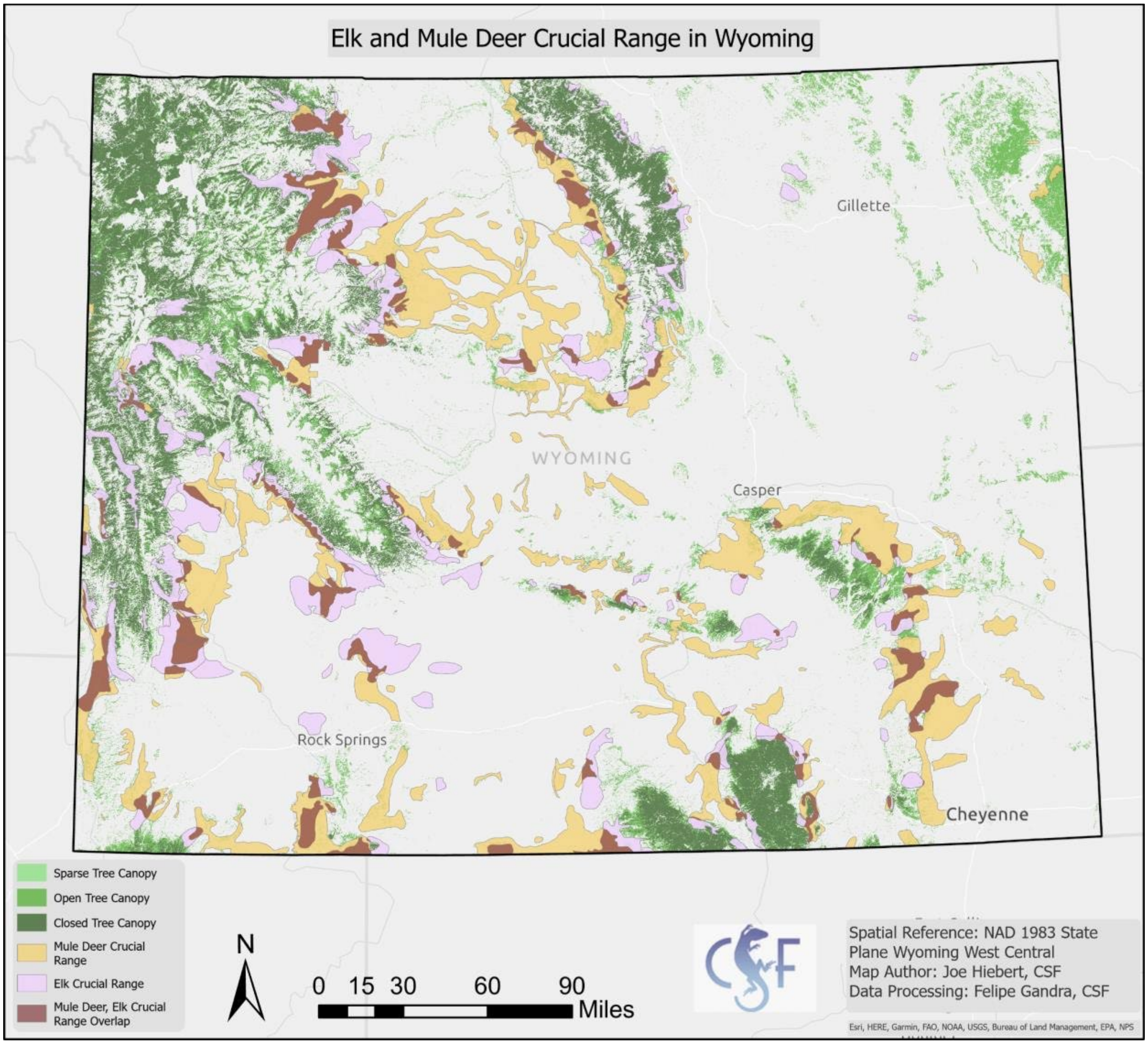

Figure 4.1 Elk and mule deer crucial range in Wyoming.
Source: Wyoming Game and Fish Department.

Both resident and non-resident populations value the continued existence of these species. For this valuation, we calculated their value using population counts from Wyoming's Game & Fish Department (Frost, 2021) and different market proxy values per head. Two proxies were utilized for the analysis: the lower bound was constituted by hunting license fees provided by the Wyoming Game & Fish Dept for the year 2018, and the upper bound value was comprised of hunting restitution fees (or, the fee paid for illegally killing an animal in Wyoming), also provided by the Wyoming Game & Fish Department for the year 2011. These indicators were corrected for inflation and annualized by dividing the total estimated value by their average lifespan. Under the premise that these numbers are maintained by the standing forest of

Wyoming, we then distribute this habitat value to all forest acres by dividing the annual value by the forest acreage. All numbers described here are described in Table 4.2.

Table 4.2 Calculator for the value attributed to elk and mule deer.

Species	Population in Wyoming	Avg. Life Expectancy	Value p/ Individual	Value range (acre/year)
Mule deer	330,700	10 years	Lower bound: ~$47 Higher bound: ~$4,940	$0.17 - $17.74
Elk	110,200	9 years	Lower bound: $64 Higher bound: $7,410	$0.09 - $9.85

These numbers are an underestimate as they only account for two of the many iconic species that use Wyoming's forests. They are illustrative of the types of value that we place on these species. To get a more comprehensive value, one could expand this list to include other species and also identify other ways that people place value on each individual animal.

4.2.2. Wildlife habitat in contiguous forests

In addition, large areas of forest provide wildlife corridors and habitat for many large and small species through a complex web of interrelationships and ecological functions. In Wyoming there are many large stretches of uninterrupted forest, which was estimated to be about 5.2 million acres, or about 57% of the forest area. For this attribute, we identified two valuation studies conducted in large forest areas. These are presented in Table 4.1 and identified by their applicability to "contiguous habitat". Therefore, when forests are contiguous, their wildlife value can increase by $13 to $20 more per acre.

4.3. Wildlife Habitat Results

Overall wildlife habitat values ranged from a low of $1.09 per acre per year (for a base forest acre with no special attributes) to $2,828 per acre for critical habitat forests (applied to riparian forests within contiguous landscapes only). Each forest type is associated with a different value. To get an overall value we multiplied each forest type by each wildlife habitat value and obtained an overall value of between $813 million to $5.2 billion in economic benefits provided every year by the maintenance of wildlife habitat. This value is conservative as it does not consider many species supported by Wyoming's forests.

5. Global Climate Regulation

5.1. Introduction to Climate Regulation in Wyoming

Carbon dioxide and other greenhouse gasses emitted by humans are quickly warming up the Earth's climate. The concentration of these pollutants in the atmosphere has increased by 40% since the 18th century, and they have changed the planet's temperature by about 1˚F over the last 50 years. The climate in Wyoming has also gotten warmer: over the past 100 years, average temperatures in the state have increased by 1°F to 3°F. Heat waves are increasingly common, with recent droughts affecting soils, raising tree mortality and increasing the risk of forest fires, as well as enabling outbreaks of pests (EPA, 2016a).

While longer growing seasons and increased carbon dioxide levels can increase the productivity of forests, warmer and drier conditions make them more susceptible to pests such as the bark beetle, which has impacted millions of forest acres in the Western U.S. in recent decades. With higher temperatures during winter, some pests can persist year-round, and new ones could surge − in addition to diseases. Perhaps most worrying, droughts also weaken the capacity of trees to defend against these hazards. Forests will also suffer with the increased severity, frequency and extent of wildfires in the state, which cause not only environmental problems but also economic damage to property, livelihoods and human health each year (EPA, 2016a).

In Wyoming, climate change is also decreasing snow precipitation and causing snow to melt earlier in spring, which has led to a decline in snowpack measurements since the 1950s. Higher temperatures and longer seasons without snow may threaten alpine tundra ecosystems, as subalpine fir and other high-altitude trees begin growing at higher elevations. The state's 1,500 glaciers are retreating and some can disappear entirely (EPA, 2016a). Mountain snowpacks retain less water, affecting the steady supply and conveyance of water downstream during spring and summer months and thus harming other ecosystems, reservoirs and dams. Besides the environmental impacts, these trends also jeopardize recreation and tourism in Wyoming such as fishing, boating and other activities (EPA, 2016a).

Finally, the likely decrease of water availability in Wyoming will reduce agricultural yields over the next few decades. Higher rates of evapotranspiration will create greater demand for irrigation, with less of it available. Hotter temperatures may lead to cattle eating less, growing slower and losing health. Warmer and shorter winters can promote the growth of weeds and pests, and shorten the dormancy for several winter crops which may result in spring freeze losses (EPA, 2016a). In some parts of the state, annual rainfall may increase but soils are likely to become drier, with greater rainfall intervals and more severe droughts. This could overwhelm water dependence from the Green River Basin and the High Plains aquifer, amongst others (WGFD, 2017).

5.2. Methods for Valuation of Carbon Sequestration and Storage in Wyoming

Each year, trees, shrubs, and grasslands in Wyoming use photosynthesis to remove carbon dioxide from the atmosphere and “sequester” it. This captured carbon biomass, along with the carbon already stored by vegetation, provides economic value by contributing to climate stability. This section describes the approach taken to arrive at an annual dollar value for carbon storage and sequestration per acre of forest in the state of Wyoming.

For both sequestration and storage, two separate components are needed to arrive at an annual dollar value per acre of forest: a) information on the carbon biomass contained and captured in Wyoming’s forests, and b) a monetary (dollar) value attributed to each ton of carbon sequestered or stored − in other words, how much each metric ton of carbon is worth. Multiplying these two components leads to the total carbon sequestration / storage benefit for a particular area − in this case, the forest extent of the state of Wyoming.

5.2.1. Amount of Carbon Biomass

Global data on forest carbon storage and sequestration (measured in tons of carbon) is well documented and published in the literature. For this assessment, both forest carbon sequestration rates and forest carbon stock values for Wyoming were provided by TNC’s Resilient Land Mapping Tool (TNC, 2022), obtained directly from TNC. The estimates for forest carbon stocks (storage) in the Resilient Mapping Tool are based on a study by Williams et al. (2021b) following methods described for the Southeast United States in Gu et al. (2019). The map represents the condition of carbon stocks in 2010, with a resolution (or size that each pixel represents in the map) of 30 meters. It was calculated through attributes such as forest type groups, disturbances, productivity and the age of standing forests, including carbon contained aboveground, belowground, in coarse woody debris and in the soil. This map is depicted in Figure 5.1.

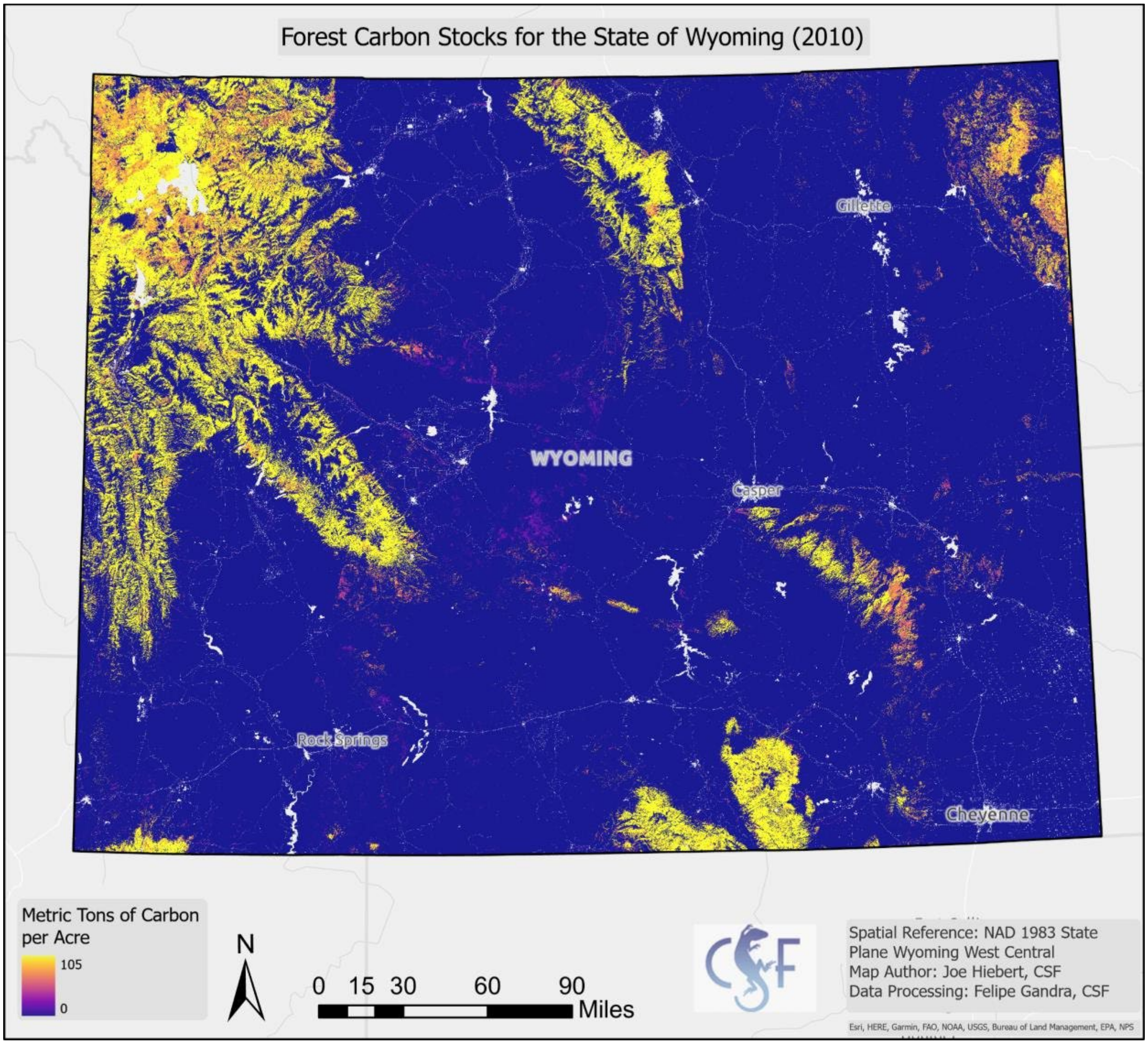

Figure 5.1 2010 forest carbon stocks for the state of Wyoming.

Based on this map's data, total forest carbon stored in Wyoming was estimated to be 335,677,140 metric tons. Dividing that by total forest acreage for the state, we estimate average metric tons of carbon stored per forest acre: 41.2 metric tons. These numbers are summarized in Table 5.1.

Table 5.1 Forest carbon stocks for the state of Wyoming, based on 2010 data.

2010 Forest Carbon Stocks for WY	
Total metric tons of carbon	335,677,140
Average metric tons of carbon / forest acre	41.18

Figure 5.2 shows the carbon stock distribution across forests in Wyoming. It can be noted that most forests are storing between 20 and 60 tons of carbon per acre, with a smaller proportion (around 1.5 million acres) storing less than 20 or more than 70 tons of carbon per acre.

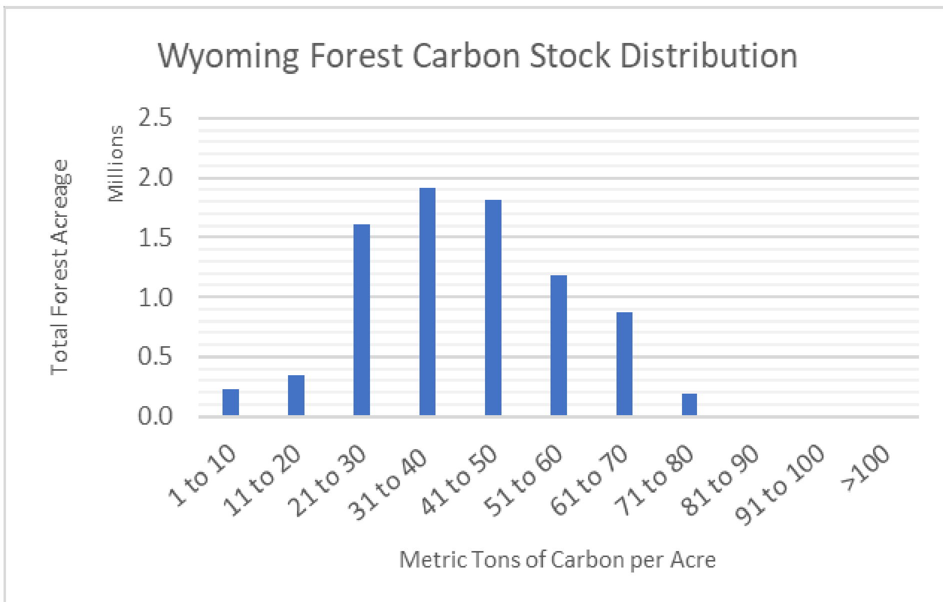

Figure 5.2 Distribution of carbon storage amounts across forest acreage.

Potential sequestration values are based on the same model described above (Williams et al., 2021b), but projecting forest carbon stocks for 2050 and assuming that no disturbances occur until that year − meaning no harvest, fire or conversion, which may drastically inflate actual sequestration rates. This map is shown in Figure 5.3.

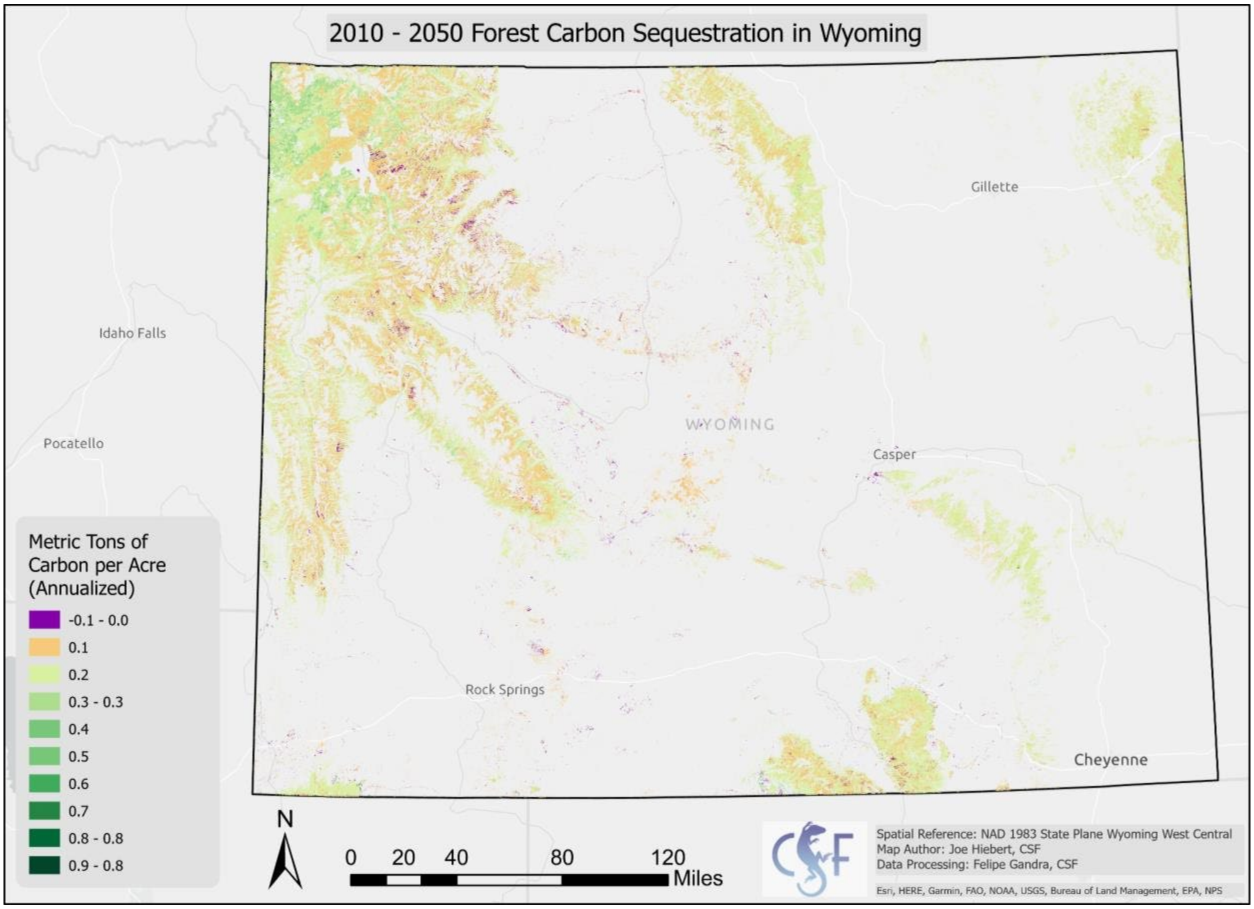

Figure 5.3 Annualized forest carbon sequestration in Wyoming.

Given that the map expresses forest carbon sequestration over a 40-year period (the difference between 2050 and 2010), we divided the total sequestration rates for the state by 40 to get annual values, leading to a total amount of carbon sequestered per year of 999,998 metric tons of carbon. Dividing that by the total forest acreage for the state, we get to an average 0.12 metric tons of forest carbon sequestered per year in Wyoming. These numbers are displayed in Table 5.2.

Table 5.2 Annual forest carbon sequestration for the state of Wyoming.

Annual (Potential) Forest Carbon Sequestration, WY (2010-2050 Average)	
Metric tons of carbon	999,998
Average metric tons of carbon / forest acre /yr.	0.12

Figure 5.4 shows the carbon sequestration distribution among forests in Wyoming. The median amount of carbon stored is between 0.125 and 0.2 metric tons of carbon, with over 4 million acres of forest storing an amount within that range.

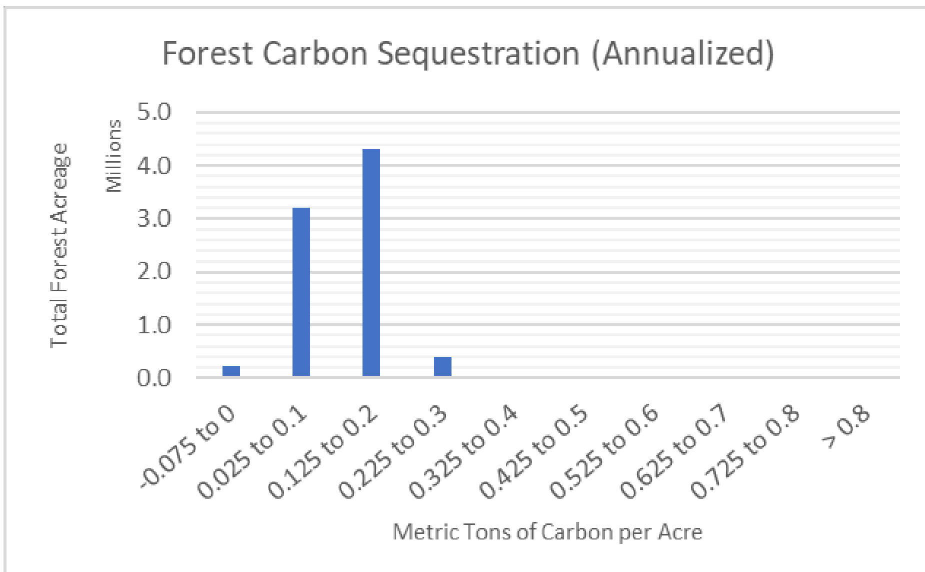

Figure 5.4 Distribution of carbon sequestration rates across different forest acreage.

5.2.2. Value per Ton of Carbon

Carbon prices are determined in markets where people, firms or governments pay for carbon sequestration. Dozens of carbon values exist today in US markets: for example, as of mid-2022, the California Carbon Auctions market traded at $29.15 per ton of carbon (California Air Resources Board, 2022). However, market prices alone do not account for the full range of benefits related to preventing carbon emissions/losses. The social cost of carbon (SCC), on the other hand, provides 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, human health, property damages from increased disasters and changes in energy costs (EPA, 2016b). 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. The SCC table in that report is depicted in Table 5.3.

Table 5.3 Social cost of COs, 2020-2050 (in 2020 USD per metric ton of COs).

Emissions Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% (95th percentile)
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

Source: IWGSCGG, 2021.

Monetary values vary based on the year of GHG emission due to GDP growth over time and the fact that a metric ton of carbon emitted in the future is more harmful than the same ton in the present, as physical and economic systems become more stressed in response to climate change (IWGSCGG, 2021). For this study, a conservative approach was taken by selecting 2020 as the emissions year. The table also presents different carbon prices based on varying discount rates, which are used to determine the net present value of future financial flows. If the discount rate is high, the net present value for a metric ton of carbon goes down, meaning that benefits for the current generation are worth proportionally more than future benefits (and vice-versa). The Interagency Working Group provides a set of possible discount rates, represented in the different chart columns.

In order to depict this variation, costs per metric ton of carbon were expressed as a range, with the least value referring to a 2.5% discount rate and the highest, 5%. After converting the unit reported above from metric tons of CO2eq to metric tons of carbon, we establish a value range from around $51 to $187 per metric ton of carbon for forests in Wyoming.

5.3. Results for Carbon Storage Values

The resulting value of stored carbon stocks in the forests of Wyoming are calculated based on the average carbon storage rate and the social cost of carbon per metric ton of carbon. Figure 5.5 displays this procedure visually.

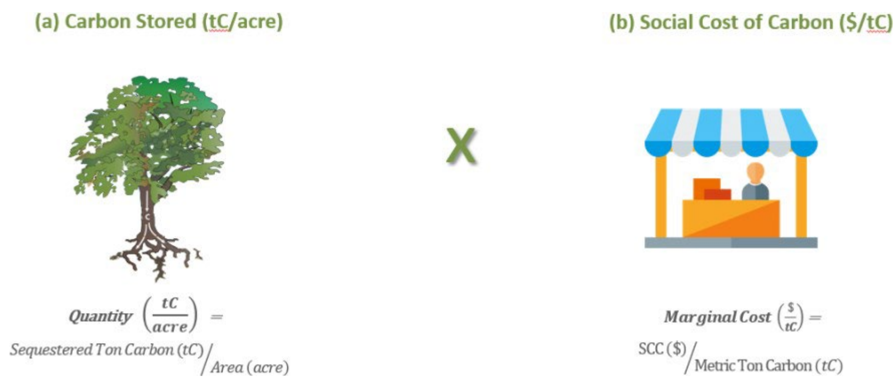

Figure 5.5 Overview of the method for calculating the value of carbon stored.

The obtained value ranges from $2,114 to $7,702 per acre of forest (Table 5.4). Across all 9.2 million acres of forest, the total carbon storage value thus ranges from $19.5 billion to $70.9 billion (Table 5.5). To note, this value is a stock and not a flow − since it refers to the total carbon pool already stored in Wyoming's forests. Thus, it will not result in an annual value, unlike carbon sequestration.

Table 5.4 Carbon storage values, 2021 USD per acre.

Ecosystem	Lower	Higher
Forests	$2,114	$7,702
* Based on social cost of carbon range from $51.34 to $187.02 per ton of C from the Interagency Working Group on Social Cost of Carbon 2021		

Table 5.5 Total carbon storage value for Wyoming's forests, 2021 USD.

Ecosystem	Acres	Lower	Higher	Total Lower	Total Higher
Forest	9,207,068.25	$2,114	$7,702	$19,467,158,808	$70,914,453,452

5.4. Results for Carbon Sequestration Values

Following the same procedure as above, Figure 5.6 summarizes the two components that were used to calculate carbon sequestration: a) the average carbon sequestration rate multiplied by b) the social cost of carbon per metric ton of carbon.

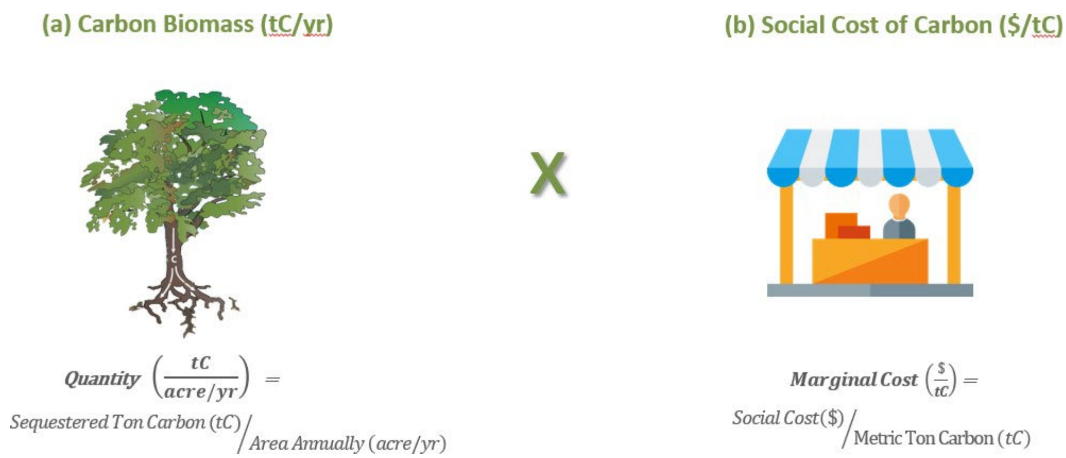

Figure 5.6 Overview of the method used for carbon sequestration.

Summing these values for all 9.2 million acres of forest in Wyoming, we obtain a total annual carbon sequestration value of $58 to $211.3 million per year (Table 5.7). This value represents the flow of benefits derived from carbon sequestration annually – it is not a stock value. For carbon sequestration, we end up with a range from $6.3 to $23 per acre (Table 5.6).

Table 5.6 Carbon sequestration values, 2021 USD per acre per year.

Ecosystem	Lower	Higher
Forests	$6.30	$22.95
* Based on social cost of carbon range from $51.34 to $187.02 per ton of C from the Interagency Working Group on Social Cost of Carbon 2021		

Table 5.7 Total forest carbon sequestration in Wyoming.

Ecosystem	Acres	Lower	Higher	Total Lower	Total Higher
Forest	9,207,068.25	$6	$23	$57,993,557	$211,257,401
* Based on social cost of carbon range from $51.34 to $187.02 per ton of C from the Interagency Working Group on Social Cost of Carbon 2021					

6. Water Values

6.1. Introduction to Water Ecosystem Services

Forests in Wyoming catch and store water, regulate water cycles and flows, and provide clean water to consumers. It has been shown that forests process about two-thirds of the nation's freshwater supply, serving around 40 percent of the nation's communities and 180 million people nationwide (National Research Council, 2008). Wyoming's watersheds are characterized by their forest cover (Figure 6.1). Wyoming is also a headwaters state that supplies water to four of the country's main river basins, including the Big Horn Basin,[8] the Powder River Basin,[9] and the North Platte and Laramie rivers in southeast Wyoming. Wyoming's headwaters drain into important river systems in the country, including the Missouri-Mississippi basin, the Green-Colorado River Basin, and the Great Salt Lake Basin.

[8] The Yellowstone, Wind, Bighorn, and Shoshone rivers

[9] The Tongue, Powder, Belle Fourche, Cheyenne, and Niobrara rivers

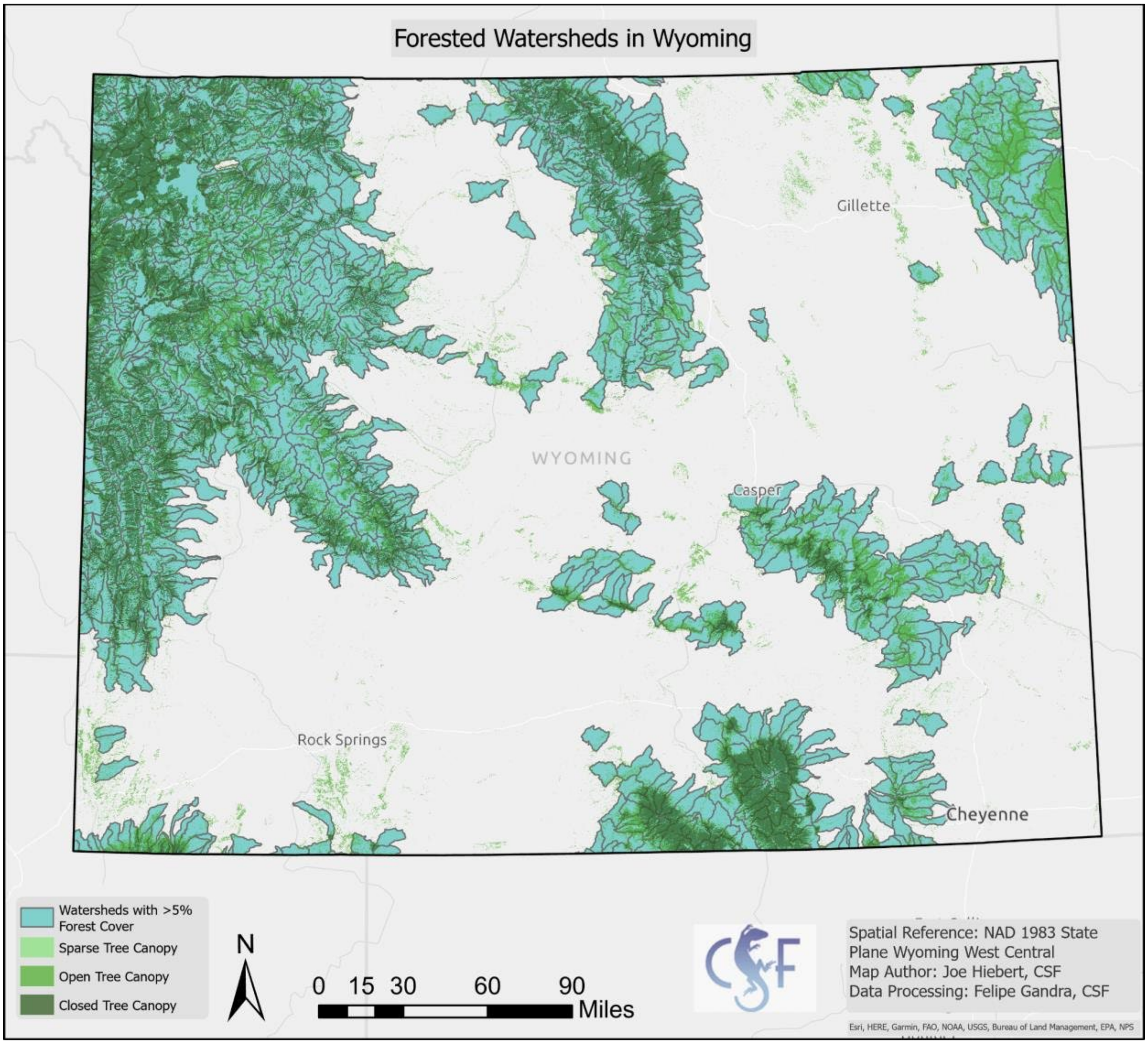

Figure 6.1 Forested watersheds in Wyoming.
Source: USFS (2019), CSF elaboration.

By stabilizing soils, forests also lower erosion and stormwater runoff, reducing erosion-related damages (such as rebuilding damaged infrastructure and treating tainted water) (National Research Council, 2008). According to the National Research Council, forests also clean two thirds of the nation's water supply by retaining nutrients and absorbing other pollutants (ibid).

In practice, the water quality and treatment costs are lower the more forestland there is near a source of drinking water (The Trust for Public Land & American Water Works Association, 2005). An increasing body of research indicates that well-controlled flow and high-quality source water can reduce treatment costs (Gartner et al., 2014). For instance, studies in the J.B. Converse Lake Watershed, which provides the bulk of the city of Mobile, Alabama's water (Journey & Gill, 2001), found that the cost of water treatment increased significantly when forest area was converted to urban land, from an average of $870,000 to $912,000 per year (Elias et al., 2013).

6.2. Methods for water values

In this study, distinct sub-categories of water provisioning services were valued separately. These include: 1) Water supply (quantity), which refers to the amount of water that is available in water bodies and that can be consumed by households, industry, agriculture or made available for habitat, 2) Water storage, which refers to the contribution towards holding and storing water for reliable and continuous consumption, and 3) Water quality improvements, which includes benefits to the environment, to water utilities as well as to final consumers.

There are other subcategories of water services that provide further benefits and that relate to the regulation of water flows and maintenance of water cycles, including the regulation of rain patterns and the regulation of peak flows and droughts. However, not all of these services could be included due to limited data availability.

Water quantity (supply), storage and quality were valued in this study using existing valuations that include several data points from forests and corresponding water provisioning services in Wyoming. Figure 6.2 depicts one of the main studies used in this valuation, Hill et al. (2014).

These studies provide both biophysical measures of the amount of water supplied by forests (in cubic meters) as well as the amounts of nutrients removed by forests (nitrogen and phosphorus) and transparently state the cost assumed both for water supply and nutrient removal if forests did not perform these tasks.

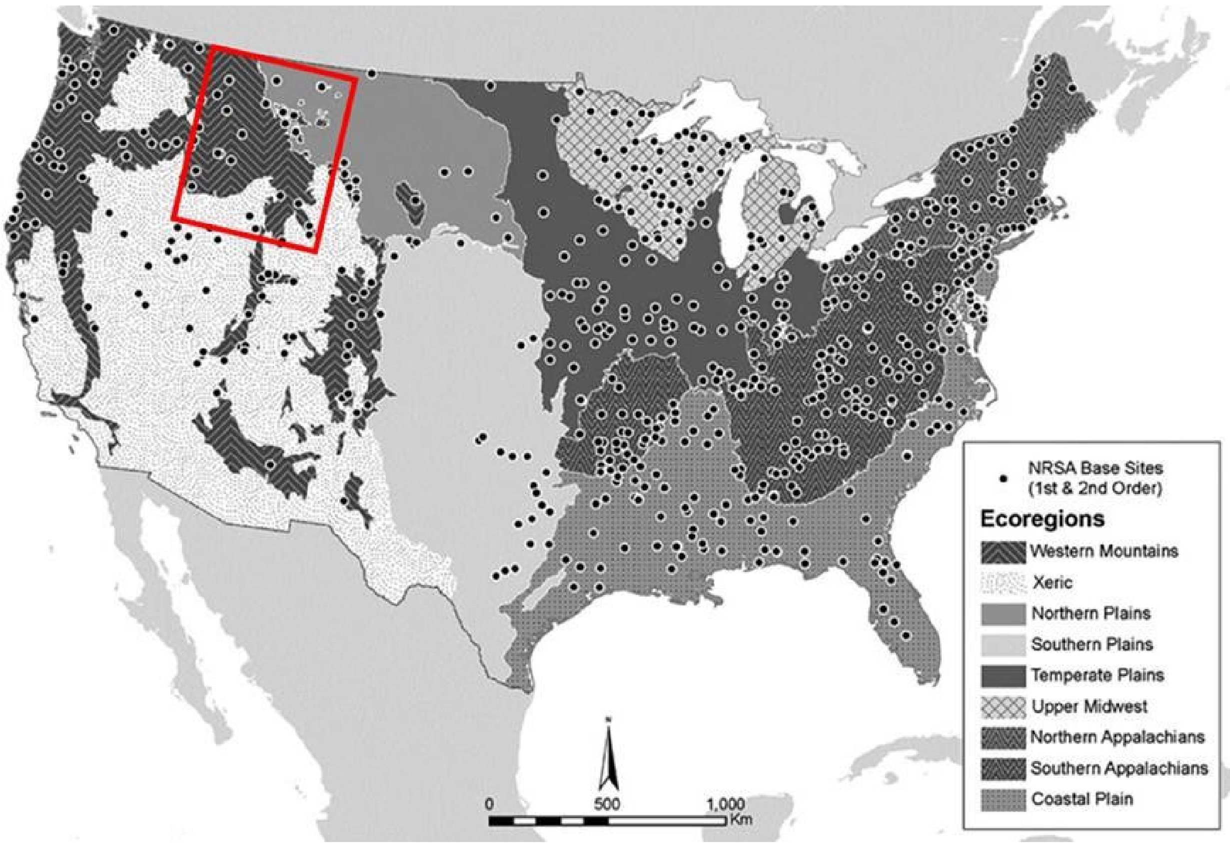

Figure 6.2 Water study data overview taken from Hill et al. (2014).

By looking at headwater catchment, our methodology focused on surface water supplies, which account for around 44% (63,200 af.) of total municipal and residential water use (Maupin et al., 2014). Measuring the contribution of forests to groundwater levels was more difficult and not enough data was available to include these sources of water in the valuation.

On average, Wyoming residents utilize 158 gallons of water per person each day (Wyoming Water Development Office, n.d.). With recent droughts, the value of clean and reliable water sources has become more apparent. According to RentCafe, these factors have affected the average water bill for Wyoming, which is relatively high when contrasted with most other states, coming to an average of $74/month making it the 6th most expensive state in terms of average water costs (Buzec, 2022). To account for the rising value of water, the stated costs of water were validated and updated using the most current available prices for water and water filtration technologies, including informal estimates based on the sale and transfer of water use rights in the state.

6.2.1. Water Supply

For riparian areas, the value for water capture, conveyance and supply were extrapolated from Hill et al. (2014), a study that analyzes 568 headwater streams and catchments in the United States with results reported per "ecoregion". As can be observed in Figure 6.2, the "Western Mountains" ecoregion encompasses the vast majority of forest acreage in Wyoming − and it also stands as one of the ecoregions with highest reported water supply quantities per unit catchment area (9,991 m3/ha/year). The study also provides a table expressing the average proportion of catchments covered by forests, grasslands, wetlands and row crop agriculture. In the Western Mountains ecoregion, 69% of the analyzed catchment areas are covered by forests, hence, we applied this ratio to the estimated value per acre.

The economic value of water provision in the study is based on commodity prices researched by the authors (Hill et al. 2014) at the time of publication and estimated to be at $0.035/m3, leading to a value of $177.28 per acre, after correcting for inflation and spatial unit conversions (hectares to acres). As stated above, we took the analysis one step further by incorporating updated water pricing information to improve the accuracy of these monetary values.

Specifically, we used the informal price of water use rights for the Glendo Reservoir in Wyoming, sold and transferred by the Bureau of Reclamation to an oil and gas company (Thuermer Jr., 2018). With this new calculated upper bound, the range of values for water supply became approximately $177 to $192 per acre per year, provided exclusively by riparian forests.

6.2.2. Water storage (snowpack retention)

Approximately 70 percent of Wyoming's surface water supply comes in the form of snow (Jacobs & Brosz, 1993). On average, 1.9 million acre-feet of water flows into the state each year this way (Ibid). In this study we looked at the impact of forests on snowpack retention, which is important to ensure a consistent and reliable water flow in surface waters.

For this, first a causal link was established, based on existing research on the relationship between forested areas and snowpack build-up (Adams et al., 2004). Trees increase the average volume of snowpack year-round and thus contribute to several ecosystem services, such as water provision, micro-climate stability and habitat maintenance.

For this study, a snow water equivalent (SWE) unit was used as a direct indicator for snowpack retention − and subsequently water storage − sustained by the forests of Wyoming. For this, publicly available historical averages of snow water equivalent were taken from the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA). As can be seen in Figure 6.3, the weather measurement stations providing this data are closely correlated with forest areas in Wyoming, which provided an opportunity to connect this metric with an ecosystem service value provided by forests.

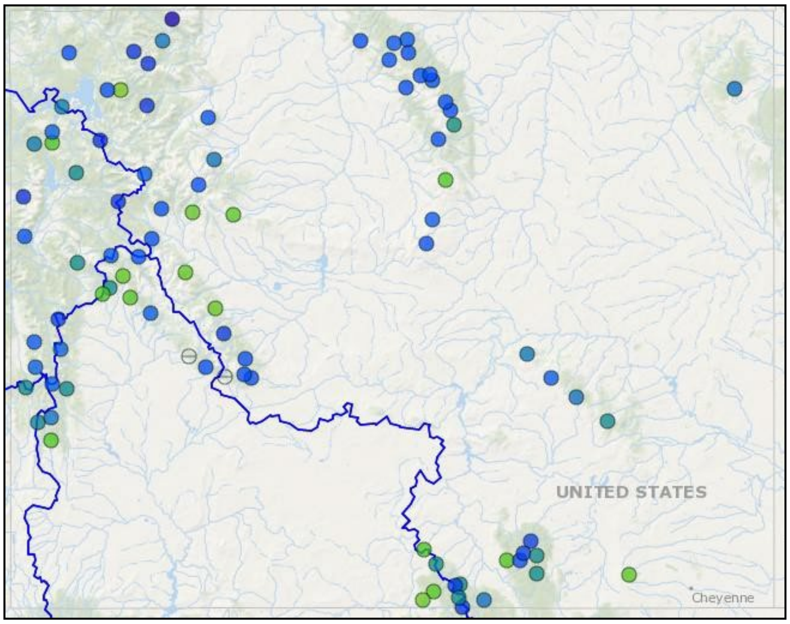

Figure 6.3 Snowpack measurement stations in Wyoming.

Source: NRCS National Water and Climate Center (USDA). (2022). Interactive Map Portal.

The NRCS tracks daily averages for snow water equivalent and also publishes historical averages from 1991 to 2020. This data was collected for all relevant weather stations in the region, rendering an average annual amount of snow water equivalent per acre of forest in Wyoming, reported in acre-feet. As can be seen in Table 6.1, this average turned out as 0.32 acre-feet, meaning that each acre of forest in Wyoming can store approximately 0.32 acre-feet of snow water.

Table 6.1 Underlying calculations for water storage through snowpack retention.

Category	Description
Avg. Snow Water Equivalent (SWE) for WY forests, 1991-2020	0.32 ft
Data Source	USDA SWE Interactive Map (84 measurements)
Valuation range	$0.59 - $8.07/acre/y
Cost data approach	Adams et al. (2004) Lake Sonoma Water Storage Valuation (Earth Economics 2017)

The next step assigned an economic value to this water stored. Following the methodology of Adams et al. (2004), replacement costs were calculated using construction costs of man-made alternatives for water storage − in this case, dam reservoirs − which would be necessary in the absence of the ecosystem service. Three dams were contemplated in the original study, but we excluded two of them because they had extremely high values, which did not seem in line with local costs. Ultimately the Glen Canyon dam, in Arizona, was used to approximate a replacement cost.

Dividing the total construction/maintenance costs of the dam by its water storage capacity, we get a value of $40 per acre-foot of water. After adjusting for inflation, this number is multiplied by the snow water equivalent for Wyoming (0.32 per acre-foot) and discounted at a 3.125% rate, leading to a value of $0.59 per acre per year, which is relatively low and was used as the lower bound of the valuation.

For the upper bound, the same method was applied with cost data from the Lake Tapps project, in Washington state. It is estimated that 65 million gallons of water are supplied by that reservoir per day (23,725 MG/year), which is equivalent to 87,440.40 acre-feet of water. The dam reports an average cost of $2,457/MG, based on capital costs and O&M, leading to a value of $666.65 per acre-ft per year (Earth Economics, 2017). This number is adjusted for inflation, multiplied by the SWE volume and discounted, rendering a value of $8.07 per acre per year. This number was used as the higher value in this study. Therefore, the value for water storage was estimated to be about $0.59 to $8.07 per forest acre per year in Wyoming.

6.2.3. Water Quality

For water quality services, four values were used to define the economic contribution of forest benefits in Wyoming. Two of these values were extracted from Hill et al. (2014) and applied specifically to riparian areas. Several water quality indicators are provided in the study, but the most relevant indicators were chosen as denitrification and phosphorus sequestration.

The “Western Mountains” ecoregion was selected for this valuation, with an average nitrogen removal rate by catchment and in-stream denitrification of 11.8 kg/ha/year and a phosphorus sequestration rate of 1.40 kg/ha/year (Hill et al., 2014). A damage cost avoidance approach is adopted to approximate the economic value of denitrification and phosphorus removal. After correcting for inflation and converting to acres, and reducing the number to account for a forest cover of 69%, a water quality value was derived, ranging from $630.48 to $748.03 per acre per year.

For non-riparian areas, two other studies on water quality were used, also involving nutrient and/or contaminant removal. These values are illustrative of water quality improvements through groundwater filtration. The study by Hauser and van Kooten (1993) uses a contingent valuation approach to quantify water quality services provided by forests located in the Abbotsford aquifer of British Columbia. The study by Wilson (2008) uses an avoided cost methodology to infer water quality services of Greenbelt forests in Ontario. These studies resulted in a water quality value for non-riparian forests that ranges from $12.67 to $51.42 per acre per year.

6.3. Water Results and Beneficiaries

This analysis noted that forests are important for water supply, water storage and water quality. Different types of forests provide these services in different ways. Forests near water bodies are important to regulate precipitation patterns, catch and convey water. These functions translate into the service of water supply, which was valued at $177 to $192 per acre per year and applied exclusively to riparian forests. The service of water storage was studied via the function of snowpack retention. By maintaining cooler temperatures and preventing erosion, forests regulate water flow from snow melt. Approximately 70 percent of Wyoming's surface water supply comes in the form of snow (Jacobs & Brosz, 1993). The value for water storage was estimated to be about $0.59 to $8.07 per forest acre per year and was applied to all forest acres. Finally, forests retain nutrients and sediment, improving water quality in water bodies. Riparian forests are particularly important for this service, with a water quality value ranging from $630.48 to $748.03 per acre per year. Non-riparian forests also perform this function for groundwater, which was estimated to range from $12.67 to $51.42 per acre per year. These values may be additive, depending on the forest type, and result in a range of values for all water related services from $13.26 to $948 per acre per year. The overall value for all water-related services provided by the 9.2 million acres of forests in Wyoming amount to about $1.4 billion to $2.1 billion in benefits provided every year.

These benefits accrue to households, industry, recreational activities, water utilities and millions of users downstream (from Colorado to Louisiana) who depend on the water enabled by Wyoming's forests. Water reliability and availability is one of the most important determinants of wealth and wellbeing in a region. In a recent analysis conducted by USGS on water accounts in the country (Bagstad et al., 2020), the state of Wyoming was singled out for having the largest increase in water consumption (52% increase) between 2000 and 2015, this was driven primarily by increased crop irrigation. It was also the only state to not increase its water productivity, as its growth in water consumption outpaced the state's GDP growth. These increases in demand are associated with increases in the value of water, and potentially the price of water in the state. They also raise a concern to manage the ecological functions and the ecosystems that support water appropriately.

7. Overall Results

7.1. Results for all Ecosystem Services Included

A total of 15 ecosystem services provided by forests were valued in this study. These do not include all of the ecosystem services provided by forests but instead include a subset of those that had data available. Five of these were described in depth in previous chapters (recreation, wildlife habitat, global climate stability, and water supply and quality). The other ten ecosystem services valued are presented here. These include the following:

- **Aesthetic information**: Also commonly referred to as visual amenity services, which are often valued as the increase in real estate value due to proximity to natural areas (i.e., forests).
- **Air quality:** This refers to the removal of air pollutants from the air performed by trees, including particulate matter and other harmful gasses with adverse impacts on human health.
- **Biological control:** Involves the mitigation of pests through healthy and balanced ecosystems.
- **Cultural value:** Forests can make up part of people's identity or be perceived as valuable in and of themselves. In this case this is valued through a willingness to pay survey to ensure the continued existence of forests in the Washakie Wilderness Area (Barrick and Beazley 1990).
- **Energy and raw materials:** Includes the use of timber, contributions towards pulp production and animal products such as antlers and animal furs.
- **Flood risk reduction**: By stabilizing soils, absorbing excess water and buffering water flow, forests help to reduce flood risks.
- **Food:** Trees and bushes with forests can provide foraging opportunities, including fruits, nuts, herbs, mushrooms and even vegetables.
- **Local climate stability**: Forests regulate local temperatures, providing refuge to wildlife and people from extreme temperatures in the summer and winter. When in proximity to people, this can translate to energy savings.
- **Science and education**: People are constantly learning from nature and about nature. Having access to the complex and unique forests of Wyoming, provides valuable learning opportunities.
- **Soil retention:** Forest and their root systems retain soil and prevent erosion. As river flows change and when vegetation is lost, erosion can happen, sweeping away lands adjacent to rivers, impacting property owners.

The values for these ecosystems are combined with the per acre values obtained for recreation, wildlife habitat, global climate stability, and water services (supply, storage and quality) to derive an overall result for Wyoming's forests. There are different values for different types of forests. Table 7.1 below illustrates the per acre value for forests near water (riparian forests, non-contiguous).

Table 7.1 Per acre ecosystem service values for riparian forests (noncontiguous) in Wyoming.

Riparian Forest Benefits	Lower per Acre (Sum)	Higher per Acre (Sum)
Aesthetic Information	**$1,028.96**	**$1,028.96**
Real Estate Value		
Air Quality	**$0.06**	**$77.56**
Removal of Air Pollutants		
Biological Control	**$10.76**	**$10.76**
Pest Control		
Cultural Value	**$4.79**	**$6.03**
Existence		
Energy & Raw Materials	**$17.07**	**$42.56**
Animal Products (antlers and fur)	$0.01	$0.04
Energy	$12.26	$12.26
Plant Products	$4.80	$30.26
Flood Risk Reduction	**$360.22**	**$360.22**
Stormwater Runoff Reduction		
Food	**$0.02**	**$4.81**
Fishery / Fishing		
Wildlife Habitat	**$422.38**	**$2,809.08**
Bird Habitat	$0.83	$0.95
Fish Habitat	$421.29	$2,780.54
Iconic Species Habitat	$0.26	$27.60
Global Climate Regulation	**$6.30**	**$22.95**
Carbon Sequestration		
Local Climate Regulation	**$1,217.94**	**$1,217.94**
Energy savings		
Recreation	**$213.53**	**$213.53**
Hiking	$59.09	$59.09
Fishing	$29.57	$29.57
Camping	$25.68	$25.68
Hunting	$10.99	$10.99
Wildlife Viewing	$88.20	$88.20
Science & Education	**$5.38**	**$5.38**
Education		
Soil Retention	**$23.34**	**$147.82**
Soil Retention		
Water Storage	**$0.59**	**$8.07**
Snowpack / Ice		
Water Capture, Conveyance, & Supply	**$117.28**	**$191.85**
Headwater Catchment		
Water Quality	**$630.48**	**$748.03**
Nutrient and/or Contaminant Removal		
Total	**$4,059.10**	**$6,895.55**

Some of the highest per-acre values include wildlife habitat, water-related ecosystem services, local climate stability as well as aesthetic values. These numbers reflect average values for riparian forests in Wyoming, presented as a range of values. And as noted, not all acres of forests are the same. Some places have higher ecosystem service production than others (See Appendix A. Ecosystem service values by forest type). For example, riparian contiguous forests will have higher values than those of Table 7.1, which represent the values for riparian forest.

We looked at some of the attributes that impact ecosystem service production to see how values may differ across forest types. Of the ones considered, proximity to rivers and other water bodies (i.e., riparian forests) had the largest impact. According to our estimates, proximity to water produced per acre values from $4,059 (lower range for riparian to $6,915 (higher value for riparian and contiguous forest), primarily driven by higher values for aesthetic values, the influence on fisheries as food and as a recreational activity, and higher values for water supply and water quality improvements. Non-riparian forests (forests that are not near water bodies) have a per acre value of between $2,035 to $2,231 per acre. When we consider only values for large, contiguous forests we saw an increase in habitat value of somewhere between

$13 to $20 per acre, compared to other forests, resulting in a value per acre of between $2,048 to $6,915. These numbers should be interpreted as conservative, since we were limited by the availability of data looking at the difference in values due to these attributes (riparian versus non riparian or contiguous versus non-contiguous). More detail on the ecosystem services that are found in each forest type is provided in Appendix A. Ecosystem service values by forest type.

7.2. Overall value for Wyoming's Forests

To get an overall value for Wyoming's forests, we multiplied the values per acre for each forest type (e.g., riparian, contiguous) by the acreage of each forest type, as shown in Table 7.2. This resulted in about $22.3 billion to almost $28.8 billion in economic value provided by Wyoming's forests every year.

Table 7.2 Annual flow of ecosystem service values, 2021 USD.

Forest Classes	Acres	Lower Per Acre	Higher Per Acre	Lower Total	Higher Total
Forest Riparian & Contiguous	818,782.27	$4,072	$6,915	$3,333,828,811	$5,661,988,355
Forest Riparian & Non-Contiguous	930,807.05	$4,059	$6,896	$3,778,234,443	$6,418,423,648
Forest Non-Riparian & Contiguous	4,450,432.41	$2,048	$2,250	$9,114,247,288	$10,014,092,198
Forest Non-Riparian & Non-Contiguous	3,007,046.52	$2,035	$2,231	$6,120,392,637	$6,707,376,490
Total	**9,207,068.25**			**$22,346,703,179**	**$28,801,880,692**

These are flows of benefits obtained by Wyoming residents, tourists and downstream communities that benefit from the many services provided by these forests.

Forests should be treated as assets. Just like a factory or a coal mine has the ability to produce revenue over time, a forest can continue to produce ecosystem services indefinitely into the future, as long as it is managed wisely. To understand the asset value of Wyoming's forests, we also calculated a net present value (NPV) over a 100-year period using a 2% discount rate. This calculation incorporates into an overall value, the expected future stream of benefits from these forests if managed correctly. It also includes the carbon stored in these forests, in addition to the carbon sequestered every year (Table 5.5). Therefore, if we continue to harness and receive these benefits for 100 years, and assuming a slight preference for benefits closer to today than further in the future (i.e., the 2% discount rate), these forests will produce between $983 billion to $1.3 trillion dollars over that time period, as shown in Figure 7.1.

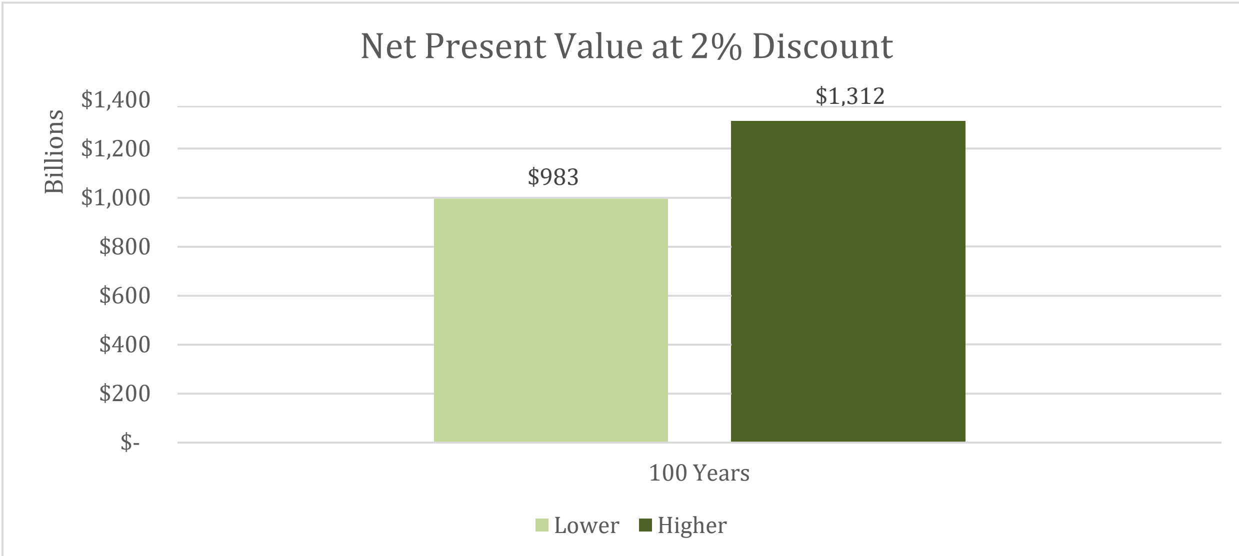

Figure 7.1 Asset value for Wyoming's forests.

8. Discussion

Overall, this analysis shows the economic value of forests as producers of ecosystem services that benefit both Wyoming residents and communities across the country. Some of the most valuable services include wildlife habitat, water-related ecosystem services, climate regulation and aesthetic value.

The survey conducted in this analysis showed that Wyoming residents greatly value their forests. Almost 77% of those interviewed had visited a local forest in the past year and 46.3% said to already contribute in-kind or with money towards forest conservation. When it came to their expressed willingness to pay for further protection, the survey showed that they would be willing to contribute between $50 to $350 per year to protect Wyoming's forests, considering the ecosystem services they provide. If we extrapolate these results to the Wyoming population of voting age (446,379 Wyoming residents in 2022) (Wyoming Election Division, 2021) and divide these numbers by the 9,207,068 acres of forests that were valued in this study, we would get a value per acre of between $2.42 to $16.97. This represents the value ascribed only by Wyoming residents, which is only a subset of the beneficiaries from all the services produced by these forests. More details on the survey results are provided in Appendix B. Contingent Valuation Survey.

The survey conducted as part of this study also showed that "Wildlife habitat" was considered the most important ecosystem service for Wyoming residents, followed by "Water supply and storage", "Water quality" and "Recreation". Also, the degree of importance associated with ecosystem services was associated with a higher willingness to pay to conserve forests.

Therefore, communication and information regarding ecosystem service production may be a fruitful strategy to increase the community buy-in for forest conservation efforts.

The in-depth analysis showed that forest recreation is greatly valued, not only locally but also nationally and internationally. It is also a significant revenue generator for the state, responsible for about $1.5 billion in spending per year, fueling local businesses and economies. Forest recreation also generates important quality of life benefits that amount to at least $770 million per year (in consumer surplus). These only account for some of the many recreational activities that happen in Wyoming's forests and do not consider important benefits such as the health benefits of recreating in forests. By better understanding the benefits of recreation, there can be more concerted efforts with the recreation industry to work together on forest conservation.

Wildlife habitat was the most valued service by survey respondents. There are many iconic species that depend on the vast forest land of Wyoming, such as elk and mule deer, which are not only valuable for wildlife viewing and hunting, but also for the ecological roles they play in maintaining healthy forests. Forests also maintain cool water temperatures, important for fish populations and other riparian wildlife. This study valued fish, bird, and iconic species habitat as well as biodiversity and the increased value obtained by having large, contiguous forest space. Wildlife habitat values ranged from $1.09 per acre (for non-riparian, non-contiguous forests) to $2,829 per acre for more critical forest habitat. The overall wildlife habitat value was between $813 million to $5.2 billion in benefits provided every year.

Global climate stability is an important ecosystem service, given the capacity of trees to store and sequester carbon. Climate change is also one of the biggest challenges of the current century and having an integrated forest management strategy that includes climate change mitigation and adaptation is a must. Our estimates showed yearly average values for carbon sequestration of about $6.30 to $22.95 for an acre of forest. Carbon storage, which was not calculated as a yearly value, amounted to between $2,114 to $7,702 per acre.

Forests play an important role in water cycles. They regulate water flows, clean water, store it, and even affect local rain cycles. As Wyoming becomes increasingly vulnerable to droughts and changes in water availability, understanding the role of local forests in providing and cleaning water will be important. In this study, we looked at water quality through nutrient and contaminant removal. The water quality value ranged from $12.67 to $748 per acre, water supply through headwater catchment ranged from $117.28 to $192 per acre per year, and water storage through forests' impact on snowpack ranged from $0.59 to $8.07 per acre. These benefits accrue to households, industry, recreational activities, water utilities and millions of users downstream (from Colorado to Louisiana) who depend on the headwaters of Wyoming. The overall value for all water-related services provided by the different types of forests in Wyoming amount to about $1.4 billion to $2.1 billion in benefits provided every year.

Overall, we found that an acre of forest in Wyoming provides an economic value of $2,035 to $6,915 every year. This amounts to about $22 billion to almost $29 billion in benefits every year provided by the 9.2 million acres of forest of Wyoming. The beneficiaries are many and diverse. And a coordinated effort is needed to protect and grow this vast wealth encapsulated in Wyoming's rich natural lands.

This study focused on the positive (ecosystem service) values provided by these forests. However, one important risk that is linked to forests is that of forest fires. This link is particularly salient for forests with no fire risk management. In these cases, forest fires may be a "negative service" or disservice" that detracts from the calculated asset values. Due to limitations in scope of this report, high severity wildfire and the risks posed to both people and ecosystem services was not studied. The risk of fire is widespread and has significant impacts throughout Wyoming. 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 and should be studied further in conjunction with this ecosystem service analysis.

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 forest management practices. Better understanding of these trends is essential to mitigate the risk of high impact wildfires in the future. Research has indicated that the fuel reduction treatments would improve the health and resilience of fire-prone forests by reducing the risk of wildfire and post-fire flooding and landslides.

Due to its scope, this study also did not propose to comprehend the positive marginal effects of Wyoming's forests on livestock grazing areas. This choice was based on the fact that the primary land cover type supporting grazing are grasslands and herbaceous vegetation types. Nonetheless, well-known ecosystem service impacts provided by forests, such as the provision of local micro-climate regulation to grasslands, shade for livestock, productivity gains and the attenuation of environmental damages related to these activities, should be further dissected from an economic perspective.

9. Recommendations

This high-level valuation study is best suited for communication purposes, raising awareness, identifying stakeholders, and prioritizing further research. The results should be used to highlight the potential economic impact of investments in forest health in Wyoming.

The beneficiaries of Wyoming's forest ecosystems are many and diverse, and a coordinated effort is needed to protect and grow this vast wealth encapsulated in Wyoming's rich natural lands. Conserving healthy forests as a critical and unique asset should be a clear priority for stakeholders and forest land managers in Wyoming. Increased and more targeted investments in forest restoration treatments give us our best chance to reduce the worst risks of climate change, and create healthier air, lands, and waters. Realizing those benefits will require a whole-of-society approach to reducing risk and restoring resilience − one with input and efforts from all levels of government, the private sector, communities, and other stakeholders.

Stakeholders should work collaboratively to develop sustainable sources of private and public capital for forest management. For example, at the state level, economic data can be used by the Wyoming State Legislature and Governor's Office to support their work in enhancing and protecting local communities. At the federal level, these findings can assist Congressional representatives in making the case for federal investments in Wyoming's forests due to the high economic value they provide to the larger region and country. Additionally, agencies such as the US Forest Service can use the results of this report as an example of the economic impact of investments into national forests and to inform upcoming Forest Plan revisions.

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Appendix A. Ecosystem service values by forest type

Table A-1 Ecosystem service values for non-riparian, non-contiguous forests.

Non-Riparian, Non-Contiguous Forest Benefits	Lower per Acre (Sum)	Higher per Acre (Sum)
Aesthetic Information	**$207.70**	**$207.70**
Other	$5.89	$5.89
Real Estate Value	$201.81	$201.81
Air Quality	**$0.06**	**$77.56**
Removal of Air Pollutants		
Biological Control	**$10.76**	**$10.76**
Pest Control		
Cultural Value	**$4.79**	**$6.03**
Existence		
Energy & Raw Materials	**$17.07**	**$42.56**
Animal Products	$0.01	$0.04
Energy	$12.26	$12.26
Plant Products	$4.80	$30.26
Flood Risk Reduction	**$360.22**	**$360.22**
Stormwater Runoff Reduction		
Food	**$0.69**	**$1.33**
Forage	$0.16	$0.16
Other	$0.53	$1.17
Wildlife Habitat	**$1.09**	**$28.54**
Bird Habitat	$0.83	$0.95
Iconic Species Habitat	$0.26	$27.60
Global Climate Regulation	**$6.30**	**$22.95**
Carbon Sequestration		
Local Climate Regulation	**$1,217.94**	**$1,217.94**
Energy savings		
Recreation	**$183.96**	**$183.96**
Hiking	$59.09	$59.09
Camping	$25.68	$25.68
Hunting	$10.99	$10.99
Wildlife Viewing	$88.20	$88.20
Science & Education	**$5.38**	**$5.38**
Education		
Soil Retention	**$6.14**	**$6.14**
Erosion Control		
Water Storage	**$0.59**	**$8.07**
Snowpack / Ice		
Water Quality	**$12.67**	**$51.42**
Nutrient and/or Contaminant Removal		
Total	**$2,035.35**	**$2,230.55**

Table A-2 Ecosystem service values for riparian, non-contiguous forests.

Riparian Forest Benefits	Lower per Acre (Sum)	Higher per Acre (Sum)
Aesthetic Information	**$1,028.96**	**$1,028.96**
Real Estate Value		
Air Quality	**$0.06**	**$77.56**
Removal of Air Pollutants		
Biological Control	**$10.76**	**$10.76**
Pest Control		
Cultural Value	**$4.79**	**$6.03**
Existence		
Energy & Raw Materials	**$17.07**	**$42.56**
Animal Products	$0.01	$0.04
Energy	$12.26	$12.26
Plant Products	$4.80	$30.26
Flood Risk Reduction	**$360.22**	**$360.22**
Stormwater Runoff Reduction		
Food	**$0.02**	**$4.81**
Fishery / Fishing		
Wildlife Habitat	**$422.38**	**$2,809.08**
Bird Habitat	$0.83	$0.95
Fish Habitat	$421.29	$2,780.54
Iconic Species Habitat	$0.26	$27.60
Global Climate Regulation	**$6.30**	**$22.95**
Carbon Sequestration		
Local Climate Regulation	**$1,217.94**	**$1,217.94**
Energy savings		
Recreation	**$213.53**	**$213.53**
Hiking	$59.09	$59.09
Fishing	$29.57	$29.57
Camping	$25.68	$25.68
Hunting	$10.99	$10.99
Wildlife Viewing	$88.20	$88.20
Science & Education	**$5.38**	**$5.38**
Education		
Soil Retention	**$23.34**	**$147.82**
Soil Retention		
Water Storage	**$0.59**	**$8.07**
Snowpack / Ice		

Water Capture, Conveyance, & Supply	**$117.28**	**$191.85**
Headwater Catchment		
Water Quality	**$630.48**	**$748.03**
Nutrient and/or Contaminant Removal		
Total	**$4,059.10**	**$6,895.55**

Table A-3 Additional value from contiguous forest.

Riparian, Non-Contiguous Forest Benefits	Lower per Acre (Sum)	Higher per Acre (Sum)
Wildlife Habitat	**$12.60**	**$19.59**
Biodiversity	$1.19	$8.17
Habitat	$11.41	$11.41
Total	**$12.60**	**$19.59**

Appendix B. Contingent Valuation Survey

B.1 Template of the survey distributed

7/28/22, 3:27 PM Wyoming Forests Survey

Wyoming Forests Survey

Wyoming's forests are important ecosystems that regulate and supply water, clean air, provide habitat for valued species, timber, recreational opportunities such as hunting and hiking, regulate micro-climates, have scenic beauty, and offer many other important benefits to the people of Wyoming.

The Nature Conservancy in Wyoming (TNC) is working with Conservation Strategy Fund (CSF) in a study to estimate the value of the state's forests to inform forest conservation and restoration activities. In this survey we are seeking data on how important forests are to the people in Wyoming and how much money they would be willing to pay to guard them against growing threats, including invasive species, fire risks, development, and habitat degradation, among others.

* Required

1. In the past year, how many times have you visited a forest in Wyoming for pleasure or recreation? *

   Mark only one oval.

   - None
   - 1-2 times
   - 2-5 times
   - > than 5 times

2. Do you currently contribute in-kind or with money towards forest conservation? *

   Mark only one oval.

   - Yes
   - No

https://docs.google.com/forms/d/1Oj0SReV-RuKK2KkSFQtqWokHmsRJq7EcS1yOSQ7TTwA/edit 1/4

3. On a scale from 1-5 (1= not important and 5= extremely important), how would you rate the following benefits provided by forests? *

Mark only one oval per row.

	1 (Not important)	2	3	4	5 (Extremely important)
Water supply and storage	◯	◯	◯	◯	◯
Wood/timber	◯	◯	◯	◯	◯
Climate change impact reduction	◯	◯	◯	◯	◯
Temperature regulation	◯	◯	◯	◯	◯
Erosion control	◯	◯	◯	◯	◯
Air filtration	◯	◯	◯	◯	◯
Water quality	◯	◯	◯	◯	◯
Flood risk reduction	◯	◯	◯	◯	◯
Wildlife habitat	◯	◯	◯	◯	◯
Soil quality	◯	◯	◯	◯	◯
Recreation	◯	◯	◯	◯	◯
Scenic views	◯	◯	◯	◯	◯
Cultural values	◯	◯	◯	◯	◯

Hypothetical scenario

In a hypothetical scenario, where a voluntary contribution was sought by Wyoming's forest managers to ensure forest health in Wyoming for the foreseeable future...

4. What is the maximum amount you would be willing to pay as an annual contribution to Wyoming's forest managers to implement forest conservation activities? *

____

5. If you are not willing to contribute any money towards conservation as proposed in this hypothetical scenario, what are the reasons for your answer?

Mark only one oval.

- ◯ I do not trust Wyoming's forest managers
- ◯ I do not think money should be spent on forest conservation
- ◯ I do not think I should pay more for conservation since I already pay taxes
- ◯ I agree with forest conservation but cannot afford any payment
- ◯ Other: _______________________________

6. What is your annual household income? *

Mark only one oval.

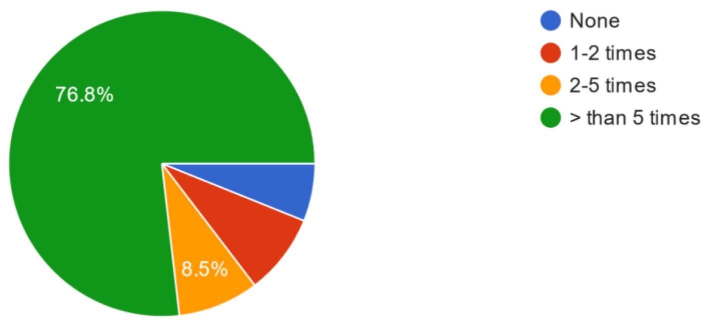
- ◯ Less than $35,000
- ◯ Between $35,000 and $65,000
- ◯ Between $65,000 and $95,000
- ◯ Greater than $95,000

7. Do you have any further comments on the importance of Wyoming's forests?

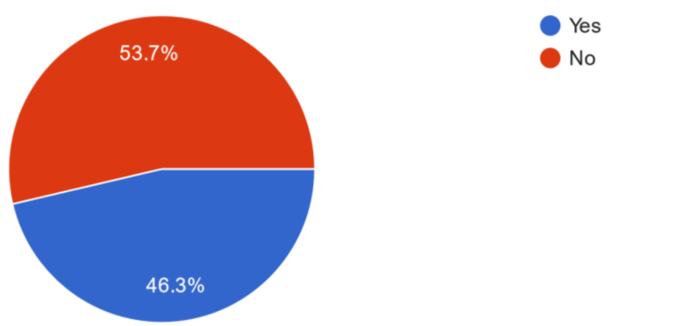
____
____
____
____
____

B.2 Other General Statistics of Survey Responses

In the past year, how many times have you visited a forest in Wyoming for pleasure or recreation?
82 responses



Do you currently contribute in-kind or with money towards forest conservation?
82 responses



If you are not willing to contribute any money towards conservation as proposed in this hypothetical scenario, what are the reasons for your answer?
44 responses

Appendix C. Recreation results by land manager

Benefits per acre by land manager. Ranges in contributions between land managers are mainly due to variations in visitation and forest acreage. For example, state park forests have relatively high contributions compared to BLM forests because state park forests have a relatively low acreage but relatively high visitation.

Table C-1 U.S. Forest Service values by activity.

Activity	Activity Days	Consumer Surplus	Expenditure / Acre	Total Forest Benefits / Acre
Hiking	8,852,565	$8.70	$42.84	$51.54
Fishing	969,392	$1.37	$6.58	$7.95
Camping	2,249,722	$0.80	$18.52	$19.33
Hunting	603,584	$0.43	$4.63	$5.06
Wildlife Viewing	8,175,819	$3.60	$62.18	$65.77
Total	**20,851,082**	**$14.90**	**$134.75**	**$179.65**

Table C-2 National Park Service values by activity.

Activity	Activity Days	Consumer Surplus	Expenditure / Acre	Total Forest Benefits / Acre
Hiking	3,904,397	$4.62	$66.67	$71.29
Fishing (and other)	1,208,504	$6.11	$28.94	$35.05
Camping	1,580,351	$3.17	$45.91	$49.08
Wildlife Viewing	5,949,558	$16.13	$159.64	$175.77
Total	**12,642,810**	**$30.02**	**$301.17**	**$331.19**

Table C-3 Bureau of Land Management values by activity.

Activity	Activity Days	Consumer Surplus	Expenditure / Acre	Total Forest Benefits / Acre
Hiking	131,646	$0.02	$0.81	$0.84
Fishing	114,412	$0.02	$0.99	$1.01
Camping	769,675	$0.08	$8.09	$8.17
Hunting	41,689	$0.01	$0.41	$0.42
Wildlife Viewing	91,417	$0.01	$0.89	$0.90
Total	**1,148,839**	**$0.15**	**$11.19**	**$11.34**

Table C- 4 Fish and Wildlife Service values by activity.

Activity	Activity Days	Consumer Surplus	Expenditure / Acre	Total Forest Benefits / Acre
Fishing	3,123,000	$33.84	$348.27	$459.58
Hunting	1,726,000	$29.30	$425.74	$201.12
Wildlife Viewing	3,125,000	$24.79	$171.81	$373.06
Total	**7,974,000**	**$87.93**	**$945.83**	**$1,033.76**

Table C- 5 Wyoming State Parks values by activity.

Activity	Activity Days	Consumer Surplus	Expenditure / Acre	Total Forest Benefits / Acre
Hiking	1,965,370	$91.32	$271.01	$362.33
Fishing	1,836,493	$57.71	$455.74	$513.45
Camping	2,008,329	$31.03	$1,107.49	$1,138.51
Hunting	134,247	$7.24	$171.97	$179.21
Wildlife Viewing	2,813,808	$93.26	$388.00	$481.25
Total	**8,758,247**	**$280.55**	**$2,394.20**	**$2,674.75**

Appendix D. Recreation Studies for Valuation

Economic Valuation Studies for Recreation

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Appendix E. General Benefit Transfer Valuation Studies

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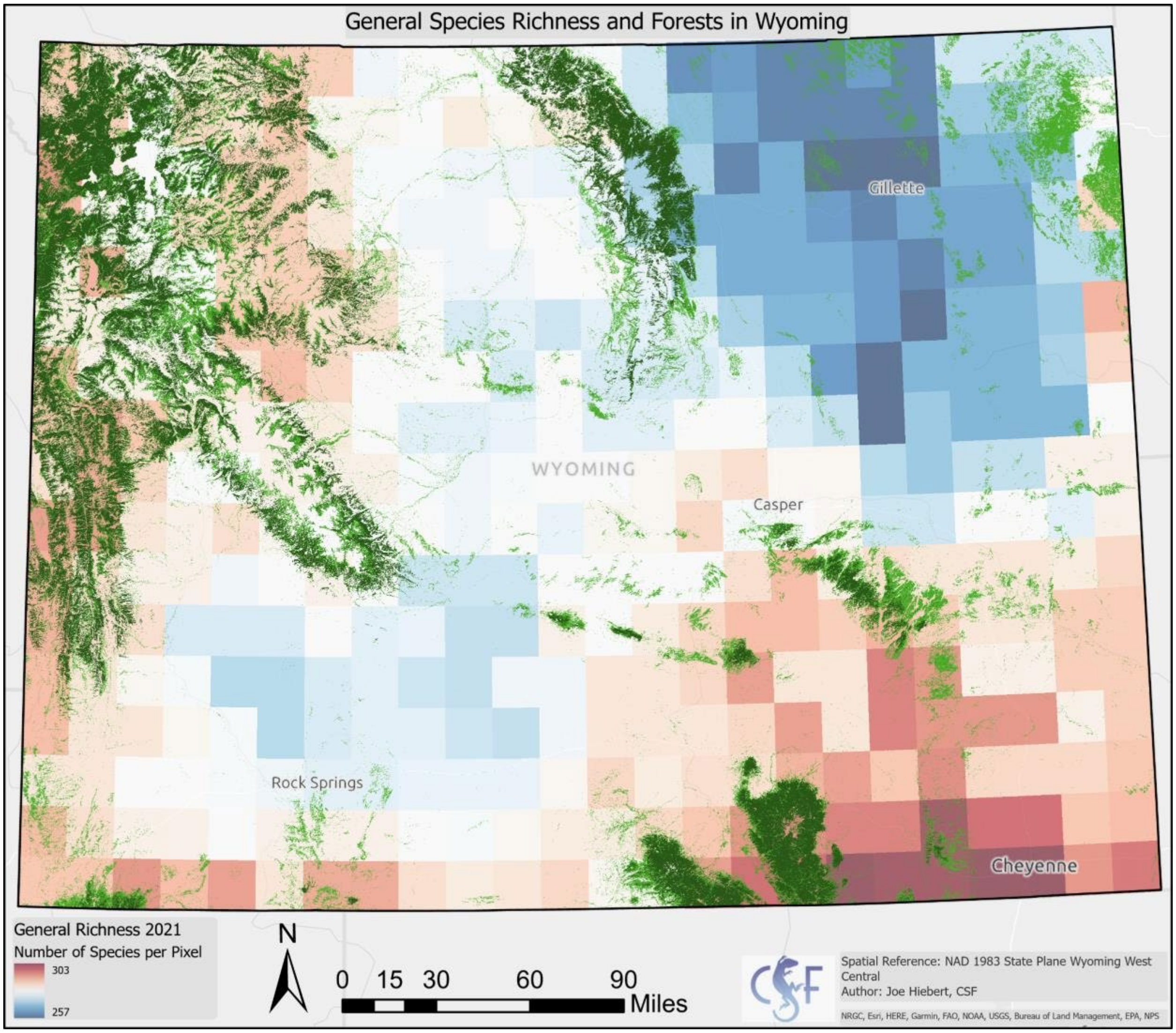
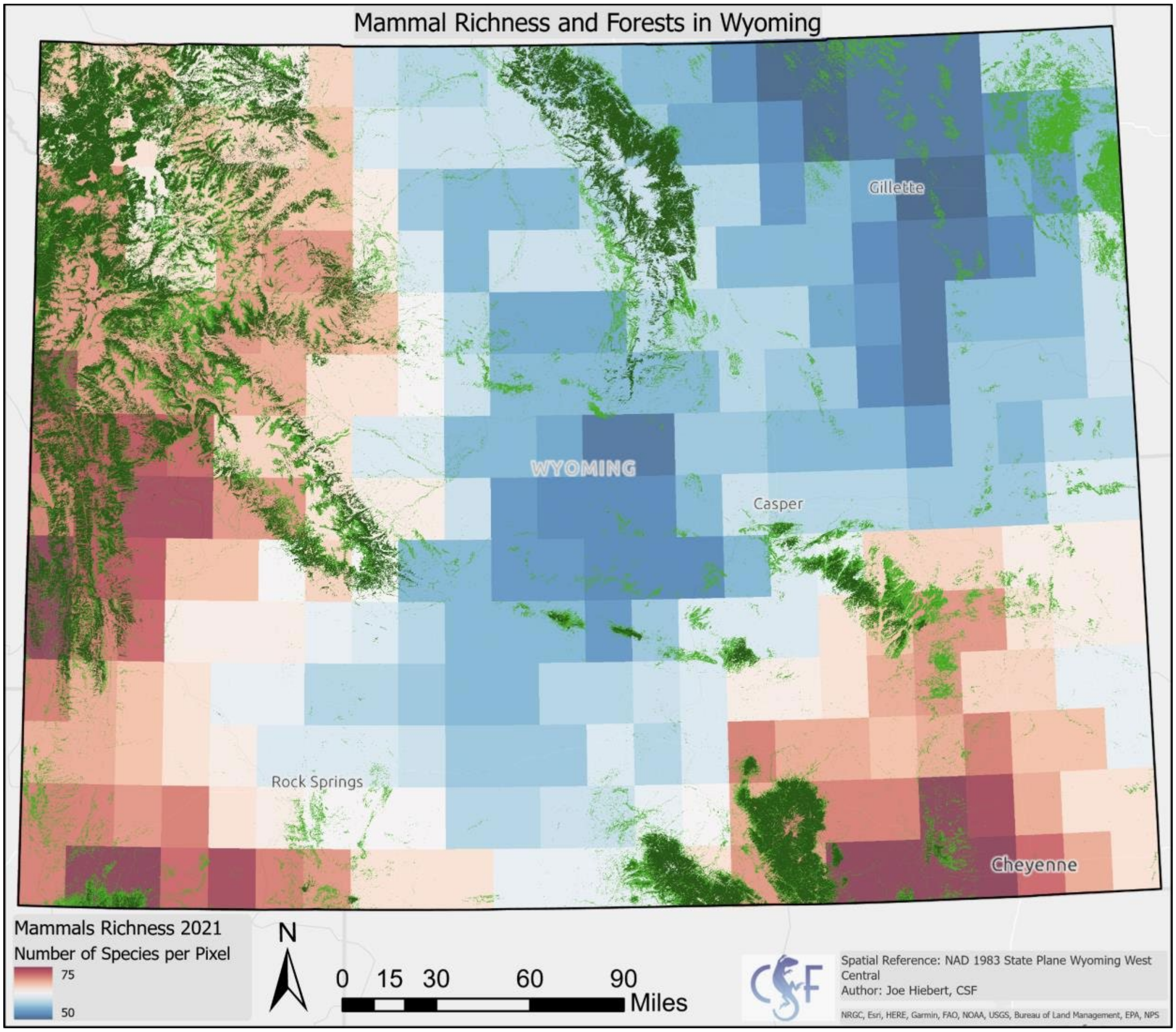
Appendix F. IUCN Biodiversity richness maps




Mammal Richness and Forests in Wyoming
Gillette
WYOMING
Casper
Rock Springs
Cheyenne
Mammals Richness 2021
Number of Species per Pixel
75
50
N
0 15 30 60 90
Miles
Spatial Reference: NAD 1983 State Plane Wyoming West Central
Author: Joe Hiebert, CSF
NRGC, Esri, HERE, Garmin, FAO, NOAA, USGS, Bureau of Land Management, EPA, NPS