Roanoke River Basin Ecosystem Service Value Assessment

Working Draft

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Prepared for:

Roanoke River Basin Association
&
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Study Overview

Recent studies in the Roanoke River Basin (RRB) have addressed ecosystem services at a conceptual level and conservation measures have sought to protect such services as water supply, water purification, and water-based recreation (Rashleigh B., Lagutov V., Salathe T., 2012; Roanoke River Basin Association. n.d.). This project examines a broad suite of services, including their spatial distribution and value, across the entire RRB (including the Dan River and Lower Roanoke subbasins). In the baseline assessment, basin-wide information provides a foundation on which citizens, planners, and resource managers at state and federal agencies can build an understanding and prioritize actions to restore ecosystem function in the RRB.

The next step involves analyzing, quantifying, and mapping priority services in two focal sub-basins, the Lower Roanoke, and (together) the Upper and Lower Dan. This focus involves participatory research techniques (National Research Council, 2008) to establish which ecosystem services are of greatest importance to these stakeholders. The tools and techniques outlined in the National Ecosystem Service Partnership (NESP) Guidebook also provide a framework for ecosystem service analysis (National Ecosystem Services Partnership, 2016).

Finally, and in the interest of supporting broader efforts to quantify and understand ecosystem services, the project will develop and publish code to connect spatial and tabular information on land cover/land use and ecosystem benefits and ease aggregate ecosystem service value calculations. The code will be created in Python for use in QGIS, an open-source geographic information system package. Accordingly, the code itself will be open-source and available as a free download and/or distributed as a QGIS “plugin”. This will enable less technical users to develop custom ecosystem services assessments for other subbasins, other regions entirely, and for various purposes.

The very big picture or vision of which the proposed work is a small part is the transformation of society, and especially the economy, in ways that bring the health of ecosystems and the associated welfare of people to bear on everyday economic decisions. In the course of doing its small part, this project will:

- Advance understanding of the relationships among human and natural systems in the RRB and especially in the Dan and Lower Roanoke watersheds
- Equip key stakeholders with information to support land conservation, river restoration, and sustainable economic development actions, such as smart growth planning, green infrastructure projects, the purchase of or easements for areas important for the provision of key ecosystem services
- Apply and test tools and techniques described in the NESP guidebook, thereby providing further lessons learned and examples to follow for federal agencies and others incorporating ecosystem services thinking into land and resource management decisions.

Ecosystem Service Valuation

The idea that people receive benefits from nature is not new, but “ecosystem services” as a term describing the phenomenon is more recent, emerging in the 1960s (Millennium Ecosystem Assessment, 2005). “Benefits people obtain from ecosystems” is perhaps the simplest and most commonly heard definition of ecosystem services (Reid et al., 2005).

“Ecosystem services” is sometimes lengthened to “ecosystem goods and services”. This makes it explicit that some are tangible, like physical quantities of food, water for drinking, and raw materials, while others are truly

services, like cleaning the air and providing a set of attributes that are conducive to recreational experiences or aesthetic enjoyment. We use the simpler "ecosystem services" here. Appendix B lists the provisioning, regulating, and cultural ecosystem services included in this study.

By estimating the total value of ecosystem services currently provided by the Roanoke River Basin, we gain a picture of the potential revenue that could be obtained if these services were monetized. At a minimum, we gain a fuller accounting of the value provided by the lands encompassed in the basin.

Ecosystem Service Estimation Methods

Economists have developed widely used methods to estimate the monetary value of ecosystem services and/or natural capital. The most commonly known example is from a study by Costanza et al. (1997) that valued the natural capital of the entire world. That paper and many others employ the Benefit Transfer Method (BTM) to establish a value for the ecosystem services produced or harbored by a particular place. According to the Organization for Economic Cooperation and Development, BTM is "the bedrock of practical policy analysis," particularly when collecting new primary data is not feasible (OECD, 2006).

BTM takes a rate of ecosystem benefit delivery calculated for one or more "source areas" and applies that rate to conditions in the "study area." Typically, the rates are drawn from previous studies that estimate the value of various ecosystem services from similar land cover/biome types. Benefits (in dollars per unit area) from the source areas are transferred and applied to the study area land with the same land cover. For example, data from the source area may include the value of forestland for recreation. In that case, the per-acre value of recreation from the source area can be applied to the number of acres of forestland in the study area. Multiplying that value by the number of acres of forestland in the study area to produce the estimate of the recreational value of the study area's forests. Furthermore, it is important to use source studies that are from regions with similar underlying economic, social, and other conditions to the study area. This ensures that the estimated values are accurate given the study area's specific demographics.

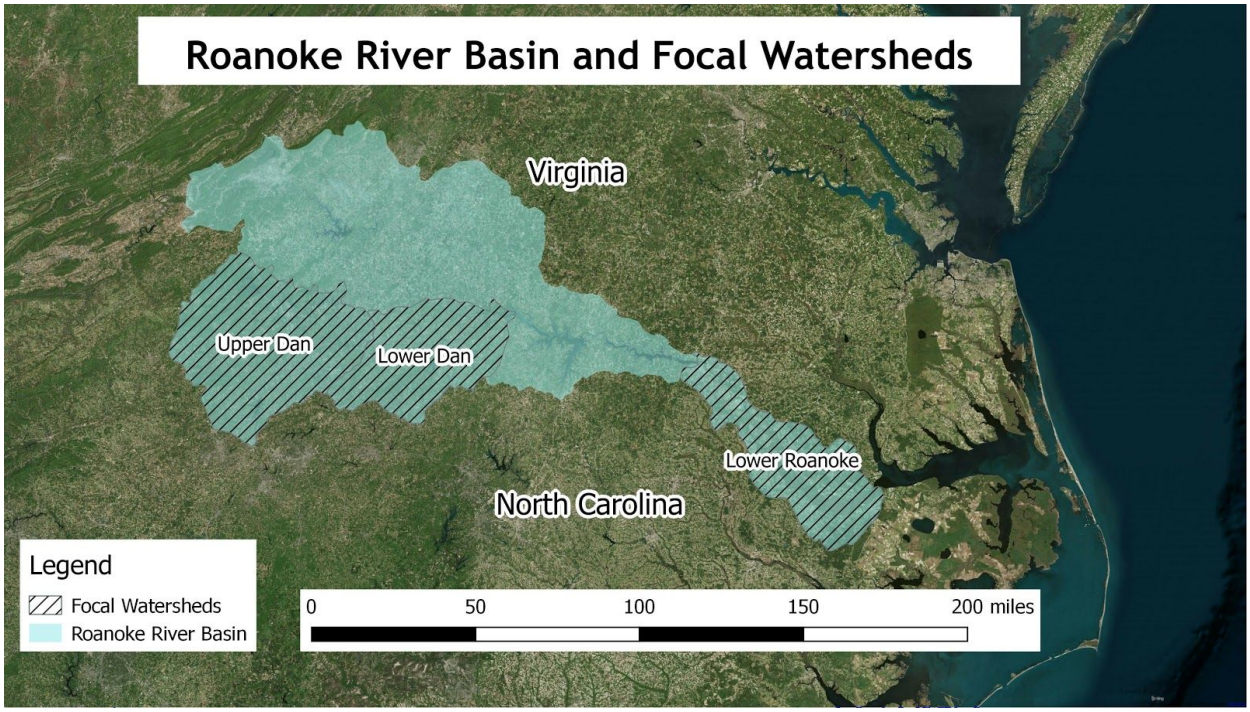
Estimation of ecosystem service value requires two general steps:

1. Identify total hectares within each land cover classification within the Roanoke River Basin and within the subwatersheds: Upper Dan, Lower Dan, and Lower Roanoke.
    a. This was performed in GIS, by clipping the NLCD layer to a shapefile of the Roanoke River Basin, delineated by watershed boundaries. There are seven subwatersheds in the Roanoke River Basin: Upper Roanoke River, Middle Roanoke River, Upper Dan River, Lower Dan River, Banister, Roanoke Rapids, and Lower Roanoke River.

2. Multiply total hectares in each land cover classification by the ecosystem service value per hectare per year for each individual ecosystem service, where applicable, to arrive at a final value of ecosystem service value in ($/yr) for each land cover in each subwatershed.
    a. Some land types, such as shrub/scrub and deciduous forests, only have one ecosystem service with quantified value(s) that were appropriate for benefit-transfer valuation. Others, particularly wetlands, have a handful of measured ecosystem service values, ranging from air quality to recreation.
    b. The variety in ecosystem services measures and number of studies for each land cover is a result of both the existence of any primary studies in each type of land and service, and by the suitability of those values in application to the Roanoke River Basin. For example, there are a handful of ecosystem service valuation studies for grasslands, but nearly all of the studies estimated values in African grasslands, and were not applied to grasslands in the Roanoke River Basin. Similarly, ecosystem service values for river basins in large cities, such as the Charles River Basin in Massachusetts, were excluded in this assessment.

The result is a three-dimensional dataset with dollar-value estimates of ecosystem services in each hectare of the study region based on land cover type. This provides a preliminary[1] baseline assessment of the region's ecosystem service value that will allow us to create land-use change scenarios and measure the impact of potential actions or policies.

Figure 1: Study Region



Baseline Land Cover in the Roanoke River Basin

The project study region, covering 2,540,000 hectares, stretches from Central and Southwest Virginia to the eastern coast of North Carolina, encompassing seven subwatersheds, including the Upper and Lower Dan River and the Lower Roanoke River (Figure 1). Clipping the most recent (2011) NLCD data to the study region provided the land cover distribution for the broader Roanoke River Basin.

[1] These baseline values for the region may change if more or better-suited studies are discovered in the deeper literature review.

Figure 2: NLCD Distribution of the Roanoke River Basin

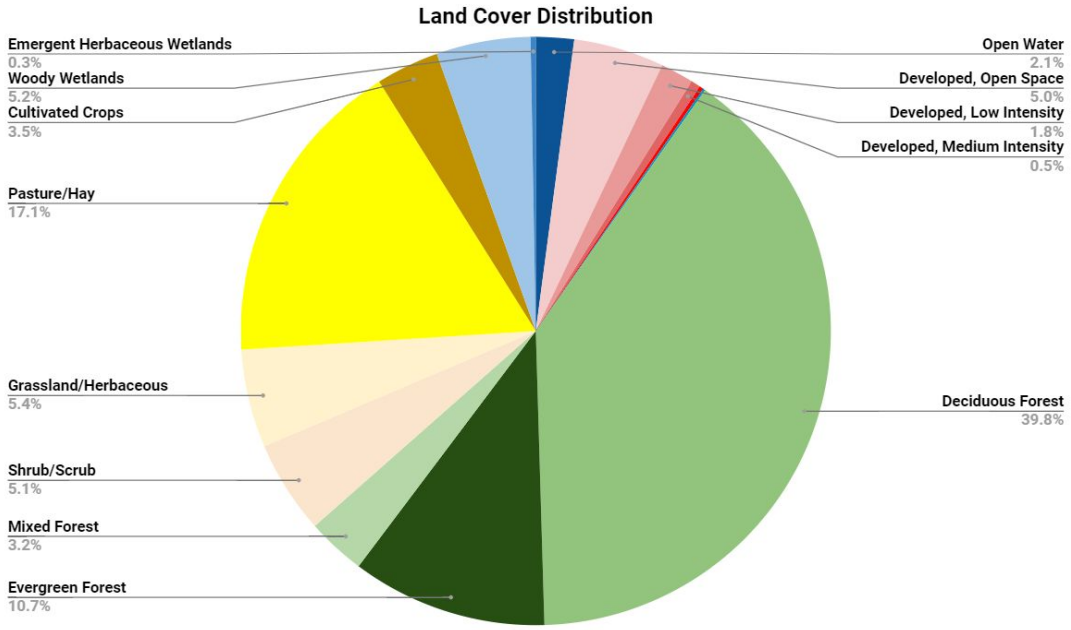


Table 1: Land Cover Distribution: Roanoke River Basin

Land Use	Total Hectares
Open Water	52,900
Developed, Open Space	126,000
Developed (Low, Medium, High Intensity)	64,849
Barren Land	3,143
Deciduous Forest	1,010,000
Evergreen Forest	272,000
Mixed Forest	81,600
Shrub/Scrub	130,000
Grassland/Herbaceous	137,000
Pasture/Hay	434,000
Cultivated Crops	87,800
Woody Wetlands	131,000
Emergent Herbaceous Wetlands	7,150

As described above, the next step is to apply per-hectare values (in dollars) for a variety of ecosystem services to the estimates of the area (in hectares) in each land cover category. For many combinations of land cover and ecosystem service, there is a range of such values from which to choose. After winnowing our database down to those candidate values most likely to be applicable in the study region, we have chosen to apply the minimum of the candidate per-hectare values. Preliminary estimates for the entire Roanoke River Basin and the Upper and Lower Dan River (combined) Subbasin are presented in the next sections.

Baseline Ecosystem Service Value Estimates

Basin-Wide Results

Table 2: Ecosystem Service Value in the Roanoke River Basin

NLCD Description	Service	Minimum Value ($/yr)	NLCD Description	Service	Minimum Value ($/yr)
Barren Land	Aesthetic	$2,014,446	Mixed Forest	Aesthetic	$31,885,087
	Recreation	$52,445,692		Air quality	$6,200,762
Barren Land Total		**$54,460,138**		BioControl	$529,582
Cultivated Crops	Aesthetic	$7,863,727		Climate	$684,622
	BioControl	$3,229,431		Cognitive	$8,833,985
	Climate	$93,950		Erosion	$645,454
	Erosion	$6,135,744		Extreme events	$161,104,755
	Food	$1,753,725,296		Food	$505,324,972
	Pollination	$2,278,514		Genepool	$137,904
	Recreation	$486,434		Pollination	$294,575
	Soil fertility	$1,635,789		Raw Materials	$34,827,572
	Waste	$29,712,877		Recreation	$581,806
Cultivated Crops Total		**$1,805,161,764**		Soil fertility	$1,270,507
Deciduous Forest	Air quality	$766,607,296		Waste	$16,320
Deciduous Forest Total		**$766,607,296**		Water	$42,671,752
Developed	Climate	$28,211,331		Water Flows	$48,020,613
	Water	$518,460	**Mixed Forest Total**		**$843,030,268**
Developed Total		**$28,729,791**	Open Water	Aesthetic	$529,108,303
Developed, Open Space	Aesthetic	$146,680,724		Energy	$5,052,642
	Air Quality	$10,470,711		Food	$3,484,399
	Climate	$135,787,655		Genepool	$342,095
	Extreme events	$101,778,333		Recreation	$1,375,254
	Recreation	$861,518,219		Waste	$1,449,806
	Water flows	$2,453,462		Water	$3,109,522
Developed, Open Space Total		**$1,258,689,105**	**Open Water Total**		**$543,922,020**

Emergent Herbaceous Wetlands	Aesthetic	$441,158
	Air Quality	$1,381,175
	Climate	$16,088
	Erosion	$3,245,122
	Extreme events	$5,099,845
	Food	$105,106
	Genepool	$5,646,180
	Nursery	$48,620
	Raw materials	$523,527
	Recreation	$104,033
	Soil Formation	$9,670,800
	Waste	$513,374
	Water	$9,451,866
	Water flows	$68,453,292
Emergent Herbaceous Wetlands Total		**$104,700,184**
Evergreen Forest	Food	$95,025
	Raw materials	$17,886,420
Evergreen Forest Total		**$17,981,445**
Grassland/Herbaceous	Aesthetic	$35,787,312
	BioControl	$5,318,775
	Climate	$10,930
	Erosion	$6,109,829
	Extreme events	$21,418,557
	Food	$12,889,116
	Pollination	$5,672,632
	Recreation	$5,123,756,856
	Soil fertility	$1,240,547
	Waste	$1,639,489
	Water flows	$886,690
Grassland/Herbaceous Total		**$5,214,730,733**
Pasture/Hay	Aesthetic	$113,762,004
	Food	$24,842,279
Pasture/Hay Total		**$138,604,283**
Shrub/Scrub	Aesthetic	$95,410,656
	Extreme events	$36,625,767
	Recreation	$571,334,905
	Water	$801,218,238
Shrub/Scrub Total		**$1,504,589,565**
Woody Wetlands	Aesthetic	$8,059,588
	Air Quality	$25,232,912
	Climate	$293,907
	Erosion	$59,285,653
	Extreme events	$93,169,887
	Food	$1,920,194
	Genepool	$103,150,975
	Raw Materials	$16,765,773
	Recreation	$26,974,149
	Soil Formation	$176,677,412
	Waste	$22,399,647
	Water	$172,677,661
	Water flows	$1,310,348,001
Woody Wetlands Total		**$2,016,955,760**

Dan River Subbasin Results

Table 3: Ecosystem Service Value in the Upper and Lower Dan River Subbasins

NLCD Description	Service	Minimum Value ($/yr)	NLCD Description	Service	Minimum Value ($/yr)
Barren Land	Aesthetic	$736,679		Food	$6,283,044
	Recreation	$19,179,281		Pollination	$2,765,232
Barren Land Total		$19,915,959		Recreation	$2,497,672,494
Cultivated Crops	Aesthetic	$277,745		Soil fertility	$604,728
	BioControl	$114,063		Waste	$799,200
	Climate	$3,318		Water flows	$432,234
	Erosion	$216,713	Grassland/Herbaceous Total		$2,542,019,436
	Food	$61,941,225	Mixed Forest	Aesthetic	$10,745,625
	Pollination	$80,477		Air quality	$2,089,725
	Recreation	$17,181		BioControl	$178,475
	Soil fertility	$57,776		Climate	$230,725
	Waste	$1,049,453		Cognitive	$2,977,150
Cultivated Crops Total		$63,757,951		Erosion	$217,525
Deciduous Forest	Air quality	$318,406,480		Extreme events	$54,294,075
Deciduous Forest Total		$318,406,480		Food	$170,300,075
Developed, High Intensity	Climate	$913,511		Genepool	$46,475
	Water	$16,788		Pollination	$99,275
Developed, High Intensity Total		$930,299		Raw Materials	$11,737,275
Developed, Low Intensity	Climate	$6,408,094		Recreation	$196,075
	Water	$117,766		Soil fertility	$428,175
Developed, Low Intensity Total		$6,525,860		Waste	$5,500

Developed, Medium Intensity	Climate	$1,894,682		Water	$14,380,850
	Water	$34,820		Water Flows	$16,183,475
Developed, Medium Intensity Total		$1,929,502	Mixed Forest Total		$284,110,475
Developed, Open Space	Aesthetic	$52,935,610	Open Water	Aesthetic	$101,059,288
	Air Quality	$3,778,775		Energy	$965,051
	Climate	$49,004,410		Food	$665,518
	Extreme events	$36,730,785		Genepool	$65,340
	Recreation	$310,913,330		Recreation	$262,672
	Water flows	$885,430		Waste	$276,912
Developed, Open Space Total		$454,248,340		Water	$593,916
Emergent Herbaceous Wetlands	Aesthetic	$15,299	Open Water Total		$103,888,697
	Air Quality	$47,897	Pasture/Hay	Aesthetic	$39,264,806
	Climate	$558		Food	$8,574,280
	Erosion	$112,535	Pasture/Hay Total		$47,839,086
	Extreme events	$176,853	Shrub/Scrub	Aesthetic	$25,746,552
	Food	$3,645		Extreme events	$9,883,458
	Genepool	$195,799		Recreation	$154,174,644
	Nursery	$1,686		Water	$216,208,629
	Raw materials	$18,155	Shrub/Scrub Total		$406,013,283
	Recreation	$3,608	Woody Wetlands	Aesthetic	$479,252
	Soil Formation	$335,365		Air Quality	$1,500,438
	Waste	$17,803		Climate	$17,477
	Water	$327,773		Erosion	$3,525,335
	Water flows	$2,373,829		Extreme events	$5,540,211

Emergent Herbaceous Wetlands Total		$3,630,801			Food	$114,182
Evergreen Forest	Food	$26,775			Genepool	$6,133,722
	Raw materials	$5,039,820			Raw Materials	$996,952
Evergreen Forest Total		$5,066,595			Recreation	$1,603,978
Grassland/Herbaceous	Aesthetic	$17,445,204			Soil Formation	$10,505,864
	BioControl	$2,592,738			Waste	$1,331,962
	Climate	$5,328			Water	$10,268,025
	Erosion	$2,978,352			Water flows	$77,917,932
	Extreme events	$10,440,882		Woody Wetlands Total		$119,935,331

Land Management Scenarios

[To be developed through the workshops and further conversations]

Ecosystem Services Impacts

[Application of BTM and other tools to assess the effects of land use/land management and other changes on ecosystem services and ecosystem service values in the Roanoke River Basin.]

Conclusions & Recommendations

[Education, Management, Policy, and other Actions to preserve, protect, or enhance ecosystem service delivery in the Roanoke River Basin.]

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Appendix A: NLCD Classifications

NLCD Classification	NLCD Description
Open Water	areas of open water, generally with less than 25% cover of vegetation or soil.
Perennial Ice/Snow	areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover
Developed, Open Space	areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed, Low Intensity	areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
Developed, Medium Intensity	areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed, High Intensity	highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren Land	areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover
Deciduous Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage
Mixed Forest	areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Dwarf Scrub	Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This

	type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
Shrub/Scrub	areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Grassland/Herbaceous	areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Sedge/Herbaceous	Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
Lichens	Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
Moss	Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Pasture/Hay	areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Cultivated Crops	areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Woody Wetlands	areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Appendix B: Ecosystem Service Descriptions

Provisioning Services[a]
Food Production: The harvest of agricultural produce, including crops, livestock, and livestock by-products; the food value of hunting, fishing, etc.
Raw Materials: Fuel, fiber, fertilizer, minerals, and energy.
Water Supply: Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, watering livestock, irrigation, industrial processes, hydroelectric generation, and other uses.
Regulating Services[a]
Air Quality: Removing impurities from the air to provide healthy, breathable air for people.
Climate Regulation: Storing atmospheric carbon in biomass and soil as an aid to the mitigation of climate change, and/or keeping regional/local climate (temperature, humidity, rainfall, etc.) within comfortable ranges.
Erosion Control: Retaining arable land, stabilizing slopes, shorelines, riverbanks, etc.
Pollination: Contribution of insects, birds, bats, and other organisms to pollen transport resulting in the production of fruit and seeds. May also include seed and fruit dispersal.
Protection from Extreme Events: Preventing and mitigating impacts on human life, health, and property by attenuating the force of winds, extreme weather events, floods, etc.
Soil Formation: Creation of soil, inducing changes in depth, structure, and fertility, including through nutrient cycling.
Waste Treatment: Improving soil and water quality through the breakdown and/or immobilization of pollution.
Water Flows: Regulation by land cover of the timing of runoff and river discharge, resulting in less severe drought, flooding, and other consequences of too much or too little water available at the wrong time or place.
Genepool: Preservation of biodiversity
Nursery: Suitable reproduction habitat
Biological Control: Population control through trophic-dynamic relations
Cultural Services[a]
Aesthetic Value: The role that beautiful, healthy natural areas play in attracting people to live, work, and recreate in a region.
Recreation: The availability of a variety of safe and pleasant landscapes—such as clean water and healthy shorelines—that encourage ecotourism, outdoor sports, fishing, wildlife watching, hunting, etc.
Cognitive: Variety in nature with scientific and educational value

a. Descriptions follow Balmford (2010, 2013), Costanza et al. (1997), Reid et al. (2005), and Van der Ploeg, et al. (2010).