FEMA Ecosystem Service Value Updates

June 2022

FEMA

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1. Background and Purpose of this Report

Natural disasters are increasing in frequency and severity in the United States (U.S.) and around the globe. Climate change and other factors—including land use planning decisions that have allowed people to live in hazard-prone areas—are effectuating the increase. Since 1980, the U.S. has experienced 323 weather and climate disasters that reached or exceeded $1 billion in damages (as of April 2022), with the total cost exceeding $2.195 trillion.[1] The impacts of these natural disasters are compounded by the effects of COVID-19 and tend to disproportionately impact low-income communities and communities of color, further exacerbating inequity.

The Federal Emergency Management Agency (FEMA) provides billions of dollars each year to communities through its Hazard Mitigation Assistance (HMA) programs to reduce or eliminate long-term risk from natural disasters. FEMA defines hazard mitigation as "Any sustained action taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects." HMA programs include the Hazard Mitigation Grant Program (HMGP), Building Resilient Infrastructure and Communities (BRIC) and Flood Mitigation Assistance (FMA). FEMA also provides hazard mitigation funding through the Public Assistance (PA) program, sometimes referred to as 406 Hazard Mitigation.

FEMA requires that hazard mitigation projects be cost-effective to the federal government; therefore, the project must demonstrate a Benefit-Cost Analysis (BCA) that compares the net present value of a project's future benefits and costs. A Benefit-Cost Ratio (BCR) of 1.0 or greater indicates that the risk reduction benefits of a project outweigh the costs, thereby deeming the project "cost-effective" and a worthwhile and eligible investment for the federal government. A BCA is required for the vast majority of FEMA-funded hazard mitigation activities, with few exceptions (e.g., 5% Initiative projects). For this reason, FEMA developed a BCA Toolkit to assist subapplicants in conducting BCAs for a range of mitigation actions.

In recent years, FEMA began to recognize and emphasize the value of investing in Nature-Based Solutions (NBS) for mitigating the impacts of floods, wildfires, droughts and other natural hazards. FEMA defines NBS as "Sustainable planning, design, environmental management, and engineering practices that weave natural features or processes into the built environment to build more resilient communities."[2] NBS can include the use of natural features such as wetlands, open space and urban green infrastructure to help buffer communities from damages caused by natural hazards, thereby reducing costs to taxpayers and harm to vulnerable communities. For example, coastal wetlands can reduce coastal storm damage, riverfront trail systems can capture and store water during floods, forested areas managed for vegetation can serve as wildfire buffers, and urban trees can mitigate the impacts of dangerous heatwaves. Economic studies have shown that NBS can often be more cost-effective than traditional, man-made solutions, such as levees or seawalls, while providing multiple community and environmental benefits. Ecosystem services are an important benefit of hazard mitigation projects that incorporate NBS, and they also establish hazard mitigation approaches that are not considered NBS, per se (e.g., acquisition and relocation can improve floodplain health in the footprint of the removed structures).

FEMA's new emphasis on NBS has been reflected through several important policy advances and updates to the BCA Toolkit that have made it easier for subapplicants to calculate the benefits of NBS in a BCA. A key foundation for these advances has been the adoption of monetary values for "ecosystem services" into the BCA Toolkit. Ecosystem services are defined by FEMA as "direct or indirect contributions that ecosystems make to the environment and human populations." Pre-calculated ecosystem service values are embedded into FEMA's BCA Toolkit, calculated as "dollar per acre per year" ($/acre/year) values according to land cover type, creating a relatively simple framework for subapplicants who would like to value the ecosystem services associated with their mitigation project.

FEMA's notable policy updates related to ecosystem services[i] have included:

- **2013: Creation of first ecosystem services policy.** FEMA issued its first ecosystem services policy in 2013,[3] incorporating dollar values for ecosystem services into the BCA Toolkit for the "riparian" and "green open space" land cover categories. Earth Economics developed the framework and values for these land cover categories and associated ecosystem services, under subcontract to Ideation, Inc. Note that this policy has now been superseded by the 2016 and 2020 policies below.

- **2016: Update and expansion of ecosystem services policy.** FEMA issued another ecosystem services policy in 2016,[4] which introduced ecosystem service values for new land cover categories ("wetlands," "forest," and "marine and estuary"). The policy also introduced new eligible activities, including floodplain and stream restoration, green infrastructure,[ii] post-wildfire mitigation and aquifer storage and recovery. Earth Economics developed the values for these new land cover categories, and updated values for existing land cover categories, under subcontract to—and with significant input and guidance from—CDM Federal Programs Corporation, which were summarized for FEMA in the 2015 report *Update to FEMA Ecosystem Services Values*.[5]

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[i] Note that ecosystem services were referred to as "environmental benefits" in both the 2013 and 2016 policies but will be referred to in this report only as "ecosystem services" to avoid confusion.

[ii] In the supporting materials for FEMA's 2016 environmental benefits policies, the agency had not yet adopted the term "Nature-Based Solutions." Instead, it used the term "green infrastructure," which it defined as "A sustainable approach to natural landscape preservation and storm water management that can be used for hazard mitigation activities as well as provide additional ecosystem benefits." However, since then, it appears that FEMA has moved towards the term "Nature-Based Solutions" to refer to a similar set of concepts, as seen in the definition above. In the 2020 guide *Building Community Resilience with Nature-Based Solutions*, FEMA notes that the term "nature-based solutions" is largely interchangeable with terms used by other agencies and organizations such as "green infrastructure," "natural infrastructure," or "Engineering with Nature"® (a U.S. Army Corps of Engineers program). For consistency with FEMA's approach, this report uses the term "Nature-Based Solutions" to encompass all these related terms, though it is recognized that other agencies and experts use the terms in different ways (e.g., EPA uses Green Infrastructure to refer to specific kinds of stormwater practices).

- **2020: Removal of limitations on use of ecosystem services in BCA.** One limitation of the 2013 and 2016 policies was that projects were required to achieve a benefit-cost ratio of 0.75 using "traditional" risk reduction benefits, such as reduced damage to structures, before the ecosystem service values could be included in a BCA. However, in September 2020, FEMA released a significant policy update, building directly on the 2013 and 2016 policies. FEMA Policy FP-108-024-02, titled "Ecosystem Service Benefits in Benefit-Cost Analysis for FEMA's Mitigation Programs Policy,"[6] recognized that the natural environment is an important component of a community's resilience strategy, and removed the 0.75 benefit-cost ratio threshold requirement. In other words, nature-based hazard mitigation projects could now be considered cost-effective based on the value of their ecosystem services alone. The policy is still relatively new at the time of writing this report, but it seems likely that this policy will reduce the technical and monetary burden on subapplicants that would like to advance nature-based solutions, by eliminating the need for complex modeling in many cases, and open FEMA's hazard mitigation funding programs to a larger pool of nature-based project types and subapplicants.

The purpose of this report is to provide details and guidance on a proposed, updated set of land cover categories and ecosystem service values for FEMA's BCA Toolkit. Key changes to the FEMA's 2016 ecosystem service values, referenced above, include an expansion in the number of land cover categories (from the existing 5 to 10), incorporation of many additional source studies for values associated with the new and existing land cover categories and removal of some source studies. This report also includes more detailed guidance on how to interpret and use the land cover categories in the context of a mitigation project BCA, including hypothetical project examples.

This report is structured as follows:

- **Classifying Ecosystem Services:** This section describes the framework used for classifying and defining ecosystem services.

- **Methods for Valuing Ecosystem Services.** This section summarizes the valuation methods used by the source studies that are the basis for the proposed ecosystem service value updates.

- **Proposed Updates to FEMA's Ecosystem Service Values:** This section summarizes the land cover categories and associated ecosystem service values proposed in this update, summarizes changes to FEMA's 2016 ecosystem service values, provides definitions for each land cover category, and summarizes project useful life (PUL) considerations for each land cover category.

- **Using Ecosystem Service Values in the FEMA BCA Toolkit:** This section provides conceptual and real examples of how the land cover categories and ecosystem service values can be used in the context of a BCA for a mitigation project.

- **Appendices A–I:** Each of these Appendices contains detailed information for one of the 10 land cover categories, including the proposed ecosystem service values associated with the category, PUL considerations for that land cover category, Feasibility & Effectiveness criteria for that land cover category and mitigation project use cases that might involve that land cover category (including both conceptual and real examples). Finally, under each ecosystem service value associated with a given land cover category, there is a description of the source study/studies that were used to develop the value, the methods for deriving the value and discussion.

- **Appendix J:** This appendix provides more details on source studies and values that have been added or removed in comparison with FEMA's 2016 ecosystem service values.

2. Classifying Ecosystem Services

Nature contributes substantial value to the economy, providing essential goods and services that communities, governments and businesses depend on. These goods and services are collectively known as "ecosystem services," and are often defined as the benefits that people receive from nature. Ecosystem services are essential to human survival and economic prosperity, and include clean air, drinkable water, nourishing food, hazard risk reduction, habitat for fish and wildlife and a stable climate.

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 initiated an assessment of 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 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."[7] This study produced the landmark Millennium Ecosystem Assessment, which classified ecosystem services into four broad categories according to how they benefit people:

- **Provisioning Services** provide the physical materials that economies and communities use. Community gardens grow food. Rivers provide drinking water, as well as fish for food.
- **Regulating Services** are benefits obtained from ecosystem processes. Intact ecosystems provide regulation of climate, water quality/supply and soil erosion control. They also keep disease organisms in check.
- **Supporting Services** refer to the habitats which support food webs and all life on the planet.
- **Information Services** 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.

Table 1: Categories of Ecosystem Services

Ecosystem Service	Definition	Economic Value Assigned
Provisioning		
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy	-
Food Provisioning	Producing crops, fish, game, and fruits	X
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms	-

Ecosystem Service	Definition	Economic Value Assigned
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	X
Biological Control	Providing pest, weed, and disease control	X
Climate Regulation	Supporting a stable climate at global and local levels through carbon sequestration and other processes	X
Hazard Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts	X
Pollination	Pollinating wild and domestic plant species via wind, insects, birds, or other animals	X
Soil Formation	Accumulating soils (e.g., via plant matter decomposition or sediment deposition in riparian/coastal systems) for agricultural and ecosystem integrity	-
Soil Quality	Maintaining soil fertility and capacity to process waste inputs (bioremediation)	-
Erosion Control	Retaining arable land, slope stability, and coastal integrity	X
Water Filtration	Removing water pollutants via soil filtration and transformation by vegetation and microbial communities	X
Water Supply	Regulating the rate of water flow through an environment and ensuring adequate water availability for all water users	X
Supporting		
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity	X
Pollination	Pollinating wild and domestic plant species via wind, insects, birds, or other animals	X
Nutrient Cycling	Transfer of nutrients from one place to another; transformation of critical nutrients and unusable to usable forms	-

Ecosystem Service	Definition	Economic Value Assigned
Information		
Aesthetic Value	Enjoying and appreciating the scenery, sounds, and smells of nature	X
Existence Value	Well-being gained by the knowledge that an environmental resource exists, even without on-site use of that resource	X
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious and historic importance	-
Research and Education	Using natural systems for education and scientific research	X
Recreation/Tourism	Experiencing the natural world and enjoying outdoor activities	X

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3. Methods for Valuing Ecosystem Services

While nature is priceless in one sense, it also generates tremendous economic value, which can be measured using a variety of established methods. Furthermore, most planning and infrastructure decisions are considered in economic terms, using tools such as BCA. When nature-based solutions are not valued in these same terms, they are effectively given a default value of zero, putting them at a big disadvantage compared with traditional, engineered approaches. With recent advances in the economic literature, the economic value of nature-based solutions to communities, governments and businesses can now be estimated in dollars, and the ecosystem services framework provides a comprehensive approach for capturing these benefits.

Though ecosystem services provide real and quantifiable economic value, they are generally not bought or sold on a market (i.e., they are non-market benefits), and therefore their value must be estimated by means other than market prices. Over the past several decades, the fields of environmental and natural resource economics have developed and refined several methods for estimating the value of ecosystem services. These valuation methods fall into three broad categories: (1) direct market valuation, (2) revealed preferences and (3) stated preference. **Table 2** describes the most common valuation techniques within each of these categories

Table 2: Ecosystem Service Valuation Methods

Method	Description	Example
Direct Market Valuation		
Market Price	Valuations are directly obtained from the prices paid for the good or service in markets	The price of wheat sold on open markets
Replacement Cost	Cost of replacing the ecosystem service with engineered systems	The cost of replacing a watershed's natural filtration capacity with a water filtration plant
Avoided Cost	Costs that are incurred when the ecosystem service is lost	Wetlands absorb and retain water, reducing flooding to downstream infrastructure. Flooding increases when the wetlands are lost or degraded.
Production Approaches	Value created from an ecosystem service through increases to dependent economic outputs	Better grazing land health may increase stocking rates for livestock
Revealed Preference Approaches		
Travel Cost	Costs incurred to consume or enjoy ecosystem services reflects a minimum implicit value of the service	Tourists who travel to visit a locale must value that resource at least as much as the cost of traveling there.

Method	Description	Example
Hedonic Pricing	Value implied by the additional price consumers are willing to pay for the service in related markets.	Property values near lakes and parks tend to exceed similar properties without such nearby amenities.
Stated Preference Approaches		
Contingent Valuation	Value elicited by posing hypothetical, valuation scenarios	What people are willing to pay to protect an endangered species

The approaches described above are *primary* methods, meaning they rely on new data generated by the authors of the study. There are also approaches to ecosystem service valuation that are *secondary* methods, meaning they rely on values, data and/or models that already exist from previously conducted primary studies. This approach is often referred to as benefit transfer or value transfer, which can be broadly defined as the process of estimating the value of an ecosystem service at the site of interest by using an existing valuation estimate(s) that has been developed at another site. Benefit transfer is often used to estimate the value of ecosystem services, as it can generate defensible estimates quickly and at a fraction of the cost of conducting local, primary studies, which typically require much more time and funding.

The United Nations Environmental Program, in its *Guidance Manual on Value Transfer Methods for Ecosystem Services*[8] defines three main types of value transfer (direct quote):

- **Unit value transfer** uses values for ecosystem services at a study site, expressed as a value per unit, combined with information on the quantity of units at the policy site to estimate policy site values. Unit values can be adjusted to reflect differences between the study and policy sites (e.g., income and price levels).
- **Value function transfer** uses a value function estimated for an individual study site in conjunction with information on policy site characteristics to calculate the unit value of an ecosystem service at the policy site. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service.
- **Meta-analytic function transfer (or simply "meta-analysis")** uses a value function estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on policy site characteristics to calculate the unit value of an ecosystem service at the policy site. Since the value function is estimated from the results of multiple studies it can represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics.

4. Ecosystem Service Value Updates

4.1. Summary of Proposed Land Cover Categories and Ecosystem Service Values

Table 3 summarizes the differences in the land cover categories, as well as total value by land cover category, between the 2016 adopted ecosystem services and the values proposed in this update.

Table 3. Summary of Changes to Land Cover Categories and Ecosystem Service Values

2016 Adopted Values		2022 Proposed Values	
Land Cover Category	Value (2014 USD/acre/year)	Land Cover Category	Value (2021 USD/acre/year)
Forest	554	Forest	12,589
Green Open Space	8,308	Urban Green Open Space	15,541
		Rural Green Open Space	10,632
Riparian	39,545	Riparian	37,199
Wetland	6,010	Coastal Wetland	8,955
		Inland Wetland	8,171
Marine and Estuary	1,799	n/a*	n/a
n/a	n/a	Coral Reefs	7,120
n/a	n/a	Shellfish Reefs	2,757
n/a	n/a	Beaches and Dunes	300,649

*The Marine and Estuary category (and most of its associated values) was merged with the Coastal Wetland category

Table 3 summarizes the full proposed updated set of land cover categories and ecosystem service values.

Table 4. Summary of Proposed Land Cover Categories and Ecosystem Service Values

Ecosystem Service	Value by Land Cover Category (2021 USD/acre/year)								
	Urban Green Open Space	Rural Green Open Space	Riparian	Forest	Coastal Wetland	Inland Wetland	Coral Reefs	Shellfish Reefs	Beaches and Dunes
Aesthetic Value	7,010	7,505	767	1,477	1,648	1,303	327	-	223,840
Air Quality	201	-	254	711	-	-	-	-	-
Biological Control	-	-	199	-	-	-	-	-	-
Climate Regulation	54	77	96	199	125	56	-	-	-
Erosion Control	78	78	13,823	1,672	-	-	-	-	-
Existence Value	-	-	-	7,531	-	-	-	-	-
Flood and Storm Hazard Reduction	316	-	6,052	368	1,035	1,264	3,269	-	-
Food Provisioning	-	-	736	-	-	-	18	1,905	-
Habitat	5,890	2,021	2,547	-	2,420	1,416	2,222	-	-
Pollination	350	350	-	-	-	-	-	-	-
Recreation/Tourism	1,642	601	6,215	94	1,624	1,906	1,261	253	76,809
Research and Education	-	-	-	-	-	-	23	-	-
Water Filtration	-	-	6,239	435	1,558	1,584	-	600	-
Water Supply	-	-	272	103	544	643	-	-	-
Total Estimated Benefits	15,541	10,632	37,199	12,589	8,955	8,171	7,120	2,757	300,649

4.2. Summary of Changes to FEMA's 2016 Land Cover Categories and Ecosystem Service Values

Key updates in the proposed ecosystem service value sets, in comparison with FEMA's 2016 values, include:

- **An increase in the number of land cover categories**, from the current five to nine, including both modification of existing land cover categories and addition of new land cover categories:
  - The **Wetlands** category has been broken out into **Inland Wetlands** and **Coastal Wetlands.**
  - **Marine and Estuary** was removed as a category, and many of the source studies and associated values were incorporated into the **Coastal Wetlands** category.
  - The **Green Open Space** category has been broken out into **Urban Green Open Space** and **Rural Green Open Space.**
  - **Coral Reefs**, **Shellfish Reefs**, and **Beaches and Dunes** are new proposed land cover categories.
  - The **Forest** and **Riparian** categories remain unchanged.
- **An increase in the number of source studies and ecosystem service values.** Publications on ecosystem services have expanded rapidly in the past decade, with 30 percent of new studies globally being published in the U.S.[9] In total, ~50 new source studies have been added compared with the 2016 values, forming the basis for >50 new or updated value estimates. Some source studies were also removed. Appendices A–I include more detailed information about all ecosystem service values by land cover, including source studies, calculations, and assumptions. Appendix J includes more information about specific source studies and values that were added or removed.

A greater emphasis on values derived from meta-analyses. Meta-analyses, discussed above, are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. For many combinations of land cover category and ecosystem service (Appendices A–I contain details), meta-analyses exist which can estimate multiple ecosystem services at once. In these cases, meta-analysis was relied upon to provide generalized value estimates that could be representative of ecosystems throughout the U.S. This approach results in a more defensible and broadly applicable value for the BCA Toolkit, which uses the same set of ecosystem service values no matter where in the U.S. the mitigation project is located.

- **All values have been adjusted for inflation to 2021 U.S. dollars,** including values for which source studies were not added or removed.

Table 5 summarizes the full set of proposed land cover category-ecosystem service combinations and indicates which have been updated from FEMA's 2016 values. Bold, underlined values represent newly added values, or values for which source studies were added or removed, while the remaining values were updated for inflation only (from 2014 to 2021 U.S. dollars).

Table 5. Summary of Changes to FEMA's 2016 Ecosystem Service Values

Ecosystem Service	Value by Land Cover Category (2021 USD/acre/year)								
	Urban Green Open Space	Rural Green Open Space	Riparian	Forest	Coastal Wetland	Inland Wetland	Coral Reefs	Shellfish Reefs	Beaches and Dunes
Aesthetic Value	7,010	7,505	767	1,477	1,648	1,303	327	-	223,840
Air Quality	201	-	254	711	-	-	-	-	-
Biological Control	-	-	199	-	-	-	-	-	-
Climate Regulation	54	77	96	199	125	56	-	-	-
Erosion Control	78	78	13,823	1,672	-	-	-	-	-
Existence Value	-	-	-	7,531	-	-	-	-	-
Flood and Storm Hazard Reduction	316	-	6,052	368	1,035	1,264	3,269	-	-
Food Provisioning	-	-	736	-	-	-	18	1,905	-
Habitat	5,890	2,021	2,547	-	2,420	1,416	2,222	-	-
Pollination	350	350	-	-	-	-	-	-	-
Recreation/Tourism	1,642	601	6,215	94	1,624	1,906	1,261	253	76,809
Research and Education	-	-	-	-	-	-	23	-	-
Water Filtration	-	-	6,239	435	1,558	1,584	-	600	-
Water Supply	-	-	272	103	544	643	-	-	-
Total Estimated Benefits	15,541	10,632	37,199	12,589	8,955	8,171	7,120	2,757	300,649

It should also be noted that, as in the 2016 update, in cases where more than one appropriate value was available for a given land cover/ecosystem service combination, the average of those values was taken. However, not every land cover/ecosystem service combination could be valued due to lack of appropriate literature for a nation-wide estimate. That a specific combination of landcover and ecosystem service value has not been included here does not necessarily mean such ecosystems do not produce a given service—or that the service is not valuable—but rather reflects a lack of an appropriate source study/studies relevant to that combination. For this reason, value estimates may in some cases be underestimates, since not all ecosystem services could be valued. Additionally, caution should be exercised when comparing total ecosystem service values across landcover types, as differences in total value may reflect information gaps, rather than real differences in ecosystem productivity or the value of such services. It should be noted that inclusion of newer valuation studies or additional studies that bring more context to the values previously may affect average values per service, leading to increases or decreases in value compared with the 2016 values.

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5. Using Ecosystem Service Values in the FEMA BCA Toolkit

This section provides step-by-step guidance on how to apply the ecosystem service values in FEMA's BCA Toolkit for a mitigation action or project. Steps are described in the general order in which they are likely to be followed, though subapplicants can follow the steps in a different order depending upon their context and needs.

First, guidance is provided on how to define the land cover category (or categories) associated with the mitigation project, including definitions for each category that has associated dollar values. Next, general guidance is provided on Feasibility & Effectiveness criteria that the subapplicant must meet for each land cover category used. General guidance is then provided on selecting an appropriate PUL associated with the land cover category. Next, several conceptual examples describe how each land cover category might be used in the context of a mitigation project. Finally, several "real world" examples illustrate how these steps could be followed to generate values in a FEMA BCA.

Appendices A–I provide more detailed guidance associated with specific land cover categories; references are made to these appendices as appropriate. It should be noted that, in addition to following the criteria and guidance related to land cover categories discussed below and in Appendices A–I, all mitigation projects must comprise eligible risk reduction activities and meet any other relevant FEMA programmatic requirements (e.g., cost-effectiveness, Environmental and Historic Preservation) to be eligible for FEMA funding.

5.1. Identify each Land Cover Category Associated with the Mitigation Action

The subapplicant should first identify the land cover category (or categories) that will be restored, created, enhanced or protected as a result of the project.

As described earlier, FEMA's BCA Toolkit includes pre-calculated benefits for a range of land cover categories. Each land cover category has a total "dollar per acre per year" ($/acre/year) value, based on a set of ecosystem services that have been valued for that land cover. The BCA Toolkit will automatically calculate the annual and net present value of ecosystem services according to the area (i.e., acres or square feet) of each land cover category that is entered by the subapplicant.

It should be emphasized that, for any mitigation project, the area of each land cover category that is counted in the BCA Toolkit must be part of the footprint of the project, where the land cover category is being restored, created, enhanced or protected. The ecosystem service values associated with each land cover category will capture and account for the broader "area of benefit" associated with the project, which may extend beyond the project footprint. For example, for a 5-acre riparian restoration project, the subapplicant should input 5 acres of "riparian" into the BCA Toolkit; the ecosystem service benefits built into the per-acre value for riparian include climate regulation (global), air quality (regional) and flood hazard reduction (downstream).

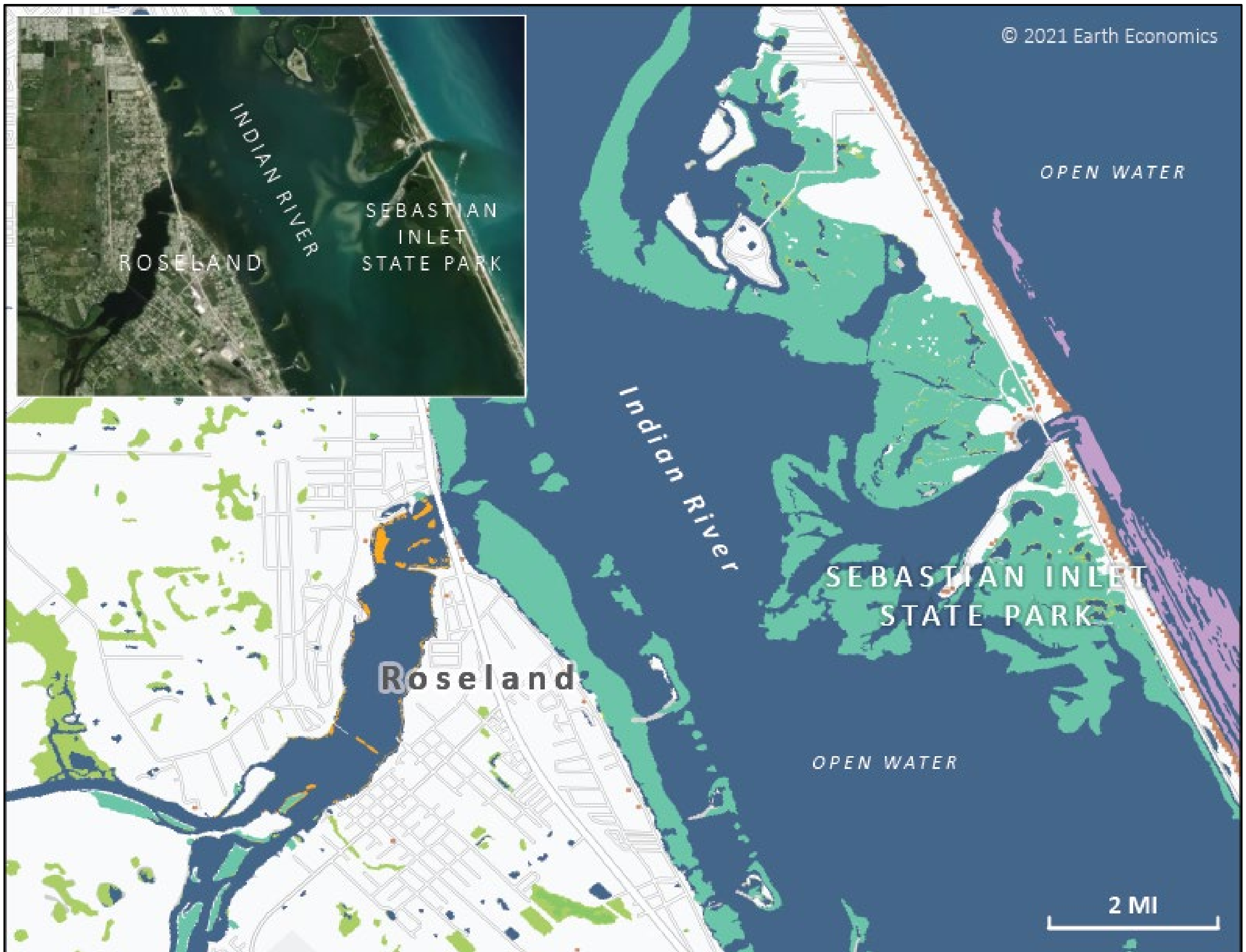
Table 6 provides definitions for each land cover category. **Figure 1** and **Figure 2** provide examples to illustrate where each land cover category might be located in a landscape. More guidance on interpreting the definitions, along with potential sources of geospatial data for identifying appropriate land cover categories for a mitigation project BCA, can be found in Appendices A–I.

Note, the example maps display the land cover categories as they currently exist on the landscape. A mitigation project may add new—or transform existing—areas of land cover through creation or restoration of an ecosystem, per the “Feasibility & Effectiveness Considerations” in Appendices A–I, and the specific land cover categories and boundaries will need to be identified and justified by the subapplicants.

Table 6. Land Cover Category Definitions

Land Cover Category	Definition
Urban Green Open Space	Green open space areas are those in which vegetated pervious surfaces account for at least 80% of total cover (impervious surfaces account for less than 20% of total cover) and include a mixture of some constructed materials. Green open space is considered “urban” if it meets the criteria specified in the U.S. Census Bureau’s “2010 Census Urban and Rural Classification and Urban Area Criteria,” which includes both Urbanized Areas (population of 50,000 or more) and Urban Clusters (population between 2,500 and 50,000). Examples of urban green open space include urban parks and recreational sites, neighborhood green spaces, pocket parks, green corridors and lawns.
Rural Green Open Space	Areas where vegetation accounts for at least 80% of total cover (impervious surfaces account for less than 20% of total cover) and have a mixture of some constructed materials located in a rural setting. A rural setting is any area outside the definitions for 2010 Census Urbanized Areas (population of 50,000 or more) or Urban Clusters (population between 2,500 and 50,000). Examples include rural parks and open space, open fields and rangelands.
Riparian	Areas where plant communities are contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic waterbodies (rivers, streams, lakes or drainage ways). Riparian areas are usually transitional between wetland and upland. Riparian areas have one or both of the following characteristics: (1) distinctly different vegetative species than adjacent areas, (2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Subapplicants can also use one of the following methods as an alternative to the definition above. 1. Meets the definition of “riparian” based on the professional judgement of a recognized expert. 2. Meets the definition of “riparian” adopted by the jurisdiction (e.g., state) in which the project is being proposed.

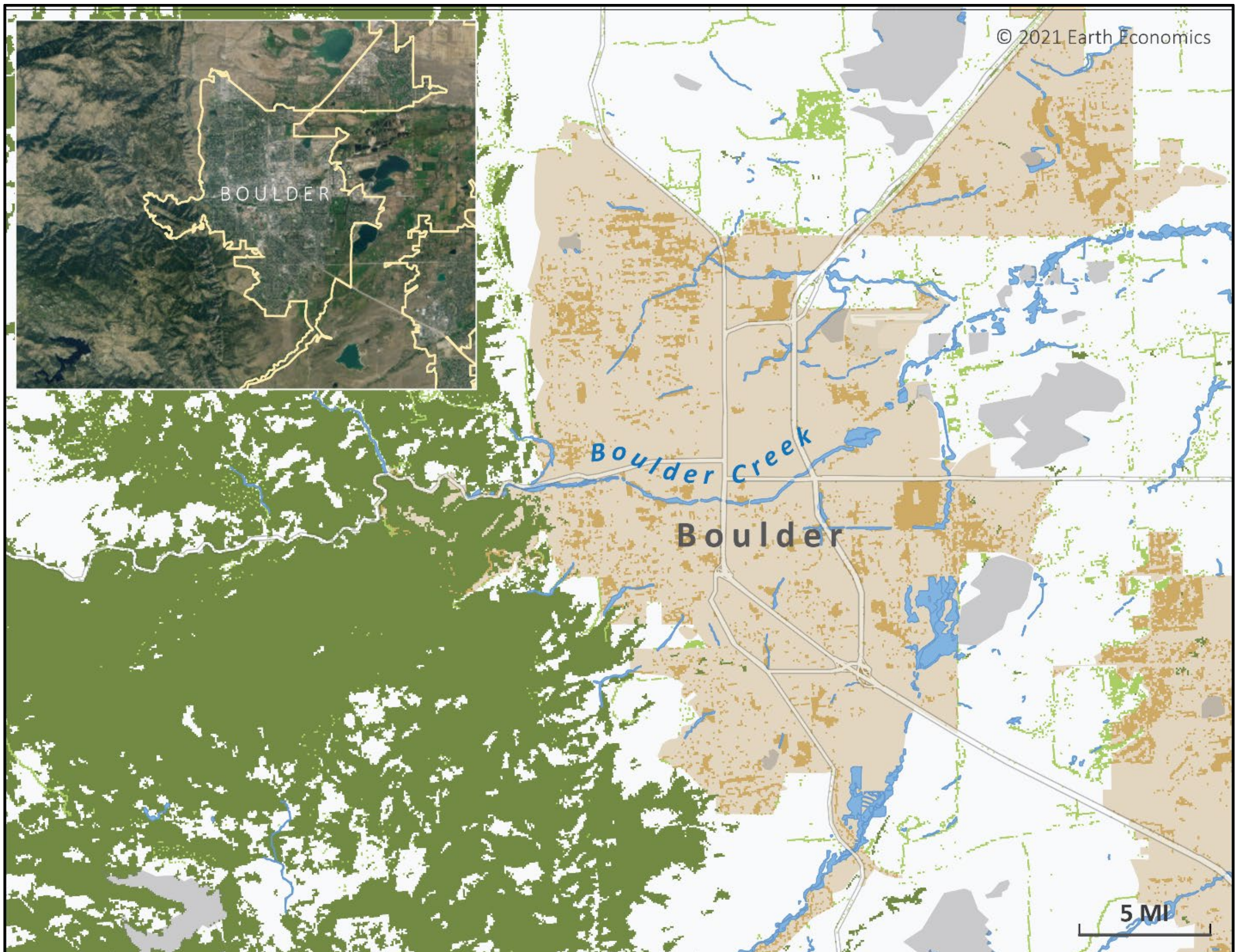
Land Cover Category	Definition
Forest	Areas dominated by trees (evergreen and/or deciduous) generally greater than 5 meters tall that—on average—comprise greater than 20% of the total vegetation cover within the area or unit of analysis (e.g., pixel, polygon, parcel). In other words, areas with a tree-crown areal density of greater than 20%.
Coastal Wetland	Areas of tidal wetlands (herbaceous and/or woody vegetation) or deepwater habitats in which plants grow and form a continuous cover principally on or at the surface of the water (e.g., algal mats, kelp beds, submerged aquatic vegetation); AND vegetation coverage is greater than 20%; AND these waters are tidally influenced and have a salinity greater than or equal to 0.5 parts per thousand.
Inland Wetland	Areas dominated by perennial herbaceous vegetation, shrubland vegetation or forest; AND the soil or substrate is at least periodically saturated with or covered with water; AND these waters are not tidally influenced and have a salinity of less than 0.5 parts per thousand.
Coral Reefs	Areas of hardened, fixed substrate or structures created by deposition of calcium carbonate by reef-building coral species. May include both deep- and shallow-water coral species.
Shellfish Reefs	Areas where many shell reefs exist and are surrounded and intermixed with channels and unvegetated flats, typically occurring in the intertidal zone.
Beaches and Dunes	Gently sloping zone adjacent to the edge of a waterbody, such as an ocean or lake, consisting of unconsolidated material such as sand, pebbles, rocks or shell fragments. Beaches extend landward from the low-water line to either a line of permanent vegetation or a definite change in material or physiographic form, such as a cliff.



Legend

FEMA Land Cover Categories	Data Source
Coastal wetland Inland wetland	*C-CAP Regional Land Cover*, NOAA
Coral reef	*Coral and Hard Bottom Habitats*, Florida Fish and Wildlife Conservation Commission
Oyster reef	*Oyster Beds in Florida*, Florida Fish and Wildlife Conservation Commission
Beach/Sand dunes	*National Land Cover Database 2019*, USGS

Figure 1. Land Cover Example (1/2)



Legend

Zones	Data Source
Urban Area	*TIGER/Line - Urban Areas*, US Census Bureau

FEMA Land Cover Categories	Data Source
Forest	*National Land Cover Database 2019*, USGS
Urban green open space*	
Rural green open space	
Riparian	*National Wetlands Inventory*, US FWS

** created by intersecting US Census Bureau Urban areas with NLCD*

Figure 2. Land Cover Example (2/2)

5.2. Ensure Each Land Cover Category Meets Feasibility & Effectiveness Criteria

Appendices A–I include Feasibility & Effectiveness criteria and resources specific to each land cover category. However, in general, to use the ecosystem service values for a given land cover category in a FEMA BCA, the project should meet the following criteria:

- Final land cover associated with the mitigation project should be consistent with the definition of the land cover category provided in this document (Table 5 in the previous section and Appendices A–I).
- Project must demonstrate a significant level of ecosystem restoration, creation, enhancement or protection of the relevant land cover category (or categories).
  - Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[10] According to the EPA,[iii] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
  - In the context of a FEMA BCA, the ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After-Mitigation" scenario relative to the "Before-Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement or protection (of areas at risk of degradation in a No Action scenario).
    - A common example would be a standard FEMA Acquisition and Relocation/Demolition project that results in the restoration, creation, enhancement or protection of ecosystems within the parcel.
    - Another example would be the acquisition of a parcel that does not contain structures, followed by restoration, creation or enhancement of ecosystems on that parcel for the purpose of reducing the risk of a hazard such as flood or wildfire. It should be emphasized that, per the 2015 FEMA HMA Guidance document, projects "with the sole purpose of open space acquisition of unimproved land" are an ineligible activity, However, if acquisition of an existing unimproved parcel is part of a broader, eligible mitigation action, it may be eligible. For example, the subapplicant may be proposing a Floodplain and Stream Restoration, Flood Diversion and Storage, or Hazardous Fuels Reduction project that involves acquisition of an open space parcel containing a degraded forested area. If the subapplicant could show that 1) Acquisition is required in

[iii] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

order to make the project feasible and effective (i.e., other options such as easements or landowner agreements have been considered but ruled out); AND 2) Restoration, creation and/or enhancement[iv] of forested areas on that parcel would result in a quantifiable risk reduction benefit (as demonstrated through modeling and/or the BCA Toolkit), then such an action may be quantified and considered for ecosystem service benefits in the BCA. Examples could include: 1) Acquisition and restoration of a forested area to increase the floodwater storage potential on the land, thereby reducing flood risk to downstream people and property; or 2) Acquisition and enhancement of a forested area through hazardous fuels reduction activities, thereby reducing the potential risk and severity of a wildfire to adjacent people and property. However, because such approaches are relatively new from a FEMA HMA perspective, the subapplicant should always seek guidance and clarification on this matter from their FEMA regional office and State Hazard Mitigation Officer.

- In general, restoration, creation, enhancement and protection should follow internally or externally established principles, guidelines, policies and techniques associated with the specific land cover category.

5.3. Select an Appropriate Project Useful Life

The term Project Useful Life (PUL) refers to the length of time the project will provide benefits. FEMA's BCA Toolkit provides a standard PUL for many eligible mitigation actions, or components of mitigation actions, and in some cases allows the subapplicant to select from a range (depending upon the nature of the project and available documentation). For example, Acquisition/Relocation has a default PUL of 100 years, and both Floodplain and Stream Restoration and Flood Diversion and Storage have a default PUL of 30 years, but the BCA Toolkit notes "Higher PUL values acceptable with documentation" in the case of the latter.

In general, if subapplicants meet the Feasibility & Effectiveness criteria for a land cover category (see Appendices A–I), and they—or other entity—continue to provide some minimum level of maintenance and/or protection, most of the ecosystems represented by these land cover categories should be largely self-maintaining and generate their respective ecosystem services in perpetuity. For this reason, it is recommended that, in most cases, the PUL associated with each land cover category be tied to the length of time subapplicants can demonstrate they will be providing maintenance and/or protection, as evidenced through appropriate documentation, as described further below.

[iv] "Protection" is not included here, because it is assumed that the FEMA-compliant deed restriction placed on the parcel following acquisition already represents protection.

The following guidelines are recommended for determining an appropriate PUL for all land cover categories, with the exception of Beaches and Dunes (Table 7).[v]

- Subapplicant can use a standard value of 50 years without the need for justification or documentation.
- If the land cover restoration, creation, enhancement or protection is part of a larger mitigation project, which includes other eligible mitigation actions, then the subapplicant can select a PUL equal to that of the primary mitigation action (e.g., as reflected by total share of project budget). For example, if riparian restoration, creation, enhancement or protection is part of a "major infrastructure" project with a documented PUL of 75 years, then the subapplicant can select 75 years as the PUL of the riparian area. This approach assumes that the land cover will be maintained at least as long as the primary infrastructure associated with the project.
- If the subapplicant can provide documented assurances that the land cover will be maintained beyond the standard PUL of 50 years, then the subapplicant can select a PUL of between 51 and 100 years (100 years representing "perpetuity"). Examples of assurances, in order of preference, may include:
    - Subapplicant owns or acquires the parcel(s) (i.e., transfers title) and places a FEMA-compliant deed restriction on the parcel(s) (CFR, Title 44, Part 80), requiring the property be maintained as open space in perpetuity. This example represents a typical FEMA acquisition and demolition/relocation project. Ideally, the subapplicant can also show evidence of a permanent endowment that will be set up to maintain the land in perpetuity, or a similar assurance such as a documented agency commitment.
    - Subapplicant acquires the parcel(s) (i.e., transfers title) and places a deed restriction on the parcel(s), consistent with FEMA's requirements, requiring the property be maintained as open space for some other specified period into the future (i.e., 51–99 years). Ideally, the subapplicant can also show evidence of a permanent endowment that will be set up to maintain the land for the specified period, or a similar assurance such as an agency commitment letter.
    - Subapplicant does not acquire the land but purchases an easement on the land (e.g., purchase of development rights) that requires the land remain in uses consistent with open space for a specified period into the future (i.e., 51–100 years, with 100 years representing "perpetuity").
    - Subapplicant does not acquire the land but signs a maintenance agreement with the property owner (private or government), requiring the property owner to continue to provide

[v] All examples assume the subapplicant is meeting the Effectiveness & Feasibility criteria for the respective land cover category

some minimum level of maintenance on the land—and/or allowing the subapplicant to access the land and conduct ongoing maintenance—for a specified period into the future (i.e., 51–100 years, with 100 years representing "perpetuity").

Based on the guidelines above, FEMA could consider adding the following rows to the BCA Toolkit's PUL table:

Table 7. Project Useful Life Guidance

<table>
<tr><th rowspan="2">Project Type</th><th colspan="2">Project Useful Life (Years)</th><th rowspan="2">Comment</th></tr>
<tr><th>Standard Value</th><th>Acceptable Limits (Documentation Required)</th></tr>
<tr><td rowspan="2">Elements of eligible projects that involve restoration, creation, enhancement or protection of:
▪ Forest
▪ Urban Green Open Space
▪ Rural Green Open Space
▪ Riparian</td><td>100</td><td>-</td><td>Land is owned or acquired, and FEMA-compliant deed restrictions (CFR, Title 44, Part 80) or equivalent perpetual easement recorded on property.
Feasibility & Effectiveness criteria must also be met for the land cover category.</td></tr>
<tr><td>50</td><td>50–100</td><td>Land is not owned, acquired or controlled.
Feasibility & Effectiveness criteria must be met to use the standard value of 50 years for the land cover category. PUL can be increased up to 100 years (representing perpetuity) depending upon how long the land cover will be maintained/ protected, as evidenced through documented assurances, such as deed restriction, easement or maintenance agreement with landowner.</td></tr>
</table>

Project Type	Project Useful Life (Years)		Comment
Elements of eligible projects that involve restoration, creation, enhancement or protection of: ▪ Coastal Wetland ▪ Inland Wetland ▪ Coral Reefs ▪ Shellfish Reefs	50	50–100	Feasibility & Effectiveness criteria must be met to use the standard value of 50 years for the land cover category. PUL can be increased up to 100 years, depending upon how long the land cover will be maintained/ protected, as evidenced through documented assurances, including agency commitments, formation of protected areas. Final land cover is ideally owned or controlled by a government or non-profit organization.
Elements of eligible projects that involve restoration, creation, enhancement or protection of: ▪ Beaches and Dunes	20	20-50	Dune restoration, creation, enhancement or protection as a mitigation action is only eligible within the context of the PA 406 Hazard Mitigation. If the standard value is not used, the PUL of dunes should be based on the average recurrence interval of a storm event that would overtop or breach the dunes (which assumes the dune will need to be rebuilt after that event). Feasibility & Effectiveness criteria must also be met for the land cover category.

5.4. Conceptual Examples

Table 8 provides conceptual examples of how the individual land cover categories might be included in a mitigation project. It should be reiterated that, in addition to following the criteria and guidance related to land cover categories discussed above and in Appendices A–I, all mitigation projects must be comprised of eligible risk reduction activities and meet any other relevant FEMA programmatic requirements (e.g., cost-effectiveness, Environmental and Historic Preservation) to be eligible for FEMA funding.

Table 8. Conceptual Examples of Mitigation Projects that Include Land Cover Categories

Land Cover Category	Conceptual Example	Link to Detailed Guidance
Forest	Restoration, creation, enhancement or protection of a forested area as a component of a Flood Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff and decrease flood risk to downstream, upstream or adjacent people and structures. This example would apply to forested areas within an FDS or FSR project that are not defined as "riparian."	Appendix A
Forest	Hazardous fuels reduction and other ecosystem health improvement actions in an existing forested area to mitigate wildfire risk while generating additional ecosystem services (e.g., erosion control, recreation)	Appendix A
Forest	Reforestation of urban areas (e.g., as a component of an Acquisition and Relocation/Demolition project or other eligible mitigation project) to mitigate natural hazards such as heat and pluvial flooding, while generating other ecosystem services (e.g., aesthetic value, air quality, recreation).	Appendix A
Coastal Wetland	Restoration, creation, enhancement or protection of coastal wetland as part of a mitigation project to support erosion reduction, sediment trapping and building, wave attenuation, surge attenuation, and/or flood storage.[11]	Appendix B
Inland Wetland	Restoration, creation, enhancement or protection of an existing inland wetland area or creation of a new inland wetland area as a component of a Flood Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff and decrease flood risk to downstream, upstream or adjacent people and structures. This example would apply to forested areas within an FDS or FSR project that are not defined as "riparian."	Appendix C
Urban Green Open Space	Open space areas created because of Acquisition and Relocation/Demolition projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum. Open space areas must also specifically meet the definition of "urban" and other criteria.	Appendix D

Land Cover Category	Conceptual Example	Link to Detailed Guidance
Urban Green Open Space	Creation of an urban park to support hazard risk reduction (e.g., pluvial flooding, heat) and other social and environmental benefits.	Appendix D
Urban Green Open Space	Areas associated with Floodplain and Stream Restoration or Flood Diversion and Storage projects in areas that are within the floodplain and meet the definition/criteria for "urban green open space."	Appendix D
Rural Green Open Space	Open space areas created because of Acquisition and Relocation/Demolition projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum. Open space areas must also meet the definition of "rural" and other criteria.	Appendix E
Rural Green Open Space	Creation of a rural park to support hazard risk reduction (e.g., pluvial/riverine flooding, wildfire) and other social and environmental benefits.	Appendix E
Rural Green Open Space	Areas associated with Floodplain and Stream Restoration or Flood Diversion and Storage projects in areas that are within the floodplain and meet the definition/criteria for "rural green open space."	Appendix E
Riparian	Open space areas that meet the definition of "riparian," which are created because of Acquisition and Relocation/Demolition projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum.	Appendix F
Riparian	Restoration, creation, enhancement or protection of a riparian area as a component of a Floodplain Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff or streambank erosion and decrease flood risk to downstream, upstream or adjacent people and structures. Areas within an FDS or FSR project that meet the definition of "riparian" can often be adjacent to "forest" and/or "wetland" areas, as defined in this guidance, and care should be taken to avoid double counting the same area (e.g., a given acre) twice.	Appendix F

Land Cover Category	Conceptual Example	Link to Detailed Guidance
Riparian	Restoration of urban riparian areas to mitigate natural hazards such as heat and pluvial flooding, while generating other ecosystem services (e.g., aesthetic value, air quality, recreation). Like the example above, restoration of riparian areas is likely to occur as part of a broader restoration effort, possibly adjacent to “wetland” and “forest” areas as defined in this guidance.	Appendix F
Riparian	Hazardous fuels reduction and other ecosystem health improvement actions in an existing riparian area to mitigate wildfire risk while generating additional ecosystem services (e.g., erosion control, recreation).	Appendix F
Coral reefs	Restoration, creation, enhancement or protection of coral reefs to support coastal storm/flood risk reduction.	Appendix G
Beaches and Dunes	Restoration, creation, enhancement or protection of dunes for coastal storm/flood risk reduction.	Appendix H
Shellfish reefs	Restoration, creation, enhancement or protection of shellfish reefs for coastal storm/flood risk reduction.	Appendix I

5.5. “Real World” Examples

The following examples demonstrate in more detail how a subapplicant could incorporate the land cover categories provided earlier, and how that would be reflected in the BCA, along with PUL considerations. Not all possible hazards, project types or land cover categories have been included.

5.5.1. Example 1: Urban Floodplain Acquisition and Restoration Project

Project Description

The City of Resilience is a medium-sized city on the West Coast. The City submitted an HMGP subapplication to FEMA, requesting $3 million in federal cost share to implement a flood risk reduction project in a neighborhood that experienced frequent flooding.

The scope of work included acquisition of private properties from willing sellers and demolition/relocation of structures that were on those parcels; restoration of riparian habitat areas along the river; reconnection of the floodplain to the river, including removal of existing roads and bridges to allow flood water to access the restored floodplain; and creation of an urban park with ADA-accessible trails, a parking lot and other basic amenities (including installation of thousands of native trees, shrubs and grasses).

Benefits of the project include floodwater storage, reducing flood risk to downstream structures and adjacent roads; habitat for fish and wildlife, including endangered salmon species; improved water quality; and recreational opportunities.

Figure 3 provides a map of the project site before mitigation, while **Figure 4** and **Figure 5** provide a map and satellite image of the project after mitigation, respectively.

Relevant Land Cover Categories

In total, the footprint of the project encompassed 65 acres, of which 15 acres met the definition of "Riparian" and 50 acres met the definition of "Urban Green Open Space," as well as relevant Feasibility & Effectiveness considerations (Table 5 and Appendices D and F). Because the entire site was restored and converted to a publicly accessible park, all 65 acres were counted in the BCA.

Project Useful Life Considerations

Following acquisition of the private parcels, the City recorded deed restrictions on the parcels, consistent with the FEMA Model Deed Restriction, ensuring the property would be maintained in perpetuity for uses that are compatible with open space. As a result, the City was able to use a default value of 100 years for the PUL in the BCA.

Figures

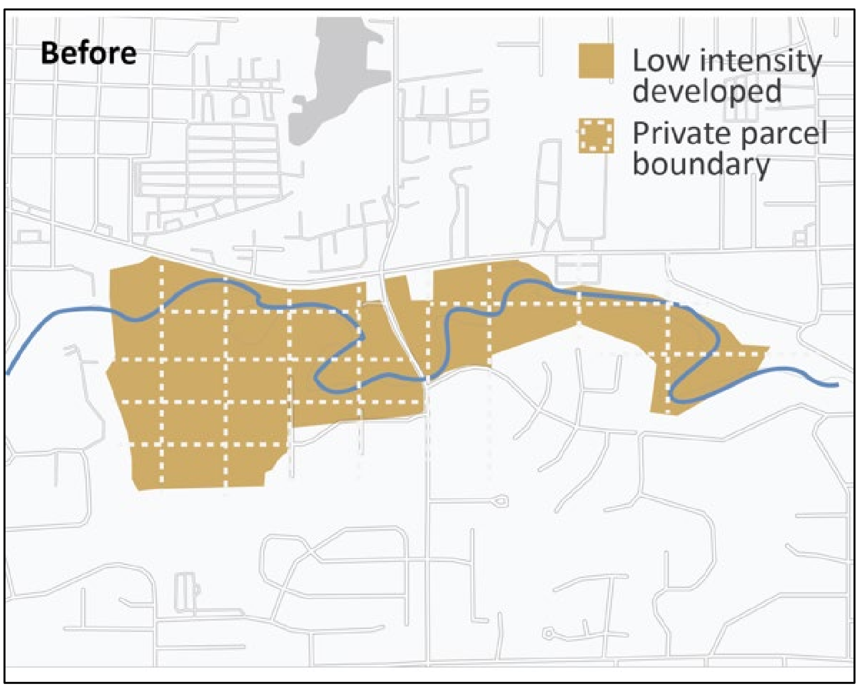


Figure 3. Urban Floodplain Restoration – Before Mitigation

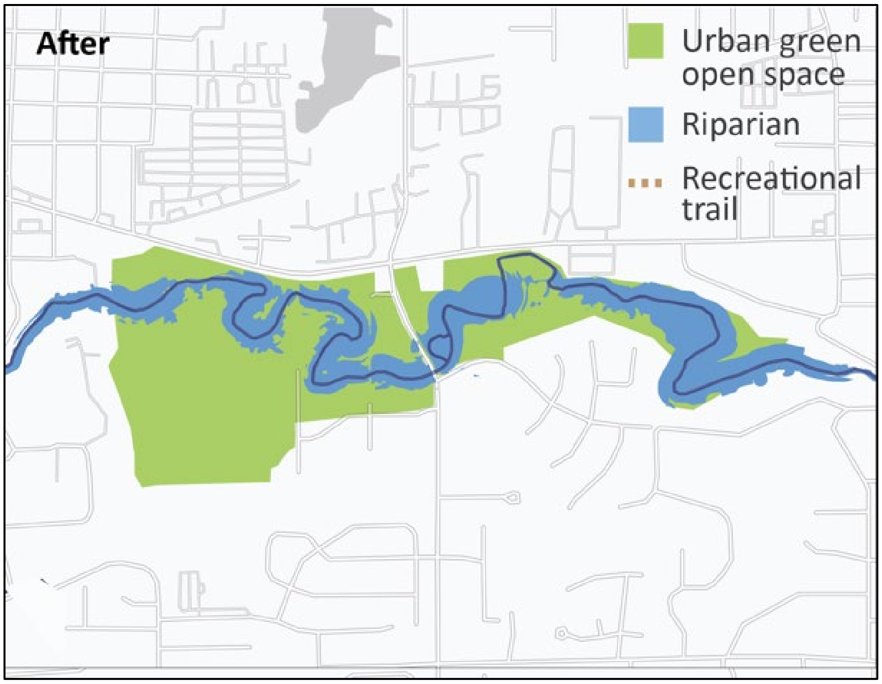


Figure 4. Urban Floodplain Restoration – After Mitigation

Figure 5. Urban Floodplain Restoration – After Mitigation (satellite image)

5.5.2. Example 2: Rural Park and Floodplain Storage Project

Project Description

Springfield is a town of 2,500 people on the Front Range in Colorado. The Town submitted an HMGP subapplication to FEMA, requesting $2 million in federal cost share for a mitigation project.

The scope of work included conversion of a former industrial site, which was already owned by the Town (and leased out until recently), into a riverside park that could hold floodwaters during flood events and included trails, bathrooms, and a kiosk; restoration of riparian habitat areas along the river; and restoration and hazardous fuels reduction in a privately held forested area to the south west of the park to reduce wildfire risk.

Benefits of the project include floodwater storage, reducing flood risk to downstream structures; habitat for fish and wildlife; wildfire risk reduction; and recreational opportunities.

Figure 6 provides a map of the project site before mitigation, while Figure 7 and Figure 8 provide a map and satellite image of the project after mitigation, respectively.

Relevant Land Cover Categories

In total, the footprint of the project encompassed 50 acres, of which 10 acres met the definition of "Riparian," 20 acres met the definition of "Rural Green Open Space," and 20 acres met the definition of "Forest" (Table 5). All final land cover categories also met relevant Feasibility & Effectiveness considerations (Appendices A, D and F).

Project Useful Life Considerations

The Town already owned the areas of "Riparian" (10 acres) and "Rural Green Open Space" (20 acres), but opted to record deed restrictions on the parcels, consistent with the FEMA Model Deed Restriction, to ensure the property would be maintained in perpetuity for uses that are compatible with open space. As a result, the Town was able to use a PUL of 100 years for those 30 acres in the BCA.

The 20 acres of "Forest" to the southwest of the park remained in private ownership. However, the Town signed a contract with the landowner allowing the Town to enter the property and conduct ongoing, hazardous fuels reduction activities on the land for 50 years into the future. The Town therefore used a PUL of 50 years for those 20 acres in the BCA.

Figures

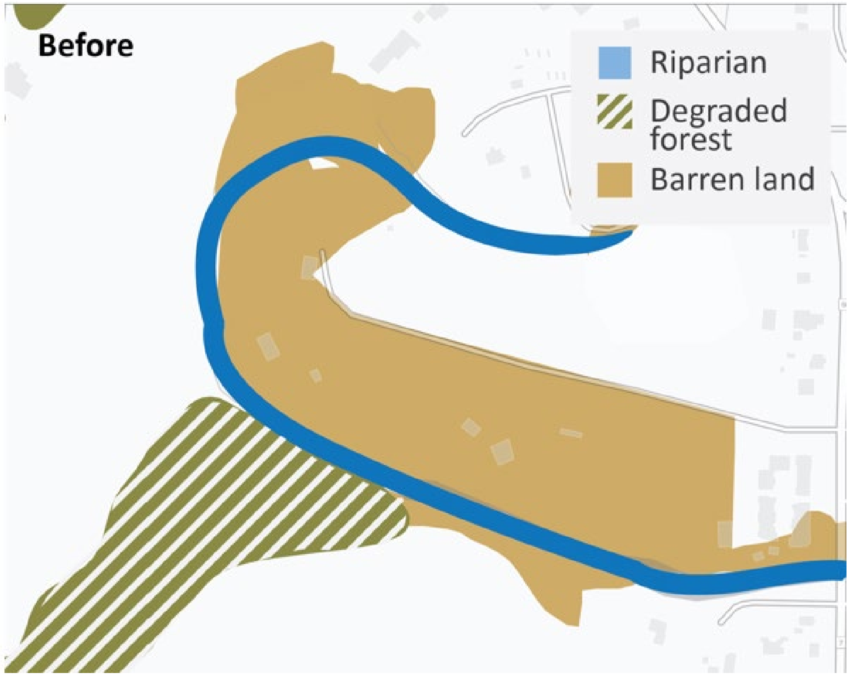


Figure 6. Rural Floodplain Restoration – Before Mitigation

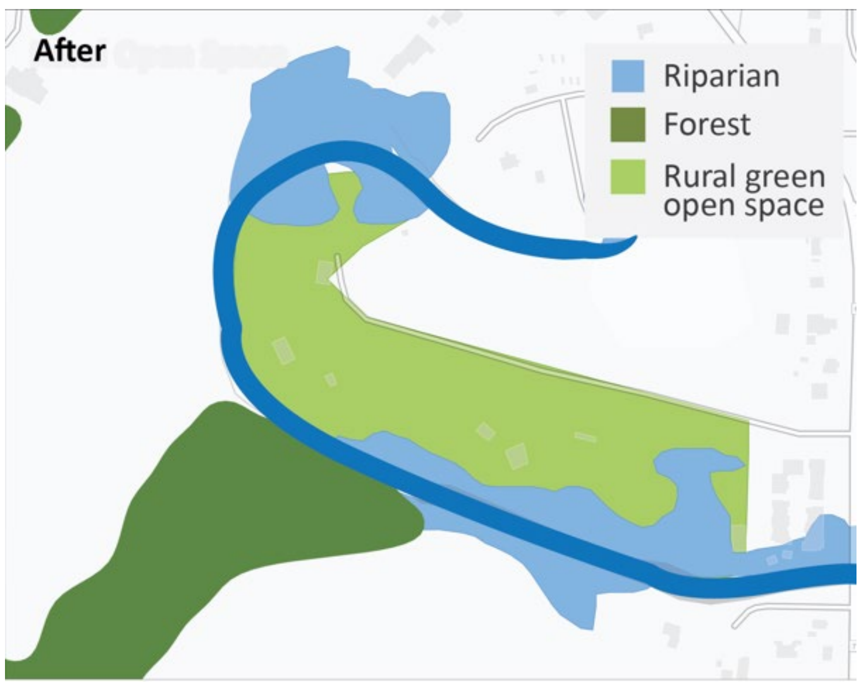


Figure 7. Rural Floodplain Restoration – After Mitigation

Figure 8. Rural Floodplain Restoration – After Mitigation (satellite image)

5.5.3. Example 3: Coastal Wetland Restoration Project

Project Description

Beach Haven is a mid-sized city on the east coast of Florida. The City submitted an HMGP subapplication to FEMA, requesting $4 million in federal cost share for a mitigation project.

The scope of work included restoration of 50 acres of coastal wetlands that had become degraded by human impacts.

Benefits of the project include coastal flood risk reduction for residential structures, roads and critical facilities; habitat for fish and wildlife; and water quality improvements for nearby beaches.

Figure 9 provides a map of the project site before mitigation, while **Figure 10** and **Figure 11** provide a map and satellite image of the project after mitigation, respectively.

Relevant Land Cover Categories

In total, the footprint of the project encompassed 50 acres, all of which met the definition of "Coastal Wetland" (Table 5) and the relevant Feasibility & Effectiveness considerations (Appendix B). All 50 acres were therefore included in the BCA.

To the west of the project, there were approximately 40 acres of existing Coastal Wetland and 30 acres of existing Inland Wetland—all healthy and not requiring any restoration. To the east of the project was open water (not a FEMA land cover category) and 100 acres of seagrass beds (captured as "Coastal Wetland" under FEMA's definition). Since the footprint of the project did not include any of these areas, and there was no change in the After Mitigation compared with Before Mitigation, they were not included in the BCA.

Project Useful Life Considerations

The City intended to monitor and maintain the wetlands in perpetuity; however, it could not provide documentation to show this, and therefore opted to use the standard PUL of 30 years in the BCA.

Figures

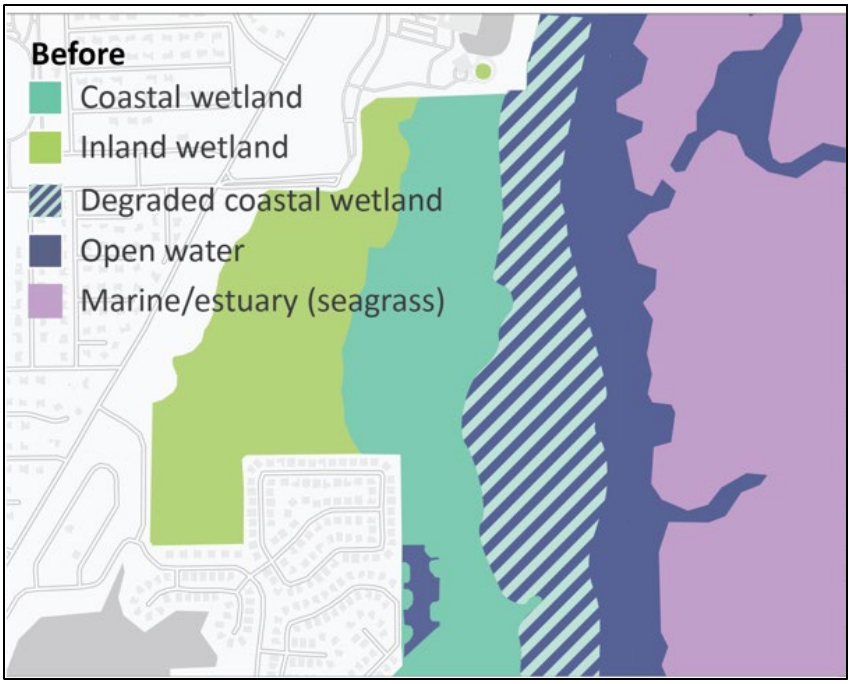


Figure 9. Coastal Wetland Restoration Project – Before Mitigation

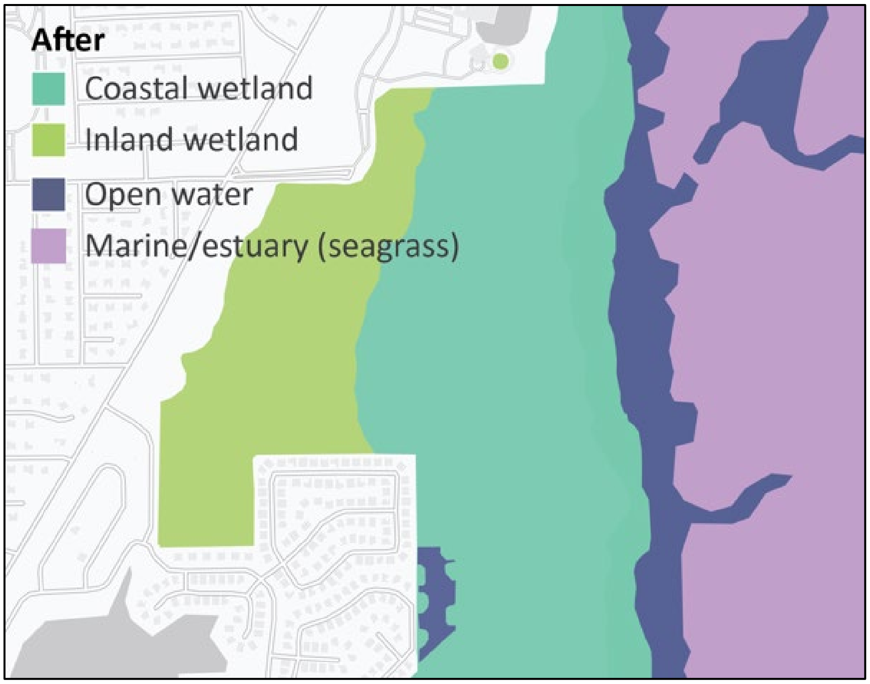


Figure 10. Coastal Wetland Restoration Project – After Mitigation

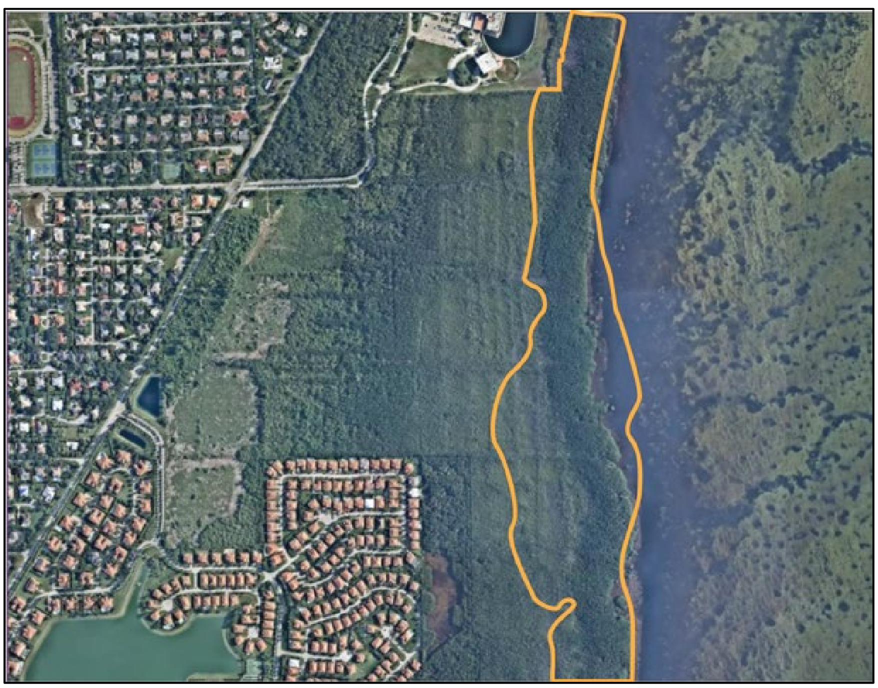


Figure 11. Coastal Wetland Restoration Project – After Mitigation (satellite image)

Appendix A. Forest

Land Cover Definition

Forest is defined as:

Areas dominated by trees (evergreen and/or deciduous) generally greater than 5 meters tall that – on average – comprise greater than 20% of the total vegetation cover within the area or unit of analysis (e.g., pixel, polygon, parcel). [vi]

This definition of forest is based on the 2019 National Land Cover Database (NLCD), a product that is developed and regularly updated by the Multi-Resolution Land Characteristics (MRLC) consortium, a "group of federal agencies who coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications." [12] The NLCD, in turn, has been modified from the Anderson Land Cover Classification System. [13]

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for forest in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "forest" (provided above).
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." [14] This definition has also been adopted by the U.S. Forest Service Restoration Framework Team. [15]
- According to the EPA, [vii] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement or protection (of areas at risk of degradation in a No Action scenario).

[vi] In other words, areas with a tree-crown areal density of greater than 20%.

[vii] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

- In general, forest restoration, creation, enhancement or protection should follow internally or externally established principles, guidelines, policies and techniques.
- According to the SER International document referenced above,[16] plans for restoration projects include, at a minimum, the following:
    - Clear rationale as to why restoration is needed
    - Ecological description of the site designated for restoration
    - Statement of the goals and objectives of the restoration project
    - Designation and description of the reference
    - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
    - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
    - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
    - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

The following examples demonstrate how the "forest" land cover category might be used in a mitigation project (and associated BCA):

- Restoration, creation, enhancement or protection of a forested area as a component of a Flood Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff and decrease flood risk to downstream, upstream or adjacent people and structures. This example would apply to forested areas within an FDS or FSR project that are not defined as "riparian."
- Hazardous fuels reduction and other ecosystem health improvement actions in an existing forested area to mitigate wildfire risk while generating additional ecosystem services (e.g., erosion control, recreation).
- Reforestation of urban areas (e.g., as a component of an Acquisition and Relocation/Demolition project or other eligible mitigation project) to mitigate natural hazards such as heat and pluvial flooding, while generating other ecosystem services (e.g., aesthetic value, air quality, recreation).

Project Useful Life Considerations

In general, provided that forested areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard PUL of 50 years can be applied. A higher PUL may be applied in the following cases:

- If the forested area is owned or acquired, and a FEMA-compliant deed restriction (CFR, Title 44, Part 80) or equivalent perpetual easement is recorded on the property, then a PUL of 100 years can be used. A typical example would be a standard FEMA Acquisition and Relocation/Demolition project that results in the restoration, creation, enhancement or protection of the forested area.
- If the land is not owned, acquired or controlled, but the subapplicant can demonstrate that the land cover will be maintained/protected beyond 50 years (as evidenced through documented assurances, such as deed restriction, easement or maintenance agreement with the landowner), then a PUL of 51–100 years can be used (with 100 years representing perpetuity), depending upon the nature of the assurances.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	–	0	1,477	3	
Air Quality	–	0	711	3	
Biological Control					
Climate Regulation	153	5	199	1	2
Erosion Control	–	0	1,672	1	
Existence Value	–	0	7,531	1	
Flood Hazard Risk Reduction	321	4	368	0	0
Food Provisioning					
Habitat					
Pollination					

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Recreation/Tourism	–	0	94	1	
Water Filtration	–	0	435	1	
Water Supply	80	1	103	1	0
Total Estimated Benefits	**554**		**12,589**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Forest
Ecosystem Service: Aesthetic Value
FEMA Value: $1,477/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Revealed Preference, Hedonic Pricing
Geographic Area of Studies: Western and Central United States
Source Studies:

> **Reference 1:** Kousky, C., Walls, M. 2013. Floodplain Conservation as a Flood Mitigation Strategy: Estimating Costs and Benefits. Resources for the Future, Washington, DC.
> **Reference 2:** McPherson, G., Simpson, J.R., Peper, P.J., Maco, S.E., Xiao, Q. 2005. "Municipal forest benefits and costs in five U.S. cities." *Journal of Forestry* 103(8): 411–416.

Methodology Description: Kousky & Walls (2013) estimated multiple benefits of floodplain conservation based on a case study of the Meramac River greenway in St. Louis County, Missouri.[17] Aesthetic benefits were estimated through a hedonic model analyzing property values based on the proximity to the greenway. Total values are estimated in 2012 USD/year, which we divided by the total acres of the Meramac greenway and then converted to 2021 USD/acre/year listed in the table below. McPherson et al. (2005) estimated multiple benefits of street and park trees in five U.S. cities.[18] Aesthetic benefits were estimated based on a previous hedonic price study which was applied through a biophysical model to tree and home distribution data for each city. Values are estimated as a single citywide 2005 USD net present value per city. We adjusted these values by dividing by total acres of citywide street and park trees and then divided that resulting value by the average years of home ownership (13) to arrive at a final 2005 USD/acre/year value. We then converted this to 2021 USD/acre/year values listed in the table below. Values were only taken from three of the five cities, as information on canopy cover was not readily available for two of the cities.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Kousky & Walls (2013)	St. Louis County, MO	1,004
McPherson et al. (2005)	Fort Collins, CO	4,177
McPherson et al. (2005)	Cheyenne, WY	197
McPherson et al. (2005)	Berkeley, CA	530
Average		**1,477**

*All values are presented in 2021 USD

Discussion: The aesthetic value benefits of these studies are estimated in multiple cities throughout the U.S. They cover cities of differing demographic and economic contexts influencing values attributed to property sale prices. The values are all derived for more urban areas and thus may have limited applicability to a rural context.

Air Quality

Summary

Land Cover: Forest
Ecosystem Service: Air Quality
FEMA Value: $711/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Avoided Cost
Geographic Area of Studies: United States
Source Studies:

Reference 1: Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E. 2014. "Tree and forest effects on air quality and human health in the United States." *Environmental Pollution* 193: 119–129.
Reference 2: Nowak, D.J., Hirabayashi, S., Bodine, A., Hoehn, R. 2013. "Modeled $PM_{2.5}$ removal by trees in ten U.S. cities and associated health effects." *Environmental Pollution* 178: 395–402.
Reference 3: Nowak, D.J., Crane, D.E., Stevens, J.C. 2006. "Air pollution removal by urban trees and shrubs in the United States." *Urban Forestry & Urban Greening* 4(3-4): 115–123.

Methodology Description: Nowak et al. (2013) estimated the total average effects of forests on improving air quality (specifically fine particulate matter less than 2.5 microns) in 10 cities across the U.S.[19] This benefit is valued based on the avoided costs of human mortality and morbidity resulting from improved air quality. Values were estimated in 2010 USD/square meters/year of tree cover, which we converted to 2021 USD/acre/year. These converted values can be found in the table below. Nowak et al. (2006) estimated the total average effects of forests on improving air quality via removal of five different pollutants: O_3, PM_{10}, NO_2, SO_2, and CO in 55 cities across the U.S.[20] The change in pollutant levels is valued using monetized externality values, which represent the estimated cost of pollution to society. Values were estimated in 1994 USD/square meters/year of tree cover, which we converted to 2021 USD/acre/year listed in the table below. The average of all converted values can also be found in the table below. Nowak et al. (2014) estimated urban and rural forest effects on air pollution removal (NO_2, O_3, $PM_{2.5}$, SO_2) across the conterminous U.S.[21] This benefit is valued based on the avoided costs of human mortality and morbidity resulting from improved air quality. An average value in 2010 USD/hectare/year for the coterminous U.S. was used, which we converted to 2021 USD/acre/year listed in the table below. In Nowak et al. (2013) and (2014), dollar values for pollution reduction were produced by EPA and based on the agency's primary air quality standards.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Nowak et al. (2014)	Conterminous U.S.	13
Nowak et al. (2013)	Atlanta, GA	250
Nowak et al. (2013)	Baltimore, MD	651
Nowak et al. (2013)	Boston, MA	1,152
Nowak et al. (2013)	Chicago, IL	1,202
Nowak et al. (2013)	Los Angeles, CA	451
Nowak et al. (2013)	Minneapolis, MN	250
Nowak et al. (2013)	New York, NY	1,903
Nowak et al. (2013)	Philadelphia, PA	701
Nowak et al. (2013)	San Francisco, CA	1,252
Nowak et al. (2013)	Syracuse, NY	301
Nowak et al. (2006)	55 U.S. cities	399
Average		**711**

*All values are presented in 2021 USD

Discussion: The benefits of improved air quality from these studies are estimated in multiple contexts throughout the U.S. They cover cities at many different scales and population densities, as well as rural areas.

Climate Regulation

Summary

Land Cover: Forest
Ecosystem Service: Climate Regulation
FEMA Value: $199/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Avoided Cost
Geographic Area of Studies: National
Source Studies:

Reference 1: Interagency Working Group on Social Cost of Greenhouse Gases. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990.
Reference 2: Hoover, C.M., Bagdon, B., Gagnon, A. 2021. Standard Estimates of Forest Ecosystem Carbon for Forest Types of the United States. U.S. Department of Agriculture, Forest Service, Northern Research Station, Madison, WI. Available online at: https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs202.pdf
Reference 3: Goulden, M.L., Munger, J.W., Fan, S.M., Daube, B.C., Wofsy, S.C. 1996. "Exchange of carbon dioxide by a deciduous forest: response to interannual climate variability." *Science* 271(5255): 1576–1578.
Reference 4: Hamilton, J.G., DeLucia, E.H., George, K., Naidu, S.L., Finzi, A.C., Schlesinger, W.H. 2002. "Forest carbon balance under elevated CO_2." *Oecologia* 131: 250–260.
Reference 5: Black, T.A., Chen, W.J., Barr, A.G., Arain, M.A., Chen, Z., Nesic, Z., Hogg, E.H., Neumann, H.H., Yang, P.C. 2000. "Increased carbon sequestration by a boreal deciduous forest in years with a warm spring." *Geophysical research letters* 27(9): 1271–1274.

Methodology Description: Carbon sequestration of forests was calculated in two parts. First, a database of over 6,000 carbon values[viii] was used to estimate the carbon sequestration in metric tons of carbon per acre per year of forest types across the U.S. Four studies comprising 717 individual carbon sequestration values were selected from the database to construct an average value estimate. Second, the social cost of carbon was used to calculate a dollar value of carbon sequestration. The social cost of carbon (SCC) represents the average societal costs associated with

[viii] Internal Earth Economics database

each additional ton of carbon emissions (measured in CO_2e[ix]), such as losses to agriculture, impacts to human health and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., forest restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG). The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990.[22] Specifically, the 2020 value was used: $51/metric ton CO_2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Hoover et al. (2021)[23]	0.74	195.81	145
Goulden et al. (1996)[24]	0.85	195.81	166
Hamilton et al. (2002)[25]	1.76	195.81	344
Black et al. (2000)[26]	0.71	195.81	139
Average			**199**

* All values are presented in 2021 USD

Discussion: The above assessment combined 717 carbon values estimated across the U.S. to arrive at a single dollar value for the value of climate regulation provided by forests. The values are averaged across different stages of ecological health, species, stand age, and climate types of newly established. The carbon value used was standardized by the latest data produced by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. Two studies were removed from the value sets that FEMA adopted for the 2016 environmental benefits policy. Smith et al. (2006)[27] was replaced by Hoover et al. (2012), which represents an update of the older report produced by the Forest Service. Heath et al. (2003)[28] was removed as it only represented carbon sequestration in soils and undercounted the benefit, unlike the other studies included, which included rates for the whole ecosystem (i.e., both above and below ground carbon).

Erosion Control

Summary

Land Cover: Forest

[ix] Carbon Dioxide Equivalent (CO_2e) represents the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas.

Ecosystem Service: Erosion Control
FEMA Value: $1,672/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Study: Global
Source Studies:

Reference 1: Taye, F.A., Folkersen, M.V., Fleming, C.M., Buckwell, A., Mackey, B., Diwakar, K.C., Le, D., Hasan, S., Ange, C.S. 2021. "The economic values of global forest ecosystem services: A meta-analysis." *Ecological Economics* 189 (107145): 1–14.

Methodology Description: Taye et al. (2021) estimated a meta-analysis of the economic value of ecosystem services for forest ecosystem services.[29] The study included a dataset of 261 primary studies published around the world, covering 624 values. The meta-regression reports were reported in 2017 USD/hectare/year, which we converted to 2021 USD/acre/year. The estimate used for this value was the global mean for the "mass flow regulation" ecosystem service from Table 3 in the study.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Taye et al. (2014)	Global	1,672
Average		**1,672**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce.

Existence Value

Summary

Land Cover: Forest
Ecosystem Service: Existence Value
FEMA Value: $7,531/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Replacement Cost; Meta-Analysis
Geographic Area of Studies: U.S. Cities and Global
Source Studies:

Reference 1: Nowak, D.J., Crane, D.E., Dwyer, J.F. 2002. "Compensatory value of urban trees in the United States." *Journal of Arboriculture* 28(40): 194–199.

Methodology Description: Nowak et al. (2002) estimated the existence value of trees based on their replacement costs in eight cities.[30] The study assessed trees as structural assets and used valuation methods of the Council of Tree and Landscape Appraisers with field data from the cities to determine compensatory values for tree populations. Values are estimated in 2001 USD/square meter/life span of a tree, which we regularized to dollars per acre and then divided by the average life span of a tree. These results were then converted to 2021 USD/acre/year values, as listed in the table below.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Nowak et al. (2002)	Oakland, CA	5,868
Nowak et al. (2002)	Jersey City, NJ	4,952
Nowak et al. (2002)	Syracuse, NY	7,139
Nowak et al. (2002)	Baltimore, MD	13,731
Nowak et al. (2002)	Philadelphia, PA	7,038
Nowak et al. (2002)	Atlanta, GA	6,374
Nowak et al. (2002)	Boston, MA	8,466
Nowak et al. (2002)	New York, NY	6,680
Average		**7,531**

* All values are presented in 2021 USD

Discussion: The studies above represent values from cities across the U.S. to estimate this value.

Recreation/Tourism

Summary

Land Cover: Forest
Ecosystem Service: Recreation/Tourism
FEMA Value: $94/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Travel Cost
Geographic Area of Studies: United States
Source Studies:

Reference 1: Rosenberger, R.S., White, E.M., Kline, J.D., Cvitanovich, C. 2017. Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. Available online at: https://www.fs.fed.us/pnw/pubs/pnw_gtr957.pdf

Reference 2: U.S. Forest Service. 2020. National Visitor Use Monitoring Survey Results: National Summary Report. U.S. Department of Agriculture, Forest Service, Washington DC. Available online at: https://www.fs.usda.gov/sites/default/files/2020-National-Visitor-Use-Monitoring-Summary-Report.pdf

Methodology Description: Rosenberger et al. (2017) conducted a meta-analysis of travel cost studies measuring the consumer surplus value of recreation throughout the U.S. in dollars per trip.[31] We used the U.S. Forest Service (USFS) National Visitor Use Monitoring (NVUM) Survey to find the total number of recreational trips taken to National Forest lands in the U.S. annually, as well as the average length of each trip in days.[32] Total annual trips was multiplied by days per trip and the dollar per trip consumer surplus value, then divided by the total acreage of USFS lands to produce a dollar-per-acre value.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Rosenberger et al. (2017) & USFS (2020	United States	94
Average		**94**

* All values are presented in 2021 USD

Discussion: While this value estimate is specific to National Forests, the data represents forests from a variety of contexts throughout the country and a variety of recreational activities that are tracked by the USFS. It also incorporates standard values, methods, and data collected by other Federal Agencies.

Flood Hazard Risk Reduction

Summary

Land Cover: Forest
Ecosystem Service: Flood Hazard Risk Reduction
FEMA Value: $368/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost, Alternative Cost

Geographic Area of Studies: Northern California, Southern California, Arizona, Southern Ontario, Canada

Source Studies:

> **Reference 1:** McPherson, G.E., Simpson, J.R., Peper, P.J., Xiao, Q. 1999. "Benefit-Cost Analysis of Modesto's Municipal Urban Forest." *Journal of Arboriculture* 25: 235–248.
>
> **Reference 2:** McPherson, G.E., Simpson, J.R. 2002. "A Comparison of Municipal Forest Benefits and Costs in Modesto and Santa Monica, California, USA." *Urban Forestry* 1: 61–74.
>
> **Reference 3:** McPherson, G.E. 1992. "Accounting for benefits and costs of urban green space." *Landscape and Urban Planning* 22: 41–51.
>
> **Reference 4:** Wilson, S.J. 2008. Ontario's wealth: Canada's future: Appreciating the value of the Greenbelt's eco-services. David Suzuki Foundation, Vancouver, BC.

Methodology Description: McPherson et al. (1999) assessed Modesto, California's citywide stormwater flood mitigation benefits from trees in parks and along street public rights-of-way.[33] Values are estimated citywide in 1998 USD/year, which we regularized by dividing by the total acreage of street and park tree cover and then converted to 2021 USD/acre/year values, as listed in the table below. McPherson and Simpson (2002) estimated the stormwater flood mitigation benefits of urban trees in two cities in California.[34] Values are estimated citywide in 2001 USD/year, which we regularized by dividing by citywide public tree cover acreage and then converted to 2021 USD/acre/year values, as listed in the table below. McPherson (1992) conducted a similar assessment in a smaller-scale case study, calculating the stormwater mitigation benefits of small forests in an urban context.[35] Values are estimated in 1991 USD/tree/year, which we regularized by multiplying by the number of citywide trees and then divided by the acres of citywide tree cover. We converted the resulting value into 2021 USD/acre/year, as listed in the table below. Wilson (2008) used CITYgreen software to estimate the flood hazard reduction benefits of forests at a landscape scale in terms of the alternative cost of built infrastructure that provides the same level of service.[36] The value is estimated in 2005 Canadian dollars/hectare/year, which we converted to 2021 USD/acre/year value and listed in the table below.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
McPherson et al. (1999)	Modesto, CA	832
McPherson et al. (1999)	Modesto, CA	146
McPherson & Simpson (2002)	Modesto, CA	103
McPherson & Simpson (2002)	Santa Monica, CA	442
McPherson (1992)	Tucson, AZ	10

Source Study	Study Location	Value ($/acre/year)*
Wilson (2008)	Ontario, Canada	676
Average		**368**

* All values are presented in 2021 USD

Discussion: The flood hazard risk reduction benefits of forests estimated by these studies are from various urban areas in the U.S. and Canada. The values are all derived from urban areas and thus may have limited applicability in certain rural contexts. The studies included in the construction of this value have not been modified from the values adopted in FEMA's 2016 environmental benefits policy other than to update them for inflation.

Water Filtration

Summary

Land Cover: Forest
Ecosystem Service: Water Filtration
FEMA Value: $435/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Meta-Analysis
Geographic Area of Study: Global
Source Studies:

> **Reference 1:** Taye, F.A., Folkersen, M.V., Fleming, C.M., Buckwell, A., Mackey, B., Diwakar, K.C., Le, D., Hasan, S., Ange, C.S. 2021. "The economic values of global forest ecosystem services: A meta-analysis." *Ecological Economics* 189 (107145): 1–14.

Methodology Description: Taye et al. (2021) estimated a meta-analysis of the economic value of ecosystem services for forest ecosystem services.[37] The study included a dataset of 261 primary studies published around the world, covering 624 values. The meta-regression reports were reported in 2017 USD/hectare/year, which we converted to 2021 USD/acre/year. The estimate used for this value is the global mean for the "bioremediation" and "dilution, filtration, and sequestration" ecosystem services from Table 3 in the study, which represented two ways that forests help to provide clean water.

Calculation:

Source Study	Study Location	Type of Water Filtration	Value ($/acre/year)*
Taye et al. (2021)	Global	Bioremediation	648

Source Study	Study Location	Type of Water Filtration	Value ($/acre/year)*
Taye et al. (2021)	Global	Dilution, filtration, and sequestration	222
Average			**435**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce.

Water Supply

Summary

Land Cover: Forest
Ecosystem Service: Water Supply
FEMA Value: $103/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Avoided Cost, Meta-Analysis
Geographic Area of Study: National
Source Studies:

Reference 1: Hill, B.H., Kolka, R.K., McCormick, F.H., Starry, M.A. 2013. "A synoptic survey of ecosystem services from headwater catchments in the United States." *Ecosystem Services* 7: 106–115.

Reference 2: Taye, F.A., Folkersen, M.V., Fleming, C.M., Buckwell, A., Mackey, B., Diwakar, K.C., Le, D., et al. 2021. "The economic values of global forest ecosystem services: A meta-analysis." *Ecological Economics* 189 (107145): 1–14.

Methodology Description: Hill et al. (2013) calculated the water supply of 568 upland headwaters catchments in first- and second-order streams throughout the U.S.[38] The sampling design was spatially balanced and employed an unequal probability survey with an unequal selection biased on stream order. Hydrological features were collected from stream gauge data. Water supply was calculated as a function of mean annual precipitation (1981–2010), mean annual discharge, reported water runoff and evapotranspiration, all spatially explicit and derived using geographic information system and other spatial interpolation models. The value of water supply was based on an average cost of alternative water sources, including groundwater extraction, desalinization and surface water collection and treatment. The economic outputs were reported as averages across nine U.S. ecoregions. Taye et al. (2021) estimated a meta-analysis of the economic value of ecosystem services for forest ecosystem services.[39] The study included a dataset of 261 primary studies published around the world, covering 624 values. The meta-regression reports were reported in 2017 USD/hectare/year, which we converted to 2021 USD/acre/year. The estimate used for this value was the global mean for the "water supply" ecosystem service.

Calculation:

Source Study	Study Location (ecoregion)	Value ($/acre/year)*
Hill et al. (2013)	Northern Appalachian Mountain Catchments	186
Hill et al. (2013)	Southern Appalachian Mountain Catchments	138
Hill et al. (2013)	Coastal Plains Catchments	122
Hill et al. (2013)	Xeric Catchments	42
Hill et al. (2013)	Western Mountain Catchments	165
Hill et al. (2013)	Northern Plains Catchments	18
Hill et al. (2013)	Southern Plains Catchments	19
Hill et al. (2013)	Temperate Plains Catchments	63
Hill et al. (2013)	Upper Midwest Catchments	74
Taye et al. (2021)	Global	114
Average		**103**

* All values are presented in 2021 USD

Discussion: Hill et al. conclude that the values do not represent an exhaustive sampling of forests in the U.S., particularly in lowland areas. However, this survey of forest catchments likely provides the best available national study for the U.S. Given that water storage capacity of upland forests often supplies downstream water users, these values apply to most cases in the U.S. The authors recognize these are conservative estimates and acknowledge that values can vary widely. Low-end values ensure that at least a value greater than zero is given to the value of water supply provided by forests. The addition of the meta-regression results support those produced by Hill et al., since it covers a wide range of contexts around the world.

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Appendix B. Coastal Wetland

Land Cover Definition

Coastal wetland[x] is defined as:

Areas of tidal wetlands (herbaceous and/or woody vegetation) or deepwater habitats in which plants grow and form a continuous cover principally on or at the surface of the water (e.g., algal mats, kelp beds, and submerged aquatic vegetation); AND vegetation coverage is greater than 20%; AND these waters are tidally influenced and have a salinity greater than or equal to 0.5 parts per thousand.

This definition of coastal wetland is a combination of several categories within the Coastal Change Analysis Program (C-CAP) Regional Land Cover Classification Scheme for Estuarine Wetlands developed by NOAA,[40] which is a nationally standardized inventory of land cover for the coastal areas of the U.S. Specifically, the following categories have been captured: Estuarine Forested Wetland (16); Estuarine Scrub/Shrub Wetland (17); Estuarine Emergent Wetland (18); and Estuarine Aquatic Bed (23).

Subapplicants can use the U.S. Fish and Wildlife Service Wetlands Mapper[41] to determine whether the wetlands in their proposed project are likely to meet the definition of "coastal," based on the project's location. To do this, subapplicants should use the map to zoom to their project's location and compare the location with nearby comparable wetlands that already exist. If those wetlands are designated as "Estuarine and Marine Wetland" according to the Wetland Mapper legend, then their project's wetlands are likely to be "Coastal"; if they are designated as "Freshwater Emergent Wetland" or "Freshwater Forested/Shrub Wetland" then their project's wetlands are likely to be considered "Inland" and subapplicants should refer to the section in this document for "inland wetland." If the Wetlands Mapper cannot be used to make this determination, subapplicants should seek an expert's opinion on the likely classification of their wetlands (i.e., coastal or inland), based on the definition provided above.

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for coastal wetland in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "coastal wetland" above.

[x] As noted in the introductory section of this report, a number of the source studies and values associated with the former "Marine and Estuary" land cover category have now been incorporated into the Coastal Wetlands category. The land cover definitions have also been partially combined.

- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[42] This definition has also been adopted by the Interagency Workgroup on Wetland Restoration, a team comprised by the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the U.S. Army Corps of Engineers, the Fish and Wildlife Service and the Natural Resources Conservation Service.[43]
- According to the EPA,[xi] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement or protection (of areas at risk of degradation in a No Action scenario).
- In general, wetland restoration should follow internally or externally established principles, guidelines, policies and techniques. Examples include:
    - One example of a guidance document is the *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*,[44] which was published in September 2021 by the U.S. Army Corps of Engineers' Engineering With Nature® (EWN) Initiative, in collaboration with government agencies in The Netherlands and the United Kingdom. The document includes detailed guidance on the use of wetlands and other features for flood risk management.
    - The SER International document, referenced above,[45] states that plans for restoration projects include, at a minimum, the following:
        - Clear rationale as to why restoration is needed
        - Ecological description of the site designated for restoration
        - Statement of the goals and objectives of the restoration project
        - Designation and description of the reference
        - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials

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[xi] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

  - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
  - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
  - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

The following examples demonstrate how the "coastal wetland" land cover category might be used in a mitigation project (and associated BCA):

- Restoration, creation, enhancement or protection of coastal wetland as part of a mitigation project to support coastal storm risk reduction and/or coastal flooding to people and structures. Examples:
  - Virginia Point Wetland Protection Project (Galveston County, TX).[46] This project restored roughly 10,000 feet of the Virginia Point shoreline and 25 acres of marsh in Galveston Bay. The marsh will act as an additional line of storm defense behind the existing levee, protecting urban areas, Galveston Causeway and the Bayport Industrial Wastewater Treatment Facility. Other benefits of the project include coastal erosion control, aesthetic value and habitat for fish and wildlife.
  - Cameron Meadows Marsh Creation and Terracing project (Cameron Parish, LA).[47] This $32 million project will include creation of 308 acres of additional marsh along the Louisiana coastline, helping to provide hurricane protection for populated areas including Calcasieu Parish. Other benefits of the project include reduced saltwater intrusion along the coast.
  - The Sears Point Wetland Restoration (Sonoma County, CA). The Sonoma Land Trust purchased a 2,327-acre property in the northern edge of San Pablo Bay with the goal of restoring tidal marsh. The project allowed tidal flow to return to approximately 1,000 acres of the property. Round marsh mounds were also built to attenuate wind wave energy and the flow of water, allowing sediment accretion and helping to naturally build up the marsh elevation. Benefits of the project include flood risk reduction, habitat for wildlife and recreational opportunities.

Project Useful Life Considerations

In general, provided that coastal wetland areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied.

If the subapplicant can demonstrate that the coastal wetland will continue to be maintained/ protected beyond 50 years, as evidenced through documented assurances such as agency commitments or formation of protected areas, then a PUL of 51–100 years can be applied (with 100 years representing perpetuity), depending on the nature of the assurances. Also, the coastal wetland should ideally be owned or controlled by a government or non-profit organization.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates[xii]

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	3,640	2	1,648	1	2
Air Quality					
Biological Control					
Climate Regulation	136	4	125	4	1
Erosion Control					
Existence Value					
Flood and Storm Hazard Risk Reduction	-	0	1,035	5	0
Food Provisioning					
Habitat	-	0	2,420	6	0
Nutrient Cycling	536	1	-	0	1
Pollination					
Recreation/Tourism	-	0	1,624	6	0
Water Filtration	1,406	2	1,558	2	0
Water Supply	292	2	544	2	0
Total Estimated Benefits	**6,010**		**8,955**		

[xii] The land cover category "wetlands" in the 2016 policy was broken into "coastal wetland" and "inland wetland" for this proposed update. The values provided in the "2016 Policy" column represent those associated with the original "wetland" land cover category.

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Aesthetic Value
FEMA Value: $1,648/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global
Source Studies:

> **Reference 1:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.

Methodology Description: Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world.[48] We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from the global model. We used the reduced model estimated in the study, which had 416 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) Non-coastal wetland variables were set to 0, and estuarine and the marine wetland variables were averaged; 2) The "amenity and aesthetics" variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita[49] to the units specified by the model; 4) Wetland size was set to the average size of coastal wetlands in the U.S.[50] 5) All other methodological variables were set to their mean value. The dependent variable was reported as 2003 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Study Location (ecoregion)	Value ($/acre/year)*
Ghermandi et al. (2010)	Global	1,648
Average		**1,648**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. We removed the two relevant coastal wetlands studies used in the 2016 policy and propose replacing them with this customized meta-analysis. This is justified as the two studies removed—Johnston et al. (2001)[51] and Johnston et al. (2002)[52]—are very local in scale and the study site is in an affluent area which would have inflated the value of this service.

Climate Regulation

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Climate Regulation
FEMA Value: $125/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: Global, North America, USA Coastal Areas; Florida; Snohomish County, WA; Port Susan, WA
Source Studies:

> **Reference 1:** Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. "The carbon balance of North American wetlands." *Wetlands* 26(4): 889–916.
> **Reference 2:** Chmura, C., Anisfeld, S.C., Cahoon, D.R., Lynch, J.C. 2003. "Global carbon sequestration in tidal, saline wetland soils." *Global biogeochemical cycles* 17(4).
> **Reference 3:** Choi, Y., Wang, Y. 2004. "Dynamics of carbon sequestration in a coastal wetland using radiocarbon measurements." *Global Biogeochemical Cycles* 18: 1–12.
> **Reference 4:** Crooks, S., Rybczyk, J., O'Connell, K., Devier, D.L., Poppe, K., Emmett-Mattox, S. 2014. Coastal blue carbon opportunity assessment for the Snohomish Estuary: The Climate Benefits of Estuary Restoration. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries, Seattle, WA. Available online at: https://estuaries.org/wp-content/uploads/2020/11/Crooks.-Coastal-Blue-Carbon-Opportunity-Assessment-for-the-Snohomish-Estuary-ilovepdf-compressed.pdf
> **Reference 5:** Duarte, C.M., Middelburg, J.J., Caraco, N. 2005. "Major role of marine vegetation on the oceanic carbon cycle." *Biogeosciences* 2: 1–8.
> **Reference 6:** Laffoley, D., Grimsditch, G. (eds). 2009. *The management of natural coastal carbon sinks*. IUCN, Gland, Switzerland. 53 pp.
> **Reference 7:** Poppe, K., Rybczyk, J. 2019. A blue carbon assessment for the Stillaguamish River estuary: Quantifying the climate benefits of tidal marsh restoration. Department of Environmental Sciences, Western Washington University, Bellingham, Washington.

Methodology Description: Carbon sequestration of coastal wetland was calculated in two parts. First, a database of over 6,000 carbon values was used to estimate the carbon sequestration in metric tons of carbon per acre per year of coastal wetland types across the U.S. Five studies comprising 72 individual carbon sequestration values were selected from the database to construct an average value estimate. Second, the social cost of carbon was used to calculate a dollar value of carbon sequestration. The social cost of carbon (SCC) represents the average societal costs associated with each additional ton of carbon emissions (measured in CO_2e), such as losses to agriculture, impacts to human health, and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., wetland restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG). The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990.[53] Specifically, the 2020 value was used: $51/metric ton CO^2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Bridgeham et al. (2006)[54]	0.86	195.81	170
Chmura et al. (2003)[55]	0.87	195.81	171
Choi & Wang (2004)[56]	0.38	195.81	75
Crooks et al. (2014)[57]	0.64	195.81	125
Duarte et al. (2005)[58]	Not provided	Not provided	36
Laffoley and Grimsditch (2009)[59]	Not provided	Not provided	114
Poppe & Rybczyk (2019)[60]	0.94	195.81	183
Average			**125**

* All values are presented in 2021 USD

Discussion: Coastal ecosystems, including wetlands and submerged aquatic vegetation, are important for the global ocean carbon cycle through permanent carbon burial. Vegetative structures that live in these ecosystems capture carbon and are thus generally called “blue carbon.” Carbon budget analyses suggest blue carbon structures store a vast amount of organic carbon, in part because coastal vegetation is often dominated by long-lived organisms. The above assessment combined 72 carbon values estimated across the U.S. to arrive at a single-dollar value for the value of climate regulation provided by coastal wetlands. The values are averaged across different stages of ecological health, species, age and climate types present in U.S. wetlands. The carbon value used was standardized by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. Two studies from the 2016 policy was removed from the value calculation. Smith et al. 2006 was removed as more recent studies relevant to wetlands were found.[61] Nellemann et al. 2009 was removed as it represented an extreme outlier and was more applicable to vast expanses of marine open water, not nearshore ecosystems.[62]

Habitat

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Habitat
FEMA Value: $2,420/acre/year
Currency Value: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis, Contingent valuation, Choice experiment, Productivity Value
Geographic Area of Studies: Global, United States, Florida, New York
Source Studies:

Reference 1: Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
Reference 2: Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
Reference 3: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
Reference 4: Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M., Diamantedes, J. 2002. "Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study." *Coastal Management* 30(1): 47–65.
Reference 5: Hazen and Sawyer Environmental Engineers & Scientists. 2008. Indian River Lagoon Economic Assessment and Analysis Update.
Reference 6: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[63] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[64] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[65] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[66]

We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting coastal wetlands were set to 1 and other wetland variables set to 0; 2) the variable describing habitat provisioning was set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[67] converted to the units specified by the model;

4) if applicable, wetland size was set to the average size of coastal wetlands in the U.S.[68] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[69] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value.

The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year. In another study of the National Estuary Program by Johnston et al. (2002), the authors studied the Peconic Estuary System and found the value of nursery and habitat services using a productivity value method that was designed and implemented with physical scientists and coastal managers as part of the Peconic Estuary research program.[70] Their study estimated the economic value of eelgrass, inter-tidal salt marsh and sand/mud bottoms, based on the value of fish, shellfish and bird species that these ecosystems help produce. Another stated preference study conducted by the Hazen and Sawyer (2008) firm of environmental engineers and scientists used contingent valuation and revealed preference approaches to estimate residents' and visitors' nonuse values of the Indian River Lagoon in Florida.[71] The authors found that visitors and residents were willing to pay a one-time tax to protect as well as restore that lagoon, values that have been combined in the table below.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Adusumilli (2015)	United States	124
Brander et al. (2006)	Global	2,072
Ghermandi et al. (2010)	Global	3,046
Johnston et al. (2002)	New York (Saltwater fish habitat)	450
Johnston et al. (2002)	New York (Seagrass Habitat)	11,708
Johnston et al. (2002)	New York (Bird habitat)	391
Hazen & Sawyer (2008)	Florida	28
Woodward & Wui (2001)	Global	1,545
Average		**2,420**

* All values are presented in 2021 USD

Discussion: The studies used to derive a habitat value for this land cover include a wide sample of regions within the U.S. Studies were chosen based on their ability to assess sensitive habitat and nursery conditions under various coastal habitat types, in a variety of protected statuses, as well as studies that use multiple valuation methodologies. The range of species habitat considered in the chosen studies include fish species, eelgrass and kelp, estuarine cord grass, wetlands, and general habitat types in coastal conditions for fish and birds. Improvements in the ecological integrity of coastal habitats can lead to measurable increases in populations of fish, birds, and other forms of plant and animal life—some of which may have commercial, recreational, or nonuse value. The inclusion of meta-analyses, which produce value estimates from the results of typically dozens or hundreds of studies at once, control for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer. Two studies—Bockstael et al. (1989) [72] and Whitehead et al. (1997) [73]—were removed from the 2016 Policy and replaced with newer valuation estimates. Jordan et al. (2012) was removed as it was a secondary study that could be replaced by newer primary studies. [74] Two other studies—Hicks et al. (2004) [75] and Isaacs et al. (2004) [76]—were removed and placed into a new land cover type for shellfish reefs.

Recreation/Tourism

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Recreation/Tourism
FEMA Value: $1,624/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis, Contingent Valuation, Travel Cost
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
> **Reference 2:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
> **Reference 3:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
> **Reference 4:** Hazen and Sawyer Environmental Engineers & Scientists. 2008. Indian River Lagoon Economic Assessment and Analysis Update.
> **Reference 5:** Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M., Diamantedes, J. 2002. "Valuing estuarine resource services using economic and ecological models: The Peconic Estuary System study." *Coastal Management* 30(1): 47–65.

Reference 6: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: Johnston et al. (2002) studied the Peconic Estuary System, finding the value of outdoor recreation activities like swimming, boating, fishing, and bird and wildlife viewing, using a travel cost method that was designed and implemented with physical scientists and coastal managers as part of the Peconic Estuary research program. The authors found that bird and wildlife watching, and recreational fishing were the most highly valued activities. Hazen and Sawyer (2008) examined a very different geography and calculate the recreational value residents and visitors derive from the Indian River Lagoon in Florida. To do so, authors conducted a survey and examined only primary recreational activities. In general, they found that visitors spend more than twice as many days per year recreating in the Indian River Lagoon and that the most popular activities were fin fishing, swimming or wading, and power boating (including water skiing, tubing, or cruising). We also performed function transfer, a type of benefit transfer method, to construct United States–specific values from several meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducts a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[77] Brander et al. (2006) is a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[78] Ghermandi et al. (2010) create a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[79] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[80] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting coastal wetlands were set to 1 and other wetland variables set to 0; 2) variables describing recreational activities were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[81] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of coastal wetlands in the U.S.[82]; 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[83] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Adusumilli (2015)	United States	582
Brander et al. (2006)	Global	172
Ghermandi et al. (2010)	Global	639
Johnston et al. (2002)	New York	201

Source Study	Study Location	Value ($/acre/year)*
Hazen & Sawyer (2008)	Florida	4,337
Woodward & Wui (2001)	Global	3,816
Average		**1,624**

* All values are presented in 2021 USD

Discussion: Coastal ecosystems offer unique opportunities for recreational activities as they create a wide range of habitats for many types of wildlife (both migratory and not) that can enhance recreational experiences. Recreational value is also highly dependent upon location, activities, ecosystem types, and valuation methods. The group of selected studies employs a wide variety of estimating methodologies, recreational activity types, and examines very diverse geographies. Such spread in the evidence is important for robustness and validity of a final estimate. In addition, meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer.

Flood and Storm Hazard Risk Reduction

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Flood and Storm Hazard Risk Reduction
FEMA Value: $1,035/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Sun, F., Carson, R.T. 2020. “Coastal wetlands reduce property damage during tropical cyclones.” *PNAS* 117(11): 5719–5725.
> **Reference 2:** Adusumilli, N. 2015. “Valuation of ecosystem services from wetlands mitigation in the United States.” *Land* 4(1): 182–196.
> **Reference 3:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. “The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature.” *Environmental & Resource Economics* 33: 223–250.

Reference 4: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., and Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.

Reference 5: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: Sun and Carson (2020) analyzed property damage from 88 tropical storms hitting the U.S. between 1996 and 2016.[84] The expected economic value of storm hazard risk reduction for coastal wetlands was determined for all 237 coastal counties along the Atlantic and Gulf coasts. The median value of wetlands across all counties was presented in 2016 USD/square kilometer/year, which we converted to USD/acre/year and then inflated to 2021 USD/acre/year (as provided in the table below). We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[85] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[86] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[87] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[88] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting coastal wetlands were set to 1 and other wetland variables set to 0; 2) variables describing flood or storm hazard risk reduction were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[89] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of coastal wetlands in the U.S.,[90] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[91] to the units specified by the model; 6) for Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	75
Brander et al. (2006)	1,040
Ghermandi et al. (2010)	1,496
Sun & Carson (2020)	415
Woodward & Wui (2001)	1,986
Average	**1,035**

* All values are presented in 2021 USD

Discussion: Sun and Carson (2020) conducted a robust study based on a decade of observed storm damage data. We converted the median value from this study, which is conservative in comparison to the mean value, indicating that study results tended to skew on the lower end of the range. Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer.

Water Filtration

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Water Filtration
FEMA Value: $1,558/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
> **Reference 2:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
> **Reference 3:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
> **Reference 4:** Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[92] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[93] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[94] Woodward & Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[95] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows:

1) variables denoting coastal wetlands were set to 1 and other wetland variables set to 0; 2) variables describing water quality improvement or water filtration by wetlands were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[96] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of coastal wetlands in the U.S.,[97] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[98] to the units specified by the model; 6) For Woodward & Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	417
Brander et al. (2006)	1,697
Ghermandi et al. (2010)	2,009
Woodward & Wui (2001)	2,108
Average	**1,558**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer. The two studies from the 2016 FEMA policy were originally derived using value transfer; herein we present updated values using function transfer methods. This variation in methodology application accounts for the difference in values attributed to Brander et al. (2006) and Woodward & Wui (2001) between the 2016 policy and those listed here.

Water Supply

Summary

Land Cover: Coastal Wetland
Ecosystem Service: Water Supply
FEMA Value: $544/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis

Geographic Area of Studies: Global, United States

Source Studies:

Reference 1: Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.

Reference 2: Brander, L.M., Florax, R. J., Vermaat, J. E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.

Reference 3: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.

Reference 4: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[99] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[100] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[101] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[102] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting coastal wetlands were set to 1 and other wetland variables set to 0; 2) variables describing water supply were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[103] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of coastal wetlands in the U.S.,[104] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[105] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	307
Brander et al. (2006)	350
Ghermandi et al. (2010)	879

Source Study	Value ($/acre/year)*
Woodward & Wui (2001)	642
Average	**544**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer. The two studies from the 2016 FEMA policy were originally derived using value transfer; herein we present updated values using function transfer methods. This variation in methodology application accounts for the difference in values attributed to Brander et al. (2006) and Woodward & Wui (2001) between the 2016 policy and those listed here.

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Appendix C. Inland Wetland

Land Cover Definition

Inland wetland is defined as:

Areas dominated (20 percent or more) by perennial herbaceous vegetation, vegetation that grows and forms a continuous cover on or at the surface of the water, shrubland vegetation, or forest; AND the soil or substrate is at least periodically saturated with or covered with water; AND these waters are tidally influenced and have a salinity less than 0.5 parts per thousand.

This definition is based on the Coastal Change Analysis Program (C-CAP) Regional Land Cover Classification Scheme definitions for Palustrine wetlands and aquatic beds. This is a nationally standardized inventory of land cover for the coastal areas of the U.S. developed by NOAA.[106]

Subapplicants can use the U.S. Fish and Wildlife Service Wetlands Mapper[107] to determine whether the wetlands in their proposed project are likely to meet the definition of “inland,” based on the project’s location. To do this, subapplicants should use the map to zoom to their project’s location and compare the location with nearby comparable wetlands that already exist. If those wetlands are designated as “Freshwater Emergent Wetland” or “Freshwater Forested/Shrub Wetland” according to the Wetland Mapper legend, then their project’s wetlands are likely to be “inland”; if they are designated as “Estuarine and Marine Wetland” then their project’s wetlands are likely to be considered “coastal” and subapplicants should refer to the section in this document for “coastal wetland.” If the Wetlands Mapper cannot be used to make this determination, subapplicants should seek an expert’s opinion on the likely classification of their wetlands (i.e., coastal or inland), based on the definition provided above.

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for inland wetland in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of “inland wetland” above.
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.”[108] This definition has also been adopted by the Interagency Workgroup on Wetland Restoration, a team comprising the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the U.S. Army Corps of Engineers, the Fish and Wildlife Service, and the Natural Resources Conservation Service.[109]

- According to the EPA,[xiii] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.

- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).

- In general, wetland restoration should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:

    - One example of a guidance document is the *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*,[110] which was published in September 2021 by the U.S. Army Corps of Engineers' Engineering With Nature® (EWN) Initiative, in collaboration with government agencies in The Netherlands and the United Kingdom. The document includes detailed guidance on the use of wetlands and other features for flood risk management.

    - The SER International document, referenced above,[111] states that plans for restoration projects include, at a minimum, the following:

        - Clear rationale as to why restoration is needed
        - Ecological description of the site designated for restoration
        - Statement of the goals and objectives of the restoration project
        - Designation and description of the reference
        - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
        - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
        - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
        - Strategies for long-term protection and maintenance of the restored ecosystem

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[xiii] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

Mitigation Project Use Cases

The following examples demonstrate how the “inland wetland” land cover category might be used in a mitigation project (and associated BCA):

- Restoration, creation, enhancement, or protection of an existing inland wetland area or creation of a new inland wetland area as a component of a Flood Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff, and decrease flood risk to downstream, upstream, or adjacent people and structures. This example would apply to forested areas within an FDS or FSR project that are not defined as “riparian.”

Project Useful Life Considerations

In general, provided that inland wetland areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied.

If the subapplicant can demonstrate that the inland wetland will continue to be maintained/protected beyond 50 years, as evidenced through documented assurances such as agency commitments or formation of protected areas, then a PUL of 51–100 years can be applied (with 100 years representing perpetuity), depending on the nature of the assurances. Also, the inland wetland should ideally be owned or controlled by a government or non-profit organization.

Please see the section in the main report body titled “Select an Appropriate Project Useful Life” for more background and detail.

Summary of Values Updates[xiv]

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	3,640	5	1,303	1	5
Air Quality					
Biological Control					
Climate Regulation	136	4	56	3	1

[xiv] The land cover category “wetlands” in the 2016 policy was broken into “coastal wetland” and “inland wetland” for this proposed update. The values provided in the “2016 Policy” column represent those associated with the original “wetland” land cover category.

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Erosion Control					
Existence Value					
Flood and Storm Hazard Risk Reduction	-	0	1,264	4	0
Food Provisioning					
Habitat	-	0	1,416	4	0
Nutrient Cycling	536	1	-	0	1
Pollination					
Recreation/Tourism	-	0	1,906	4	0
Water Filtration	1,406	2	1,584	2	0
Water Supply	292	2	643	2	0
Total Estimated Benefits	**6,010**		**8,171**		

Ecosystem Service Value

Aesthetic Value

Summary

Land Cover: Inland Wetland
Ecosystem Service: Aesthetic Value
FEMA Value: $1,303/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global
Source Studies:

Reference 1: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.

Methodology Description: Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world.[112] We performed function transfer—a type of benefit transfer method—to construct a United States–specific value from the global model. We used the reduced model estimated in the study, which had 416 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) freshwater and inland wetland variables were averaged, and estuarine and the marine wetland variables were set to 0; 2) the "amenity and aesthetics" variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita[113] to the units specified by the model; 4) wetland size was set to the average size of inland freshwater wetlands in the U.S.[114]; 5) all other methodological variables were set to their mean value. The dependent variable is reported as 2003 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Ghermandi et al. (2010)	1,303
Average	1,303

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. We removed all the relevant inland wetlands studies used in the 2016 policy and propose replacing them with this customized meta-analysis. This is justified for several reasons: two of these studies—Mahan (1997)[115] and Thibodau & Ostro (1981)[116]—use data that is more than two decades old, and Qiu & Prato (2006)[117] studies ecosystems which are better suited for the Riparian land cover type.

Climate Regulation

Summary

Land Cover: Inland Wetland
Ecosystem Service: Climate Regulation
FEMA Value: $56/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: United States
Source Studies:

Reference 1: Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. "The carbon balance of North American wetlands." *Wetlands* 26(4): 889–916.
Reference 2: Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., et al. 2012. Chapter 5: Baseline Carbon Storage, Carbon Sequestration, and Greenhouse-Gas Fluxes in Terrestrial Ecosystems of the Western United States. In: Zhu, Z., Reed, B.C. (eds.). *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States* (p. 45-63). U.S. Geological Survey Professional Paper, Reston, Virginia. Available online at: https://pubs.er.usgs.gov/publication/pp1797

Reference 3: Fennessy, M.S., Wardrop, D.H., Moon, J.B., Wilson, S., Craft, C. 2018. "Soil carbon sequestration in freshwater wetlands varies across a gradient of ecological condition and by ecoregion." *Ecological Engineering* 114: 129–136.

Methodology Description: Carbon sequestration for inland wetlands were calculated in two phases. First, a database of over 6,000 carbon values3 was used to estimate the carbon sequestration in metric tons of carbon per acre per year of inland wetland types across the U.S. Three studies comprising 11 individual carbon sequestration values were selected from the database to construct an average value estimate. Second, the social cost of carbon was used to calculate a dollar value of carbon sequestration. The social cost of carbon (SCC) represents the average societal costs associated with each additional ton of carbon emissions (measured in CO_2e), such as agricultural losses, human health impacts, and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., wetland restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG). The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990.[118] Specifically, the 2020 value is used: $51/metric ton CO_2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Bridgeham et al. (2006)[119]	0.11	195.81	22
Liu et al. (2012)[120]	0.47	195.81	92
Fennessy et al. (2018)[121]	0.27	195.81	53
Average			**56**

* All values are presented in 2021 USD

Discussion: In the U.S., most wetland areas are comprised of freshwater inland wetlands. Nevertheless, carbon stored in inland freshwater wetlands is often overlooked. Instead, many studies have focused on quantifying the carbon held in terrestrial ecosystems, and on "blue carbon." By reviewing, evaluating, and synthesizing existing literature, this effort contributes to the larger goal of allowing the inclusion of inland wetlands in valuation and decision-support tools. Our assessment covers a variety of stages of ecological health, species, age, and climate types present in U.S. wetlands. The carbon value used was standardized by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. One study was removed from the value calculation—Smith et al. (2006)[122]—as more recent studies relevant to wetlands were found.

Flood Hazard Risk Reduction

Summary

Land Cover: Inland Wetland
Ecosystem Service: Flood Hazard Risk Reduction
FEMA Value: $1,264/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
> **Reference 2:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
> **Reference 3:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
> **Reference 4:** Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." Ecological Economics 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[123] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[124] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[125] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[126] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows:

1) variables denoting freshwater or inland wetlands were set to 1 and other wetland variables set to 0; 2) the variable describing flood or storm hazard risk reduction was set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[127] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of inland freshwater wetlands in the U.S.[128]; 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[129] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	204
Brander et al. (2006)	361
Ghermandi et al. (2010)	1,183
Woodward & Wui (2001)	2,286
Average	**1,264**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer.

Habitat

Summary

Land Cover: Inland Wetland
Ecosystem Service: Habitat
FEMA Value: $1,416/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

Reference 1: Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
Reference 2: Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
Reference 3: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
Reference 4: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[130] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[131] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[132] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[133] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting freshwater or inland wetlands were set to 1 and other wetland variables set to 0; 2) the variable describing habitat provisioning was set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[134] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of inland freshwater wetlands in the U.S.[135]; 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[136] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	336
Brander et al. (2006)	699
Ghermandi et al. (2010)	2,408
Woodward & Wui (2001)	2,219
Average	**1,416**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer.

Recreation/Tourism

Summary

Land Cover: Inland Wetland
Ecosystem Service: Recreation/Tourism
FEMA Value: $1,906/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
> **Reference 2:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
> **Reference 3:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.
> **Reference 4:** Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[137] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[138] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[139] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[140] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting freshwater or inland wetlands were set to 1 and other wetland variables set to 0; 2) variables describing recreational activities were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[141] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of inland freshwater wetlands in the U.S.;[142] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[143] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	1,581
Brander et al. (2006)	60
Ghermandi et al. (2010)	505
Woodward & Wui (2001)	5,478
Average	**1,906**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer.

Water Filtration

Summary

Land Cover: Inland Wetland
Ecosystem Service: Water Filtration
FEMA Value: $1,584/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.

Reference 2: Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.

Reference 3: Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water Resources Research* 46(12): W12516.

Reference 4: Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[144] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[145] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[146] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[147] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting freshwater or inland wetlands were set to 1 and other wetland variables set to 0; 2) variables describing water quality improvement or water filtration by wetlands were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[148] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of inland freshwater wetlands in the U.S.[149]; 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[150] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	1,131
Brander et al. (2006)	590
Ghermandi et al. (2010)	1,589
Woodward & Wui (2001)	3,025
Average	**1,584**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer. The two studies from the 2016 FEMA policy were originally derived using value transfer; herein we present updated values using function transfer methods. This variation in methodology application accounts for the difference in values attributed to Brander et al. (2006) and Woodward & Wui (2001) between the 2016 policy and those listed here.

Water Supply

Summary

Land Cover: Inland Wetland
Ecosystem Service: Water Supply
FEMA Value: \$643/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global, United States
Source Studies:

> **Reference 1:** Adusumilli, N. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." *Land* 4(1): 182–196.
> **Reference 2:** Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature." *Environmental & Resource Economics* 33: 223–250.
> **Reference 3:** Ghermandi, A., van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A. 2010. "Values of natural and human-made wetlands: A meta-analysis." Water Resources Research 46(12): W12516.
> **Reference 4:** Woodward, R., Wui, Y. 2001. "The economic value of wetland services: A meta-analysis." *Ecological Economics* 37: 257–270.

Methodology Description: We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from two meta-analyses on the economic value of wetlands. The function transfers were all performed in a similar manner. Adusumilli (2015) conducted a meta-analysis describing the value of wetlands from 72 observations in the U.S., producing a model with an adjusted R^2 of 0.753.[151] Brander et al. (2006) conducted a global meta-analysis using 202 observations with an adjusted R^2 of 0.45.[152] Ghermandi et al. (2010) created a meta-analysis describing the value of wetlands from 170 studies around the world; we used the reduced model which included 416 observations and an adjusted R^2 of 0.44.[153] Woodward and Wui (2001) conducted a meta-analysis on 39 wetland valuation studies.[154] We selected Model C for the function transfer, which included 65 observations with an R^2 of 0.582. Model variables were set as follows: 1) variables denoting freshwater or inland wetlands were set to 1 and other wetland variables set to

0; 2) variables describing water supply were set to 1, all other ecosystem service variables were set to 0; 3) if applicable, any income per capita variables were set to the average annual household income in the U.S.,[155] converted to the units specified by the model; 4) if applicable, wetland size was set to the average size of inland freshwater wetlands in the U.S.;[156] 5) if applicable, variables describing GDP per capita were calculated by converting the current U.S. GDP per capita[157] to the units specified by the model; 6) For Woodward and Wui (2001), "publish" was set to 1, indicating the results should reflect published values; 7) all other variables were set to their mean value. The dependent variables were all at various dollar years and either per-hectare or per-acre, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Adusumilli (2015)	833
Brander et al. (2006)	121
Ghermandi et al. (2010)	695
Woodward & Wui (2001)	921
Average	**643**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Additionally, function transfer can provide value estimates tailored to the transfer site and often produces smaller error than traditional value transfer. The two studies from the 2016 FEMA policy were originally derived using value transfer; herein we present updated values using function transfer methods. This variation in methodology application accounts for the difference in values attributed to Brander et al. (2006) and Woodward & Wui (2001) between the 2016 policy and those listed here.

Appendix D. Urban Green Open Space

Land Cover Definition

Urban green open space is defined as:

Green open space areas are those in which vegetated pervious surfaces account for at least 80% of total cover (impervious surfaces account for less than 20% of total cover) and include a mixture of some constructed materials. Green open space is considered "urban" if it meets the criteria specified in the U.S. Census Bureau's "2010 Census Urban and Rural Classification and Urban Area Criteria," which includes both Urbanized Areas (population of 50,000 or more) and Urban Clusters (population between 2,500 and 50,000).[xv] *Examples of urban green open space include urban parks and recreational sites, neighborhood green spaces, pocket parks, green corridors, and lawns.*

This definition of urban green open space is based on the 2019 National Land Cover Database (NLCD), a product that is developed and regularly updated by the Multi-Resolution Land Characteristics (MRLC) consortium, a "group of federal agencies who coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications.[158] Examples included are from the valuation literature selected for this land cover type.

Subapplicants can determine whether their project area is within an "urban" setting, as defined by the 2010 U.S. Census, by visiting following link: https://tigerweb.geo.census.gov/tigerweb/. First, select "BVP 2020" from the "Select Vintage" drop-down box. Then, click the check box next to "Urban Areas" on the sidebar, which will highlight both Urbanized Areas and Urban Clusters on the map. Enter an address within your project area on the map to determine whether it is located within one of these areas.

Feasibility & Effectiveness Criteria

Urban green space can take on a variety of forms. In general, to include the ecosystem service values for urban green open space in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "urban green open space" above.
- Typically, the project would demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or

[xv] Definition available here: https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html.

destroyed."[159] According to the EPA,[xvi] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.

- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).
- The area designated as urban open space must be consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum.[160]
- The creation of urban open space should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:
  - In 2011, the White House Council on Environmental Quality published the report "Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes",[161] which includes a number of general best practices and principles "to be used by Federal agencies for landscape practices when constructing new, or rehabilitating existing, owned or leased facilities, or when landscaping improvements are otherwise planned." Though developed for federal agencies, many of the best practices and principles are broadly applicable to areas consistent with the definition of urban green open space presented here.
  - Examples of internal guidance documents developed by local agencies include:
    - County of Los Angeles Department of Parks and Recreation's Park Design Guidelines and Standards.[162]
    - County of San Diego Department of Parks and Recreation's *Park Design Manual.*[163]
  - For urban green space projects that seek to maximize the use of green infrastructure, the National Recreation and Park Association in 2017 published the "Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks."[164]

Mitigation Project Use Cases

The following examples demonstrate how the "urban green open space" land cover category might be used in a mitigation project (and associated BCA):

- Open space areas created because of acquisition and demolition/relocation projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space"

[xvi] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum. Open space areas must also specifically meet the definition of "urban" and other criteria discussed above.

- Creation of an urban park to support hazard risk reduction (e.g., pluvial flooding, heat) and other social and environmental benefits.
- Areas associated with Floodplain and Stream Restoration or Flood Diversion and Storage projects in areas that are within the floodplain and meet the definition/criteria for "urban green open space" discussed above. Example:
    - The Exploration Green Stormwater Park in Houston, TX, expected to be completed in 2022, seeks to create 200 acres of park area that will reduce flood damages for approximately 30,000 people living within one-half mile of the park. The park will contain five large detention basins, recreational facilities, a visitor center, nature areas, practice fields, and multiuse paths.

Project Useful Life Considerations

In general, provided that urban green open space areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied. A higher Project Useful Life may be applied in the following cases:

- If the urban green open space area is owned or acquired, and a FEMA-compliant deed restriction (CFR, Title 44, Part 80) or equivalent perpetual easement is recorded on the property, then a PUL of 100 years can be used. A typical example would be a standard FEMA acquisition and demolition/relocation project that results in the restoration, creation, enhancement, or protection of the urban green open space area.
- If the land is not owned, acquired, or controlled, but the subapplicant can demonstrate that the land cover will be maintained/protected beyond 50 years (as evidenced through documented assurances, such as deed restriction, easement, or maintenance agreement with the landowner), then a PUL of 51-100 years can be used (with 100 years representing perpetuity), depending on the nature of the assurances.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	1,707	2	7,010	3	2
Air Quality	215	3	201	2	2
Biological Control					
Climate Regulation	61	2	54	1	1
Erosion Control	68	1	78	0	0
Existence Value					
Flood Hazard Risk Reduction	308	2	316	1	0
Food Provisioning					
Habitat	-	0	5,890	1	0
Pollination	305	1	350	0	0
Recreation/Tourism	5,644	4	1,642	2	1
Water Filtration					
Water Supply					
Total Estimated Benefits	**8,308**		**15,541**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Urban green open space
Ecosystem Service: Aesthetic Value
FEMA Value: $7,010/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis, Hedonic price
Geographic Area of Studies: Global; Portland, OR; Los Angeles, CA
Source Studies:

Reference 1: Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics* 169: 106480.
Reference 2: Lutzenhiser, M., Netusil, N.R. 2001. "The effect of open spaces on a home's sale price." Contemporary Economic Policy 19(3): 291–298.
Reference 3: Trust for Public Land. 2017. The Economic Benefits of the Public Park and Recreation System in the City of Los Angeles, California. Available online at: https://www.tpl.org/econbenefits-losangeles

Methodology Description: Bockarjova et al. (2020) created a meta-analysis describing the value of green open spaces from 147 observations across 60 studies conducted around the world.[165] We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from Model 2, which had an adjusted R^2 of 0.699. Model variables were set as follows: 1) the "park" and "small urban green" variables were averaged, and the other greenspace type variables set to 0; 2) the "aesthetics" variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita[1] to the units specified by the model; 4) population density was calculated using the average population density in the U.S.,[166] converted to the units specified by the model; 5) all other variables were set to their mean value. The dependent variable is reported as 2016 USD per hectare per year, which we converted to 2021 USD per acre per year. In an attempt to extend the existing hedonics price literature, Lutzenhiser & Netusil (2001) break the catch-all "park" category into different categories.[167] For this value we chose the average of the urban and natural area park categories, which most closely relate to the type of greenspace valued by the FEMA BCA process. Following the 2009 report from the National Association of Realtors, the Trust for Public Land (2017) determined that parks in the City of Los Angeles add 5% to the market value of all dwellings within 500 feet.[168]

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Bockarjova et al. (2020)	Global	21,873
Lutzenhiser & Netusil (2001)	Portland	540
Trust for Public Land (2017)	City of Los Angeles	5,087
Average		**7,010**

* All values are presented in 2021 USD

Discussion: Urban open spaces, such as public parks, lawns, and golf courses help provide attractive views for nearby residents. A revision of the literature concluded in the selection of representative studies that examine willingness to pay for proximity to urban green open spaces or the net effect that such proximity has on a home's price. An important consideration is that proximity to green open spaces may also be associated with aesthetic disamenities, such as traffic congestion and noise or if the site is a poor-quality park. The studies examined did not find evidence of these negative effects. Two studies were removed from the 2016 Policy values. Bolitzer & Netusil (2000)[169] was replaced with a newer study which uses the same data, and Qiu et al. (2006)[170] was replaced with the newer studies which represent land cover types more relevant to the urban green open space category.

Air Quality

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Air Quality
FEMA Value: $201/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: United States; Seattle, WA; Los Angeles, CA
Source Studies:

> **Reference 1:** Gopalakrishnan, V., Hirabayashi, S., Ziv, G., Bakshi, B.R. 2018. "Air quality and human health impacts of grasslands and shrublands in the United States." *Atmospheric Environment* 182: 193–199.
> **Reference 2:** Trust for Public Land. 2011. The Economic Benefits of Seattle's Park and Recreation System. Available online at: http://cloud.tpl.org/pubs/ccpe-seattle-park-benefits-report.pdf
> **Reference 3:** Trust for Public Land. 2017. The Economic Benefits of the Public Park and Recreation System in the City of Los Angeles, California. Available online at: https://www.tpl.org/econbenefits-losangeles

Methodology Description: Several studies have estimated the pollution removal capacity of vegetated land covers, but little work has been done to estimate the human health benefits associated with pollution removal. In their 2018 study, Gopalakrishnan and colleagues undertake a comprehensive effort to do just that, and using the i-Tree Eco model as well as the EPA's BenMAP program, they examine the adverse health effects (morbidity and mortality) from ozone, nitrogen oxides, particulates, and sulfur oxides in urban areas across the U.S.[171] In turn, the two chosen local studies by the Trust for Public Land also utilize the i-Tree Eco model in conjunction to the BenMAP program to estimate air quality benefits from urban parks and open spaces in Seattle, WA[172] and Los Angeles, CA.[173] All three selected studies follow an avoided cost approach by valuing avoided adverse health effects (i.e., respiratory illness, emergency room visits, and hospital admissions) through the removal of pollutants with vegetation. Specifically, using the Leaf Area Index as well as percentage land cover data and local air pollution metrics, they examine vegetated land covers impact on adverse health effects from respiratory illness. In their economic valuation method, they follow a "cost-of-illness" by accounting for the cost of emergency room visits, hospital admissions, and school loss days.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Gopalakrishnan et al. (2018)	United States	42
Trust for Public Land (2011)	Seattle, WA	513
Trust for Public Land (2017)	Los Angeles, CA	47
Average		**201**

* All values are presented in 2021 USD

Discussion: Landcover changes can help improve local air quality, as more leaves absorb gases such as nitrogen dioxide, sulfur dioxide, carbon monoxide, and ozone. Particulate matter can also be removed when it adheres to plant surfaces. The estimations presented here are subject to the underlying assumptions in the integrated models. Some of the underlying assumptions that are important to consider are the health impact functions upon which the BenMAP tool operates. These health impact functions are of a rather general form and may be improved on by using specific information about the respiratory illnesses being modeled. In addition, there are other impacts related to air pollution that are not captured in these health impact functions—not only on human health but also on the health of the ecosystem. For instance, it is known that during high temperature events, ozone levels become particularly problematic for people with preconditions, such as asthma. The i-Tree Eco model+BenMAP approach is silent on these additional impacts. Two studies were removed from the 2016 Policy values. Wilson (2008)[174] is a secondary study that was replaced with the more relevant primary studies included above. McPherson et al. (1998)[175] was replaced with newer studies which represent land cover types more relevant to the urban green open space category.

Climate Regulation

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Climate Regulation
FEMA Value: $54/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: United States

Source Studies:

Reference 1: Milesi, C., Elvidge, C.D., Dietz, J.B., Tuttle, B.T., Nemani, R.R., Running, S.W. 2005. "A strategy for mapping and modeling the ecological effects of U.S. lawns." Liang, S., Liu, J., Li, X. (eds.). The 9th International Symposium on Physical Measurements and Signatures in Remote Sensing. ISPRS, Beijing, China. Available online at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.215.5813&rep=rep1&type=pdf

Reference 2: Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., et al. 2012. Chapter 5: Baseline Carbon Storage, Carbon Sequestration, and Greenhouse-Gas Fluxes in Terrestrial Ecosystems of the Western United States. In: Zhu, Z., Reed, B.C. (eds.). *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States* (p. 45-63). U.S. Geological Survey Professional Paper, Reston, Virginia. Available online at: https://pubs.er.usgs.gov/publication/pp1797

Methodology Description: Carbon sequestration of green open space was calculated in two parts. First, a database of over 6,000 carbon values[176] was used to estimate the carbon sequestration (metric ton of carbon per acre per year) of green open space across the U.S. Two studies were applied in the estimates for this value. Milesi et al. (2005) simulated five possible scenarios of the carbon sequestration potential of U.S. lawns under different management regimes (including a control scenario).[177] Liu et al. (2012) modeled greenhouse gas flux of grassland and shrubland ecosystems across the western U.S.[178] Second, the social cost of carbon was used to calculate a dollar value of carbon sequestration. The social cost of carbon (SCC) represents the average societal costs associated with each additional ton of carbon emissions (measured in CO_2e), such as losses to agriculture, impacts to human health, and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., forest restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG). The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990.[179] Specifically, the 2020 value is used: $51/metric ton CO_2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Milesi et al. (2005)	0.21	195.81	40
Liu et al (2012)	0.36	195.81	68
Average			**54**

* All values are presented in 2021 USD

Discussion: Urban green spaces can moderate anomalous climate events at a local level. Vegetative covers have a natural colling effect. In addition, natural processes like evapotranspiration and runoff interception help reduce hazards. Finally, green spaces are natural carbon sinks and can therefore serve as a cost-effective mitigation strategy for addressing climate change. The included assessment combined 11 carbon values to arrive at a single estimate for the value of climate regulation provided by green open space. These estimates covered different vegetation types that could represent the different vegetation types that make up typical green open spaces. These ranges represent different stages of ecological health and ages of newly established green spaces, as well as the diversity of vegetation types that can exist in this broadly defined category. The carbon value used was standardized by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. One study was removed from the 2016 Policy values. Smith et al. (2006)[180] was replaced with studies representing land cover types more relevant to the urban green space category.

Erosion Control

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Erosion Control
FEMA Value: $78/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Market Price
Geographic Area of Studies: United States
Source Studies:

> **Reference 1:** Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., Blair, R. 1995. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." *Science* 267: 1117–1123.

Methodology Description: Using a market price approach, Pimentel et al. (1995) estimated the cost of soil erosion in the U.S.[181] The authors considered multiple factors that influence soil erosion rates in the U.S. and globally, including slope of land, soil composition, extent of vegetative cover and its influences. They used data from a 20-year period to confirm that water and nutrient loss are heavily influenced by conversions of grassland and open space to cropland, also by animal grazing and general human activities. After detailing all the energy, on-site and off-site costs, the study concluded that erosion costs are above the global average in the U.S.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Pimentel et al. (1995)	United States	78
Average		**78**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Soil erosion is a serious problem in urban areas because of anthropogenic activities. In addition to vegetation loss, impervious surfaces that are common in urban contexts prevent water infiltration, concentrating water flows and runoff across exposed soil—thereby magnifying the soil erosion problem. Vegetated land covers can help prevent soil loss and erosion by promoting water infiltration and preventing further development. When economic costs of soil loss and degradation are accounted for in a BCA, it starts to make sound economic sense to invest in programs that are effective in the control of widespread erosion. Furthermore, to the extent that soil erosion brings in additional negative consequences, such as water quality challenges related to increased runoff, it becomes apparent that addressing the soil erosion potential is even more important.

Flood Hazard Risk Reduction

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Flood Hazard Reduction
FEMA Value: $316/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: Long Island, NY; Seattle, WA; Los Angeles, CA
Source Studies:

> **Reference 1:** Trust for Public Land. 2010. The Economic Benefits and Fiscal Impact of Parks and Open Space in Nassau and Suffolk Counties, New York. Available at: http://cloud.tpl.org/pubs/ccpe-nassau-county-park-benefits.pdf
>
> **Reference 2:** Trust for Public Land. 2011. The Economic Benefits of Seattle's Park and Recreation System. Available online at: http://cloud.tpl.org/pubs/ccpe-seattle-park-benefits-report.pdf
>
> **Reference 3:** Trust for Public Land. 2017. The Economic Benefits of the Public Park and Recreation System in the City of Los Angeles, California. Available online at: https://www.tpl.org/econbenefits-losangeles

Methodology Description: The Trust for Public Land has conducted several valuation studies of services and contributions from urban parks and open spaces. A selection of three distinct but representative cases show how these public spaces can represent substantial savings for city governments in terms of stormwater management. All three studies follow an avoided cost methodology, where the value of parks and open greenspace systems is approximated using a sophisticated model of retained runoff due to vegetation developed by the Western Research Station of the U.S. Forest Service in Davis, California. In these studies, authors used geospatial information on land cover and U.S. weather data on rainfall to estimate the model and compare the amount of water held back under a current land use/land cover scenario to the amount that would be held back if the area were as developed as a reference area. To estimate the cost-savings in stormwater management, information on water treatment is paired with the results from the biophysical model.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Trust for Public Land (2010)[182]	Long Island, NY	198
Trust for Public Land (2011)[183]	Seattle, WA	513
Trust for Public Land (2017)[184]	Los Angeles, CA	237
Average		**316**

* All values are presented in 2021 USD

Discussion: Urban parks and open greenspace intercept and capture precipitation. In addition, through their role in infiltration and evapotranspiration, they help slow down runoff, therefore reducing risks of flooding and stormwater and wastewater management costs. Recent projections suggest that precipitation could increase in certain parts of the country due to climate change. Thus, the value of parks and open greenspaces in these regions could be significantly higher in these areas. It is important to note that the value estimated is silent on impacts on water quality that are related to reduced runoff and pollutant removal through infiltration. Finally, it is important to acknowledge that costs will vary from location to location and are likely to be subject to institutional factors and administrative arrangements.

Habitat

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Habitat
FEMA Value: $5,890/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global
Source Studies:

> **Reference 1:** Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics* 169: 106480.

Methodology Description: Bockarjova et al. (2020) created a meta-analysis describing the value of green open spaces from 147 observations across 60 studies conducted around the world.[185] We performed a function transfer—a type of benefit transfer method—to construct a United States–

specific value from Model 2, which had an adjusted R^2 of 0.699. Model variables were set as follows: 1) the “park” and “small urban green” variables were averaged, and the other greenspace type variables set to 0; 2) the “biodiversity and habitat” variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita1 to the units specified by the model; 4) population density was calculated using the average population density in the U.S.,186 converted to the units specified by the model; 5) all other variables were set to their mean value. The dependent variable is reported as 2016 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Bockarjova et al. (2020)	5,890
Average	**5,890**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce.

Pollination

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Pollination
FEMA Value: $350/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Market Price
Geographic Area of Studies: United States
Source Studies:

> **Reference 1:** Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, et al. 1997. “Economic and Environmental Benefits of Biodiversity.” BioScience 47(11): 747–757.

Methodology Description: Pollinators thrive on the wildflowers provided by these natural areas. The benefit of pollination from grasslands and prairies is essential to sustaining many cropland yields, and the conversion of grasslands and prairies to agriculture is a hindrance to pollination levels locally as wild pollinators are lost. In a comprehensive study, Pimentel et al. (1997)[187] estimated the value of pollination in the U.S. and the economic contribution of pollination services to the world’s agriculture using the value of the increased yield and quality achieved through pollination by honeybees alone.[188] Data was collected from across the nation to provide estimates of these ecosystem services. Pimentel et al. showed how the 4,000 species of bees and other insects in the U.S. produced approximately $40 billion per year in pollination benefits when considering the values of insects pollinated legumes fed to cattle. The authors used this figure to conservatively estimate the national value of insect pollination alone. Data from approximately 990 million acres of agricultural land was taken to derive the value of pollination from open green space sources outside of these agricultural areas.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Pimentel et al. (1997)	United States	350
Average		**350**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Pollinators thrive on the wildflowers provided by these natural areas. Pollination is essential to sustaining cropland yields and plant diversity. Pollinators, such as bees, butterflies, birds, and bats, provide substantial benefits to the maintenance, diversity, and productivity of agricultural and natural ecosystems. Moreover, some crops and plants rely exclusively on pollinators to reproduce. Although most estimates of the economic value of pollination focus on honeybees, other pollinators are also essential. Diseases and pesticides impact pollination systems. Growing threats to pollinators should be accounted for when estimating the economic value of existing species and colonies.

Recreation/Tourism

Summary

Land Cover: Urban Green Open Space
Ecosystem Service: Recreation/Tourism
FEMA Value: $1,642/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis, Travel Cost, Market Price
Geographic Area of Studies: Global; Santa Rosa, CA; Los Angeles, CA
Source Studies:

Reference 1: Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics*, 169, 106480.
Reference 2: Hanauer, M.M., Reid, J. 2017. "Valuing urban open space using the travel-cost method and the implications of measurement error." *Journal of Environmental Management*, 198, 50–65.

Methodology Description: Using a variety of estimating methodologies is thought to improve robustness of estimates. Thus, for the recreation value of urban green open space, results from studies using rather diverse methods were used. First, the recreation value of urban green open spaces in the U.S. was approximated using U.S. values to estimate the meta-regression function presented by Bockarjova et al. (2020).[189] The meta-regression was based on a comprehensive review of the global contingent valuation literature. In a second study by Hanauer & Reid (2017), the authors developed an enhanced version of the travel-cost method and used detailed surveys and precise mapping methods to estimate the recreational value of urban open space.[190]

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Bockarjova et al. (2020)	Global	1,753
Hanauer & Reid (2017)	Santa Rosa, California	1,530
Average		**1,642**

* All values are presented in 2021 USD

Discussion: Urban green spaces fulfil a range of different roles, such as social spaces and areas for recreation and cultural purposes. A few points where these studies are silent are important to acknowledge. First, the quality of urban green space is likely going to influence the value of a given recreational experience (e.g., parks in poor quality may attract criminal activities). Second, recreational values differ between residents and tourists. Lastly, there are other benefits that accompany recreational activities in parks and urban green spaces that are not captured by these estimates such as health and productivity impacts from increased physical activity and reduced risks of illness, as well as community benefits such as reinforcing a sense of place and helping build social cohesion. One study was removed from the 2016 Policy values. Costanza et al. (2006) is a secondary study that was replaced with the more relevant primary study and meta-analysis included above.[191]

Appendix E. Rural Green Open Space

Land Cover Definition

Rural green open space is defined as:

Areas where vegetation accounts for at least 80% of total cover (impervious surfaces account for less than 20% of total cover) and have a mixture of some constructed materials located in a rural setting. A rural setting is any area outside 2010 Census Urbanized Areas (population of 50,000 or more) or Urban Clusters (population between 2,500 and 50,000) definitions.[192] *Examples include rural parks and open space, open fields, and rangelands.*

This definition of rural green open space is based on the 2019 National Land Cover Database (NLCD), a product that is developed and regularly updated by the Multi-Resolution Land Characteristics (MRLC) consortium, a "group of federal agencies who coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications."[193]

Applicants can find their rural status by visiting this referenced website.[194] First, choose BVP 2020 from the "Select Vintage" drop-down box. Then, click the check box next to Urban Areas on the sidebar. Find your project area on the map and determine if it is located outside either an Urbanized Area or Urban Cluster.

Feasibility & Effectiveness Criteria

Rural green space can take on a variety of forms. In general, to include the ecosystem service values for rural green open space in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "rural green open space" above.
- Typically, the project would demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[195] According to the EPA,[xvii] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be

[xvii] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).

- The area designated as rural open space must be consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum.[196]
- The creation of rural open space should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:
  - In 2011, the White House Council on Environmental Quality published the report "Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes,"[197] which includes a number of general best practices and principles "to be used by Federal agencies for landscape practices when constructing new, or rehabilitating existing, owned or leased facilities, or when landscaping improvements are otherwise planned." Though developed for federal agencies, many of the best practices and principles are broadly applicable to areas consistent with the definition of rural green open space presented herein.
  - As an example of guidance for rural park design, in 2013 the U.S. Bureau of Reclamation published its *Recreation Facility Design Guidelines*.[198]
  - For rural green space projects that seek to maximize the use of green infrastructure, the National Recreation and Park Association in 2017 published the "Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks."[199]

Mitigation Project Use Cases

The following examples demonstrate how the "rural green open space" land cover category might be used in a mitigation project (and associated BCA):

- Open space areas created because of acquisition and demolition/relocation projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum. Open space areas must also meet the definition of "rural" and other criteria discussed above.
- Creation of a rural park to support hazard risk reduction (e.g., pluvial/riverine flooding, wildfire) and other social and environmental benefits.
- Areas associated with Floodplain and Stream Restoration or Flood Diversion and Storage projects in areas that are within the floodplain and meet the definition/criteria for "rural green open space" discussed above.

Project Useful Life Considerations

In general, provided that rural green open space areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied. A higher Project Useful Life may be applied in the following cases:

- If the rural green open space area is owned or acquired, and a FEMA-compliant deed restriction (CFR, Title 44, Part 80) or equivalent perpetual easement is recorded on the property, then a PUL of 100 years can be used. A typical example would be a standard FEMA acquisition and demolition/relocation project that results in the restoration, creation, enhancement, or protection of the rural green open space area.
- If the land is not owned, acquired, or controlled, but the subapplicant can demonstrate that the land cover will be maintained/protected beyond 50 years (as evidenced through documented assurances, such as deed restriction, easement, or maintenance agreement with the landowner), then a PUL of 51-100 years can be used (with 100 years representing perpetuity), depending on the nature of the assurances.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	1,707	2	7,505	1	1
Air Quality	215	1	-	0	1
Biological Control					
Climate Regulation	61	5	77	1	1
Erosion Control	68	1	78	0	0
Existence Value					
Flood Hazard Risk Reduction	308	2	-	0	0
Food Provisioning					
Habitat	-	0	2,021	1	0
Pollination	305	1	350	0	0

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Recreation/Tourism	5,644	4	601	1	4
Water Filtration					
Water Supply					
Total Estimated Benefits	**8,308**		**10,632**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Aesthetic Value
FEMA Value: $7,505/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global
Source Studies:

Reference 1: Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics* 169: 106480.

Methodology Description: Bockarjova (2020) created a meta-analysis describing the value of green open spaces from 147 observations across 60 studies conducted around the world.[200] We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from Model 2, which had an adjusted R^2 of 0.699. Model variables were set as follows: 1) the "peri-urban greenspace" variables was used to denote rural greenspaces; 2) the "aesthetics" variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita1 to the units specified by the model; 4) population density was calculated using the average population density in the U.S.,

[xviii] U.S. Census Bureau. QuickFacts – United States. https://www.census.gov/quickfacts/fact/table/US/PST045219

converted to the units specified by the model; 5) all other variables were set to their mean value. The dependent variable is reported as 2016 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Bockarjova et al. (2020)	Global	7,505
Average		**7,505**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. One study was removed from the 2016 Policy values. Qiu et al. (2006)[201] was replaced with the newer studies which represent land cover types more relevant to the rural green space category.

Climate Regulation

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Climate Regulation
FEMA Value: $77/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: United States
Source Studies:

Reference 1: Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., et al. 2012. Chapter 5: Baseline Carbon Storage, Carbon Sequestration, and Greenhouse-Gas Fluxes in Terrestrial Ecosystems of the Western United States. In: Zhu, Z., Reed, B.C. (eds.). Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States (p. 45–63). U.S. Geological Survey Professional Paper, Reston, Virginia. Available online at: https://pubs.er.usgs.gov/publication/pp1797
Reference 2: Lu, X., Kicklighter, D.W., Melillo, J.M., Reilly, J.M., Xu, L. 2015. “Land carbon sequestration within the conterminous United States: Regional- and state-level analyses.” *Journal of Geophysical Research: Biogeosciences* 120(2): 379–398.

Reference 3: DeLonge, M.S., Ryals, R., Silver, W. 2013. “A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands.” *Ecosystems* 16: 962–979.

Reference 4: Ryals, R., Silver, W.L. 2013. “Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands.” *Ecological Applications* 23: 46–59.

Reference 5: Schuman, G.E., Janzen H.H., Herrick J.E. 2002. “Soil carbon dynamics and potential carbon sequestration by rangelands.” *Environmental Pollution* 116: 391–396.

Methodology Description: Carbon sequestration of green open space was calculated in two parts. First, a database of over 6,000 carbon values[xix] was used to estimate the carbon sequestration (metric ton of carbon per acre per year) of green open space across the U.S. Two studies were applied in the estimates for this value. The studies chosen represent a range of vegetation types that may occur in green spaces set in rural settings. The social cost of carbon (SCC) represents the average societal costs associated with each additional ton of carbon emissions (measured in CO^2e), such as losses to agriculture, impacts to human health, and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., forest restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG). The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990.[202] Specifically, the 2020 value is used: $51/metric ton CO_2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Lu et al. (2015)[203]	0.33	195.81	64
Liu et al. (2012)[204]	0.36	195.81	68
DeLong et al. (2013)[205]	0.7	195.81	137
Ryals & Silver (2013)[206]	0.46	195.81	90
Schuman et al. (2002)[207]	0.13	195.81	26
Average			**77**

* All values are presented in 2021 USD

Discussion: The above assessment combined 19 carbon values to arrive at a single estimate for the value of climate regulation provided by green open space. These estimates covered different

[xix] Internal Earth Economics database

vegetation types that could represent the different vegetation types that make up typical green open spaces. These ranges represent different stages of ecological health and ages of newly established green spaces, as well as the diversity of vegetation types that can exist in this broadly defined category. The carbon value used was standardized by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. One study was removed from the 2016 Policy values. Smith et al (2006) was replaced with studies representing land cover types more relevant to the rural green space category.[208]

Erosion Control

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Erosion Control
FEMA Value: $78/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Market Price
Geographic Area of Studies: United States
Source Studies:

> **Reference 1:** Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., et al. 1995. "Environmental and Economic Costs of Soil Erosion and Conservation Benefits." Science 267: 1117–1123.

Methodology Description: Using a market price approach, Pimentel et al. (1995) estimated the cost of soil erosion in the U.S.[209] The authors considered multiple factors that influence soil erosion rates in the U.S. and globally, including slope of land, soil composition, extent of vegetative cover and its influences. They used data from a 20-year period to confirm that water and nutrient loss are heavily influenced by conversions of grassland and open space to cropland, also by animal grazing and general human activities. After detailing all the energy, on-site and off-site costs, the study concludes that erosion costs are above the global average in the U.S.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Pimentel et al. (1995)	United States	78
Average		**78**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Soil erosion is a serious problem in rural areas because of anthropogenic activities. In addition to vegetation loss, impervious surfaces that are common in rural contexts prevent water infiltration, concentrating water flows and runoff across exposed soil—thereby magnifying the soil erosion problem. Vegetated land covers can help prevent soil loss and erosion by promoting water infiltration and preventing further development. When economic costs of soil loss and degradation are accounted for in a BCA, it starts to make sound economic sense to invest in programs that are effective in the control of widespread erosion. Furthermore, to the extent that soil erosion brings in additional negative consequences, such as water quality challenges related to increased runoff, it becomes apparent that addressing the soil erosion potential is even more important.

Habitat

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Habitat
FEMA Value: $2,021/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: Global
Source Studies:

> **Reference 1:** Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics* 169: 106480.

Methodology Description: Bockarjova et al. (2020) created a meta-analysis describing the value of green open spaces from 147 observations across 60 studies conducted around the world.[210] We performed a function transfer—a type of benefit transfer method—to construct a United States–specific value from Model 2, which, had an adjusted R^2 of 0.699. Model variables were set as follows: 1) the "peri-urban greenspace" variables was used to denote rural greenspaces; 2) the "biodiversity and habitat" variable was set to 1, all other ecosystem service variables were set to 0; 3) GDP per capita was calculated by converting the current U.S. GDP per capita[1] to the units specified by the model; 4) population density was calculated using the average population density in the U.S.,[211] converted to the units specified by the model; 5) all other variables were set to their mean value. The dependent variable is reported as 2016 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Value ($/acre/year)*
Bockarjova et al. (2020)	2,021
Average	**2,021**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of typically dozens or hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce.

Pollination

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Pollination
FEMA Value: $350/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Market Price
Geographic Area of Studies: United States
Source Studies:

> **Reference 1:** Pimentel D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., et al. 1997. Economic and Environmental Benefits of Biodiversity." BioScience 47(11): 747–757.

Methodology Description: The benefit of pollination from grasslands and prairies is essential to sustaining many cropland yields, and the conversion of grasslands and prairies to agriculture is a hindrance to pollination levels locally as wild pollinators are lost. Pollinators thrive on the wildflowers provided by these natural areas. In a comprehensive study, Pimentel at al. (1997)[212] estimated the value of pollination in the U.S. and the economic contribution of pollination services to the world's agriculture using the value of the increased yield and quality achieved through pollination by honeybees alone.[213] Data was collected from across the nation to provide estimates of these ecosystem services. Pimentel et al. showed how the 4,000 species of bees and other insects in the U.S. produced approximately $40 billion per year in pollination benefits when considering the values of insects pollinated legumes fed to cattle. The authors used this figure to conservatively estimate the national value of insect pollination alone. Data from approximately 990 million acres of agricultural land was taken to derive the value of pollination from open green space sources outside of these agricultural areas.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Pimentel et al. (1997)	United States	350
Average		**350**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Pollinators, such as bees, butterflies, birds, and bats, provide substantial benefits to the maintenance, diversity, and productivity of agricultural and natural ecosystems. Moreover, some crops and plants, rely exclusively on pollinators to reproduce. Although most estimates of the economic value of pollination focus on honeybees, other pollinators are also essential. Diseases and pesticides impact pollination systems. Growing threats to pollinators should be accounted for when estimating the economic value of existing species and colonies.

Recreation/Tourism

Summary

Land Cover: Rural Green Open Space
Ecosystem Service: Recreation/Tourism
FEMA Value: $601/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis; Hedonic Price; Contingent Valuation
Geographic Area of Studies: United States; Kentucky
Source Studies:

> **Reference 1:** Bockarjova, M., Botzen, W.J., Koetse, M.J. 2020. "Economic valuation of green and blue nature in cities: A meta-analysis." *Ecological Economics* 169: 106480.

Methodology Description: Two general methods can be used to estimate the monetary value of ecosystem services: stated and revealed preference methods. For the recreation value of rural green open space, results from studies using a mix of these methods are taken. First, the recreation value of rural green open spaces in the U.S. is approximated using U.S. values to estimate the meta-regression function presented by Bockarjova et al. (2020).[214] The meta-regression is based on a comprehensive review of the global contingent valuation literature.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Bockarjova et al. (2020)	Global	601
Average		**601**

* All values are presented in 2021 USD

Discussion: Rural green spaces are the source to a myriad of benefits experienced by both rural and urban dwellers. One of them is outdoor recreation. Using a variety of methodologies, a monetary value was assigned to green open spaces in rural contexts the U.S. It is important to note the types of recreational activities that are possible in rural greenspaces that are not farmland may differ widely between each other. Also, they may be seasonal in nature (e.g., cross country skiing can only occur in the winter months). This level of spread in activity types, and the associated value of experience, is difficult to represent with a single number. In addition, there are other benefits that accompany recreational activities in rural greenspaces that are not captured by these estimates, such as preventing overdevelopment and sprawl, and reinforcing a sense of place and helping build or strengthen local identities. Four studies were removed from the 2016 Policy values. These were either secondary value transfer studies—Costanza et al. (2006)[215]—or dated and too site-specific and could be replaced with a customized function transfer value for the U.S.—Butler & Workman (1993),[216] Ready et al. (1997),[217] and Breffle et al. (1997).[218]

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Appendix F. Riparian

Land Cover Definition

Riparian areas have been defined in a variety of ways by different federal agencies.[xx] For example, the U.S. Fish and Wildlife Service[219] defines riparian areas as:

Areas where plant communities are contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas are usually transitional between wetland and upland. Riparian areas have one or both of the following characteristics: 1) distinctly different vegetative species than adjacent areas; 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms.

As another example, the USDA's Natural Resources Conservation Service has used the following definition:

Riparian areas are ecotones that occur along watercourses or water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecotones occupy the transitional area between the terrestrial and aquatic ecosystems. Typical examples would include perennial and intermittent streambanks, floodplains, and lake shores.

Subapplicants can used one of three methods, listed below, to determine which parts of their project area can be defined as riparian. In all cases the method should be stated explicitly and supporting information should be provided:

- Meets the definition of "riparian" developed by the U.S. Fish and Wildlife Service (FWS), provided above.[xxi]
- Meets the definition of "riparian" based on the professional judgement of a recognized expert.
- Meets the definition of "riparian" adopted by the jurisdiction (e.g., state) in which the project is being proposed.

[xx] For example, see here for a collection of definitions: https://cals.arizona.edu/extension/riparian/chapt1/table.html

[xxi] The U.S. Fish and Wildlife Service has developed a mapping tool for riparian areas here: https://www.fws.gov/wetlands/Other/Riparian-Product-Summary.html

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for riparian areas in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "riparian" above.
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[220]
- According to the EPA,[xxii] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).
- In general, riparian restoration should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:
    - *Function Based Stream Restoration Project Process Guidelines,*[221] published by the U.S. Fish and Wildlife Service in 2016, guides "users through the stream restoration process from developing well-articulated goals and objectives, selecting watershed and reach-level assessment parameters and measurement methods, conducting alternatives analysis, developing restoration designs and establishing quantifiable and measurable monitoring performance standards." Though focused on stream restoration broadly, the guidance is also applicable to riparian areas specifically.
    - *California Riparian Habitat Restoration Handbook*,[222] published by the Riparian Habitat Joint Venture in 2009, provides "guidelines for planning and implementing riparian restoration projects." While the guidance is focused on riparian ecosystems in California's Central Valley, many of the general concepts and processes would be applicable throughout the U.S.
    - The SER International document, referenced above,[223] states that plans for restoration projects include, at a minimum, the following:

[xxii] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

  - Clear rationale as to why restoration is needed
  - Ecological description of the site designated for restoration
  - Statement of the goals and objectives of the restoration project
  - Designation and description of the reference
  - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
  - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
  - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
  - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

The following examples demonstrate how the "riparian" land cover category might be used in a mitigation project (and associated BCA):

- Open space areas that meet the definition of "riparian," which are created because of acquisition and demolition/relocation projects, and restriction of the parcel(s) as "open space" consistent with the "Allowable Uses of Open Space" in Section A.6.1. of FEMA's 2015 HMA Guidance Addendum.
- Restoration, creation, enhancement, or protection of a riparian area as a component of a Floodplain Diversion and Storage (FDS) or Floodplain and Stream Restoration (FSR) project to increase flood storage capacity on the land/floodplain, reduce runoff or streambank erosion, and decrease flood risk to downstream, upstream, or adjacent people and structures. Areas within an FDS or FSR project that meet the definition of "riparian" can often be adjacent to "forest" and/or "wetland" areas, as defined in this guidance, and care should be taken to avoid double counting the same area (e.g., a given acre) twice. Example:
  - A 1998 FEMA Hazard Mitigation Grant funded a project to protect neighborhoods in the City of Petaluma along the Payran Reach of the Petaluma River. The project was designed to reduce damage from floods up to 100-year levels. Project activities combined hard infrastructure interventions as well as nature-based solutions, which included 10 acres of mitigation planting to restore riparian areas.
- Restoration of urban riparian areas to mitigate natural hazards such as heat and pluvial flooding, while generating other ecosystem services (e.g., aesthetic value, air quality, recreation). Like the

example above, restoration of riparian areas is likely to occur as part of a broader restoration effort, possibly adjacent to “wetland” and “forest” areas as defined in this guidance.

- Hazardous fuels reduction and other ecosystem health improvement actions in an existing riparian area to mitigate wildfire risk while generating additional ecosystem services (e.g., erosion control, recreation).

Project Useful Life Considerations

In general, provided that riparian areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied. A higher Project Useful Life may be applied in the following cases:

- If the riparian area is owned or acquired, and a FEMA-compliant deed restriction (CFR, Title 44, Part 80) or equivalent perpetual easement is recorded on the property, then a PUL of 100 years can be used. A typical example would be a standard FEMA acquisition and demolition/relocation project that results in the restoration, creation, enhancement, or protection of the riparian area.
- If the land is not owned, acquired, or controlled, but the subapplicant can demonstrate that the land cover will be maintained/protected beyond 50 years (as evidenced through documented assurances, such as deed restriction, easement, or maintenance agreement with the landowner), then a PUL of 51–100 years can be used (with 100 years representing perpetuity), depending on the nature of the assurances.

Please see the section in the main report body titled “Select an Appropriate Project Useful Life” for more background and detail.

Summary of Value Updates

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	612	1	767	2	0
Air Quality	226	4	254	0	0
Biological Control	173	1	199	0	0
Climate Regulation	81	7	96	1	1
Erosion Control	12,042	1	13,823	0	0
Existence Value					

Ecosystem Service	2016 Policy		This Update		
	Value (2014 USD/acre/year)	Source Studies Included (#)	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Flood Hazard Risk Reduction	4,215	1	6,052	2	0
Food Provisioning	641	1	736	0	0
Habitat	878	1	2,547	1	0
Pollination					
Recreation/Tourism	15,967	1	6,215	2	0
Water Filtration	4,473	2	6,239	0	0
Water Supply	237	2	272	0	0
Total Estimated Benefits	**39,545**		**37,199**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Riparian
Ecosystem Service: Aesthetic Value
FEMA Value: $767/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Hedonic Pricing, Contingent Valuation
Geographic Area of Studies: Missouri, Alaska
Source Studies:

Reference 1: Qiu, Z., Prato, T., Boehm, G. 2006. "Economic Valuation of Riparian Buffer and Open Space in a Suburban Watershed." *Journal of the American Resources Association* 42(6): 1583–1596.

Reference 2: Berman, M., Armagost, J. 2013. Contribution of Land Conservation and Freshwater Resources to Residential Property Values in the Matanuska-Susitna Borough. Institute of Social and Economic Research, University of Alaska, Anchorage.

Reference 3: Kousky, C., Walls, M. 2014. “Floodplain conservation as a flood mitigation strategy: Examining costs and benefits.” *Ecological Economics* 104: 119–128.

Methodology Description: Aesthetic value for riparian areas was measured with both contingent valuation and hedonic pricing methods. Qiu et al. (2006) adopted a hedonic pricing method to measure the increased value to residential properties within proximity of a riparian area.[224] A contingent valuation survey was used to compare to the hedonic results to confirm the validity of the calculated values. The approach addressed bias inherent in the econometric models. Berman & Armagost (2013) investigate the enhanced value of private residential property that arises from being in proximity to freshwater resources.[225] They use a hedonic pricing model based on property sales in the Matanuska-Susitna Borough from 2009 to 2010, and find homes located within riparian zones have increased property values. Kousky & Walls (2014) conduct a hedonic analysis of households in proximity to the Meramec River in Missouri using sales data from 2008 to 2012.[226] They also found proximity to the riparian area provided positive impacts on house prices.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Qiu et al. (2006)	Missouri	702
Berman & Armagost (2013)	Alaska	596
Kousky & Walls (2014)	Missouri	1,004
Average		**767**

* All values are presented in 2021 USD

Discussion: Qiu et al. conducted both a hedonic and contingent valuations for aesthetic value. They showed that the hedonic valuation came well within the contingent valuation range. The use of the willing-to-pay survey allowed for the comparison of aesthetic values from the econometric models. The survey was also created to provide study participants with sufficient information to accurately judge payments for aesthetic benefits. The addition of two more recent hedonic studies corroborate the findings of the paper included in the 2015 Policy.

Air Quality

Summary

Land Cover: Riparian
Ecosystem Service: Air Quality
FEMA Value: $254/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost

Geographic Area of Studies: Washington, California, New Jersey, Ontario

Source Studies:

Reference 1: Mates, W.J., Reyes, J.L. 2004. The Economic Value of New Jersey State Parks and Forests. New Jersey Department of Environmental Protection, Trenton, New Jersey. Available at: www.nj.gov/dep/dsr/economics/parks-report.pdf

Reference 2: Wilson, S.J., 2008. Ontario's wealth, Canada's future: Appreciating the value of the Greenbelt's eco-services. David Suzuki Foundation, Vancouver, Canada. Available at: http://www.davidsuzuki.org/publications/downloads/2008/DSF-Greenbelt-web.pdf

Reference 3: McPherson, E.G., Scott, K.I., Simpson, J.R. 1998. "Estimating Cost-Effectiveness of Residential Yard Trees for Improving Air Quality in Sacramento, California, Using Existing Models." *Atmospheric Environment* 32(1): 75–84.

Reference 4: Trust for Public Land. 2011. The Economic Benefits of Seattle's Park and Recreation System. Available at: http://cloud.tpl.org/pubs/ccpe-seattle-park-benefits-report.pdf

Methodology Description: Riparian areas provide air quality value by reducing pollutants like carbon dioxide, nitrogen dioxide, sulfur dioxide, ozone, and particulates. This ecosystem service value is based on an average between the air quality values of both forests and green open space. All methodologies used in these sources utilized the avoidance cost of pollution-related illnesses (and the resulting health costs). Estimates of pollutants absorbed per unit were valued using the market prices of alternative methods of air purification. These benefits are usually much higher in urban areas. Specifying the different values between urban and rural forest and green open spaces would add greater detail to the economic value provided by riparian areas for air quality.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Mates & Reyes (2004)[227]	New Jersey	274
Wilson (2008)[228]	Ontario, Canada	193
McPherson et al. (1998)[229]	Sacramento, California	37
Trust for Public Land (2011)[230]	Seattle, Washington	513
Average		**254**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation.

Biological Control

Summary

Land Cover: Riparian
Ecosystem Service: Biological Control
FEMA Value: $199/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: Elkhorn Slough Salt Marsh Wetland in California
Source Studies:

> **Reference 1:** Rein, F. 1999. "An Economic Analysis of Vegetative Buffer Strip Implementation. Case Study: Elkhorn Slough, Monterey Bay, California." *Coastal Management* 27(4): 377–390.

Methodology Description: Rein (1999) used the avoided cost method to analyze the ecosystem service benefits to both farmers and the local community.[231] The author showed that buffers act as a strip of protection against invasive weeds. With a healthy riparian buffer, crop growers avoid the cost of having to spray their field borders with herbicides. Rein also demonstrated how society also benefits of mosquito abatement. Riparian buffers prevent soil erosion, which would otherwise cause sediment build-up downstream, creating mosquito breeding grounds. In some cases, both of these values will be present, and they would be additive. A conservative approach is to assume that one or the other of these services are provided, thus an average of weed and mosquito abatement provides a more general number for national use. This figure is conservative because there are many other insect, fungus, plant, and animal pests not included here.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Rein (1999)	Elkhorn Slough, CA	199
Average		**199**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation.

Climate Regulation

Summary

Land Cover: Riparian
Ecosystem Service: Climate Regulation

FEMA Value: $96/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: National
Source Studies:

Reference 1: Post, W., Kwon, K. 2000. "Soil carbon sequestration and land-use change: processes and potential." *Global Change Biology* 6(3): 317–327.
Reference 2: Chmura, C., Anisfeld, S.C., Cahoon, D.R., Lynch, J.C. 2003. "Global carbon sequestration in tidal, saline wetland soils." *Global Biogeochemical Cycles* 17(4): 22-1 – 22-12.
Reference 3: Duarte, C.M., Middelburg, J.J., Caraco, N. 2005. "Major role of marine vegetation on the oceanic carbon cycle." *Biogeosciences* 2: 1–8.
Reference 4: DeLonge, M.S., Ryals, R., Silver, W. 2013. "A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands." *Ecosystems* 16: 962–979.
Reference 5: Crooks, S., Rybczyk, J., O'Connell, K., Devier, D.L., Poppe, K., Emmett-Mattox, S. 2014. *Coastal blue carbon opportunity assessment for the Snohomish Estuary: The Climate Benefits of Estuary Restoration*. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries, Seattle, WA. Available online at: https://estuaries.org/wp-content/uploads/2020/11/Crooks.-Coastal-Blue-Carbon-Opportunity-Assessment-for-the-Snohomish-Estuary-ilovepdf-compressed.pdf
Reference 6: Hoover, C.M., Bagdon, B., Gagnon, A. 2021. Standard Estimates of Forest Ecosystem Carbon for Forest Types of the United States. U.S. Department of Agriculture, Forest Service, Northern Research Station, Madison, WI. Available online at: https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs202.pdf
Reference 7: Schuman, G.E., Janzen H.H., Herrick J.E. 2002. "Soil carbon dynamics and potential carbon sequestration by rangelands." *Environmental Pollution* 116: 391–396.
Reference 8: Interagency Working Group on Social Cost of Greenhouse Gases. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. White House, Washington, DC. Available online at: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Methodology Description: Carbon sequestration of riparian areas was calculated in two parts.

First, a database of over 6,000 carbon values[xxiii] was used to estimate the carbon sequestration (metric ton of carbon per acre per year) of riparian areas across the U.S. By the definition provided in

[xxiii] Internal Earth Economics database

Section 1, riparian areas represent all different vegetation types within proximity to a riverine system, which can include forests, grasslands, shrubs, and other vegetation. A total of six studies, accounting for almost 800 carbon sequestration values, were applied in the estimates for this value. Of these values, carbon sequestered per acre has a wider value range than other land cover types, given the diversity of vegetation considered in the riparian definition.

Second, the social cost of carbon was used to calculate a dollar value of carbon sequestration. The social cost of carbon (SCC) represents the average societal costs associated with each additional ton of carbon emissions (measured in CO_2e), such as losses to agriculture, impacts to human health, and increased disaster risk. In the context of actions that reduce carbon emissions (e.g., energy efficiency) or actively sequester carbon (e.g., forest restoration), the SCC represents the value of these actions in terms of avoided cost to society and is used by federal agencies in the U.S. and updated on a regular basis by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWGSCGG).[232] The value for carbon sequestration used was derived from the IWGSCGG—a result of Executive Order 13990. Specifically, the 2020 value is used: $51/metric ton CO_2e, or $195.81/metric ton C in 2021 USD.

Calculation:

Source Study	Average C Sequestration Rate (metric tons C/acre/year)	Social Cost of Carbon ($/metric ton C)	Value ($/acre/year)
Duarte et al. (2005)[233]	0.12	195.81	24
Crooks et al. (2014)[234]	0.64	195.81	125
DeLonge et al. (2013)[235]	0.70	195.81	137
Schuman et al. (2002)[236]	0.13	195.81	26
Post & Kwon (2000)[237]	0.23	195.81	45
Chmura et al. (2003)[238]	0.87	195.81	171
Hoover et al. (2021)[239]	0.74	195.81	145
Average			**96**

* All values are presented in 2021 USD

Discussion: The above assessment combined almost 800 carbon values to arrive at a single dollar value for the value of climate regulation provided by riparian areas. Of these values, there are six vegetation types that represent a consolidation of riparian areas that can exist throughout the U.S. The ranges represent different stages of ecological health and ages of newly established riparian areas as well as the diversity of the vegetation types that can exist in this broadly defined category. The carbon value used was standardized by the latest data produced by the Interagency Working Group on Social Cost of Greenhouse Gases, a group appointed by the White House. One study was replaced from the value sets that FEMA adopted for the 2016 environmental benefits policy. Smith et al. (2006)[240] was replaced by Hoover et al. (2021), which represents an update of the older report produced by the Forest Service.

Erosion Control

Summary

Land Cover: Riparian
Ecosystem Service: Erosion Control
FEMA Value: $13,823/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost and Replacement Cost
Geographic Area of Studies: California
Source Studies:

> **Reference 1:** Rein, F. 1999. "An Economic Analysis of Vegetative Buffer Strip Implementation. Case Study: Elkhorn Slough, Monterey Bay, California." *Coastal Management* 27(4): 377–390.

Methodology Description: This value is based on the avoided cost methodology both to private farmers and to society. The total avoided damages to public roads were calculated by estimating reduced road repairs and maintenance overtime. Finally, avoided dredging costs for shipping channels downriver were found to be extremely valuable in this case study.[241] These costs are included in the value below. Though this is a localized value, dredging costs exist for most of the land area of the U.S. because these lands generally drain to river deltas where ports exist. Consider the Mississippi, Columbia, Colorado, Great Lakes, California, New England, Mid-Atlantic, and South Atlantic River Basins. These basins all require significant dredging costs at the associated coastal ports.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Rein (1999)	California	13,823
Average		**13,823**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Harbor dredging accounts for the highest costs resulting from soil erosion upstream. Although freight shipping lines are primarily located along ocean systems, several major rivers are used by cargo ships for national traveling. Clearing costs from soil erosion are also found in river and creek systems of all sizes, even those that do not support cargo ships. The U.S. Army Corps of Engineers has detailed and available cost data for dredging throughout the U.S. Because of the limited number of studies on the cost of sediment clearing in river systems, the value above will be used as a proxy for all river systems that enable cargo transportation and those that do not. This study represents the only analyses found of both farmer and societal costs from soil retention reduction with lost riparian buffer. Published in the *Coastal Management Journal*, the paper was cited in many publications.

Flood Hazard Risk Reduction

Summary

Land Cover: Riparian
Ecosystem Service: Flood Hazard Risk Reduction
FEMA Value: $6,052/acre/year
Currency Value: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost
Geographic Area of Studies: California, Missouri, Vermont
Source Studies:

> **Reference 1:** Rein, F. 1999. "An Economic Analysis of Vegetative Buffer Strip Implementation." Case Study: Elkhorn Slough, Monterey Bay, California. *Coastal Management* 27(4): 377–390.
> **Reference 2:** Kousky, C., Walls, M. 2013. Floodplain conservation as a flood mitigation strategy: Examining Costs and Benefits. Resources for the Future, Washington, DC.
> **Reference 3:** Watson, K., Ricketts, T., Galford, G., Polasky, S., O'Niel-Dunne, J. 2016. "Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT." *Ecological Economics* 130: 16–24.

Methodology Description: Rein (1999) showed how riparian buffers along rivers can serve as temporary flood storage areas, thereby reducing flood damage.[242] The Pajaro River, north of the Elkhorn Slough has a hydrological connection to the study region. This area witnessed extensive flooding damage in 1995 and 1998. Economic data from these flood events allowed Rein to calculate the avoided cost of future floods given the installation of the riparian buffers. Kousky & Walls (2013) used the Hazus flood modeling software to estimate avoided flood damages resulting from conservation of riparian land.[243] Watson et al. (2016) mapped flood extents for 10 real-life flood events and calculated the avoided damages that would be mitigated by upstream riparian areas.[244]

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Rein (1999)	California	4,838
Kousky & Walls (2013)	Missouri	13,299
Watson et al. (2016)	Vermont	18
Average		**6,052**

* All values are presented in 2021 USD

Discussion: Two studies used historical flood data (Rein 1999 and Watson et al. 2016) as the basis for analysis, allowing the authors to appropriately estimate flood damage in an area that will see increased flooding. The addition of two new studies (Kousky & Walls 2013 and Watson et al. 2016) bring more context to this value range, being from both urban (St. Louis, MO) and rural (Middlebury, VT) contexts in other regions of the U.S. The disparity in the two new values is due to the amount of infrastructure protected—the urban study had much higher avoided damages than the rural study.

Food Provisioning

Summary

Land Cover: Riparian
Ecosystem Service: Food Provisioning
FEMA Value: $736/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Method: Avoided Cost and Market Price
Geographic Area of Studies: Wiltshire, England
Source Studies:

Reference 1: Everard, M., Jevons, S. 2010. Ecosystem Services Assessment of Buffer Zone Installation on the Upper Bristol Avon, Wiltshire. Environment Agency. Almondsbury, Bristol. Available online at: http://publications.environment-agency.gov.uk/PDF/SCHO0210BRXW-E-E.pdf

Methodology Description: The cost avoidance value is based on the production savings to farmers and improved farm profitability. A riparian buffer limits nutrient runoff, this results in less fertilizer and manure usage (more nitrogen is retained on the fields) avoiding additional input costs. The riparian buffer also provides benefits to people who utilize the river downstream, like irrigation and public water supply that would otherwise be lost to contaminated water.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Everard & Jevons (2010)[245]	Wiltshire, England	736
Average		**736**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Given that farming practices are very similar in the U.S. and U.K., the cost savings associated with farming in the U.K. can be used to compare to the potential savings in the U.S. This study is the only one found that values the water-based food provisioning services for agricultural areas. Despite the fact that this study resides in the U.K., the methodology used allows for the transferability of this to the U.S. The riparian conditions and crops are similar to the U.S., as are farm costs and the value of farm products.

Habitat

Summary

Land Cover: Riparian
Ecosystem Service: Habitat
FEMA Value: $2,547/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Production Function, Choice Experiment
Geographic Area of Studies: New York, New Mexico, Oregon, Washington
Source Studies:

> **Reference 1:** Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M., Diamantedes, J. 2002. "Valuing Estuarine Resource Services Using Economic and Ecological Models: The Peconic Estuary System Study." *Coastal Management* 30: 47–65.
> **Reference 2:** Berrens, R.P., Bohara, A.K., Silva, C.L., Brookshire, D., McKee, M. 2000. "Contingent values for New Mexico instream flows: With tests of scope, group-size reminder and temporal reliability." *Journal of Environmental Management* 58: 73–90.

Methodology Description: In Johnston et al. (2002), the productivity value estimates included both values owing to food web productivity and values related to habitat.[246] Results are provided for the 1) marginal value of existing wetlands and riparian areas, and 2) the marginal value of restored wetlands and riparian areas. The annual value is the sum of the food web values and the habitat values for a year. Berrens et al. (2000) conducted a choice experiment to estimate the nonuse value of instream flows, one benefit of which is protecting biodiversity and riparian areas along rivers.[247] In the study area, several species of endangered fish depend upon healthy riparian habitats. Results from the study show there are substantial nonmarket benefits to protecting these areas.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Johnston et al. (2002)	New York	1,008
Berrens et al. (2000)	New Mexico	4,085
Average		**2,547**

* All values are presented in 2021 USD

Discussion: Johnston et al. (2002) captures the value within five different areas with existing riparian buffers. This study considers different population densities where one region is near a small farm and others are located near parks that allow access to recreational fishing. This variation in surroundings allows for the comparability among many different land types within the U.S., offering the ability for the values above to be applied nationally. The addition of Berrens et al. (2000) offers additional context from a different part of the U.S.

Recreation/Tourism

Summary

Land Cover: Riparian
Ecosystem Service: Recreation/Tourism
FEMA Value: $6,215/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Replacement Cost, Contingent Valuation, Travel Cost
Geographic Area of Studies: California, Arizona
Source Studies:

> **Reference 1:** Rein, F. 1999. "An Economic Analysis of Vegetative Buffer Strip Implementation. Case Study: Elkhorn Slough, Monterey Bay, California." *Coastal Management* 27(4): 377–390.
> **Reference 2:** Colby, B., Smith-Incer, E. 2005. "Visitor Values and Local Economic Impacts of Riparian Habitat Preservation: California's Kern River Preserve." *Journal of the American Water Resources Association* 41(3): 709–717.
> **Reference 3:** Weber, M., Berrens, R. 2006. "Value of Instream Recreation in the Sonoran Desert." *Journal of Water Resources Planning and Management* 132(1): 53–60.

Methodology Description: Rein (1999) found that uncontrolled erosion and nutrient deposition were significant threats to ecotourism resources in the Elkhorn Slough region.[248] Recreational activities included kayaking, boating, nature tours, fishing, birding, and biking. Rein based these costs on the lost recreation due to diminished resources that attract tourists. Uncontrolled nutrient deposition and sedimentation of the Slough damages downstream habitat and reduces recreational benefits. The implementation of riparian buffer decreased the rate of erosion and nutrient deposition by 50%. This provides measurable downstream recreational economic benefits. Colby & Smith-Incer (2005) examines visitor values through a survey for a popular riparian birding area in southern California.[249] Results showed that recreation visitation would drop if riparian habitat were allowed to decline in the study area, indicating that preservation of riparian habitat is important to the local economy. Weber & Berrens (2006) conducted a travel cost study investigating recreation in the Aravaipa Canyon Wilderness in Arizona.[250] Their study focuses on desert riparian recreation in an area that provides critical habitat for millions of birds each year.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Rein (1999)	California	18,328
Colby & Smith-Incer (2005)	California	275
Weber & Berrens (2006)	Arizona	41
Average		**6,215**

* All values are presented in 2021 USD

Discussion: The Rein paper is one of few publications that analyzed the recreational benefits of riparian buffers. Nearly all studies on recreation in natural water systems are attributed to rivers and lakes, not riparian areas. This study examined the benefits of avoided sediment build-up and nutrient deposition on downstream recreational values dependent upon habitat quality for recreational use. Past reviewers have commented that recreation values in Monterey Bay (Rein 1999) may be higher than elsewhere in the nation, so it is important to include other study areas and contexts. Weber & Berrens (2006) conducted their study in a remote region, while Colby & Smith-Incer (2005) added variation to the final estimate by including a different valuation methodology type.

Water Filtration

Summary

Land Cover: Riparian
Ecosystem Service: Water Filtration
FEMA Value: $6,239/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Replacement Cost

Geographic Area of Studies: Clark County, Ohio; Wiltshire, England

Source Studies:

Reference 1: Everard, M., Jevons, S. 2010. Ecosystem Services Assessment of Buffer Zone Installation on the Upper Bristol Avon, Wiltshire. Environment Agency. Almondsbury, Bristol. Available online at: http://publications.environment-agency.gov.uk/PDF/SCHO0210BRXW-E-E.pdf

Reference 2: Zhongwei, L. 2006. Water Quality Simulation and Economic Valuation of Riparian Land-Use Changes (Doctoral Dissertation). University of Cincinnati, Cincinnati, Ohio.

Methodology Description: Everard & Jevons (2010) analyzed the potential costs of contaminated water sources from agricultural sources such as dairy farming.[251] The downstream beneficiaries face the costs of developing potable water supplies from contaminated wells. Zhongwei (2006) conducted an analysis on the purification potential of several types of riparian buffers of varying sizes (60 m, 90 m, and 120 m), which were averaged in the calculations below.[252] All buffer analyses investigated the filtration of nitrogen and phosphorus removal from agriculture sources upstream. Hydrological computer models such as BASINS and HSPF along with GIS geospatial maps were used in this analysis.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Everard & Jevons (2010)	Wiltshire, England	2,988
Zhongwei (2006)	Ohio Riparian Forests	336
Zhongwei (2006)	Ohio Riparian Wetlands	7,911
Zhongwei (2006)	Ohio Riparian Grasslands	13,719
Average		**6,239**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. The level of detail provided in Zhongwei (2006) (full reference above) is the level of analysis one would hope to find for all environmental service valuations. The 257-page document analyzes three different types of riparian buffer: forest buffer, grassland filter strips and grassed swales (wetland-based grasslands). Zhongwei went into further detail by studying the riparian benefits at different buffer widths. As Zhongwei's research was focused on pollutants from applied fertilizers, Everard and Jevons' study was included to incorporate other elements of water pollution, particularly from dairy farming practices. Despite the fact that this study resides in the U.K., the methodology used allows for the transferability of this to the U.S.

Water Supply

Summary

Land Cover: Riparian
Ecosystem Service: Water Supply
FEMA Value: $272/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Replacement Cost, Avoided Cost, Market Value
Geographic Area of Studies: Southwest U.S. (CA, AZ, UT, NM, NV, CO), Minnesota, and South Dakota
Source Studies:

Reference 1: Zavaleta, E. 2000. "The Economic Value of Controlling an Invasive Shrub." *AMBIO: A Journal of the Human Environment*. 29(8): 462–467.

Reference 2: Roberts, L.A., Leitch, J.A. 1997. Economic valuation of some wetland outputs of mud lake, Minnesota-South Dakota. Department of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University. Fargo, ND.

Methodology Description: Riparian areas include wetland, shrub, forest, grassland, and other vegetation types. As the boundary of creeks, rivers and lakes, riparian areas provide water supply by storing water. Zavaleta (2000) used multiple avoided cost calculations to arrive at an average value for the value of water supply provided by riparian areas.[253] Utility market data was then used to monetize the amount of water stored in riparian areas, which, once released, would flow to a downstream dam where utility pumping infrastructure was located. Storage in riparian areas was valued based on the volume stored in riparian vegetation and the market price of water. The function of riparian areas provided added water supply. The added water supply provided water that would have been spilled and lost during high rainfall events and peak flows. The water stored in riparian areas is released after the peak flow and when there was storage space in downstream retention dams. Roberts and Leitch (1997) used the replacement cost and avoided cost methods to value the amount of water stored in wetland and lakeside riparian vegetation.[254] The method incorporated the avoided costs of alternative water supply infrastructure, such as dams.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Roberts & Leitch (1997)	Minnesota, South Dakota	155
Zavaleta (2000)	Western U.S.	389
Average		**272**

* All values are presented in 2021 USD

Discussion: No changes to this value were made other than to adjust for inflation. Zavaleta's research incorporates rigorous on-the-ground data collection to assess ecological conditions of various sites where there are healthy restored riparian areas and where the invasive shrub tamarisk is dominant. Tamarisk plants consume large amounts of water relative to native vegetation found in these areas. Zavaleta combined ecological data with hydrologic data (water storage) and market data (utility prices) to derive a robust water supply value across areas in the Southwest U.S. The study suggests that riparian restoration take place in those areas where tamarisk is rampant in order to allow the stretches of river to become more drought resistant. This report only used the value under normal, non-drought, conditions. The technical report by Roberts and Leitch was conducted to inform riparian restoration and conservation in the broader region. The authors assess multiple ecosystem services using rigorous cost data. The data used to estimate the avoided cost of water supply combined four sources, including a U.S. Army Corps of Engineers report on water supply infrastructure costs. Both references represent multiple case studies from across the U.S. and include multiple climate zones. Both studies also survey regions with different and varying scales of water demand, scarcity and drought risk.

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Appendix G. Coral Reefs

Land Cover Definition

Coral Reefs are defined as:

Areas of hardened, fixed substrate or structures created by deposition of calcium carbonate by reef-building coral species. May include both deep- and shallow-water coral species.

This definition of coral reefs is based on the Coastal and Marine Ecological Classification Standard (CMECS),[255] a national framework which organizes information about coasts and oceans. CMECS is endorsed by the Federal Geographic Data Committee (FGDC) as the national standard for classifying coastal and marine areas.

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for coral reefs in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "coral reefs" above.
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[256]
- According to the EPA,[xxiv] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).
- In general, restoration should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:

[xxiv] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

- The SER International document, referenced above,[257] states that plans for restoration projects include, at a minimum, the following:
  - Clear rationale as to why restoration is needed
  - Ecological description of the site designated for restoration
  - Statement of the goals and objectives of the restoration project
  - Designation and description of the reference
  - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
  - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
  - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
  - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

The following examples demonstrate how the "coral reefs" land cover category might be used in a mitigation project (and associated BCA):

- Restoration, creation, enhancement, or protection of coral reefs to support coastal storm/flood risk reduction. Example:
  - In recent decades, the demand for and interest in active restoration of coral reefs has grown. In the U.S., there are several coral restoration projects in Florida, Puerto Rico, and Hawaii, and they address different challenges—including invasive species control, coral species enhancement to restore reefs damaged by bleaching, hurricanes, and disease. The scientific community, restoration practitioners, and coral reef managers have found that reefs can reduce wave strength and storm surge, helping break up waves that accompanied the hurricanes. After Hurricanes Maria and Irma, a FEMA-supported partnership of multiple organizations launched a project on coral assessment and response to minimize losses to coral reefs in Florida and Puerto Rico. Three years later, more than 10,000 broken corals had been reattached and the monitoring efforts revealed the restored corals were healthy and thriving with survival rates at more than 90 percent.[258] This program is an example of socially responsible, community-supported initiatives, as former combat divers and special operation veterans were at the forefront of the restoration project. An interactive story map shows more about this coral restoration effort. Restoring damaged corals can speed up recovery time by 40 years and substantially reduces the costs of future recovery missions,

saving money and improving species health in the long term. This program was a clear example of how coral restoration can bring people together to help vulnerable social groups, vulnerable species, while improving the economic outlook for local communities in terms of reduced damages and relief-providing organizations through future savings.

Project Useful Life Considerations

In general, provided that coral reef areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied.

If the subapplicant can demonstrate that the coral reef area will continue to be maintained/protected beyond 50 years, as evidenced through documented assurances such as agency commitments or formation of protected areas, then a PUL of 51–100 years can be applied (with 100 years representing perpetuity), depending on the nature of the assurances. Also, the coral reef area should ideally be owned or controlled by a government or nonprofit organization.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates

Ecosystem Service	This Update		
	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	327	2	-
Air Quality			
Biological Control			
Climate Regulation			
Erosion Control			
Existence Value			
Flood Hazard Risk Reduction			
Food Provisioning	18	3	-
Habitat	2,222	1	-
Pollination			
Recreation/Tourism	1,261	2	-

Ecosystem Service	This Update		
	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Research and Education	23	1	-
Storm Hazard Risk Reduction	3,269	1	-
Water Filtration			
Water Supply			
Total Estimated Benefits	**7,120**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Coral Reefs
Ecosystem Service: Aesthetic Value
FEMA Value: $327/acre/year
Currency Year: 2021 USD

Source studies and Value Derivation

Valuation Methods: Meta Analysis, Hedonic Price
Geographic Area of Studies: United States and island territories
Source Studies:

> **Reference 1:** van Beukering, P., Brander, L., van Zanten, B., Verbrugge, E., Lems, K. 2011. The Economic Value of the Coral Reef Ecosystems of the United States Virgin Islands. Institute for Environmental Studies, VU University Amsterdam. Amsterdam.
> **Reference 2:** Brander, L., van Beukering, P. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland.

Methodology Description: Brander and van Beukering (2013) conduct a meta-analysis of coral reef value studies in the U.S. We performed a function transfer—a type of benefit transfer method—to construct a generalized national estimate from this model.[259] We used the reduced model estimated in the study, which had 69 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) state domestic product per capita was set to the average GDP per capita in the U.S.;[260] 2) area of coral cover was set to the regional average of hectares of coral in the U.S. estimated in the study; 3) the "amenity" variable was set to 1, all other ecosystem service variables were set to 0. The dependent variable is reported as 2007 USD per hectare per year, which we converted to 2021 USD per acre per year. Van Beukering et al. (2011) used the hedonic price method to estimate the value that proximity to coral reefs brings to housing prices in the U.S. Virgin Islands.[261] They found a positive relationship of *coral proximity to house price* equivalent to $37 million annually.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Brander and van Beukering (2013)	United States	114
van Beukering et al. (2011)	U.S. Virgin Islands	540
Average		**327**

* All values are presented in 2021 USD

Discussion: Part of the amenity value of beachfront properties can be attributed to the presence of coral reefs, thus degradation of the reefs (e.g., bleaching and coral erosion) can make properties less attractive. Beachfront houses along a beautiful coast with clean beaches and healthy coral reefs generally sell for higher prices. In their 2011 study of the U.S. Virgin Islands, van Beukering et al. used results from a hedonic price analysis to complement an elaborate local resident survey and an extensive tourist survey and estimate the value proximity to coral reefs bring to real estate values. They established a relationship between coral reefs and protection from property damage due to reduced wave energy. Their study found a positive relationship of coral proximity to house prices equivalent to $37 million annually. Brander and van Beukering (2013) have a more general geographical scope and study the value of coral reef in the U.S. They conduct a meta-analysis of hedonic pricing and value transfer studies examining seven states and territories with coral reefs (American Samoa, Florida, Guam, Hawaii, Puerto Rico, Commonwealth of the North Mariana Islands, and the U.S. Virgin Islands). They then developed a meta-regression model that can be used to estimate coral reef values in other geographies or under different scenarios. As the authors point out, understanding long-term processes that affect the functions of coral reefs that impact aesthetic value is essential for better estimation and scenario planning.

Food Provisioning

Summary

Land Cover: Coral Reefs
Ecosystem Service: Food Provisioning
FEMA Value: $18/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta Analysis, Market Price, Net Factor Income
Geographic Area of Studies: United States and island territories
Source Studies:

> **Reference 1:** Cesar, H., van Beukering, P. 2004. "Economic Valuation of the Coral Reefs of Hawaii." *Pacific Science* 58(2): 231–242.
> **Reference 2:** Brander, L., van Beukering, P. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland.
> **Reference 3:** van Beukering, P., Brander, L., van Zanten, B., Verbrugge, E., Lems, K. 2011. The Economic Value of the Coral Reef Ecosystems of the United States Virgin Islands. Institute for Environmental Studies, VU University Amsterdam. Amsterdam.

Methodology Description: Brander and van Beukering (2013) conducted a meta-analysis of coral reef value studies in the U.S. We performed a function transfer—a type of benefit transfer method—to construct a generalized national estimate from this model.[262] We used the reduced model estimated in the study, which had 69 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) state domestic product per capita was set to the average GDP per capita in the U.S.;[263] 2) area of coral cover was set to the regional average of hectares of coral in the U.S. estimated in the study; 3) the "commercial fishing" variable was set to 1, all other ecosystem service variables were set to 0. The dependent variable is reported as 2007 USD per hectare per year, which we converted to 2021 USD per acre per year. Cesar and van Beukering (2004) estimated the coral reef-associated share of commercial fishing activity in Hawaii using statistics from the Division of Aquatic Resources.[264] The total annual value was then divided by the area of coral reefs to arrive at a dollar-per-acre-per-year estimate. Van Beukering et al. (2011) estimate the value of commercial fisheries activity attributable to coral reefs in the U.S. Virgin Islands.[265] The authors use the net factor income approach to estimate the annual value of this service, combining landings data produced by the local government, the approximate proportion of catch dependent on corals, and local market prices.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Brander and van Beukering (2013)	United States	27
Cesar and van Beukering (2004)	Hawaii	7
van Beukering et al. (2011)	U.S. Virgin Islands	21
Average		**18**

* All values are presented in 2021 USD

Discussion: Coral reefs are essential for many inhabitants through the provision of food from subsistence fisheries. In a first attempt to value various reef-related goods and services in Hawaii, Cesar and van Beukering used the Simple Coral Reef Ecological Economic Model to link ecology and economy in a dynamic manner. For commercial fishing, they studied the effect on production (output) as the basis of valuing reef services. They computed a net present value using official statistics on subsistence and recreational fisheries and for the actual coral reef area from the Division of Aquatic Resources (DAR) of the State of Hawaii, a fisheries survey for aquarium fisheries, and a review of the published literature on reef fisheries. The authors noted that an alternative reliable data source would be preferrable over DAR statistics for estimation. The authors also noted that the size of the population that relies on coral reefs and their level of environmental awareness are key factors driving the total economic value of these ecosystems. Using answers to their surveys, the authors inferred the Hawaiian population was highly involved with coral reefs. In their 2011 study of the U.S. Virgin Islands, van Beukering et al. estimated the value of commercial fisheries activity attributable to coral reefs in the U.S. Virgin Islands using a production surplus approach. The authors used the net factor income approach to estimate the annual value of this service, combining landings data produced by the local government, the approximate proportion of catch dependent on corals, and local market prices. These data do not allow the modeling of population dynamics and prediction of future catch. In a third study, Brander and van Beukering (2013) had a more general geographical scope and studied the value of coral reef in the U.S. They conducted a meta-analysis of value transfer studies examining seven states and territories with coral reefs (American Samoa, Florida, Guam, Hawaii, Puerto Rico, Commonwealth of the North Mariana Islands, and the U.S. Virgin Islands). They then developed a meta-regression model that can be used to estimate coral reef values in other geographies or under different scenarios. As the authors stated, understanding long-term processes that affect the functions of coral reefs that impact the food value is essential for better estimation and scenario planning.

Habitat

Summary

Land Cover: Coral Reefs
Ecosystem Service: Habitat
FEMA Value: $2,222/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta Analysis, Choice Experiment
Geographic Area of Studies: United States and Island Territories
Source Studies:

> **Reference 1:** Brander, L., van Beukering, P. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland.

Methodology Description: Brander and van Beukering (2013) conducted a meta-analysis of coral reef value studies in the U.S.[266] We performed a function transfer—a type of benefit transfer method—to construct a generalized national estimate from this model. We used the reduced model estimated in the study, which had 69 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) state domestic product per capita was set to the average GDP per capita in the U.S.;[267] 2) area of coral cover was set to the regional average of hectares of coral in the U.S. estimated in the study; 3) the "nonuse" variable was set to 1, all other ecosystem service variables were set to 0. The dependent variable is reported as 2007 USD per hectare per year, which we convert to 2021 USD per acre per year.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Brander and van Beukering (2013)	USA	2,222
Average		**2,222**

* All values are presented in 2021 USD

Discussion: Coral reefs are highly productive and diverse ecosystems that face considerable impacts from anthropogenic factors. They provide essential habitat for species important to commercial and recreational activities as well as culturally important species. Many studies show that people are willing to pay to protect coral ecosystems, even if they will never visit them. The studies selected cover all U.S. states and territories that contain tropical coral reefs. Brander and van Beukering (2013) conducted a meta-analysis, which is beneficial to include because it statistically summarizes valuations from many different contexts.

Recreation/Tourism

Summary

Land Cover: Coral Reefs
Ecosystem Service: Recreation/Tourism
FEMA Value: $1,261/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta Analysis, Travel Cost
Geographic Area of Studies: United States and Island Territories
Source Studies:

> **Reference 1:** Brander, L., van Beukering, P. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland.
> **Reference 2:** van Beukering, P., Brander, L., van Zanten, B., Verbrugge, E., Lems, K. 2011. The Economic Value of the Coral Reef Ecosystems of the United States Virgin Islands. Institute for Environmental Studies, VU University Amsterdam. Amsterdam.

Methodology Description: Brander and van Beukering (2013) conducted a meta-analysis of coral reef value studies in the U.S.[268] We performed a function transfer—a type of benefit transfer method—to construct a generalized national estimate from this model. We used the reduced model estimated in the study, which had 69 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) state domestic product per capita was set to the average GDP per capita in the U.S.;[269] 2) area of coral cover was set to the regional average of hectares of coral in the U.S. estimated in the study; 3) the “all recreation activities” variable was set to 1, all other ecosystem service variables were set to 0. The dependent variable is reported as 2007 USD per hectare per year, which we converted to 2021 USD per acre per year. Van Beukering et al. (2011) investigated the tourism value of corals in the U.S. Virgin Islands using local data collected by the U.S. Virgin Islands Bureau of Economic Research and a tourist exit survey conducted by the authors.[270] The authors then used the travel cost method to estimate consumer surplus for recreational tourism activities. Annual values were then divided by the area of corals in the U.S. Virgin Islands.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Brander and van Beukering (2013)	United States	1,024
van Beukering et al. (2011)	U.S. Virgin Islands	1,498
Average		**1,261**

* All values are presented in 2021 USD

Discussion: Coral reefs are essential for the livelihood of many residents through the provision of income from tourism. In their 2011 study of the U.S. Virgin Islands, van Beukering et al. (2011) estimated the value of tourism and recreational uses attributable to coral reefs in the U.S. Virgin Islands. For tourism, the authors used statistics of the Department of Tourism to obtain a production surplus estimate and using exit surveys from the Department of Tourism to estimate consumer surplus for foreign tourists. To estimate the value of recreational uses, the authors followed a contingent valuation approach. In a third study, Brander and van Beukering (2013) had a more general geographical scope and study the value of coral reef in the U.S. They conducted a meta-analysis of travel cost studies examining seven states and territories with coral reefs (American Samoa, Florida, Guam, Hawaii, Puerto Rico, Commonwealth of the North Mariana Islands, and the U.S. Virgin Islands). They then developed a meta-regression model that can be used to estimate coral reef values in other geographies or under different scenarios. As the authors indicated, understanding long-term processes that affect the functions of coral reefs that impact the recreation and tourism value is essential for better estimation and scenario planning.

Research and Education

Summary

Land Cover: Coral Reefs
Ecosystem Service: Research and Education

FEMA Value: $23/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: United States and Island Territories
Source Studies:

Reference 1: Brander, L., van Beukering, P. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland.

Methodology Description: Brander and van Beukering (2013) conducted a meta-analysis of coral reef value studies in the U.S.[271] We performed a function transfer—a type of benefit transfer method—to construct a generalized national estimate from this model. We used the reduced model estimated in the study, which had 69 observations and an adjusted R^2 of 0.44. Model variables were set as follows: 1) state domestic product per capita was set to the average GDP per capita in the U.S.;[272] 2) area of coral cover was set to the regional average of hectares of coral in the U.S. estimated in the study; 3) the "research" variable was set to 1, all other ecosystem service variables were set to 0. The dependent variable was reported as 2007 USD per hectare per year, which we converted to 2021 USD per acre per year.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Brander and van Beukering (2013)	United States	23
Average		**23**

* All values are presented in 2021 USD

Discussion: Meta-analyses produce value estimates from the results of dozens to hundreds of studies at once, controlling for wide variations in ecosystem characteristics, human preferences, and methodological aspects of valuation studies. They are increasingly used to synthesize environmental literature and are a powerful tool that can produce customized value estimates where domestic valuation literature is scarce. Brander and van Beukering (2013) conducted a meta-analysis of net factor income, gross expenditure, and gross revenue studies examining seven states and territories with coral reefs (American Samoa, Florida, Guam, Hawaii, Puerto Rico, Commonwealth of the North Mariana Islands, and the U.S. Virgin Islands). They then developed a meta-regression model that can be used to estimate coral reef values in other geographies or under different scenarios. As the authors indicated, understanding long-term processes that affect the functions of coral reefs that impact the research and education value is essential for better estimation and scenario planning.

Storm Hazard Risk Reduction

Summary

Land Cover: Coral Reefs
Ecosystem Service: Storm Hazard Risk Reduction
FEMA Value: $3,269/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Meta-Analysis
Geographic Area of Studies: United States and Island Territories
Source Studies:

Reference 1: Storlazzi, C.D., Reguero, B.G., Cole, A.D., Lowe, E., Shope, J.B., Gibbs, A.E., Nickel, B.A., McCall, R.T., van Dongeren, A.R., Beck, M.W. 2019. Rigorously Valuing the Role of U.S. Coral Reefs in Coastal Hazard Risk Reduction. U.S. Geological Survey, Reston, Virginia. Available online at: https://pubs.er.usgs.gov/publication/ofr20191027

Methodology Description: We utilized a recent comprehensive modeling study by Storlazzi et al. (2019)[273] to create an average U.S.-wide estimate for the storm hazard risk reduction value of coral reefs. The study covered all areas in the entire U.S. and its territories, which have coral reefs in their associated waters. Storlazzi et al. (2019) provided a rigorous approach to valuing disaster hazard risk reduction in that they use high-resolution spatial and hydrodynamic modeling based on approaches used by FEMA as well as combining both infrastructure values at risk and potential impacts to local economic activity, the latter of which is not typically included in disaster hazard risk reduction studies for green infrastructure. Storlazzi et al. combined engineering, ecologic, geospatial, and economic modeling to value the coastal protection benefits of all U.S. coral reefs in the U.S. and its territories.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Storlazzi et al. (2019)	USA	3,269
Average		**3,269**

* All values are presented in 2021 USD

Discussion: Coral reefs are able to dissipate wave energy. Thus, intact reefs can prevent damage to coastal infrastructure during storm events.

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Appendix H. Beaches and Dunes

Land Cover Definition

Beaches and Dunes are defined as:

Areas consisting of material such as silt, sand, or gravel that is subject to inundation and redistribution due to water or wind. Substrates have no vegetative cover except for pioneering plants that are briefly established when growing conditions are favorable.

This definition of beaches and dunes is based on the Coastal Change Analysis Program (C-CAP) Regional Land Cover Classification Scheme definition of Unconsolidated Shore. This is a nationally standardized inventory of land cover for the coastal areas of the U.S. developed by NOAA.[274]

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for beaches and dunes in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "beaches and dunes" above.
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[275]
- According to the EPA,[xxv] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).
- In general, restoration should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:

[xxv] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

- The SER International document, referenced above,[276] states that plans for restoration projects include, at a minimum, the following:
  - Clear rationale as to why restoration is needed
  - Ecological description of the site designated for restoration
  - Statement of the goals and objectives of the restoration project
  - Designation and description of the reference
  - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
  - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
  - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
  - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

- Restoration, creation, enhancement or protection of dunes for coastal storm/flood risk reduction.

Summary of Value Updates

Ecosystem Service	This Update		
	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value	223,840	2	NA
Air Quality			
Biological Control			
Climate Regulation			
Erosion Control			
Existence Value			
Flood Hazard Risk Reduction			

Ecosystem Service	This Update		
	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Food Provisioning			
Habitat			
Pollination			
Recreation/Tourism	76,809	9	NA
Water Filtration			
Water Supply			
Total Estimated Benefits	**300,649**		

Ecosystem Service Values

Aesthetic Value

Summary

Land Cover: Beaches and Dunes
Ecosystem Service: Aesthetic Value
FEMA Value: $223,840/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Hedonic Model
Geographic Area of Studies: Georgia, North Carolina
Source Studies:

> **Reference 1:** Landry, C.E., Keeler, A.G., Kriesel, W. 2003. "An economic evaluation of beach erosion management alternatives." *Marine Resource Economics* 18(2): 105–127.
> **Reference 2:** Gopalakrishnan, S., Smith, M.D., Slott, J.M., Murray, A.B. 2011. "The value of disappearing beaches: A hedonic pricing model with endogenous beach width." *Journal of Environmental Economics and Management* 61(3): 297–310.

Methodology Description: Three values taken from two studies were selected to arrive at an average estimate for the U.S. Landry et al. (2003) used a hedonic model to study three distinct beach erosion management policies in an island in Georgia.[277] With this study they derived the aesthetic value of beaches. In general, they found that people prefer wider beaches, do not like armoring strategies (e.g., building seawalls or sand retention structures), and dislike shoreline retreat (this last finding applies only to frequent visitors). In turn, Gopalakrishnan et al. (2011) used a hedonic price model to build a dynamic optimization model and study two types of beach nourishment programs in the North Carolinian context.[278] They found that beach width contributes to property value five times as much as previously anticipated. These findings are consistent with the literature and are particularly relevant in the face of increasing population densities in coastal areas, climate change, and rising erosion rates. Both studies reported values either by linear units or a total value, which were regularized by finding the approximate area of the relevant beaches via Geographic Information Systems (GIS) methods.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Landry et al. (2003)	Georgia	44,477
Gopalakrishnan et al. (2011)	North Carolina	573,813
Gopalakrishnan et al. (2011)	North Carolina	53,229
Average		**223,840**

* All values are presented in 2021 USD

Discussion: The overall body of economics evidence indicates that beach width positively affects property values. In terms of technical concern, for studies using hedonic methods, it is important to check that the relationship between the housing market and coastal management is stable. In other words, if there is a sudden change to how property owners value given property benefits and recreational activities, results from a hedonic analysis can no longer offer useful insights into the connection of interest.

Recreation/Tourism

Summary

Land Cover: Beaches and Dunes
Ecosystem Service: Recreation/Tourism
FEMA Value: $76,809/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Travel Cost, Hedonic Model, Choice Experiment, Contingent Valuation
Geographic Area of Studies: Southern California, Georgia, Massachusetts, North Carolina, Ohio, Texas
Source Studies:

Reference 1: Pendleton, L., Mohn, C., Vaughn, R.K., King, P., Zoulas, J.G. 2011. "Size matters: The economic value of beach erosion and nourishment in Southern California." *Contemporary Economic Policy* 30(2): 223–237.
Reference 2: King, P. 2002. Economic Analysis of Beach Spending and the Recreational Benefits of Beaches in the City of San Clemente. San Francisco State University, San Francisco, California. Available online at: ftp://ftp.coast.noaa.gov/pub/socioeconomic/NSMS/California/Literature/King_2002_sanclemente.pdf
Reference 3: Lew, D.K., Larson, D.M. 2005. "Valuing recreation and amenities at San Diego County beaches." *Coastal Management* 33(1): 71–86.
Reference 4: Landry, C.E., Keeler, A.G., Kriesel, W. 2003. "An economic evaluation of beach erosion management alternatives." *Marine Resource Economics* 18(2): 105–127.
Reference 5: Kline, J.D., Swallow, S.K. 1998. "The demand for local access to coastal recreation in southern New England." *Coastal Management* 26(3): 177–190.
Reference 6: Landry, C.E., Liu, H. 2009. "A semi-parametric estimator for revealed and stated preference data: An application to recreational beach visitation." *Journal of Environmental Economics and Management* 57(2): 205–218.
Reference 7: Whitehead, J.C., Dumas, C.F., Herstine, J., Hill, J., Buerger, B. 2008. "Valuing beach access and width with revealed and stated preference data." *Marine Resource Economics* 23(2): 119–135.
Reference 8: Sohngen, B., Lichtkoppler, F., Bielen, M. 1999. The value of day trips to Lake Erie beaches. Dept. of Agricultural, Environmental, and Development Economics, Ohio State University. Available online at: https://nsgl.gso.uri.edu/ohsu/ohsus99003.pdf
Reference 9: Parsons, G.R., Kang, A.K., Leggett, C.G., Boyle, K.J. 2009. "Valuing beach closures on the Padre Island national seashore." *Marine Resource Economics* 24(3): 213–235.

Methodology Description: Beach recreation is well-studied in the ecosystem service valuation literature. Seventeen values were taken from nine studies, and the median of these values was used as a representative estimate for the U.S. In general, these studies found that increasing beach size is important to beach users but that the value they place on this benefit is different for different types of beach users and for different beach activities (e.g., fishing, boating, swimming). They also found that, in general, people prefer wider beaches, do not like armoring strategies (e.g., building seawalls or sand retention structures), and dislike shoreline retreat. Importantly, complementary beach services, such as safety (e.g., lifeguard patrols), beach amenities (e.g., restrooms), and water quality are also significant drivers of value and attendance. Studies reported values either by linear units or a total value, which were regularized by finding the approximate area of relevant beaches via Geographic Information Systems (GIS) methods.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Pendelton et al. (2011)[279]	San Clemente, California	246,695
Pendelton et al. (2011)	Huntington Beach, California	76,809
Pendelton et al. (2011)	Malibu Beach, California	231,099
Pendelton et al. (2011)	Leo Carrillo Beach, California	141,285
King (2002)[280]	Southern California	8,024
Lew & Larson (2005)[281]	Southern California	2,448,799
Landry et al. (2003)[282]	Georgia	6,206,149
Kline & Swallow (1998)[283]	Massachusetts	8,440
Landry & Liu. (2009)[284]	North Carolina	3,550,147
Whitehead et al. (2008)[285]	North Carolina	1,470,978
Sohngen et al. (1999)[286]	Ohio	438,540
Parsons et al. (2009)[287]	Jefferson County, Texas	11,266
Parsons et al. (2009)	Galveston County, Texas	32,716
Parsons et al. (2009)	Brazoria County, Texas	35,010
Parsons et al. (2009)	Calhoun County, Texas	12,073
Parsons et al. (2009)	Aransas County, Texas	5,293
Parsons et al. (2009)	Cameron County, Texas	2,801
Median		**76,809**

* All values are presented in 2021 USD

Discussion: The Unites States is home to countless beaches and various kinds, each with different features and appropriate for different types of recreation. The selected studies covered a wide range of geographies and types of beaches (e.g., coastal beaches, lake beaches). They also cover a variety of estimation techniques and topics regarding beach recreation, including preferences for beach width, sand-based activities, beach amenities, and perceived values of public access, beach erosion, and beach closures.

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Appendix I. Shellfish Reefs

Land Cover Definition

Shellfish Reefs are defined as:

Areas where the substrate is dominated by living or non-living shell reefs and are surrounded and intermixed with channels and unvegetated flats, typically occurring in the intertidal zone.

This definition of shellfish reefs is based on the 2012 Federal Geographic Data Committee (FGDC) Coastal and marine ecological classification standard.[288] Similar to the "Classification of Wetlands and Deepwater Habitats in the United States" produced by the FGDC, this document seeks to establish a formal classification strategy for estuarine, costal, and open ocean settings, which had not existed until publication.

Feasibility & Effectiveness Criteria

In general, to include the ecosystem service values for beaches and dunes in a FEMA BCA, the project should meet the following criteria:

- The final land cover associated with the mitigation project should be consistent with the definition of "shellfish reefs" above.
- The project must demonstrate some level of *ecosystem restoration*. The Society for Ecological Restoration (SER) International defines ecosystem (ecological) restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."[289]
- According to the EPA,[xxvi] the concept of restoration can also include restoration-related activities such as "creation" and "enhancement" of ecosystems.
- In the context of a FEMA BCA, ecosystem service values can be realized through an increase in the health or functionality of an ecosystem in the "After Mitigation" scenario relative to the "Before Mitigation" (No Action) scenario. Therefore, ecosystem service values could be generated through restoration, creation, enhancement, or protection (of areas at risk of degradation in a No Action scenario).
- In general, restoration should follow internally or externally established principles, guidelines, policies, and techniques. Examples include:

[xxvi] Discussed in the context of wetland restoration but broadly applicable to other ecosystem types. See the following link for more information: https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

- The SER International document, referenced above,[290] states that plans for restoration projects include, at a minimum, the following:
  - Clear rationale as to why restoration is needed
  - Ecological description of the site designated for restoration
  - Statement of the goals and objectives of the restoration project
  - Designation and description of the reference
  - Explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
  - Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections
  - Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated
  - Strategies for long-term protection and maintenance of the restored ecosystem

Mitigation Project Use Cases

The following examples demonstrate how the “shellfish reefs” land cover category might be used in a mitigation project (and associated BCA):

- Restoration, creation, enhancement, or protection of shellfish reefs for coastal storm/flood risk reduction. Examples:
  - The Harte Research Institute for Gulf of Mexico Studies has conducted several oyster reef restoration projects that provide multiple benefits, including hurricane protection, water filtration, and habitat for fisheries. Recent projects included restoration of 2.8 acres of oyster reefs in Aransas Bay, Texas[291], and restoration of a living shoreline in St. Charles Bay, which has experienced high erosion rates over the last two decades.[292]
  - The Nature Conservancy is working to restore oyster reefs in Pensacola Bay, focusing on recovering reefs important for commercial harvest, but which also provide other benefits such as protecting shorelines. Thirty-three oyster reefs will be placed along almost 7 miles of shoreline in Florida, an area where oyster habitat has declined.[293]

Project Useful Life Considerations

In general, provided that shellfish reef areas associated with the project meet the above definition and Feasibility & Effectiveness criteria, a standard Project Useful Life of 50 years can be applied.

If the subapplicant can demonstrate that the shellfish reef area will continue to be maintained/protected beyond 50 years, as evidenced through documented assurances such as agency commitments or formation of protected areas, then a PUL of 51–100 years can be applied (with 100 years representing perpetuity), depending on the nature of the assurances. Also, the shellfish reef area should ideally be owned or controlled by a government or nonprofit organization.

Please see the section in the main report body titled "Select an Appropriate Project Useful Life" for more background and detail.

Summary of Value Updates

Ecosystem Service	This Update		
	Value (2021 USD/acre/year)	Source Studies Added (#)	Source Studies Removed (#)
Aesthetic Value			
Air Quality			
Biological Control			
Climate Regulation			
Erosion Control			
Existence Value			
Flood Hazard Risk Reduction			
Food Provisioning	1,905	4	0
Habitat			
Pollination			
Recreation/Tourism	253	2	0
Water Filtration	600	4	0
Water Supply			
Total Estimated Benefits	**2,757**		

Ecosystem Service Values

Food Provisioning

Summary

Land Cover: Shellfish Reefs
Ecosystem Service: Food Provisioning
FEMA Value: $1,905/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Market Price
Geographic Area of Studies: U.S. East Coast, Louisiana, Maryland, Virginia, Washington
Source Studies:

Reference 1: Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P., Smyth, A.R. 2012. "Economic Valuation of Ecosystem Services Provided by Oyster Reefs." *American Institute of Biological Sciences*. 62: 900–909.
Reference 2: Henderson, J., O'Neil, J. 2003. Economic Values Associated with Construction of Oyster Reefs by the Corps of Engineers. Engineer Research and Development Center, U.S. Army Corps of Engineers, Vicksburg, MS.
Reference 3: Hudson, B. 2010. Washington State Shellfish Production & Restoration: Environmental and Economic Benefits & Costs. Pacific Shellfish Institute, Olympia, WA.
Reference 4: Isaacs, J.C., Keithly, W.R., Lavergne, D.R. 2004. Section 3: The Value of Louisiana Oyster Reefs to Recreational Fishermen. In: Louisiana Department of Wildlife and Fisheries (ed.). Final Report for Louisiana's Oyster Shell Recovery Pilot Project (p. 117-199). Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana. Available online at: https://www.wlf.louisiana.gov/assets/Resources/Publications/Oyster/2004_Louisiana_Oyster_Shell_Recovery_Pilot_Project.pdf

Methodology Description: Food provisioning benefits were estimated from studies recording the market benefits of commercial oyster harvesting at several sites in the U.S. Grabowski et al. (2012) estimated the producer surplus of commercial oyster harvesting activity at different levels of productivity.[294] We took the average value across all productivity levels for use in this value calculation. In a similar manner, Henderson & O'Neil (2003) estimated commercial oyster harvesting benefits at different productivity levels using market prices.[295] Hudson (2010) estimated the market value of commercial oyster harvest for both tribal and non-tribal operators.[296] Isaacs et al. (2004) estimated the market value of commercial oyster harvest coming from public reefs in Louisiana using dockside prices.[297]

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Grabowski et al. (2012)[298]	Eastern US	5,603
Henderson & O'Neil (2003)[299]	Maryland, Virginia	631
Hudson (2010)[300]	Washington	1,374
Isaacs et al. (2004)[301]	Louisiana	12
Average		**1,905**

* All values are presented in 2021 USD

Discussion: Food provisioning is an important economic benefit provided by oyster reefs throughout the U.S. Restoring oyster reefs supports commercial harvest through increased productivity and yield. The studies covered several unique areas of the country where oyster harvest is a prominent commercial activity, as well as different oyster species (Eastern oyster and Pacific oyster).

Water Filtration

Summary

Land Cover: Shellfish Reefs
Ecosystem Service: Water Filtration
FEMA Value: $600/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Avoided Cost and Replacement Cost
Geographic Area of Studies: National, including Alabama, Connecticut, Delaware, Florida, Georgia, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, Virginia, California, and Washington
Source Studies:

Reference 1: Burke, S. 2009. Estimating Water Quality Benefits from Shellfish Harvesting; a Case Study in Oakland Bay, Washington. Entrix, Inc. Seattle, Washington.
Reference 2: Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P., Smyth, A.R. 2012. "Economic Valuation of Ecosystem Services Provided by Oyster Reefs." *American Institute of Biological Sciences*. 62: 900–909.
Reference 3: Newell, R.E., Fisher, T.R., Holyoke, R.R., Cornwell, J.C. 2005. Influence of eastern oysters on nitrogen and phosphorus regeneration in Chesapeake Bay, USA. In: Dame, R., Olenin, S. (eds.) *The Comparative Roles of Suspension Feeders in Ecosystems* (p. 93-120). Springer, Netherlands.

Reference 4: Pollack, J.B., Yoskowitz, D., Kim, H., Montagna, P.A. 2013. "Role and Value of Nitrogen Regulation Provided by Oysters (Crassostrea virginica) in the Mission-Aransas Estuary, Texas, USA." *Public Library of Science* (PloS) 8: 1–8.

Methodology Description: Water filtration benefits were estimated using multiple scientific studies on the services provided by shellfish beds throughout the U.S. Shellfish consume nitrogen and phosphorus-containing plankton and detritus, playing an integral role in nutrient cycling of coastal habitats. Each study used replacement cost methods to value water filtration services from shellfish beds, which otherwise would have to be removed at a wastewater treatment plant. Results were reported as total benefits derived from the entire study site and were converted to per-acre values by dividing by the area of shellfish in the study site.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Grabowski et al. (2012)[302]	East Coast	674
Grabowski et al. (2012)	Gulf States	3,270
Newell et al. (2005)[303]	Chesapeake Bay, MD	102
Pollack et al. (2013)[304]	Copano Bay, Gulf of Mexico	21
Pollack et al. (2013)	Aransas Bay, Gulf of Mexico	11
Pollack et al. (2013)	Mesquite Bay, Gulf of Mexico	51
Burke (2009)[305]	Oakland Bay, WA	69
Average		**600**

* All values are presented in 2021 USD

Discussion: These values were removed from the former Marine and Estuary land cover category and used in the Shellfish Reef category. Separating shellfish reef-specific values into its own land cover type will make value calculations on a per-acre basis more accurate. Also, the values were reclassified from Nutrient Cycling to Water Filtration, as the studies value the service through improved water quality for direct human use. Characterizing this service as water filtration instead of nutrient cycling follows recent guidance on valuing ecosystem services, in that it assigns value to the final good or service being enjoyed by the beneficiaries, thus reducing concerns of double counting. Other than this change, these values were only updated for inflation.

Recreation/Tourism

Summary

Land Cover: Shellfish Reefs
Ecosystem Service: Recreation/Tourism
FEMA Value: $253/acre/year
Currency Year: 2021 USD

Source Studies and Value Derivation

Valuation Methods: Travel Cost, Contingent Valuation
Geographic Area of Studies: Louisiana, Maryland
Source Studies:

> **Reference 1:** Hicks, R.L., Haab, T.C., Lipton, D. 2004. Estimating the Economic Benefits of Oyster Reef Restoration and Marine Preserve Establishment in the Lower Chesapeake Bay. Chesapeake Bay Foundation. Annapolis, Maryland.
>
> **Reference 2:** Isaacs, J.C., Keithly, W.R., Lavergne, D.R. 2004. Section 3: The Value of Louisiana Oyster Reefs to Recreational Fishermen. In: Louisiana Department of Wildlife and Fisheries (ed.). Final Report for Louisiana's Oyster Shell Recovery Pilot Project (p. 117-199). Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana. Available online at: https://www.wlf.louisiana.gov/assets/Resources/Publications/Oyster/2004_Louisiana_Oyster_Shell_Recovery_Pilot_Project.pdf

Methodology Description: These studies focused on calculating the willingness to pay by recreational anglers for fishing trips over oyster reefs. Oyster reefs create crucial habitat areas for many species, especially those that are recreationally valuable. The proposed studies estimate recreational value either on a $/household or $/person scale. We calculated per-acre values by taking $/household or $/person estimates, multiplying by the relevant number of units to arrive at a total annual estimate, and dividing by the area of the study site. Values were then inflated to 2021 USD.

Calculation:

Source Study	Study Location	Value ($/acre/year)*
Isaacs et al. (2004)[306]	Louisiana	3
Hicks et al. (2004)[307]	Chesapeake Bay	503
Average		**253**

* All values are presented in 2021 USD

Discussion: These values were removed from the former Marine and Estuary land cover category and used in the Shellfish Reef category. Separating shellfish reef-specific values into its own land cover type will make value calculations on a per-acre basis more accurate. The values were reclassified from Habitat to Recreation/Tourism, as the studies value the service through surveys of recreational anglers valuing fishing at each site. Characterizing this service as recreation instead of habitat follows recent guidance on valuing ecosystem services, in that it assigns value to the final good or service being enjoyed by the beneficiaries, thus reducing concerns of double counting. Other than this change, these values were only updated for inflation.

Appendix J. Detailed Change Log: Added and Removed Studies and Values since 2016 update

Values Added

Forests

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Kousky & Walls (2013)	1,004
Aesthetic Value	McPherson et al. (2005)	4,177
Aesthetic Value	McPherson et al. (2005)	197
Aesthetic Value	McPherson et al. (2005)	530
Air Quality	Nowak et al. (2014)	14
Air Quality	Nowak et al. (2013)	250
Air Quality	Nowak et al. (2013)	651
Air Quality	Nowak et al. (2013)	1,152
Air Quality	Nowak et al. (2013)	1,202
Air Quality	Nowak et al. (2013)	451
Air Quality	Nowak et al. (2013)	250
Air Quality	Nowak et al. (2013)	1,903
Air Quality	Nowak et al. (2013)	701
Air Quality	Nowak et al. (2013)	1,252
Air Quality	Nowak et al. (2013)	300
Air Quality	Nowak et al. (2006)	400
Climate Regulation	Hoover et al. (2021)	146
Erosion Control	Taye et al. (2021)	1,672
Existence Value	Nowak et al. (2002)	5,867
Existence Value	Nowak et al. (2002)	4,952
Existence Value	Nowak et al. (2002)	7,139
Existence Value	Nowak et al. (2002)	13,731

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Existence Value	Nowak et al. (2002)	7,038
Existence Value	Nowak et al. (2002)	6,374
Existence Value	Nowak et al. (2002)	8,467
Existence Value	Nowak et al. (2002)	6,680
Recreation/Tourism	Rosenberger et al. (2017) & USFS (2020)	94
Water Filtration	Taye et al. (2021)	648
Water Filtration	Taye et al. (2021)	222
Water Supply	Taye et al. (2021)	114

*All values are presented in 2021 USD

Coastal Wetlands

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Ghermandi et al. (2010)	1,648
Climate Regulation	Crooks et al. (2014)	125
Climate Regulation	Poppe & Rybczyk (2019)	183
Habitat	Adusumilli (2015)	124
Habitat	Hazen & Sawyer (2008)	28
Habitat	Brander et al. (2006)	2,072
Habitat	Ghermandi et al. (2010)	3,046
Habitat	Woodward & Wui (2001)	1,545
Recreation/Tourism	Adusumilli (2015)	582
Recreation/Tourism	Brander et al. (2006)	172
Recreation/Tourism	Ghermandi et al. (2010)	639
Recreation/Tourism	Woodward & Wui (2001)	3,816
Flood and Storm Hazard Risk Reduction	Adusumilli (2015)	75
Flood and Storm Hazard Risk Reduction	Brander et al. (2006)	1,040

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Flood and Storm Hazard Risk Reduction	Ghermandi et al. (2010)	1,496
Flood and Storm Hazard Risk Reduction	Sun & Carson (2020)	415
Flood and Storm Hazard Risk Reduction	Woodward & Wui (2001)	1,592
Water Filtration	Adusumilli (2015)	417
Water Filtration	Ghermandi et al. (2010)	2,009
Water Supply	Adusumilli (2015)	307
Water Supply	Ghermandi et al. (2010)	879

*All values are presented in 2021 USD

Inland Wetland

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Ghermandi et al. (2010)	1,303
Climate Regulation	Liu et al. (2012)	92
Climate Regulation	Fennessy et al. (2018)	53
Flood Hazard Risk Reduction	Adusumilli (2015)	204
Flood Hazard Risk Reduction	Brander et al. (2006)	361
Flood Hazard Risk Reduction	Ghermandi et al. (2010)	1,183
Flood Hazard Risk Reduction	Woodward & Wui (2001)	2,286
Habitat	Adusumilli (2015)	336
Habitat	Brander et al. (2006)	699
Habitat	Ghermandi et al. (2010)	2,408
Habitat	Woodward & Wui (2001)	2,219
Recreation/Tourism	Adusumilli (2015)	1,581
Recreation/Tourism	Brander et al. (2006)	60

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Recreation/Tourism	Ghermandi et al. (2010)	505
Recreation/Tourism	Woodward & Wui (2001)	5,478
Water Filtration	Adusumilli (2015)	1,131
Water Filtration	Ghermandi et al. (2010)	1,589
Water Supply	Adusumilli (2015)	833
Water Supply	Ghermandi et al. (2010)	695

* All values are presented in 2021 USD

Urban Green Open Space

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Bockarjova et al. (2020)	21,873
Aesthetic Value	Lutzenhiser & Netusil (2001)	540
Aesthetic Value	Trust for Public Land (2017)	5,087
Air Quality	Gopalakrishnan et al. (2018)	43
Air Quality	Trust for Public Land (2017)	47
Climate Regulation	Milesi et al. (2005)	40
Flood Hazard Risk Reduction	Trust for Public Land (2017	238
Habitat	Bockarjova et al. (2020)	5,890
Recreation/Tourism	Bockarjova et al. (2020)	1,753
Recreation/Tourism	Hanauer & Reid (2017)	1,531

* All values are presented in 2021 USD

Rural Green Open Space

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Bockarjova et al. (2020)	7,505
Climate Regulation	Lu et al. (2015)	64
Habitat	Bockarjova et al. (2020)	2,021
Recreation/Tourism	Bockarjova et al. (2020)	601

* All values are presented in 2021 USD

Riparian

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Berman & Armagost (2013)	596
Aesthetic Value	Kousky & Walls (2014)	1,004
Climate Regulation	Hoover et al. (2021)	146
Flood Hazard Risk Reduction	Kousky & Walls (2013)	13,299
Flood Hazard Risk Reduction	Watson et al. (2016)	18
Habitat	Berrens et al. (2000)	4,085
Recreation/Tourism	Colby & Smith-Incer (2005)	275
Recreation/Tourism	Weber & Berrens (2006)	41

* All values are presented in 2021 USD

Coral Reefs

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Brander and van Beukering (2013)	114
Aesthetic Value	van Beukering et al. (2011)	540
Food Provisioning	Brander and van Beukering (2013)	27
Food Provisioning	Cesar and van Beukering (2004)	7
Food Provisioning	van Beukering et al. (2011)	21
Habitat	Brander and van Beukering (2013)	2,222
Recreation/Tourism	Brander and van Beukering (2013)	1,024
Recreation/Tourism	van Beukering et al. (2011)	1,498
Research & Education	Brander and van Beukering (2013)	23

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Storm Hazard Risk Reduction	Storlazzi et al. (2019)	3,270

* All values are presented in 2021 USD

Beaches and Dunes

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Landry et al. (2003)	44,477
Aesthetic Value	Gopalakrishnan et al. (2011)	573,813
Aesthetic Value	Gopalakrishnan et al. (2011)	53,229
Recreation/Tourism	Pendleton et al. (2011)	246,695
Recreation/Tourism	Pendleton et al. (2011)	76,809
Recreation/Tourism	Pendleton et al. (2011)	231,099
Recreation/Tourism	Pendleton et al. (2011)	141,286
Recreation/Tourism	King (2002)	8,024
Recreation/Tourism	Lew & Larson (2005)	2,448,799
Recreation/Tourism	Landry et al. (2003)	6,206,149
Recreation/Tourism	Kline & Swallow (1998)	8,441
Recreation/Tourism	Landry & Liu. (2009)	3,550,147
Recreation/Tourism	Whitehead et al. (2008)	1,470,978
Recreation/Tourism	Sohngen et al. (1999)	438,541
Recreation/Tourism	Parsons et al. (2009)	11,265
Recreation/Tourism	Parsons et al. (2009)	32,716
Recreation/Tourism	Parsons et al. (2009)	35,010
Recreation/Tourism	Parsons et al. (2009)	12,074
Recreation/Tourism	Parsons et al. (2009)	5,292
Recreation/Tourism	Parsons et al. (2009)	2,800

* All values are presented in 2021 USD

Shellfish Reefs

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Food Provisioning	Grabowski et al. (2012)	5,603
Food Provisioning	Henderson & O'Neil (2003)	631
Food Provisioning	Hudson (2010)	1,374
Food Provisioning	Isaacs et al. (2004)	12

* All values are presented in 2021 USD

Values Removed

Forests

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Climate Regulation	Heath et al. (2003)	153
Climate Regulation	Smith et al. (2006)	153

* All values are presented in 2014 USD

Discussion: For climate regulation, two studies were removed from the value sets that FEMA adopted for the 2016 environmental benefits policy. Smith et al. (2006)[308] was replaced by Hoover et al. (2012), which represents an update of the older report produced by the Forest Service. Heath et al. (2003)[309] was removed because it only represented carbon sequestration in soils and undercounted the benefit, unlike the other studies included, which provided rates for the whole ecosystem (i.e., both above and below ground carbon).

Coastal Wetlands

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Johnston et al. (2001)	976
Aesthetic Value	Johnston et al. (2002)	6,984
Aesthetic Value	Johnston et al. (2002)	9,421
Nutrient Cycling	Jenkins et al. (2010)	536
Climate Regulation	Nellemann et al. (2009)	0.01
Climate Regulation	Smith et al. (2006)	136
Habitat	Bockstael et al. (1989)	1

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Habitat	Whitehead et al. (1997)	53
Habitat	Jordan et al. (2012)	304
Habitat	Hicks et al. (2004)	438
Habitat	Isaacs et al. (2004)	3
Nutrient Cycling	Burke (2009)	60
Nutrient Cycling	Grabowski et al. (2012)	588
Nutrient Cycling	Grabowski et al. (2012)	2,849
Nutrient Cycling	Newell et al. (2005)	89
Nutrient Cycling	Pollack et al. (2013)	18
Nutrient Cycling	Pollack et al. (2013)	9
Nutrient Cycling	Pollack et al. (2013)	44

* All values are presented in 2014 USD

Discussion: For Aesthetic Value, we removed the two relevant coastal wetlands studies used in the 2016 policy and proposed replacing them with this customized meta-analysis. This was justified as the two studies removed—Johnston et al. (2001)[310] and Johnston et al. (2002)[311]—are very local in scale and the study site is in an affluent area that would have inflated the value of this service. For Climate Regulation, two studies from the 2016 policy were removed from the value calculation. Smith et al. (2006) was removed as more recent studies relevant to wetlands were found.312 Nellemann et al. (2009) was removed as it represented an extreme outlier and was more applicable to vast expanses of marine open water, not nearshore ecosystems.[313] For Habitat, five studies were removed from the 2016 policy values. Two studies—Bockstael et al. (1989)[314] and Whitehead et al. (1997)[315]—was replaced with newer valuation estimates. Jordan et al. (2012) was removed because it was a secondary study that could be replaced by newer primary studies.[316] Two other studies—Hicks et al. (2004)[317] and Isaacs et al. (2004)[318] —were removed and are now located in the new land cover type, Shellfish Reefs. For Nutrient Cycling, all five studies were removed from the 2016 policy values. Jenkins et al. (2010) was removed for two reasons: 1) it was a value transfer study that can be replaced by customized meta-analyses; and 2) the service is more accurately described as Water Filtration and would have double-counted benefits with the proposed studies. Burke (2009),[319] Grabowski et al. (2012),[320] Newell et al. (2005),[321] and Pollack et al. (2013)[322] were removed and are now located in the new land cover type, Shellfish Reefs, and recharacterized as a Water Filtration ecosystem service.

Inland Wetlands

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Mahan (1997)	10,106
Aesthetic Value	Qui et al. (2006)	251
Aesthetic Value	Qui et al. (2006)	1,230
Aesthetic Value	Thibodeau & Ostro (1981)	37
Aesthetic Value	Thibodeau & Ostro (1981)	118
Climate Regulation	Smith et al. (2006)	136
Nutrient Cycling	Jenkins et al. (2010)	536

* All values are presented in 2014 USD

Discussion: For Aesthetic Value, we removed all the relevant inland wetlands studies used in the 2016 policy and proposed replacing them with a customized meta-analysis. This is justified for several reasons: two of these studies—Mahan (1997)[323] and Thibodau & Ostro (1981)[324]—used data that is more than two decades old, and Qiu & Prato (2006)[325] studied ecosystems that are better suited for the Riparian land cover type. For Climate Regulation, we removed one study from the value calculation—Smith et al. 2006[326]—as more recent studies relevant to wetlands were found. The study used for Nutrient Cycling was removed for two reasons: 1) it was a value transfer study that can be replaced by customized meta-analyses; and 2) the service is more accurately described as Water Filtration and would have double-counted benefits with the proposed studies.

Urban Green Open Space

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Mahan (1997)	10,106
Aesthetic Value	Bolitzer & Netusil (2000)	2,101
Aesthetic Value	Qui & Boehm (2006)	1,707
Air Quality	McPherson et al. (1998)	31
Air Quality	Wilson (2008)	160
Climate Regulation	Smith et al. (2006)	61
Recreation/Tourism	Costanza et al. (2006)	3,087

* All values are presented in 2014 USD

Discussion: For Aesthetic Value, two studies were removed from the 2016 Policy values. Bolitzer & Netusil (2000)[327] was replaced with a newer study which uses the same data, and Qiu et al. (2006)[328] was replaced with the newer studies that represent land cover types more relevant to the urban green open space category. For Air Quality, two studies were removed from the 2016 Policy values. Wilson (2008)[329] is a secondary study that was replaced with the more relevant primary studies included above. McPherson et al. (1998)[330] was replaced with newer studies that represent land cover types more relevant to the urban green open space category. For Climate Regulation, one study was removed from the 2016 Policy values. Smith et al. (2006)[331] was replaced with studies representing land cover types more relevant to the urban green open space category. For Recreation/Tourism, one study was removed from the 2016 Policy values. Costanza et al. (2006) is a secondary study that was replaced with the more relevant primary study and meta-analysis included above.[332]

Rural Green Open Space

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Aesthetic Value	Qui et al. (2006)	1,707
Air Quality	Wilson (2008)	160
Climate Regulation	Smith et al. (2006)	61
Recreation/Tourism	Breffle et al. (1998)	18,922
Recreation/Tourism	Butler & Workman (1993)	1
Recreation/Tourism	Costanza et al. (2006)	3,087
Recreation/Tourism	Ready et al. (1997)	1
Flood Hazard Risk Reduction	Trust for Public Land (2010)	163
Flood Hazard Risk Reduction	Trust for Public Land (2011)	423

* All values are presented in 2014 USD

Discussion: For Aesthetic Value, one study was removed from the 2016 Policy values. Qiu et al. (2006)[333] was replaced with the newer studies that represent land cover types more relevant to the rural green open space category. For Air Quality, one study was removed from the 2016 Policy values. Wilson (2008)[334] is a secondary study that was replaced with the more relevant primary studies included above. Another study was considered[335]; however, the per-acre value estimated was too insignificant to include ($0.20/acre). For Climate Regulation, one study was removed from the 2016 Policy values. Smith et al. (2006) was replaced with studies representing land cover types more relevant to the rural green space category.[336] For Recreation/Tourism, four studies were removed from the 2016 Policy values. These were either secondary value transfer studies—Costanza et al. (2006)[337]—or dated and too site-specific and could be replaced with a customized function transfer value for the U.S.—Butler & Workman (1993),[338] Ready et al. (1997),[339] and Breffle et al. (1997).[340] Since Green Open Space was split into two land cover types describing urban and rural contexts, the flood hazard risk reduction from the original green open space land cover was not used for rural green open space, as the studies making up this value are from highly urbanized cities.

Riparian

Ecosystem Service	Source Study Added	Value Added ($/acre/year)*
Climate Regulation	Smith et al. (2006)	153

* All values are presented in 2014 USD

Discussion: For Climate Regulation, one study was replaced from the value sets that FEMA adopted for the 2016 environmental benefits policy. Smith et al. (2006)[341] was replaced by Hoover et al. (2021), which represents an update of the older report produced by the Forest Service.

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