Nature's Value in Sonoma County

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Participating Agencies

- Sonoma County Agricultural Preservation and Open Space District
- Resource Conservation District of Santa Cruz County
- Santa Clara Valley Open Space Authority

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EARTH ECONOMICS

Contents

The Healthy Lands & Healthy Economies Initiative

In 2012, the *Healthy Lands & Healthy Economies: Demonstrating the Economic Value of Natural Areas and Working Landscapes Initiative (Healthy Lands & Healthy Economies)* was undertaken as the first-ever economic valuation of natural capital (and related conservation efforts) in three counties in California: Santa Cruz, Santa Clara, and Sonoma. Led by the Resource Conservation District of Santa Cruz County, the Santa Clara Valley Open Space Authority, and the Sonoma County Agricultural Preservation and Open Space District, *Healthy Lands & Healthy Economies* partnered with Earth Economics and *Alnus* Ecological to describe the economic value and community benefits of the unique landscapes of these three counties and their stewardship activities.

Healthy Lands & Healthy Economies began with the following questions:

1. What goods and services are provided by different landscapes within each County, and who are the beneficiaries?
2. What is the economic value provided by these services to the local communities, region, and state? What is the return on investment of conservation projects that protect and enhance these services?
3. What are the roadblocks to developing cost- effective and multi-benefit conservation actions in the project areas and beyond? What solutions are possible?
4. What are innovative, sound financing mechanisms for conservation of natural areas and working landscapes?

The ecosystem service valuation reports for these three counties represent a starting point for answering these questions. Healthy Lands & Healthy Economies aligns with state, regional, and local efforts that are both currently underway and expected to come on-line in the foreseeable future to more effectively measure, manage, and finance natural capital.

This study, ***Nature's Value in Sonoma County***, represents a broad screening-level appraisal of Sonoma County's natural capital assets. The study calculates the overall economic value of natural capital in the County, and is supported by local case studies to quantify and demonstrate how conservation and stewardship actions benefit the local economy.

The *Healthy Lands & Healthy Economies Initiative* is scoping additional studies to provide finer resolution and local analyses of various conservation efforts and the economic value they create in our local, regional, and state economies. Many of these studies will focus on the linkage between terrestrial land-use/land-management and the ecosystem services of groundwater recharge, water purification, and/or water storage. These studies will create a framework for natural capital economic analysis at the asset, project, and county scales. This framework could easily be applied at the state and national scales.

How to Use this Report

Assessing the economic value of landscapes and ecosystem services is challenging. The values presented in this report represent a conservative starting point for understanding and measuring the substantial value of Sonoma's extensive natural assets. Further research and data gathering both locally and around the world will help to fill gaps and improve our understanding of the full value of the region's natural capital and its complex interactions with the local economy.

The study takes a three-step process to estimate the ecosystem service values. First, the county's natural capital assets are identified and classified by land cover type; forest, wetland, etc. Second, each land cover is evaluated to identify the ecosystem services it produces in support of the local economy. Finally, an annual economic contribution value in dollars is assigned to each ecosystem service/land cover combination. The sum of these values provides the total annual economic contribution of ecosystem services to the local economy.

Importantly, several values are not included in these calculations. Many ecosystem services, such as genetic diversity or place-based cultural significance, have tremendous *intrinsic* value to society or specific communities, but remain difficult to estimate using dollars. This study does not attempt to capture the intrinsic or symbolic values of landscapes and ecosystems, and it recognizes that there are other approaches and non-monetary methods for describing their value and making decisions based on those criteria.[1,2,3]

In addition, this study does not incorporate the *market values* of goods and services that are already monetized, traded, and regularly analyzed in traditional economic analyses. For example, the market values of commercial crops (i.e. wine grapes, milk, or poultry), which are already reported in the Sonoma County Crop Report, represent the value of labor and capital inputs required to grow those crops rather than the ecosystem services contributed. The dollar values in this study represent the contributions of nature to these goods and services before they enter the market economy.

With better data and emerging valuation methods, it is very likely that the values here represent only a fraction of nature's true contribution to the economy. Even in this early stage, these values can immediately be used to educate stakeholders, improve decision-making, and structure funding mechanisms. Here are some specific opportunities to apply these results:

Educating the public and policy-makers

For many decades, nature has largely been assumed to provide 'free' services to the local economy. However, whether through supplying water or carrying away waste products, nature provides critical services. Because we have come from a time of natural resource abundance, people and their accounting systems have valued these services at zero. This view is starting to change, and the values in this report can be used to convey a clear and detailed message that nature is critical to the economy and does indeed have a dollar value. This message is the first step in changing policy and practice.

Estimating economic rates-of-return for conservation projects

The spatial data, economic values, and methods described in this report can be used to estimate a rate of return on conservation investments such as easements, open space acquisitions, and stewardship/restoration activities. In the correct context, these values can also be applied to the economic analysis of projects included in Integrated Regional Water Management Grant applications.

Assessing economic impacts of local disasters

In the event of a flood disaster such as Sonoma's 2006 New Year's flood, California, Sonoma County, and city officials can apply the ecosystem service values calculated here in place of the general Benefit-Cost Analysis values found in FEMA's disaster mitigation toolkit to secure more appropriate post-disaster flood mitigation funding.

Scaling investments in natural capital to the size of the asset

Combining an understanding of the scale of natural capital asset value in Sonoma County with an understanding of the potential return on natural capital investment can be used to inform future investments and determine the appropriate scale of conservation activities.

Encouraging investment in natural capital and its stewardship

The information in this report can incentivize and enable private and public investment in natural capital stewardship. Values can be used to show how payments for ecosystem services or investment in natural assets (including those by the Sonoma County Agricultural Preservation and Open Space District) can support jobs, conserve biodiversity, build resiliency, and provide high returns on that investment to a broad spectrum of beneficiaries.

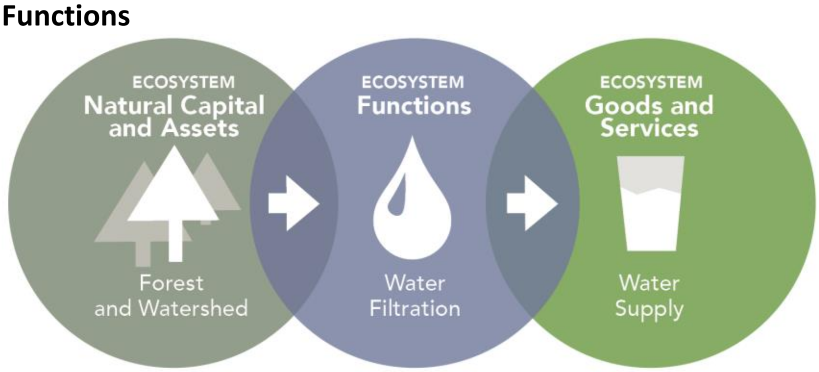
A Primer on Natural Capital: Ecosystem Goods and Services

What is Natural Capital?

Economies depend upon built, natural, and human capital. Built capital consists of cars, houses, infrastructure, machinery, computers, and all of the other "tangible systems that humans design, build and use for productive purposes".[4] All built capital is created from a combination of natural capital and human capital. It is composed of energy and materials from nature. Natural capital consists of the "minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles and other natural structures and systems] found on Earth that provide a flow of natural goods and services".[5] Human capital consists of people, their education, health, skills, labor, knowledge, and talents.[a]

Just like other forms of capital, natural capital also provides a flow of goods and services. **These ecosystem goods and services are defined as the benefits people derive from nature**. The natural capital assets of different ecosystems (e.g. forests or wetlands) within a watershed perform critical functions (such as intercepting rainfall and filtering water) and provide goods and services that humans need to survive. In fact, ecosystem goods and services provide the basis of all economic activity through a clean water supply, breathable air, nourishing food, flood risk reduction, waste treatment, and a stable climate. Without natural capital, many of the services (benefits) that we often take for granted (and receive for free) could not exist, or would need to be replaced at a very high cost. Figure 1 illustrates the relationship between natural capital assets, ecosystem functions, and the production of ecosystem goods and services.

Figure 1 - Ecosystem Goods and Services Flow from Natural Capital Assets and Ecosystem Functions



[a] This report does not discuss the importance of human capital. However, people's health and well-being, as well as their work and enjoyment, are closely tied to the built and natural capital around them and are deeply intertwined with economic prosperity.

A Framework for Assessing Ecosystem Services

In 2001, an international coalition of over 1,360 scientists and experts from the United Nations Environmental Program, the World Bank, and the World Resources Institute 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."[6] This study produced the landmark Millennium Ecosystem Assessment, which classifies ecosystem services into four broad categories according to how they benefit humans.

Ecosystem services, which are broadly defined in Table 1, can be categorized as follows:

- **Provisioning services** provide physical materials that society uses. Forests provide timber. Agricultural lands grow food. Rivers provide drinking water as well as fish for food.

- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Ecosystems regulate processes such as climate, water quality and delivery timing, and soil erosion or accumulation. Balanced ecosystems can keep disease organisms in check, whereas degraded systems propagate disease organisms, to the detriment of human health.

- **Supporting services** include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.

- **Cultural services** are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Table 1 - Ecosystem Goods and Services

Good/Service	Economic Benefit to People
Provisioning Services	
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Water Supply	Provisioning of surface and groundwater for drinking water, irrigation, and industrial use

Regulating Services	
Biological Control	Providing pest and disease control
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes
Air Quality	Providing clean, breathable air
Moderation of Extreme Events	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
Pollination	Pollination of wild and domestic plant species
Soil Formation	Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Waste Treatment	Improving soil, water, and air quality by decomposing human and animal waste and removing pollutants
Water Regulation	Providing natural irrigation, drainage, groundwater recharge, river flows, and navigation
Supporting Services	
Habitat and Nursery	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested spp.
Genetic Resources	Improving crop and livestock resistance to pathogens and pests
Cultural Services	
Natural Beauty	Enjoying and appreciating the scenery, sounds, and smells of nature
Cultural and Artistic Inspiration	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities
Science and Education	Using natural systems for education and scientific research
Spiritual and Historical	Using nature for religious and spiritual purposes

Source: Adapted from de Groot et al., 2002 and Sukhdev et al., 2010

The following sections provide more detailed descriptions of several examples of ecosystem services in Sonoma County.

Food

Providing food is one of the most important functions of an ecosystem. Agricultural lands are our primary source of food; farms are considered modified ecosystems, and food is considered an ecosystem good with inputs from humans and built capital. Agricultural lands both produce and depend on ecosystem services. Agricultural production depends on healthy soil, pollinators, a consistent water supply, and a stable climate. With these natural inputs, agricultural lands produce food and can also support a suite of other services, including groundwater recharge, carbon sequestration, flood risk reduction, biodiversity, and aesthetic value.

The dollar values of agricultural crops are not included in this study because they are already counted in the market economy, and because these values also depend on significant human inputs (labor, machinery etc.). However, this study does identify and value many of the non-market co-benefits that can be produced on agricultural lands in addition to food.

Water Supply

Watersheds provide fresh water for human consumption, agricultural production, and manufacturing. This service includes surface water and groundwater, both of which supply metropolitan areas, wells, industrial uses, and irrigation. The hydrological cycle is affected by structural elements of a watershed such as vegetation, soils, and geology, as well as processes such as evapotranspiration (the natural absorption of water into the atmosphere), percolation, and climate variability.

Climate Stability

Ecosystems help to regulate atmospheric chemistry, air quality, and climate. This process is facilitated by the capture and long-term storage of carbon as a part of the global carbon cycle. Forests, woodlands, and grasslands play essential roles in absorbing carbon and contributing oxygen to the atmosphere.

Moderation of Extreme Events

Wetlands, grasslands, riparian buffers, and forests all provide protection from flooding and other disturbances. These ecosystems are able to slow, absorb, and store large amounts of rainwater and runoff during storms. Changes in land use and the potential for more frequent storm events due to climate change make moderation of extreme events one of the most important services to economic development. Built structures in floodplains, such as houses, factories, and wastewater treatment plants, all depend on the flood protection services provided upstream. The retention of natural, permeable cover and the restoration of floodplains and wetlands contribute to flood risk reduction in these areas. Enhanced flood and storm protection can reduce the devastating effects of floods including property damage, lost work time, and human casualties.

Pollination

Pollination supports wild and cultivated plants and plays a critical role in ecosystem productivity. Many plant species, and the animals that rely on them for food, would go extinct without animal- and insect-mediated pollination. Pollination services contribute to crop productivity for many types of cultivated foods, enhancing the basic efficiency and economic value of agriculture.[7] The loss of forests, riparian areas, and shrubs reduces habitat and the capacity of wild pollinators to perform this service.

Recreation and Tourism

Attractive landscapes, clean water, and fish and wildlife populations form the basis of the recreation economy, which supports 6.1 million jobs in the United States and generates $646 billion in direct spending each year.[8] Tourism and recreation are often tied to the aesthetic values of open space and natural areas. Recreational fishing, swimming, bird watching, and hunting are all activities that can be enhanced by ecosystem services. Ecosystem goods like wildlife and clean water attract people to engage in recreational activities and can also increase property values and attractiveness for business.[9]

The Importance of Valuing and Accounting for Ecosystem Services and Natural Capital

In 1930, the United States lacked measures of Gross Domestic Product (GDP), unemployment, inflation, consumer spending, and money supply. Benefit-cost analysis and rate of return calculations were initiated after the 1930s to examine and compare investments in built capital assets such as roads, power plants, factories, and dams. Without these basic economic measures, decision-makers were blind, but these measures are now taken for granted and they help guide investment at an enormous scale in today's economy. Just as understanding the condition, production capacity, and value of built assets was important to economic progress in the 1900s, so too can valuing and accounting for natural capital assets and the ecosystem services they provide better inform investments in the 21st century.

The benefits of ecosystem goods and services are similar to the economic benefits typically valued in the economy, such as the services and outputs of skilled workers, buildings and infrastructure. Many ecosystem goods, such as salmon, strawberries, and water, are already valued and sold in markets. However, some ecosystem services, such as flood protection and climate stability, are not amenable to markets and have not been traditionally valued, even though they provide significant economic value. For example, when the flood protection services of a watershed are lost, economic damages include job losses, infrastructure repairs, reconstruction and restoration costs, and property damage.

Conversely, when investments are made to protect and support these services, local economies are more stable and less prone to the sudden need for burdensome expenditures on disaster mitigation. For example, during Superstorm Sandy, New York City's Catskills Watershed provided naturally filtered, clean, gravity-fed water with virtually no interruption in service. Previous efforts to protect and restore the watershed played a role in minimizing disruption. In contrast, New Jersey's damaged pumps, filtration plants, and contaminated intakes left much of New Jersey without potable water for weeks after the storm, and with a $2.6 billion tab for water infrastructure repair.[10,11,12] In addition to the economic value associated with these avoided costs, healthy watersheds provide a myriad of other services including water supply, carbon sequestration, water filtration, and biodiversity.

Today, economic methods are available to value natural capital and many non-market ecosystem services. When valued in dollars, these services can be incorporated into a number of economic tools, including benefit-cost analysis, accounting, environmental impact statements, asset management plans, conservation prioritization, and return on investment calculations. Inclusion of these values strengthens decision-making. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued as zero, which can lead to inefficient capital investments, higher incurred costs, and poor asset management.[13,b] Many conservation investments provide high rates of return, and demonstrating the potential for high returns on conservation investments can lead to more efficient capital investments and reduce incurred costs.[14,15]

Policy Applications of Ecosystem Services

The practice of natural capital valuation is quickly becoming more common and accepted in addressing significant, complex policy issues. As an example, Earth Economics conducted an economic assessment of the damages to natural capital caused by California's third largest fire on record, the 2013 Rim Fire.[16] After FEMA initially rejected California's application for a Major Disaster Declaration, Governor Jerry Brown appealed the decision, submitting an appeal package to FEMA and President Obama that included the analysis of impacts to natural capital and ecosystem services that evidenced significantly greater damage.[17] The appeal was granted, providing more than $21 million in federal disaster assistance to Tuolumne County, San Francisco Public Utilities Commission (SFPUC), the State of California, and affected businesses and citizens.[18] Alison Anja Kastama, a spokeswoman for the SFPUC, noted that the inclusion of a natural capital valuation report in Governor Brown's appeal package "supports the recognition of natural capital values…by assessing the impacts of the Rim Fire, this report highlights the greater dollar value we can assign to our natural lands, which are a critical portion of our water system".[19]

The value of natural capital will be increasingly reflected on the official balance sheets of water agencies and private companies. SFPUC took the first step toward accounting for its natural capital by discussing the value of its watersheds in the Transmittal Letter of its FY2012–2013 Comprehensive Annual Financial Report. Other utilities can also take this step immediately.

Advancements in bond disclosures regarding natural capital will provide information on risk and resiliency to bond purchasers. This may lower interest rates for many government, utility, and private bonds where natural capital is healthy, and raise rates where natural capital is degraded and risk is greater.

The private sector and public agencies are formally recognizing the critical importance of including ecosystem service concepts and valuation in planning, management, and decision-making. For example:

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[b] The same is true when *built* assets are not considered in economic analysis or asset management. See for example Grubisic, M., Nusinovic, M., Roje, G., 2009. Towards efficient public sector asset management. Financial Theory and Practice 33, 329-362. Available at: http://www.fintp.hr/en/archive/towards-efficient-public-sector-asset-management_283/

1. On October 7 2015, the White House released a new memorandum that directs Federal agencies "to factor the value of ecosystem services into Federal planning and decision-making."

2. The United States Federal Emergency Management Agency (FEMA) became the first federal agency to adopt ecosystem service valuation in formal policy. Faced with rising natural disaster costs and climate uncertainty, FEMA approved Mitigation Policy FP-108-024-01 in June of 2013,[20] which allows the inclusion of ecosystem services in benefit-cost analysis for acquisition projects. This policy is being applied to all flood and hurricane disaster mitigation in all 50 states, for all private residential, business, public utility, city, county, and state impacted infrastructure. Under this policy, FEMA applies ecosystem service values nationwide. See Box 1 below for more detail.

3. The State of California has also been a leader in the recognition and valuation of ecosystem services. In 2008, the California Department of Water Resources (DWR) published an Economic Analysis Guidebook that included a chapter describing valuation methods and monetization strategies for ecosystem service valuation.[21] In 2012, the North Bay Watershed Association commissioned a *Handbook for Estimating Economic Benefits of Environmental Projects*.[22] The Handbook provides guidance on how to value and incorporate ecosystem services into benefit-cost analysis for applications for DWR grants, specifically those that support Integrated Regional Water Management Program goals (funded through measures such as Proposition 84 and 1E). The Handbook, along with this study, supports the efforts of agencies like the DWR by providing federally accepted methods for valuing ecosystem services and appropriate values that local agencies in Sonoma County and the Bay Area can use to inform analysis or justification of projects that protect natural capital.

4. The United States Department of Agriculture (USDA) has long recognized the value of a healthy environment and active stewardship, providing incentives to landowners through such programs as the Conservation Reserve Program, the Environmental Quality Incentives Program, and others. More recently, the Office of Environmental Markets (OEM) was established within the USDA in response to the Food, Conservation, and Energy Act of 2008 (the "2008 Farm Bill"). One of the OEM's primary stated goals is "…to build a market-based system for quantifying, registering, and verifying environmental benefits produced by land management activities".[23] The OEM's website currently includes a number of resources and case studies on environmental markets such as water quality, carbon, and biodiversity & habitat.

5. Public agencies in the United States are exploring methods to incorporate natural capital assets into their traditional accounting systems. A coalition of water utilities, including the San Francisco Public Utilities Commission (SFPUC), has been working to reach out to the

Governmental Accounting Standards Board[c] and demonstrate the need for natural capital accounting standards, especially for water utilities, whose business model depends on healthy watersheds. Currently, natural capital only shows up for bare land or timber value. The SFPUC noted in its most recent Comprehensive Annual Financial Report that "Current financial accounting standards, relying solely on historical costs, do not take into sufficient consideration the value of the watersheds and natural resources that are part of our regional water system".[24] SFPUC further notes that of $5 billion in total assets, their most important asset – the watershed that filters and delivers water for 2.5 million people – is reflected on their books for only $28 million.

6. The private sector has also begun to utilize ecosystem services to better understand the environmental impacts of corporate decisions. The sportswear company PUMA was the first private company to include environmental and ecosystem service impacts in its Environmental Profit and Loss Account, released in 2011.[25]

Box 1: Reducing Harm, Saving Lives, and Saving Taxpayer Money: Valuing Ecosystem Services in Federal Benefit-Cost Analysis

Like other federal agencies, FEMA uses benefit-cost analysis (BCA) to determine where to invest its resources for the greatest benefits relative to taxpayer cost. FEMA's BCA Toolkit is a software package used for measuring the cost-effectiveness of disaster recovery projects eligible for funding through the agency's hazard mitigation program (such as assisting home and business owners to rebuild). However, the previous FEMA BCA Toolkit did not value floodplain lands (subject to buyout) for their flood risk reduction value. Floodplain lands reduce flood risk on other properties by storing and/or better conveying floodwaters. They also protect water quality, reduce sedimentation, provide recreation, and secure other economic benefits. The reality of larger and more frequent floods and hurricanes, with historically low flood insurance rates, has contributed to rebuilding in disaster-prone areas. As a result of recurring flood and hurricane damage payments, the National Flood Insurance Program has accumulated $24 billion of debt.[26] FEMA has moved aggressively to correct these problems and lower costs by working to reduce and eliminate repetitive flood and hurricane damage that results in increased public and private costs.

In 2012, Earth Economics provided FEMA with 17 ecosystem service values for inclusion in the updated FEMA BCA Tool. Both FEMA staff and an expert panel reviewed the values.. The values were tested on past flood applications and were found to improve decision-making, reduce repetitive damage, protect human life, and lower disaster expenditures. By valuing

[c] The Governmental Accounting Standards Board (GASB) sets accounting standards for state and local government in the US, including state agencies, counties, municipal water utilities, public utility districts, and universities. See http://www.gasb.org/ for more information.

flood protection benefits of restored floodplains, for example, FEMA has the economic tools to better spend mitigation funds to relocate, rather than rebuild, structures in areas that experience frequent flood or hurricane damage. These values were approved for use beginning in 2013. Realizing the potential savings to taxpayers, homeowners, and businesses, FEMA also adopted these values for its portion of the $59 billion of mitigation and recovery funds allocated for Hurricane Sandy.

A Countywide Appraisal of Natural Capital in Sonoma County

Monetizing Ecosystem Goods and Services

The economic goods and services produced in a region can be quantified to provide a view of the region's economy. The value of these economic goods and services, from housing to industry, is typically estimated with market or appraisal values. Similarly, the value of the natural capital of Sonoma County – and the ecosystem goods and services it provides – can be quantified as an appraisal. Each land cover type, from wetlands to forests to agricultural lands, provides a suite of ecosystem goods and services. For example, the goods provided by redwood forests in Sonoma County include timber for construction and wild mushrooms for nutrition; services include groundwater recharge (through interception and percolation of rainwater), carbon sequestration, recreational opportunities such as hiking and camping, and the removal of air pollutants such as $S0_2$ and particulate matter. Some of these ecosystem goods and services are counted in the market, but many are not. The identification and monetary valuation of these ecosystem goods and services provides insight into the economic importance of the County's natural capital – which has previously received a default value of zero. There are several methods to estimate (directly or indirectly) the monetary value of ecosystem goods and services in a particular geographic location. This study utilized a valuation method called *Benefit Transfer* to estimate the economic value of ecosystem services produced in Sonoma County.

Sonoma County's Natural Capital Valuation: Findings and Methods

This chapter provides a brief summary of valuation results and findings followed by a detailed description of the methods used, with explanations of the assumptions and limitations of this valuation and tables presenting aggregate ecosystem service values per land cover type.

Valuation Results at a Glance

Countywide Appraisal: Annual Economic Flow of Benefits

Sonoma County's landscapes and ecosystems provide between **$2.2 and $6.8 billion** in benefits each year (detailed valuation results by land cover type are presented in Table 8). These "big numbers" are important because they indicate that investments in open space can provide vast, long-term benefits when these assets are conserved or enhanced. Conversely, the numbers suggest that loss or deterioration of open space and natural assets that produce ecosystem services can result in costs to the Sonoma County economy. Moreover, investment in natural capital can yield very high rates of return because of the low cost of investment relative to building new infrastructure assets and because natural capital typically supports a suite of ecosystem services and benefits (not just a single benefit).

Asset Value of Natural Capital in Sonoma County

In addition to the annual flow of ecosystem service benefits detailed in Table 8, these economic data were used to calculate an *asset value* for the County's natural capital. Specifically, the value was calculated as the net present value of its expected future benefits (or future flows of ecosystem services).[d] An asset calculation is useful for revealing the scope and scale of the economic value that Sonoma County's natural systems hold.

Table 9 shows the results of this analysis. Treated with a 3.5 percent discount rate, the total asset value of natural capital in Sonoma County is between $60 and $188 billion. Treated as an asset that provides the same value across time (i.e. zero percent discount rate over 100 years), natural capital yields an asset value range of $217 to $677 billion.

Table 2 - Net Present Value of Sonoma County's Natural Capital

Discount Rate	Low Estimate	High Estimate
0% (100 years)	$217 billion	$677 billion
3.5% (100 years)	$60 billion	$188 billion

The significance of these annual economic benefits and asset values is better realized when compared with other revenue streams and asset values in the County. Figure 2 shows the value of annual ecosystem service benefits in comparison with total agricultural production in Sonoma County, as well as the annual budgets for the County. Figure 3 compares the asset value of natural capital in Sonoma with the assessed value of all taxable property (land, houses, buildings etc.) as estimated by the County Assessor, as well as the large Silicon Valley tech company IBM. The assessed value of property represents the "asset value" of the County's built environment, which, like natural capital, provides a flow of annual value to people (as reflected through the annual rent or mortgage payments that people make).[e]

Figure 2- Annual Value of Ecosystem Services in Sonoma County Relative to Other Revenue

[d] This approach is analogous to an "income capitalization" approach for a business valuation (i.e. the value of a business is estimated as the net present value of its expected future income).

[e] This statement requires several caveats: 1) The values used to represent Sonoma County's natural capital assets and its built capital assets are calculated through two different methods, though both are valid; 2) Many of the county's most valuable built assets, such as public infrastructure, are not assessed for taxation purposes, so the Assessed Value of Property and Structures underestimates the true value of the built landscape; 3) The actual "market value" of property in Sonoma County is likely to be significantly higher than its assessed value due to the passage of Proposition 13 in 1978, which limits increases to the assessed value.

Streams[f]

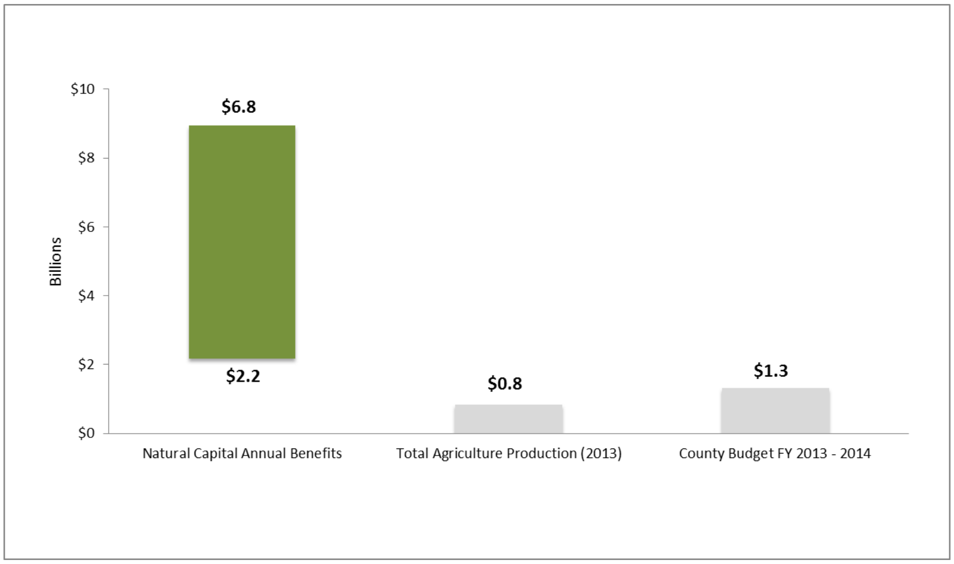
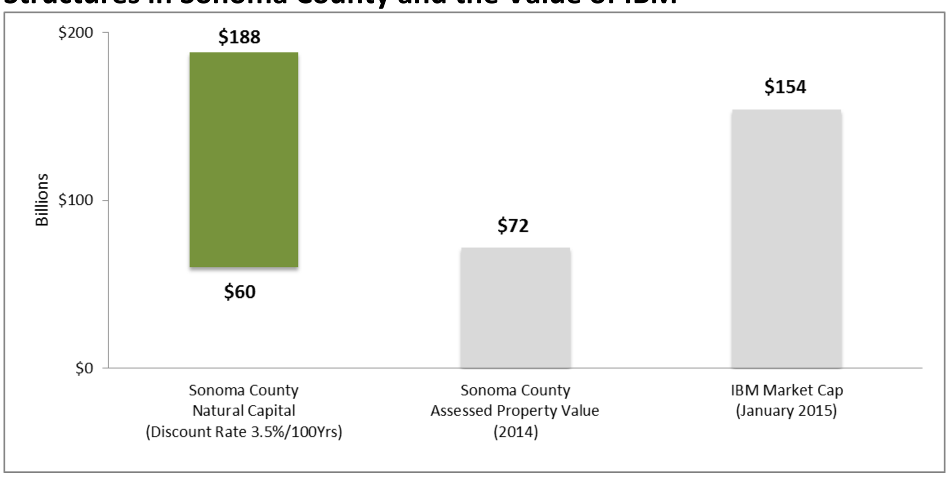


Figure 3 - Natural Capital Asset Value Ranges Relative to the Value of Assessed Property and Structures in Sonoma County and the Value of IBM[g]



Because this valuation does not include all ecosystem goods and services, it is likely an underestimate; yet even this conservative estimation demonstrates the substantial asset value of the natural capital of Sonoma County. The following sections discuss the valuation methods used to estimate these numbers in detail.

[f] Sources for data: Total Agricultural Production: County of Sonoma, Office of the Agricultural Commissioner, 2014; County Budget: County of Sonoma, 2013.
[g] Sources for data: Sonoma County Assessed Value of Property and Structures: Sonoma County Clerk-Recorder-Assessor, 2014; IBM Market Capitalization:

Benefit Transfer Methodology

Benefit Transfer is a validated and well-established methodology that estimates the value of ecological goods or services by utilizing previous valuation studies (primary studies) of similar goods or services in comparable locations.[27] The value transfer process begins by establishing a comparable land cover classification between the primary studies to be used and the region or ecosystems to be valued. Primary studies that have incompatible assumptions or land cover types are excluded. Individual primary study values are then matched to each comparable combination of land cover type and ecosystem service(s) in the area of interest.

As in a house or business appraisal,[h] benefit transfer sums the value of various attributes (e.g. square footage in a house) and establishes the value based on closely related comparable valuations. All valuation appraisals include a degree of uncertainty. A house appraisal will have several comparables that range in value, though a single value is often chosen. In this chapter's valuation, Earth Economics does not select a single value, and instead provides a low to high value range to demonstrate the difference between comparable primary study values.[i]

It is very important to note that the primary studies used in a benefit transfer valuation are conducted across a number of different socioeconomic contexts, biophysical contexts, time periods, and geographic locations, and they use a range of analytic methods. All of these factors can influence the value of the ecosystem service. The values in each primary study therefore contain a number of implicit assumptions related to the supply of- and demand for ecosystem services. For example:

1. How much capacity the ecosystems have for producing the services (e.g. due to the ecosystem's level of health or other factors);
2. Whether the services are actually occurring (e.g. flood protection is only provided when there is a flood);
3. Whether people are benefiting from the services being provided (e.g. a park can only provide recreation if people can access it);
4. How much people are willing and able to pay for those benefits (e.g. some people are willing to pay more for a service because it's more important to them, and/or they have a higher income level).

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[h] Specifically, when a house or business appraisal is using the "sales comparison" method.

[i] Because thousands of houses are sold every day in the US, significantly more historical transactional data exists as compared with ecosystem service valuation studies. Therefore the range of potential values in a house appraisal is generally narrower than for an ecosystem service value range estimate.

These and other factors can influence the correspondence between the primary study site and the benefit transfer study site (Sonoma County). In order to compensate for differences between the primary study site and the benefit transfer study site, methods have been developed to adjust values during the transfer process. These methods include “function transfer” and “meta-analysis”.[j]

The goal of this study was to provide a screening-level valuation of Sonoma County ecosystem services. Due to the large size of Sonoma County, and variety of ecosystems, ecosystem services, and socioeconomic contexts within the county, function transfer methods were not used. Instead, a “unit transfer” approach was taken, and values were not adjusted in any way during the transfer.

Transferring primary study values using a unit transfer approach assumes that supply and demand factors (such as those described above) between the primary study site and Sonoma County are the same, and this assumption can lead to under- or overestimates of the actual value of a service in Sonoma County.

For example, if the recreational value of an acre of evergreen forest in a primary study was based on a study at a moderately popular park, this primary study value would result in an underestimate if applied to an acre of forest at an especially popular park in Sonoma County.

On the other hand, a remote or inaccessible acre of evergreen forest in Sonoma County may have a lower recreational value than our results suggest, simply because people cannot access and enjoy the recreational service. It is recommended that a future benefit transfer study adjust for supply and demand factors to the extent possible.

The next section of this chapter provides details on how primary studies were selected for this valuation. Appendix A contains more detail on the general limitations of benefit transfer.

Benefit transfer is normally used when the expense and time required to conduct primary valuation studies across an entire landscape for multiple ecosystem services are prohibitive. The benefit transfer approach can be completed more quickly and at far less cost, and it serves as a defensible placeholder until local valuations can be conducted. Considering that we have identified 357 potential combinations of land cover types and ecosystem services in Sonoma County (based on the land cover classification and valuation framework employed in this report), it is likely that at least 100-150 primary studies would be required to conduct a fully

[j] For more discussion, see e.g. Rosenberger R.S., Johnston, R.J., 2013. Benefit Transfer. In: Shogren, J.F., (ed.) Encyclopedia of Energy, Natural Resource, and Environmental Economics 3, 327-333. Elsevier, Amsterdam.

original valuation of Sonoma County's natural assets.[k] A single primary study can require upwards of tens of thousands of dollars in research funding and years of effort.

The California Department of Water Resources noted in its 2008 Economic Analysis Guidebook that, "although original studies are preferable to benefit transfer, researchers agree that…benefit transfer can provide a reasonable valuation of non-market values".[28] Benefit transfer is accepted by California state agencies and at the federal level.[29,30] FEMA Mitigation Policy FP-108-024-01 (described earlier) is based on values Earth Economics developed using benefit transfer methodology. Benefit transfer has gained popularity in the last several decades as decision-makers have sought timely and cost-effective ways to value ecosystem services and natural capital.[31]

Selecting Primary Studies

Earth Economics maintains a large and comprehensive database of published, peer-reviewed primary valuation studies and scientific literature for use in benefit transfer.[l] This database contains many primary studies with valuations applicable to Sonoma County. The valuation techniques employed in these studies include market pricing, replacement cost, avoided cost, production approaches, travel cost, hedonic pricing, and contingent valuation. These techniques have been developed and vetted within environmental and natural resource economics communities over the last four decades. Earth Economics used several criteria to select appropriate primary study values for Sonoma County, including geographic location, demographic characteristics, and ecological characteristics of the primary study site. Table 3 provides descriptions of primary valuation techniques, examples of how specific studies have employed them, and how Earth Economics applied them to this valuation.

[k] Typically, a single primary study will value one (or a few) ecosystem service(s) on a particular landscape or vegetation type ("land cover type"). For example, a study might value the recreational value of redwood forests. As shown in Table 5 in this chapter, each combination of land cover type and ecosystem service represents a potential primary study. With 17 land cover types in Sonoma County that are known to provide ecosystem services, and up to 21 ecosystem services provided on each land cover type, this represents up to (17 x 21 =) 357 potential combinations/primary studies.

[l] Earth Economics Ecosystem Valuation Toolkit (EVT). More information available at www.esvaluation.org.

Table 3 - Ecosystem Service Valuation Methods and Their Application in Primary Studies Used for Sonoma County's Valuation

Revealed-preference approaches

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

The total agricultural production of Sonoma County could be used as the value for the Food ecosystem service. As noted in Chapter 2, this value is not included as part of our Benefit Transfer because 1) It is already counted in the market economy; and 2) The market price of food includes significant human inputs in addition to natural capital (e.g. labor, machinery) and would therefore overstate the value contributed by nature alone.

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

In Wade et al. (1989), the authors calculate the recreational benefits of 83 fresh lakes and reservoirs in California, estimating ecosystem service values for boating, fishing, and swimming. The model is a gravity travel cost model, which utilizes data from surveys on recreational preferences, demographic information, and data on the recreation sites themselves. After calculating a demand function with coefficients including travel cost, boat lanes, fish yield, and parking availability, dollar value benefits are estimated. The results of the model are presented as Total Benefits (in dollar terms) for each reservoir. To utilize these values in benefit transfer, we establish a range by taking the lowest and highest total reservoir values and then dividing by reservoir size.

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

Mahan (1997), prepared for the U.S. Army Corps of Engineers, values several wetland types and their effect on residential property values in Portland, Oregon. Their findings show that wetlands have a significant influence on nearby residential property values; different types of wetlands have significantly different marginal implicit prices; and wetlands and non-wetland greenspaces (e.g. public parks, lakes, or rivers) have significantly different marginal implicit prices. They utilize the hedonic price method which assumes that a consumer will price attributes embodied in a good (in this case residential property) and that these implicit prices can be disaggregated by evaluating the variability among different properties. The first step is to calculate a price function that relates the price of a property to several variables including distance to four wetland types. The authors then are able to estimate a willingness-to-pay function for different wetland types and sizes. Using their results, we calculate an annual per acre value by taking the average willingness to pay per acre of wetland and multiplying it by the number of property sales per year in the study area.

Production approaches: Service values are assigned from the impacts of those services on economic outputs. *Example: Improvement in watershed health leads to an increase in commercial and recreational salmon catch; hence the commercial value of salmon catch can be used as a proxy for the value of ecosystem services supporting salmon availability.*

Knowler et al. (2003) utilizes a production function approach by specifying a full bio-economic model of a coho fishery in British Columbia. The authors estimate the net social benefits available from the fishery assuming that it is optimally managed. The model parameters include the ocean survival rate for coho, stream habitat quality, the cost of fishing, the commercial price of salmon, and a social discount rate. They estimate the value of changing the quality of fish habitat by using empirical analyses to link fish population dynamics with indices of land use in surrounding watersheds. This allows the authors to estimate habitat ecosystem service values at different levels of degradation, which they express as a net present value per kilometer of stream length at a 5% discount rate. This length-based value (i.e. $/km of stream) was then converted to an annual area-based value ($/acre/year).

Cost-based approaches

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

Using field data from eight U.S. cities, Nowak et al. (2002) estimates the total compensatory value of tree populations to range from $101 million in Jersey City, NJ, to $5.2 billion in New York, NY (with values in Californian cities falling within this range). Compensatory value is defined as the compensation to owners for the loss of an individual tree, and can be seen as a valuation of trees as a property asset. These values are calculated based on standard procedure defined by the Council of Tree and Landscape Appraisers and are used to determine monetary settlement for damage or death of trees in litigation and insurance claims. In order to annualize the high and low values, we use the published dollars per square meter of tree cover value. We convert this value to dollars per acre. Finally, we obtain low and high values by amortizing dollars per acre over 19 years and 28 years, low and high estimates for the life span of urban trees.

Avoidance cost: Value of costs avoided or mitigated by ecosystem services that would have been incurred in the absence of those services. *Example: Wetlands buffer the storm surge of a hurricane, reducing damage along the coast. If the wetlands (and their associated hurricane buffering services) are lost, additional costs are incurred during storms as coastal property is damaged.*

Rein (1999) investigates the economics of implementing vegetative buffer strips as a tool to protect water quality from nonpoint pollution. It uses an avoided costs approach to evaluate environmental costs and benefits of implementing vegetative buffer strips (VBS), both to the grower and to society as a whole. The costs of installing a VBS include the loss of potential agriculture profits, VBS maintenance, loss of perennial seeds, and preparation of VBS. Benefits include reduction of herbicide use, limitation of farm damage from soil erosion, and avoided cost of road clearing due to sediment capture. Results indicate a net economic benefit to the grower for installing vegetative buffer strips within the first year, if the economic costs of erosion are considered. We attribute benefits to various ecosystem services including soil erosion control, water quality, recreation, and biological control. Benefits are expressed annually for a 1-acre VBS. Therefore, the only conversion necessary for benefit transfer is to adjust for inflation.

Stated-preference approaches

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

Colby and Smith-Incer (2005) measure willingness to pay for preservation and visitor expenditures in the Kern River Preserve (California), where a large number of recreational activities take place. The authors conduct a contingent valuation survey that asks for donations to promote water conservation in order to prevent streamflows from being diminished, which would lead to habitat degradation and reduced numbers and diversity of birds and other wildlife. The results estimate that visitors would be willing to pay roughly $77 per year to preserve the habitat, which is about $500,000 a year based on visitation numbers.

Group valuation: Discourse-based contingent valuation, which is conducted by bringing together a group of stakeholders to discuss values to represent society's willingness to pay. *Example: Government, citizen's groups, and businesses come together to determine the value of an area and the services it provides.*

Conjoint analysis: People are asked to choose or rank different scenarios that differ in their mix of ecosystem services. Also referred to as "conjoint choice," conjoint analysis is similar to contingent valuation. However, rather than asking people to directly state their values, values can be inferred from hypothetical choices that people make. *Example: Choosing among wetlands protection scenarios with differing levels of flood protection and fishery yields.*

Source: Description of valuation methods adapted from Farber et al., 2006

All values included in this analysis were sourced from studies conducted in temperate ecosystems. Where available, ecosystem valuation studies based in Northern California were given preference (10 out of the total 85 studies). Where local studies were not available, ecosystem service valuations conducted within the greater United States were then prioritized. In the cases where no local or national figures were available, suitable studies from countries outside the United States were used (17 out of the total 85 studies, most of which were conducted in Canada). Through this filtering process, Earth Economics ensured that estimates from areas with considerably different ecologies or demographics to Sonoma County were excluded. To use an obvious example, a valuation study that examined the soil retention value of mangroves in the Philippines was excluded due to demographic differences (most importantly income levels), and also because no equivalent land cover type existed in Sonoma County.

Once compiled, all ecosystem service values were then standardized to 2012 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator.[m] Appendix B lists the primary studies used to provide the value transfer estimates. Appendix C is an annotated bibliography that provides more information on each primary study transferred to Sonoma County, including the study's context and valuation methods used.

Assigning Comparable Land Cover Categories to Primary Study Values

Each primary study's ecosystem service value in the database was assigned a land cover category (based on the description of its study area) that was comparable to the land classification used in this valuation. In some cases, this required making the primary study's land cover classification more general (e.g. from a specific plant community to a broader land cover category), in order to enable value transferability from primary study locations in other parts of California and the U.S. to locations in Sonoma County. While grouping specific plant communities into a broader land cover category may sacrifice resolution in the analysis, it can

[m] The calculator is available online at http://www.bls.gov/data/inflation_calculator.htm

be argued that at least in certain cases from both a supply and demand side, many “different” plant communities provide similar levels of ecosystem services. But more importantly, grouping primary studies into broader land cover categories increases the number of primary valuations that can represent ecosystem services for each land cover type in the area of interest. This is similar to home appraisers using the number of rooms to compare house attributes. The rooms themselves are certainly likely to be qualitatively different, but it would be impractical for an appraiser to consider every difference in each room.

Land cover categories provided by The National Oceanic and Atmospheric Administration’s 2006 Coastal Change Analysis Program (C-CAP) Regional Land Cover dataset (NOAA, 2006), shown in Figure 4 and Table 4, were determined to provide the greatest practical resolution of land cover categories necessary for this study’s purposes. These land cover categories allowed Earth Economics to apply a wide range of studies from outside of California to this analysis through careful data review, while remaining valid and representative of the ecology in Sonoma County,

Figure 4 - NOAA's C-CAP Land Cover Classification in Sonoma County

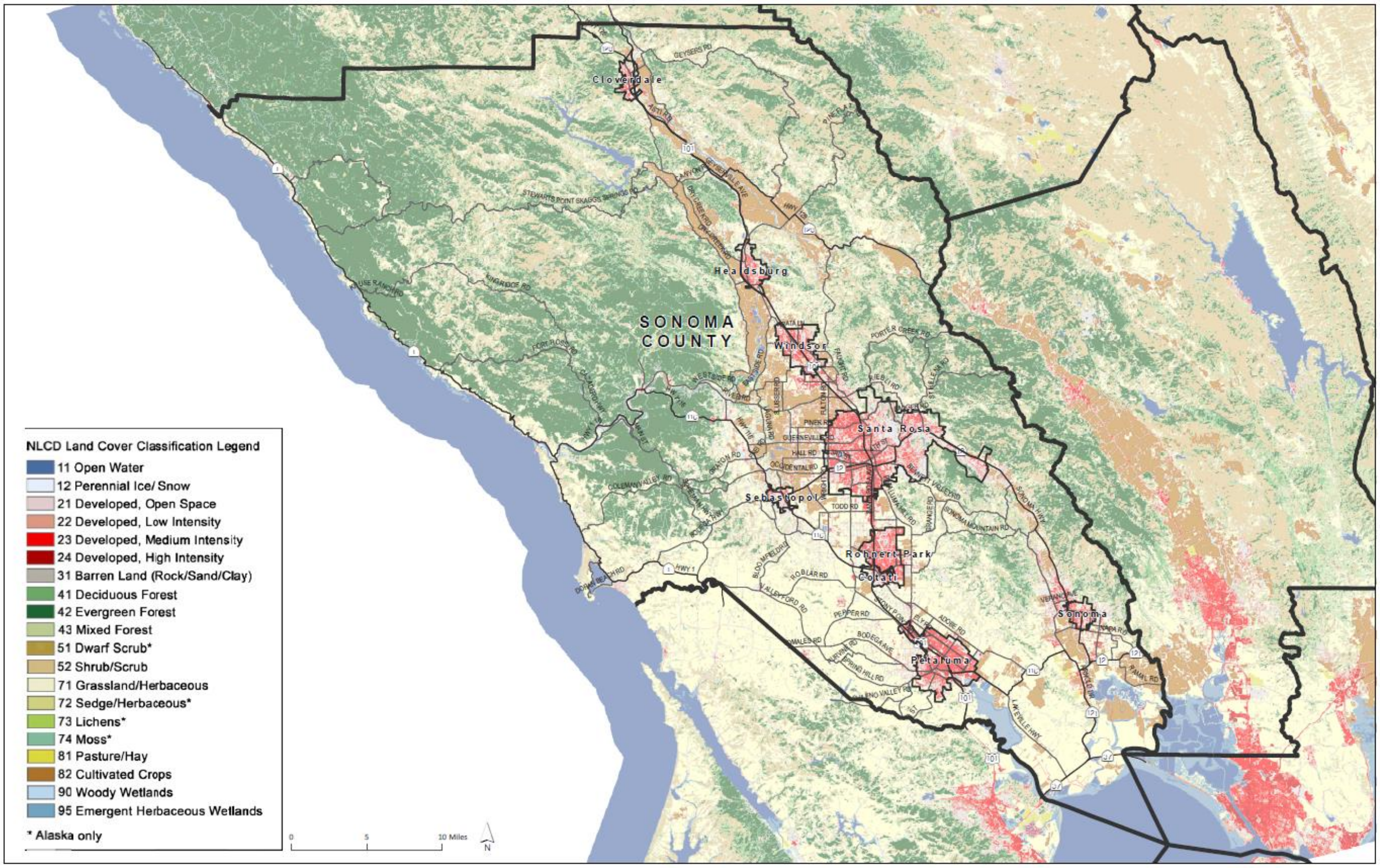

Table 4 Coastal Change Analysis Program (C-CAP) Land Cover Types in Sonoma County

C-CAP Land Cover Type[n]	Area (acres)	Description[o]
Deciduous Forest	22,813	Areas dominated by deciduous trees generally greater than 5 meters tall.
Evergreen Forest	294,737	Areas dominated by evergreen trees generally greater than 5 meters tall.
Mixed Forest	97,947	Areas including both evergreen and deciduous trees generally greater than 5 meters tall.
Scrub/Shrub	169,348	Areas dominated by shrubs; less than 5 meters tall. Includes true shrubs, young trees in an early successional stage.
Grassland	242,499	Areas dominated by grammanoid or herbaceous vegetation.
Estuarine Emergent Wetland	5,761	Tidal wetlands dominated by erect, rooted, herbaceous hydrophytes in areas with greater than 0.5 percent salinity.

[n] The land cover categories under Open Water (Bay, Lake, Reservoir, Rivers, and Salt Pond) were derived from the C-CAP dataset based on available water body data.
[o] Definitions adapted from the C-CAP Land Cover Classification Scheme. Available at: http://www.csc.noaa.gov/digitalcoast/_/pdf/ccap_class_scheme.pdf

Palustrine (fresh water) Emergent Wetland	4,930	Tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens in areas with less than 0.5 percent salinity.
Estuarine Scrub/Shrub Wetland & Estuarine Forested Wetland	170	Tidal wetlands dominated by woody vegetation less than 5 meters in height; in areas with greater than 0.5 percent salinity.
Palustrine (fresh water) Scrub/Shrub Wetland & Palustrine (fresh water) Forested Wetland	4,365	Tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters in height; in areas with less than 0.5 percent salinity.
Pasture/Hay	9,065	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Cultivated	68,100	Areas used for the production of annual crops such as vegetables and berries; includes orchards and vineyards.
Open Water		
Bay	570	Areas of open water off the coast of Sonomaanta Cruz County.
Lake	2,446	Bodies of freshwater in the county not used as reservoirs.
Reservoir	2,355	Bodies of freshwater in the county used as reservoirs.
River	3,221	Rivers and streams.
High Intensity Developed	4,691	Highly developed areas where people reside or work in high numbers such as apartment complexes, row houses and commercial/industrial.
Medium Intensity Developed	22,774	Areas with a mixture of constructed materials (50-79% cover) and vegetation. Includes multi- and single-family housing units.
Low Intensity Developed	37,711	Areas with a mixture of constructed materials (21-49% cover) and vegetation, such as single-family housing units.
Developed Open Space	19,446	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses.
Bare Land	2,235	Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation.
Unconsolidated Shore	1,187	Areas dominated by material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Generally lacks vegetation.
Beach	378	Unconsolidated shoreline consisting primarily of sand.
Total	**1,016,757**	

Some land cover/ecosystem service combinations are well represented in available valuation studies. Other combinations have few or no existing studies. Table 5 summarizes the suite of ecosystem services provided by each land cover type and the number of primary study values available for each land cover/ecosystem service combination.

Table 5 - Sonoma County Ecosystem Services Present, Valued, and Number of Applicable Primary Studies

	Deciduous Forest	Evergreen Forest	Mixed Forest	Scrub/Shrub	Grassland	Estuarine Emergent Wetland	Palustrine Emergent Wetland	Estuarine Forested & Scrub/Shrub Wetland*	Palustrine Forested & Scrub/Shrub Wetland**	Pasture/Hay	Cultivated	*Open Water*				High Intensity Developed	Medium Intensity Developed	Low Intensity Developed	Developed Open Space	Bare Land	Unconsolidated Shore	Beach
												Bay	Lake	Reservoir	River							
Provisioning Services																						
Food	1	1	1	1	1	3	3	3	3			3										
Medicinal Resources																						
Ornamental Resources																						
Energy and Raw Materials	1	1	1																			
Water Supply	3	3	3	2		6	6	6	6					1	1							
Regulating Services																						
Biological Control	2	2	2	1	2					1	1	1										
Climate Stability	4	4	4	3	3	7	7	5	5	3	3								2			
Air Quality	1	1	1									1							3			
Moderation of Extreme Events	2	2	2	1	1	8	8	6	6										1			2
Pollination	3	3	3	1	1					2	1											
Soil Formation	1	1	1	1						3	1											
Soil Retention	1	1	1	2	3					2	3											
Waste Treatment	4	4	4		2	9	9	1 1	1 1		1	6										
Water Regulation																			3			
Supporting Services																						
Habitat and Nursery	1	1	1			5	5	3	3			2			2							
Genetic Resources																						
Cultural Services																						
Natural Beauty	9	9	9	2	4	4	4	3	3	3	1		3		5				1			
Cultural and Artistic Inspiration																						

Recreation and Tourism	13	13	13	2	2	12	12	9	9	1		11	8	6	9							2
Science and Education	1	1	1																			
Spiritual and Historical																						

Key

	Ecosystem service generally produced by land cover
n	Ecosystem service generally produced by land cover and valued in this report; n = number of primary study values assessed
	Ecosystem service generally not produced by land cover

*Includes areas of both Estuarine Scrub/Shrub Wetland and Estuarine Forested Wetland, which were combined for the purposes of valuation.
**Includes areas of both Palustrine Scrub/Shrub Wetland and Palustrine Forested Wetland, which were combined for the purposes of valuation.

As Table 5 suggests, an important limitation to this analysis is a lack of primary valuation studies representing all the ecosystem services provided in Sonoma County. Many ecosystem services that clearly have economic value, such as groundwater recharge, could not be quantified due to gaps in the literature or the difficulty of valuing them using benefit transfer. Some land covers, such as grasslands, beaches and cultivated crops, were valued for relatively few ecosystem services due to the limited number of applicable values available in the literature. Additionally, values were unavailable for five land cover types (Bare Land; Unconsolidated Shore; High Intensity Developed; Medium Intensity Developed; Low Intensity Developed). While these land cover types are not represented in this study, it is recognized that land covers such as Low Intensity Developed (and even High Intensity Developed) can often contain a significant amount of vegetation, such as urban trees that (especially when managed well) provide valuable services including storm water capture, air quality, and recreational value. The lack of available studies across many of the land cover/ecosystem service combinations suggests that the results presented here should be interpreted as a conservative estimate, and also underscores the need for investment in conducting local primary valuations.[p] The data provided in Table 5 clarifies ecosystem service/land cover data gaps, and can be useful in prioritizing local primary valuations to fill these gaps and further refine ecosystem service values in the region. Appendix A contains greater detail on the limitations of this study.

[p] For example, developed by the U.S. Forest Service, "iTree" is one commonly-used tool for conducting analyses of ecosystem services provided by urban trees. More information about the tool is available at http://www.itreetools.org/.

Assigning Spatially Dependent Conditions to Primary Study Values

Ecosystem services may be spatially independent or spatially dependent on a physical location or proximity to beneficiaries. A ton of carbon sequestered in Sonoma County, for example, adds the same value to climate stability as a ton of carbon sequestered elsewhere. This is an example of a spatially *independent* service. On the other hand, the aesthetic attributes of a park are often more economically valuable (on a per-acre basis) in an urban area than in a rural area, because there are more beneficiaries in close proximity to the service and because the service is more scarce in the urban environment. Unlike carbon sequestration, this example illustrates a spatially *dependent* ecosystem service.

In order to account for the economic effects of physical location and proximity to beneficiaries on the type and magnitude of flow from dependent ecosystem services, Earth Economics tagged many of the applicable primary study values with one or more spatially dependent qualifiers or "conditions" to reflect this reality and refine the accounting methodology. Geographic Information Systems (GIS) tools were used to identify, define, and calculate acreage for five different conditions that were applied to the economic data in this study. Along with other factors already taken into account (e.g. similarities in land cover, geographic location), the five conditions were determined to broadly represent the spatial factors that commonly have a positive effect on a primary study's final calculated ecosystem services value. For example, a riparian condition for a primary study indicates that the study valued ecosystem services in a riparian corridor, and therefore its associated ecosystem service values were only applied to lands in Sonoma County that were in close proximity to a stream or river. Table 6 summarizes and defines the conditions that were applied to primary studies. It should be noted that these conditions are general, and are likely to vary throughout Sonoma County. For example, riparian corridors likely extend well beyond 50 feet of the river in many cases, but in other cases may be less than 50 feet.

Table 6 - Conditions Applied to Primary Study Values for Transfer to Sonoma County

Condition	Description	Dataset	Definition
Urban	Areas where the value of the some ecosystem services tends to be higher when near urban or suburban populations; e.g., an urban park tends to have a greater positive impact on nearby property values.	California Department of Conservation Farmland Mapping & Monitoring Program (FMMP), Sonoma County, 2010 (California Department of Conservation, 2010)	Within 2 miles of an FMMP Urban/Built-up designated area that is either within an urban service area or is over 300 contiguous acres in size.

Riparian	Areas alongside streams and rivers where ecosystem services tend to be produced or demanded in greater quantities due to the higher ecological productivity of these areas or their proximity to water; e.g., some kinds of wildlife viewing or water-based recreational activities are possible only in riparian zones.	United States Geological Survey National Hydrography Dataset - 24k (National Oceanic and Atmospheric Administration, 2006)	Within 50ft of stream channel flowlines that have either perennial status or Geographic Name Information System identification number.
Agriculture	Areas that benefit nearby farms or provide benefits to others by reducing the (usually downstream) impacts of agriculture; e.g., native vegetation near farms can be home to wild pollinators that help to increase crop yields.	California Department of Conservation Farmland Mapping & Monitoring Program, Sonoma County, 2010 (California Department of Conservation, 2010)	Located within 3 miles of FMMP Prime Farmland, Farmland of Statewide Importance, Unique Farmland, or Farmland of Local Importance designated areas that are over 40 contiguous acres in size.
Developed High Intensity	Areas where ecosystem services tend to be more valuable near highly developed zones where people reside or work in high numbers, such as near apartment complexes or commercial/industrial areas; e.g., wetlands near industrial areas often receive and detoxify a greater quantity of polluted runoff (on a per-acre basis) than those in remote areas.	National Oceanic and Atmospheric Administration 2006 Coastal Change Analysis Program (C-CAP) Regional Land Cover dataset (National Oceanic and Atmospheric Administration, 2006)	Within ¼ mile of lands identified as High Intensity Developed.
Greater than 5 contiguous acres	Continuous tract of a single land cover type that provides greater ecosystem services when it grows in size; e.g., a large urban park may provide a sense of open space (where a smaller urban park could not), adding to the value of adjacent properties.	National Oceanic and Atmospheric Administration 2006 Coastal Change Analysis Program (C-CAP) Regional Land Cover dataset (National Oceanic and Atmospheric Administration, 2006)	Greater than five contiguous acres of any single C-CAP 2006 land cover type.

Calculating Economic Value: Matching Primary Studies to Land Cover in Sonoma County

Each primary study provided a low and high value estimate (or a single estimate) for one or more ecosystem services provided by a particular land cover, and many of these were further refined by the conditions described above. Table 7 provides an example of one of these combinations, where “Evergreen Forest” is the land cover and “Riparian” and “Agriculture” are the conditions. Overall, 3,570 acres of land in Sonoma County match this combination. The table not only shows the total acreage of this combination of land cover and conditions in the County, but also the particular studies used to calculate the low and high values for each ecosystem service in dollars per acre per year. This table illustrates, for example, how the values from the study by Colby and Smith-Incer (which was conducted in California and focuses on the recreational value of riparian areas - specifically bird and wildlife viewing) were applied locally. As noted earlier, not every single acre may fall within this value range, due to supply and demand factor differences between the primary study site and different parts of Sonoma County.

Once all of these values were added to the database, the low and high values were summed for all ecosystem services that could be valued for a given land cover/condition combination, resulting in a low and high total dollar value per-acre per-year ($1,375 to $4,492 per acre per year in the Table 7 example). The total low and high values for each land cover/condition combination were then multiplied by the acreage associated with that combination to calculate the total low and high values in dollars per year. In the example provided in Table 7, the low value was $4,908,999 per year and the high value was $16,035,588 per year.

Table 7 - Ecosystem Services Valued for Areas of Evergreen Forest with the “Riparian” and “Agriculture” Conditions

Land Cover **Conditions** **Area Valued (ac)**	**Evergreen** **Riparian; Agriculture** **3,570**	
	Low Value ($/acre/year)	**High Value ($/acre/year)**
Biological Control		
Wilson, S. J.	11.28	17.27
Climate Stability		
Wilson, S. J.	10.83	124.14
Energy and Raw Materials		
Haener, M. K. and Adamowicz, W. L.	3.83	3.83
Food		
Knowler, D.J., et al.	17.51	51.19
Habitat and Nursery		
Amigues, J. P., et. al.	306.00	578.91
Moderation of Extreme Events		
Zavaleta, E.	45.61	63.07
Pollination		
Wilson, S. J.	420.20	420.20

Science and Education		
Bishop, K.	41.82	71.99
Soil Formation		
Wilson, S. J.	2.54	2.54
Soil Retention		
Wilson, S. J.	2.35	2.35
Waste Treatment		
Lant, C. L. and Tobin, G.	199.16	2,192.74
Zhongwei, L.	282.13	283.31
Water Supply		
Lant, C. L. and Tobin, G.	353.70	353.70
Zavaleta, E.	16.90	573.34
Recreation and Tourism		
Hiking		
Prince, R. and Ahmed, E.	91.09	115.69
Camping		
Boxall, P. C., et al.	0.22	0.22
Bird and Wildlife Viewing		
Colby and Smith-Incer	205.71	274.29
	Low ($/acre/year)	**High ($/acre/year)**
	1,375	4,492
	Low ($/year)	**High ($/year)**
	4,908,999	16,035,588

A total of 106 land cover/condition combinations were valued for Sonoma County (i.e. 106 tables like Table 7 were built, one for each combination). Individual tables for each combination can be found in Appendix D.

Table 8 provides a summary of the total values from each of these tables. These are the detailed value ranges of ecosystem service (or bundles of services) for each land cover type within the County. The sum of all of these values is shown at the bottom, and it represents the total annual economic flow (range) of benefits from ecosystem services in Sonoma County ($2.2 to 6.8 billion).

Table 8 - Value of Natural Capital in Sonoma County by Land Cover Type[q]

Land Cover	Conditions		Annual Per Acre Value	Total Annual Value

[q] All values are in 2012 USD.

	Urban	Riparian	Agriculture	High Intensity	5 Acre	Area (Acres)	Low ($/ac/yr)	High ($/ac/yr)	Low ($/year)	High ($/year)
Deciduous Forest						5,011.7	$727	$782	$3,642,193	$3,916,656
			*			10,782.8	$1,148	$1,322	$12,377,124	$14,253,932
		*				138.7	$768	$1,747	$106,511	$242,327
		*	*			329.9	$1,347	$5,027	$444,250	$1,658,445
	*					299.7	$8,360	$22,447	$2,504,961	$6,726,277
	*		*			6,073.8	$8,361	$22,458	$50,780,157	$136,405,284
	*	*				18.0	$3,665	$23,364	$65,864	$419,870
	*	*	*			158.5	$3,848	$25,551	$610,041	$4,050,767
Deciduous Forest Subtotal						***22,813.0***			***$70,531,100***	***$167,673,558***
Evergreen Forest						66,756.8	$727	$782	$48,515,165	$52,171,108
			*			145,827.3	$1,148	$1,322	$167,388,451	$192,770,434
		*				1,779.3	$755	$1,759	$1,343,034	$3,129,164
		*	*			3,570.0	$1,375	$4,492	$4,908,999	$16,035,588
	*					1,998.7	$7,695	$21,782	$15,378,884	$43,535,017
			*			73,633.1	$7,695	$21,793	$566,642,628	$1,604,681,776
	*	*				41.8	$3,561	$23,260	$148,956	$973,054
	*	*	*			1,130.5	$3,555	$25,258	$4,018,962	$28,554,950
Evergreen Forest Subtotal						***294,737.5***			***$808,345,079***	***$1,941,851,092***
Mixed Forest						20,853.0	$828	$883	$17,263,889	$18,405,907
			*			45,965.2	$1,249	$1,423	$57,410,258	$65,410,742
		*				620.0	$758	$1,762	$469,876	$1,092,220
		*	*			1,291.2	$1,378	$4,495	$1,779,551	$5,803,960
	*					1,470.6	$7,886	$21,974	$11,598,107	$32,315,652
	*		*			27,088.1	$7,887	$21,985	$213,653,603	$595,526,638
	*	*				60.3	$3,753	$23,452	$226,129	$1,413,218
	*	*	*			598.9	$3,747	$25,449	$2,243,805	$15,240,838
Mixed Forest Subtotal						***97,947.3***			***$304,645,217***	***$735,209,175***
Scrub/Shrub						40,907.3	$281	$316	$11,502,491	$12,923,103
			*			82,991.4	$453	$756	$37,616,966	$62,735,167
		*				700.6	$361	$1,004	$253,081	$703,110
		*	*			1,362.6	$533	$1,444	$726,659	$1,966,948
	*					2,849.8	$281	$281	$801,129	$801,129
	*				*	2,785.5	$11,539	$11,539	$32,142,094	$32,142,094
	*		*			18,802.9	$453	$721	$8,521,383	$13,559,292
	*		*		*	18,451.5	$11,711	$11,979	$216,089,462	$221,033,228
	*	*				70.4	$532	$1,513	$37,500	$106,517

	*	*			*	10.0	$613	$12,227	$6,147	$122,706
	*	*	*			303.6	$785	$2,640	$238,237	$801,649
	*	*	*		*	112.9	$785	$12,667	$88,565	$1,429,809
Shrub/Scrub Subtotal						***169,348.6***			***$308,023,714***	***$348,324,752***
Grassland						36,619.3	$2,128	$3,992	$77,939,636	$146,187,888
			*			94,589.3	$2,125	$7,502	$201,043,769	$709,603,232
		*				333.6	$2,146	$4,043	$715,967	$1,349,029
		*	*			587.6	$12,918	$23,504	$7,590,990	$13,811,231
	*					2,206.9	$2,251	$5,512	$4,966,978	$12,164,309
					*	30,420.3	$2,251	$11,959	$68,465,570	$363,806,711
	*		*			7,231.2	$2,248	$9,022	$16,253,674	$65,238,199
	*		*		*	69,548.5	$2,248	$15,469	$156,325,132	$1,075,856,571
	*	*				42.0	$5,266	$5,563	$221,189	$233,657
	*	*	*			148.9	$13,040	$25,023	$1,941,574	$3,725,708
	*	*			*	401.8	$5,266	$12,011	$2,116,124	$4,826,138
	*	*	*		*	370.3	$13,040	$31,471	$4,829,221	$11,654,502
Grassland Subtotal						***242,499.8***			***$542,409,824***	***$2,408,457,177***
Estuarine Emergent Wetland						3,514.5	$7,338	$44,318	$25,788,152	$155,755,660
				*		119.0	$7,165	$44,318	$852,398	$5,272,071
		*				11.8	$7,255	$49,470	$85,360	$582,031
		*	*			492.0	$7,249	$49,470	$3,566,660	$24,341,671
		*	*	*		24.0	$7,115	$53,718	$170,457	$1,286,993
	*					1,279.1	$1,657	$70,329	$2,120,105	$89,958,355
	*			*		89.2	$25,891	$53,197	$2,308,681	$4,743,486
	*	*				9.0	$1,650	$70,329	$14,775	$629,706
	*	*	*			212.6	$878	$67,085	$186,767	$14,263,799
	*	*	*	*		10.6	$1,580	$62,368	$16,683	$658,652
Estuarine Emergent Wetland Subtotal						***5,761.7***			***$35,110,038***	***$297,492,424***
Palustrine Emergent Wetland						2,988.0	$7,609	$48,851	$22,735,476	$145,968,344
				*		173.9	$7,816	$52,834	$1,359,387	$9,189,449
		*				71.6	$7,255	$49,470	$519,799	$3,544,258
		*	*			280.6	$7,263	$49,803	$2,038,004	$13,975,483
		*	*	*		26.1	$7,127	$54,026	$186,361	$1,412,710
	*					923.7	$1,407	$70,078	$1,299,766	$64,729,508
	*			*		260.0	$25,414	$48,760	$6,607,142	$12,676,705
	*	*				27.0	$883	$67,060	$23,861	$1,811,511
	*	*	*			132.3	$877	$67,060	$115,979	$8,872,079
	*	*	*	*		47.5	$1,063	$59,350	$50,552	$2,822,029
Palustrine Emergent Wetland Subtotal						***4,930.9***			***$34,936,325***	***$265,002,075***
Estuarine Shrub/Scrub Wetland &						9.3	$1,737	$36,298	$16,117	$336,710
				*		4.1	$1,597	$40,546	$6,556	$166,453

Estuarine Woody Wetland			*			45.6	$1,565	$36,298	$71,364	$1,654,978
			*	*		10.8	$1,599	$45,433	$17,241	$489,983
		*				0.7	$1,567	$41,185	$1,112	$29,222
		*	*			8.5	$1,560	$41,185	$13,223	$349,044
		*	*	*		1.0	$1,426	$45,433	$1,437	$45,771
	*					46.2	$1,695	$70,279	$78,337	$3,247,594
	*			*		6.3	$1,600	$71,483	$10,030	$448,023
	*		*			19.9	$1,741	$70,424	$34,693	$1,403,575
	*		*	*		0.8	$1,600	$71,483	$1,354	$60,467
	*	*				10.8	$1,568	$71,510	$16,994	$774,773
	*	*	*			5.8	$1,562	$71,510	$9,075	$415,513
	*	*	*	*		0.3	$1,428	$72,569	$406	$20,636
Estuarine Shrub/Scrub Wetland & Estuarine Woody Wetland Subtotal						***170.1***			***$277,938***	***$9,442,741***
Palustrine Shrub/Scrub Wetland & Palustrine Forested Wetland						137.0	$1,737	$36,298	$238,072	$4,973,788
				*		7.8	$1,599	$45,433	$12,515	$355,664
			*			877.0	$1,567	$41,185	$1,374,233	$36,120,173
			*	*		232.3	$1,599	$45,433	$371,312	$10,552,383
		*				66.8	$1,567	$41,185	$104,616	$2,749,711
		*	*			362.3	$1,560	$41,185	$565,352	$14,923,059
		*	*	*		116.6	$1,426	$45,433	$166,370	$5,298,943
	*					529.7	$1,741	$70,424	$921,986	$37,300,981
	*			*		107.2	$1,600	$71,483	$171,540	$7,662,746
	*		*			1,194.9	$1,741	$70,424	$2,080,002	$84,151,071
	*		*	*		138.2	$1,600	$71,483	$221,226	$9,882,267
	*	*				205.1	$1,568	$71,510	$321,724	$14,668,006
	*	*	*			332.9	$1,562	$71,510	$519,902	$23,804,352
	*	*	*	*		58.0	$1,428	$72,569	$82,771	$4,206,257
Palustrine Shrub/Scrub Wetland & Palustrine Forested Wetland Subtotal						***4,365.9***			***$7,151,620***	***$256,649,402***
Pasture/Hay						2,510.7	$453	$571	$1,137,906	$1,432,906
	*					6,554.4	$487	$10,454	$3,193,185	$68,522,311
Pasture/Hay Subtotal						***9,065.1***			***$4,331,090***	***$69,955,217***
Cultivated						68,099.5	$121	$2,517	$8,261,934	$171,399,836
High Intensity Developed						4,691.1	$0	$0	$0	$0
Low Intensity Developed						37,711.0	$0	$0	$0	$0
Medium Intensity Developed						22,774.4	$0	$0	$0	$0
Developed Open Space						19,446.0	$524	$2,960	$10,192,932	$57,569,219
Bare Land						2,235.7				

Unconsolidated Shore						1,187.4	$0	$0	$0	$0
Beach						378.0	$2,973	$9,221	$1,123,707	$3,485,268
Bay						570.7	$4,611	$15,286	$2,631,603	$8,724,267
Lake						2,446.3	$4,684	$4,684	$11,459,643	$11,459,643
Reservoir						2,355.3	$4,684	$4,684	$11,033,276	$11,033,276
River						3,221.8	$4,735	$4,735	$15,253,650	$15,253,650
TOTAL						**1,016,757**			**$2,175,718,691**	**$6,778,982,772**

It is important to note that we were not able to assign ecological health coefficients or conditions to the land cover types at the scale of a countywide analysis. Due to the large geographic scale of this analysis, these data assume an average level of ecological health for all analyzed land cover types. Also, a comparison of natural capital values across a range of stewardship conditions and management practices was not conducted. It is acknowledged that the health of the various land cover types across the county and the resulting flow of ecosystem services will vary based on a variety of factors including the patch size, abiotic and biotic factors, current and historic management, and a host of other variables that can affect the productivity and health of an ecosystem. As such, it is critical to note that land management, stewardship, and ecological restoration are essential tools to help maximize the flow of ecosystem services from a specific parcel, land cover type, or location within the County.

Asset Value of Natural Capital in Sonoma County

The annual flow of ecosystem service benefits detailed in Table 8 were used to calculate an *asset value* for the County's natural capital. Specifically, the value was calculated as the net present value of its expected future benefits (or future flows of ecosystem services).[r]

Calculating the net present value of an asset implies the use of a (positive) discount rate, which assumes that benefits to humans in the present time are more valuable than similar benefits in the future. Federal agencies like the Army Corps of Engineers use a 3.5 percent discount rate (2014 rate) for water resource projects, a rate that lowers the value of the benefits by 3.5 percent every year into the future. The private sector tends to use higher discount rates, tied to the rate of return on capital in private markets.

A number of reputable economists, such as the Nobel Laureate Kenneth Arrow, have argued for the use of discount rates close to zero in the case of natural assets. Arrow states that "an

[r] This approach is analogous to an "income capitalization" approach for a business valuation (i.e. the value of a business is estimated as the net present value of its expected future income).

argument combining the market rate of return on investment with the externality of caring about future generations might call for 'low' values of discount, in the range, say, of 0-0.5 percent per annum."[32] Arrow also notes that some of the most pre-eminent thinkers on the topic, including Ramsey, Pigou, and Harrod, "…insisted that the only ethically justifiable value for discount rate is zero."

The choice of a positive discount rate can imply that we value future generations less than the current one. Yet sustainability requires intertemporal social welfare equity, implying that future generations deserve the same benefits and productive base as people today. As a public organization, the Sonoma County Agricultural Preservation and Open Space District's mission statement reflects this perspective, stating that "[the District] *permanently* protects the diverse agricultural, natural resource, and scenic open space lands of Sonoma County *for future generations*" (italics added).

While the use of a zero percent discount rate is not common, it is used alongside the 3.5 percent discount rate in this analysis for comparison purposes. Table 9 shows the results of this analysis. Treated with a 3.5 percent discount rate, the total asset value of natural capital in Sonoma County is between $60 and $188 billion. Treated as an asset that provides the same value across time (i.e. zero percent discount rate over 100 years), natural capital yields an asset value range of $217 to $677 billion.

Table 9 - Net Present Value of Sonoma County's Natural Capital

Discount Rate	Low Estimate	High Estimate
0% (100 years)	$217 billion	$677 billion
3.5% (100 years)	$60 billion	$188 billion

Appendix A: Study Limitations

The results of the first attempt to assign monetary value to the ecosystem services rendered by Sonoma County have important and significant implications on the restoration and management of natural capital. Benefit transfer methodology estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. While these limitations must be noted, they should not detract from the core finding that ecosystems produce a significant economic value to society. Some arguments against benefit transfer include:

1. Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.

2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values.)

3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

4. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values. These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. An area with the size and landscape complexity of Sonoma County makes this approach to valuation extremely difficult and costly.

Responses to the above critiques can be summarized as follows (see Howarth and Farber, 2002 for more detailed discussion):

1. While every wetland, forest, or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts, for instance, the development of economic statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of Sonoma County's ecosystem services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modeling analysis described in other studies do not support an across-the-board claim that the per-acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, which is a major indicator of ecosystem health. It has the same position, by implication, of services tied to NPP – where each acre makes about the same contribution to the whole, regardless of whether it is part of a large plot of land or a small one. This area of inquiry needs further research, but for the most part, the assumption that average value is a reasonable proxy for marginal value is appropriate for a first approximation. Also, a range of different parcel sizes exists within the study site, and marginal value will average out.

3. As employed here, the prior studies we analyzed encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.

4. The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all, or a large portion, of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of

valuation at this scale – a purpose that is more analogous to national income accounting than to estimating exchange values (Howarth and Farber 2002).

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

The estimated value of the world's ecosystems presented in Costanza et al. (1997),[33] for example, has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire Gross World Product. These objections seem to be difficult to reconcile, but that may not be so. Just as a human life is priceless, so are ecosystems – yet people are paid for the work they do.

Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is an underestimate of the infinite value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen exceeds the value of the gross world product – and oxygen production is only a single ecosystem service.

General Limitations

- **Static Analysis.** This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.

- **Increases in Scarcity.** The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al., 2002). If Sonoma County's ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.

- **Existence Value.** The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.

- **Other Non-Economic Values.** Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns (see Janssen and Munda, 2002 and de Montis et al., 2005 for reviews). Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns.

GIS Limitations

- **GIS Data.** Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.

    - *Accuracy*: The source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use changes done after the data was sourced, inaccurate satellite readings, and other factors.

    - *Categorical Precision*: The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined.

- **Ecosystem Health.** There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value.

- **Spatial Effects.** This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e., that every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in ecosystem service levels ripple throughout the economy.

Benefit Transfer/Database Limitations

- **Incomplete coverage.** That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less.
- **Selection Bias.** Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.
- **Consumer Surplus.** Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

Primary Study Limitations

- **Willingness-to-pay Limitations.** Many estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously known.
- **Price Distortions.** Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.
- **Non-linear/Threshold Effects.** The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg et al., 2002). Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing.

- **Sustainable Use Levels.** The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

Appendix B: Value Transfer Studies Used: List of References

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Appendix C: Value Transfer Studies Used: Annotated Bibliography

1. Study: Amigues, J. P., Boulatoff, C., Desaigues, B., Gauthier, C., Keith, J.E., 2002. The benefits and costs of riparian analysis habitat preservation: a willingness to accept/willingness to pay contingent valuation approach. Ecological Economics 43, 17-31.
Land Cover: Open water (riparian buffer, inland wetlands)
Ecosystem Service: Habitat
Valuation Method: Contingent valuation
Location: France
Site Description: Garonne River near Toulouse, France. The study extended from the north of Toulouse and continued 100 km downstream. This is mainly a rural zone, except for Toulouse (750000 residents) and its outskirts. There were slightly over 400 households who own land along this reach of the river.
Description: Contingent valuation was used to obtain the willingness to pay of households in the contiguous area of the Garonne River near Toulouse. It surveyed nearby residents for their WTP and households that currently own land on the banks of the river for their WTA to provide a strip of riparian land for habitat preservation. Farmers' values reflect the value of the land and crop yield and revenue.
Notes: Applicable to riparian buffers adjacent to agricultural land

2. Study: Allen, J., Cunningham, M., Greenwood, A., Rosenthal, L. 1992. The Value of California Wetlands: An Analysis of Their Economics Benefits. Produced for The Campaign to Save California Wetlands.
Land Cover: Wetland
Ecosystem Service: Flood control, water supply, water quality, recreation, food, habitat
Valuation Method: Benefit Transfer
Location: California State
Site Description: 90% of California's wetlands have been destroyed by agriculture and development. There remained 454,000 acres in 1992.
Description: This paper reviews the literature on ecosystem service valuation in California, pre 1992. In the context of policy threatening to remove a further 50% of wetland acres, the resulting economic impact is examined. The authors use the literature to estimate the total economic value of California wetlands, providing a lower-bound, median, and upper-bound estimate. The values are disaggregated by environmental benefit. Despite being a benefit transfer paper, the primary studies used in this article were carefully chosen to represent the Californian region.
Notes:

3. Study: Anderson, G. D., Edwards, S.F. 1986. Protecting Rhode Island coastal salt ponds - an economic assessment of downzoning. Coastal Zone Management Journal 14, 67-91.
Land Cover: Emergent Herbaceous Wetlands
Ecosystem Service: Recreation
Valuation Method: Contingent Valuation
Location: Rhode Island
Site Description: Shallow salt-water embayments and lagoons that provide nursery to fish and shellfish, bordered by residential areas and vulnerable to eutrophication and bacterial contamination.

Description: Contingent valuation and hedonic pricing is applied to value coastal amenities in South Kingstown, Rhode Island, to analyze the effect of downzoning given increasing pressures from tourism and residential development. Primary activities include swimming, fishing, shell-fishing, boating, and bird-watching. The hedonic model primarily analyzes the aesthetic value of the coastal area, as reflected in the price of houses, while the contingent valuation surveys willingness to pay to avoid degradation in water quality. The number of tourists to the area was about 165,000 per summer in the early 80s.
Notes: Applicable to emergent herbaceous wetlands on the coast and within urban-suburban boundary.

4. Study: Bell, F.W., Leeworthy, V.R. 1986. An Economic Analysis of the Importance of Saltwater Beaches in Florida, Sea Grant Report SGR-82.
Land Cover: Beach
Ecosystem Service: Recreation
Valuation Method: Contingent Valuation
Location: Florida
Site Description: Salt-water beaches in the state of Florida
Description: This study carries out a valuation of salt-water beaches for recreational uses in Florida. Because Florida's beaches are accessible without fees, the recreational values are measured in terms of users' stated willingness to pay, beach recreation-related sales, employment generated, and tax revenue. Extensive socio-demographic information is provided that may make it possible to adjust to users in California.
Notes: Applicable to beach areas

5. Study: Bennett, R., Tranter, R., Beard, N., Jones, P. 1995. The value of footpath provision in the countryside: a case-study of public access to urban fringe woodland. Journal of Environmental Planning and Management 38, 409-417.
Land Cover: Forest
Ecosystem Service: Recreation
Valuation Method: Contingent valuation
Location: United Kingdom
Site Description: 1052 ha of mature, mainly Scots Pine, woodland located in Windsor Forest on the urban fringe of Bracknell in Berkshire.
Description: This study values public access to a private woodland site in Windsor, a village on the outer edge of London. Contingent valuation is used to assess the recreational benefits of walking through path networks in the forest. Access is free and amenities include parking facilities. The study participants were fairly affluent. Values are comparable to similar studies conducted.
Notes: Applicable to forest close to urban and suburban areas.

6. Study: Bergstrom, J. C., Dillman, B.L., Stoll, J.R. 1985. Public environmental amenity benefits of private land: the case of prime agricultural land. Southern Journal of Agricultural Economics 7, 139-149.
Land Cover: Cultivated Crops AND Pasture/Hay
Ecosystem service: Aesthetic
Valuation Method: Contingent Valuation
Location: South Carolina

Site Description: Greenville County, which is shifting from a more traditionally agricultural environment to an urban-industrial development.
Description: As Greenville County faces a rapid growth of urban and industrial development, aesthetically-pleasing agricultural landscapes are being lost. Contingent valuation was used to value the costs and benefits of this transition. These values represent willingness to pay of local residents to preserve amenity values associated with agricultural lands in rural settings. The amenity values associated with the rural agricultural landscape are enhanced by the threat of conversion happening in the county.
Notes:

7. Study: Berrens, R. P., Ganderton, P., Silva, C.L. 1996. Valuing the protection of minimum instream flows in New Mexico. Journal of Agricultural and Resource Economics 21, 294-308.
Land Cover: Open Water (Rivers)
Ecosystem Service: Habitat for endangered fish
Valuation Method: Contingent valuation
Location: New Mexico
Site Description: Four separate rivers (Gila, Pecos, Rio Grande, and San Juan) in New Mexico where endangered and threatened fish species are found.
Description: The authors use contingent valuation to find the nonmarket benefits of protecting instream flows (water in its natural channels without diversion) in New Mexico. Since there is no regulation protecting stream flows and a lot of competing water demand uses, the benefits of this service are studied. The focus is on minimum instream flows and endangered fish species. The annual household willingness to pay for protection of minimum instream flows is measured.
Notes: Applicable to rivers containing threatened fish species.

8. Study: Bishop, K. 1992. Assessing the benefits of community forests: An evaluation of the recreational use benefits of two urban fringe woodlands. Journal of Environmental Planning and Management 35, 63-76.
Land Cover: Forest
Ecosystem Service: Recreation and Tourism, Science and Education
Valuation Method: Contingent valuation, travel cost
Location: United Kingdom
Site Description: Urban accessible forests –woodlands on the fringes of major towns and cities in England and Wales. Many are accessible by foot. These include Derwent Walk Countryn (161 ha) in Gateshead and Whippendell Wood (67 ha) in Herfordshire.
Description: The authors assess the recreational and educational value of two woodlands in the United Kingdom using contingent valuation, travel cost, and time cost. Over 50% of visitors came from a 5 km radius. It suggests that recreational benefits exceed management costs by a factor of three.
Notes: Applicable to forest within urban boundary.

9. Study: Bockstael, N.E., McConnell, K.E., Strand, I.E. 1989. Measuring the benefits of improvements in water quality: the Chesapeake Bay. Marine Resource Economics 6, 1-18.
Land Cover: Bay
Ecosystem Service: Recreation (swimming, boating, fishing)
Valuation Method: Contingent valuation and travel cost
Location: Virginia and Maryland

Site Description: Chesapeake Bay is an estuary lying inland from the Atlantic Ocean. More than 150 rivers and streams flow into the Bay's 64,299 square miles drainage basin.
Description: This study measures the willingness to pay for changes in water quality. Current problems include nutrient overload, toxic substances, and submerged aquatic vegetation. The criteria for value derivation were biophysical. Contingent valuation asked about willingness to pay to improve water quality for swimming. Travel cost looked at beach use in the western shore of Maryland. Willingness to pay for improvement in water quality ranges from $10 to $100 million for the estuary. Virginia has a fairly dense population surrounding the Chesapeake Bay.
Notes:

10. Study: Bouwes, N. W., Scheider, R. 1979. Procedures in estimating benefits of water quality change. American Journal of Agricultural Economics 61, 635-639.
Land Cover: Open Water (Lake)
Ecosystem service: Recreation and Tourism
Valuation Method: Travel cost
Location: Wisconsin
Site Description: Pike Lake is a 500 acre lake, which has public parks, beaches and boating areas and a moderate water quality given storm sewer contamination.
Description: The authors calculate the benefit of preserving the water quality of the lake. The lake is a popular destination for recreational activities. In 1975, there were almost 170,000 visitors for hiking, swimming, fishing and other activities. A model testing number of visits versus water quality was used. The cost-benefit ratio justifies the building of a storm sewer diversion project based on recreational economic benefits.
Notes: Applicable to lakes or reservoirs with recreational/public access.

11. Study: Bowker, J.M., English, D.B., Donovan, J.A. 1996. Toward a value for guided rafting on southern rivers. Journal of Agricultural and Resource Economics 28, 423-432.
Land Cover: Open Water (Rivers)
Ecosystem Service: Recreation (whitewater rafting)
Valuation Method: Travel cost
Location: Southern United States
Site Description: Chatooga River, which forms part of the northern border between Georgia and South Carolina, and the Nantahala River in rural western North Carolina. Both of these rivers are known for rafting activities.
Description: This study finds the per trip consumer surplus of guided whitewater rafting in two rivers, one in North Carolina and one on the border of Georgia and South Carolina. This is a market proxy for streamflow. Using the travel cost method, the authors find mean per trip consumer surplus to be between $89 and $286, suggesting it is one of the most highly valuable activities for water recreation.
Notes: Applicable to rivers with rafting activities

12. Study: Boxall, P. C. 1995. The economic value of lottery-rationed recreational hunting. Canadian Journal of Agricultural Economics-Revue Canadienne D'Economie Rurale 43, 119-131.
Land Cover: Grasslands/herbaceous, pasture/hay, shrub
Ecosystem Service: Recreation (antelope hunting)

Valuation Method: Travel cost
Location: Alberta, Canada
Site Description: The eight sites in which permits were available display considerable variation in size, 1854 to 11111 square kilometers, and in some quality attributes, which are: hunting success in a previous period, amount of native grassland or antelope habitat, and the density of antelope.
Description: Lottery-rationed permits are used to allocate hunting opportunities where demand for permits exceeds sustainable levels. This paper uses a travel cost model and incorporates the expectation of receiving a permit, thereby finding the "expected value" of lottery-rationed permits. The authors focus on permits for antelope in Alberta during the 1986 hunting season.
Notes:

13. Study: Boxall, P. C., McFarlane, B.L., Gartrell, M. 1996. An aggregate travel cost approach to valuing forest recreation at managed sites. Forestry Chronicle 72, 615-621.
Land Cover: Forest
Ecosystem service: Recreation and Tourism (Camping)
Valuation Method: Travel cost
Area: Alberta
Site Description: Rocky-Clearwater forest, a 1.8 million ha (about 4.4 million acre) area containing a provincial park and located at the mountain foothills.
Description: Value derived from travel costs incurred with visits to the Rocky-Clearwater forest. The focus is on camping tourism, which is fee based, but value calculation extends beyond these fees. There are 33 forest recreational areas; containing streams, lakes, and waterfalls.
Notes: Applicable to forest outside of urban boundary.

14. Study: Breaux, A., Farber, S., Day, J. 1995. Using natural coastal wetlands systems for waste-water treatment - an economic benefit analysis. Journal of Environmental Management 44, 285-291.
Land Cover: Emergent Herbaceous Wetlands, Woody Wetlands
Ecosystem Service: Waste treatment
Valuation Method: Avoided cost
Location: Louisiana
Site Description: Three case studies included 1) adjacent wetlands to the city of Thibodaux with a receiving area of 570 acres of swamp/bottomland forested area, semi-impounded and receiving municipal waste; 2) wetlands adjacent to Dulac, with a receiving area of 2,860 acres and receiving seafood waste 3) and a bottomland hardwood wetland located near Grammercy receiving potato chip waste.
Description: Wetland systems can substitute for traditional wastewater treatment. In addition, treated wastewater can enhance wetlands by providing nutrients. This paper estimates the cost savings from using coastal wetlands for wastewater treatment in Louisiana. The value includes only the cost-savings of wetlands over conventional treatment. This study provides estimates of the benefits for three application sites in South Louisiana. The authors estimate discounted savings ranging from $785 to $34,700 per acre of wetlands used for treatment.
Notes: Applicable to wetlands adjacent to developed areas that produce municipal and industrial waste (according to NLCD categories).

15. Study: Breffle, W.S., Morey, E.R., Lodder, T.S. 1998. Using contingent valuation to estimate a neighbourhood's willingness to pay to preserve undeveloped land. Urban Studies 35 (4), 715-727.
Land Cover: Developed, Open Space
Ecosystem service: Aesthetic value
Valuation Method: Contingent Valuation
Area: Colorado
Site Description: On the foothill of mountains, the protected area is green open space within city limits; greenbelts.
Description: Contingent valuation is used to estimate the neighborhood's willingness to pay to preserve a 5.5-acre parcel of undeveloped land in Boulder, Colorado that provides views, open space, and wildlife habitat. Factors such as distance, income, and other characteristics were significant determinants. Value reflects preferences of residents living adjacent to open green spaces in medium size cities.
Notes: Applicable to Developed, Open Space within urban boundary

15. Study: Brouwer, R., Langford, I. H., Bateman, I.J., Turner, R.K. 1999. A meta-analysis of wetland contingent valuation studies. Regional Environmental Change 1 (1), 47-57.
Land Cover: Wetlands
Ecosystem Service: Various but focus on flood control, water supply, water quality, biodiversity
Valuation Method: Benefit transfer
Location: North America and Europe
Site Description: Wetlands in North America and Europe – where there is temperate climate and developed economies. Two-thirds of the studies are carried out in the USA, the rest in Europe. Half of the European studies were carried out in the UK.
Description: This paper uses meta-analysis to generate use and non-use values of wetlands. 30 different CV studies of wetlands in temperate climate zones in developed economies were compared. The study assesses values attributable to hydrological, biogeochemical, and ecological functions of environmental assets. Average benefits supplied by wetlands are between $32.25 and $78.75 per hectare per year. Because it is a meta-analysis, the study provides values for various wetland types, including variables for species diversity, geographical region, water type, and ecological function. These classifications allow for greater precision in benefit transfer. Factors like income and location had a significant influence on values.
Notes:

16. Study: Burt, O.R., Brewer. D. 1971. Estimation of net social benefits from outdoor recreation. Econometrica 39, 813-827.
Land Cover: Lakes
Ecosystem service: Recreation and Tourism
Valuation Method: Travel Cost
Area: Missouri
Site description: Values were derived based on three lakes proposed for construction by the U.S. Army Corps of Engineers. These lakes would be near the metropolitan area of St. Louis, south of the Missouri River and west of the city between 35 and 55 miles. These lakes fit the general category of "typical [Army] Corps lakes" and are assumed perfect competitors with existing lakes placed in this category. The

specific reservoirs were designated as Union, Meramec Park, and Pine Ford and they have a total surface area of 22,900 acres.
Description: The authors measure social benefits of outdoor water recreation using the travel cost method in different water bodies and surrounding settlements. They develop a set of demand functions and travel cost models based on activities in a number of lakes in the region. Only cities with over 5,000 people are taken into account. Estimated annual net benefits that are attributed to outdoor recreation at the three lakes (combined) are 8.5 million dollars and predicted household-visit-days are 1.1 million. The three crucial variables in the demand equations are quantity, price, and income. A single point was chosen in each county from which all prices were estimated and the center of each city was used as the reference point. Weighted average distances to all three lakes were used for the metropolitan subareas, with surface area of the lakes as weights. The assumed level of visits would appear not to cause serious crowding when compared to experienced visitor-days at comparable lakes.
Notes: Applicable to lakes or reservoirs with recreational access

17. Study: Canadian Urban Institute. 2006. Nature Counts: Valuing Southern Ontario's Natural Heritage. Toronto, Canada. http://www.canurb.com/media/pdf/Nature_Counts_rschpaper_FINAL.
Land Cover: Urban green space, farmland, forest
Ecosystem Service: Recreation, food production, green energy, health
Valuation Method: Benefit transfer, avoided cost
Location: Ontario, Canada
Site Description: Southern Ontario, an area undergoing significant demographic and economic change from urban growth and development. Most green space is privately owned – 5.6 million hectares of forests, for example. The traditional building blocks of the rural economy are agriculture, forestry and small manufacturing, which are increasingly complemented by green tourism and recreation.
Description: This extensive report catalogues the economic benefits of forests, recreation, health, and other benefits related to environmental amenities in Southern Ontario. Expenditure analyses are used, as well as research from secondary sources. The findings come in the form of recommendations for sustainable management of green space in the context of land cover change threats.
Notes:

18. Study: Cleveland, C.J., Betke, M., Federico, P., Frank, J.D., Hallam, T.G., Horn, J., Lopez Jr., J.D., McCracken, G.F., Medellin, R+.A., Moreno-Valdez, A., Sansone, C.G., Westbrook, J.K., Kunz, T.H. 2006. Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. Frontiers in Ecology and the Environment 4 (5), 238-243.
Land Cover: Cultivated Crops
Ecosystem service: Biological Control
Valuation Method: Avoided Cost of pest control as input to production
Area: Texas
Site Description: An eight-county region in southwest and central Texas of about 10,000 acres. The region is characterized by a high-input, high-yield agricultural system, with extensive use of irrigation water, fertilizer, pesticides, and other inputs. Cotton is a common, high-value crop.
Description: Brazilian free-tailed bats are examined for their pest control service as they prey on agricultural pests. Bats' value as pest control is estimated for cotton production in Texas. The calculated avoided cost has two components: the value of the cotton crop that would have been lost in the absence of the bats and the reduced cost of pesticide use – private and social – attributable to the

presence of bats. Sources of variation are considered in terms of the prey behavior and the existence of other pest control agents. Changes in crop vulnerability and pest life cycles are modelled to reflect average yearly values.
Notes:

19. Study: Colby, B. and 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.
Land Cover: Riparian Corridor
Ecosystem Service: Recreation and Tourism (bird and wildlife viewing)
Valuation Method: Contingent valuation
Location: California
Site Description: The Kern River Preserve (KRP) located in the South Fork Kern River Valley, 57 miles northeast of Bakersfield with an estimated 6,000 to 8,000 visitors a year. The river is home to California's largest lowland riparian forest and is one of the first Globally Important Bird Areas designated in the United States. It is a traditionally rural region.
Description: The study measures willingness to pay and visitor numbers to the Kern River Preserve, where a large number of recreational activities take place – including rafting, boating and other. The focus, however, is on bird watching as it is the primary recreational activity, attracting well-educated, high-income visitors. The contingent valuation survey asks for donations to promote regional water conservation in order to prevent streamflows from being diminished, leading to habitat degradation and reduced numbers and diversity of birds and other wildlife.
Notes: Applicable to Forest (NLCD 41-43) within riparian corridor.

20. Study: Cooper J., Loomis. J. 1991. Wildlife Resources in the San Joaquin Valley: Hunting and Viewing Values. University of California, Davis.
Land Cover: Wetlands
Ecosystem service: Recreation (hunting and bird viewing)
Valuation Method: Travel Cost and Contingent Valuation
Area: California
Site Description: San Joaquin Valley agricultural drainage areas or wetlands where wildlife is found and recreational activities take place.
Description: Willingness to pay is calculated through a survey distributed throughout the whole state of California asking questions on recreational trips and willingness to pay. About 1500 surveys were returned and used for calculation. Waterfowl hunting and bird viewing are the primary onsite recreational uses of the Valley's wildlife that are affected by agricultural drainage. An estimate of the change in waterfowl hunting benefits at Kesterson National Wildlife Refuge (NWR) resulting from control of agricultural drainage water is made by combining information on wildlife response to selenium with a quality differentiated demand equal for waterfowl hunting. This simulation illustrates how a bioeconomic analysis of waterfowl hunting benefits from reducing wildlife contamination can be performed. Hunting permit applications used in data. Values published are for each of seven Wildlife Areas or National Wildlife Refuges in the state of California.
Notes:

21. Study: Cordell, H. K., Bergstrom, J.C. 1993. Comparison of recreation use values among alternative reservoir water level management scenarios. Water Resources Research 29, 247-258.
Land Cover: Open water (Lakes and reservoirs)
Ecosystem service: Recreation
Valuation Method: Contingent Valuation
Area: North Carolina and Georgia
Site Description: Four reservoirs in western North Carolina and North Georgia were included in this study: Lakes Chatuge (132 shoreline miles), Fontana (248 shoreline miles), Hiwassee (163 shoreline miles), and Santeetlah (93 shoreline miles).
Description: Management of the Tennessee Valley Authority's reservoirs in western North Carolina and North Georgia for flood control and hydropower has historically involved large seasonal fluctuations of water levels. The authors measure the economic use value of outdoor recreation under three alternative water level management scenarios for four reservoirs in this region. The study uses contingent valuation to measure the benefit of various kinds of outdoor recreational activity – including boating, sailing, water skiing, swimming, and fishing in comparison to flood control and hydropower services. The findings suggest that maintaining high water levels for longer periods during summer and fall results in considerable gains in estimated recreational benefits compared to the other potential uses that would lower water levels.
Notes:

22. Study: Costanza, R, d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, RV., Paruelo, J., Raskin, RG., Sutton, P., van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260.
Land Cover: Open water (coastal, bay, beach, lake, reservoir), forests, grasslands, freshwater, wetlands
Ecosystem Service: Soil formation, disturbance prevention, climate regulation, soil retention, recreation, water supply, raw materials, food provision, habitat, waste treatment, biodiversity, water regulation, nutrient cycling, pollination, biological control, gas regulation, cultural
Valuation Method: Hybrid benefit transfer, replacement cost
Location: Global
Site Description: Global biomes
Description: The authors estimate the total economic value of the world's ecosystem services and natural capital, finding the value to be between US$16-54 trillion per year, with an average of US$33 trillion per year. Values for 17 ecosystem services are given. Values derived from other studies are extracted and adapted to a global simulation where these ecosystem services are replaced with man-made substitutes. Secondary values were not taken from the Costanza study. Only "hybrid" values were used, where the authors used primary data in some way.
Notes:

23. Study: Creel, M., Loomis, J. 1992. Recreation value of water to wetlands in the San-Joaquin Valley - linked multinomial logit and count data trip frequency models. Water Resources Research 28, 2597-2606.
Land Cover: Wetland
Ecosystem Service: Recreation and Tourism
Valuation Method: Travel Cost
Location: San Joaquin Valley, California

Site Description: Fourteen recreational sites in the San Joaquin Valley, including the National Wildlife Refuges, the State Wildlife Management Areas, and six adjacent river destinations.
Description: The recreational benefits from providing increased quantities of water to wildlife and fisheries habitats are estimated. The study covers waterfowl hunting, fishing, and wildlife viewing. The economic benefits incorporated changing visit patterns as a result of increasing water supplies to wildlife refuges. Suitable for water allocation policies with impacts on habitats and rivers. Relative value of water is affected by scarcity levels.
Notes:

24. Study: Croke, K., Fabian, R., Brenniman, G. 1986. Estimating the value of improved water-quality in an urban river system. Journal of Environmental Systems 16, 13-24.
Land Cover: Open water (River)
Ecosystem Service: Recreation (Water-related)
Valuation Method: Contingent Valuation
Location: Chicago
Site Description: Urban river system - 352 square miles of combined sanitary/ storm sewer waters in Cook County. The area includes the entire city of Chicago and surrounding suburbs.
Description: The study derives the value of cleaner rivers to Chicago citizens using a water quality ladder which describes it in terms of recreational opportunities; going from access to beach fronts at lower quality levels to fishing and swimming at the highest level of water quality. The baseline scenario was perception-dependent and the intention was to evaluate programs that address contamination from sewer overflows. About two thirds of the value is intrinsic or non-use value.
Notes: Applicable to urban rivers

25. Study: Duffield, J. W., Neher, C.J., Brown, T.C. 1992. Recreation benefits of instream flow - application to Montana Big Hole and Bitterroot Rivers. Water Resources Research 2, 2169-2181**.**
Land Cover: Open water (River)
Ecosystem Service: Recreation (consumptive uses of water flow)
Valuation Method: Contingent Valuation
Location: Big Hole River, Montana
Site Description: Big Hole River starts in a valley bounded by mountains and flows into two other rivers. In narrow parts of the river, fish such as browns and rainbows are abundant. The Bitterroot is more varied in its flow and used more by floaters and shoreline recreationists.
Description: The authors estimate the recreational value (mostly in terms of fishing) of instream flows and apply it to Montana's Big Hole and Bitterroot rivers through a contingent valuation. Results are also derived for the value of hydro-power generation as an additional value and a general estimate is also derived for the irrigation value for crops (extractive value). Consumptive uses were calculated using difference in value between irrigated and non-irrigated methods for a representative crop (alfalfa).
Notes: Applicable to large rivers with abundant flow

26. Study: Gascoigne, W.R., Hoag, D., Koontz, L., Tangen, B.A., Shaffer, T.L., Gleason, R.A. 2011. Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA. Ecological Economics. 70(10).
Land Cover: Grasslands, cultivated, wetlands
Ecosystem Service: Climate stability, soil retention, recreation (water quality and waterfowl production)

Valuation Method: Benefit transfer, biophysical modelling, avoided cost
Location: North and South Dakota
Site Description: Prairie Potholes Region - found within the Northern Great Plains covering approximately 900,000 km2. The study's focus area covers 224,000 km2. The region produces 50-80% of the continent's duck population in its sparse wetlands, which are surrounded by agricultural land.
Description: This study looks at land-use change scenarios where native prairies are converted to farmland and other land covers. It models biophysical changes in specific sites and counties and attributes economic values derived from other studies, but adjusted to local bio-geographical characteristics. It concludes that large investments in native prairie conservation would provide over $1 billion of benefits to society over 20 years. The largest benefits arise from increases in carbon sequestration, followed by additional waterfowl.
Notes: Applicable to grasslands with wetlands.

27. Study: Greenley, D., Walsh, R.G., Young, R.A. 1981. Option value: empirical evidence from a case study of recreation and water quality. The Quarterly Journal of Economics 96, 657-673.
Land Cover: Open water (River basin)
Ecosystem Service: Recreation (Water-based)
Valuation Method: Contingent valuation
Location: South Platte River Basin, Colorado
Site Description: Stream sites in the Colorado River basin with variation in water quality ranging from no heavy metal pollution to not suitable for fishing or wildlife; with sediment, algae, and mine-drainage sites.
Description: Water quality was valued in a contingent valuation survey focusing on the impacts of heavy metal contamination. Willingness to pay was framed in terms of costs of holding off mining activity in order to retain the possibility of recreational activities like swimming, boating, fishing, sight-seeing, picnicking, camping, hiking, driving, and others. The results showed that about 80% of households expected to continue with water-based recreation activities in the future. Option value and other preservation values represent important social benefits.
Notes: Applicable to streams and river basins with recreational activities

28. Study: Haener, M.K., Adamowicz, W.L. 2000. Regional forest resource accounting: A northern Alberta case study. Canadian Journal of Forest Research 30, 264-273.
Land Cover: Forests, wetlands (shrubs)
Ecosystem Service: Recreation (fishing, hunting, camping), energy and raw materials (subsistence resource use), climate stability (carbon sequestration) and biodiversity.
Valuation Method: Benefit transfer and direct market price
Location: Alberta, Canada
Site Description: 6.8 × 106 ha of boreal mixed wood forest in northeastern Alberta – hardwood and softwood with commercial potential. The forest also makes available other recreational activities important for aboriginal people and other recreationalists.
Description: Haener and Adamowicz develop a resource accounting model for a region of public forestland in northern Alberta, using a mix of market prices and benefit transfer. Both market and nonmarket values are quantified. Several challenges with resource accounting are highlighted. The value of the forest exhibited ranges from a low of $149 million to a high of $316 million. Forestry (logging)

accounts for more than half of the forest value. The purpose of the study is to aid the creation of green accounting.
Notes:

29. Study: Hauser, A., Cornelis van Kooten, G. 1993. Benefits of Improving Water Quality in the Abbotsford aquifer: An application of contingent valuation methods.
Land Cover: Aquifer covered by urban areas and agriculture
Ecosystem Service: Water quality in groundwater
Valuation Method: Contingent Valuation and Replacement Cost
Location: British Columbia, Canada
Site Description: The Abbotsford aquifer is the primary source of municipal water for the District of Abbotsford. It is one of the largest aquifers in B. C. and encompasses the districts of Langley, Matsqui, Abbotsford and Sumas (USA). The aquifer is shallow with a water table that is only 3 to 9 feet below the surface in many places. Approximately 20% of the aquifer's surface is now covered by urban areas with the remainder in agriculture. About three quarters of the total area in agriculture is comprised of raspberry farms, with the remainder largely comprised of poultry, hog and dairy farms. It is largely unconfined and is covered with sand and gravel deposits. It has high precipitation over the winter months, which contributes to effluent percolation into the groundwater.
Description: Water pollution is currently attributed to nitrate and occasional coliform pollution, although pesticide and heavy metal leaching problems are also a concern. Contingent valuation and defensive expenditures are used to evaluate the benefits of improved water quality in the Abbotsford Aquifer. The CV examined rankings of different goods and services to determine relative values for water quality and defense expenditures looked at actual outlays on bottled water and water filters. Bacterial and nitrate contamination of the aquifer is the result primarily of livestock wastes. Flow patterns of the aquifer are affected by large amounts of water being tapped by the Abbotsford municipal water system, by the fish hatchery system, and by the unregulated well drilling on private property. The drawdown increases risk of pollution.
Notes:

30. Study: Hayes, K.M., Tyrrell, T.J., Anderson, G. 1992. Estimating the benefits of water quality improvements in the Upper Narragansett Bay. Marine Resource Economics 7, 75-85.
Land Cover: Coastal Estuaries
Ecosystem Service: Recration (shellfishing and swimming)
Valuation Method: Contingent Valuation
Location: Rhode Island
Site Description: Upper Narranganset Bay - A temperate estuary opening into Rhode Island Sound, which covers an area of 265 square kilometers (102 square miles) and is an important spawning and feeding ground for many fish species.
Description: Pollution in the Upper Narragansett Bay is one of the most critical environmental problems in the state of Rhode Island. Agricultural, domestic and industrial borne pollutants enter the Bay from several sources: discharges from rivers and streams outside of the state boundaries, non-point runoff, combined sewer overflows, industrial discharges and sewage treatment plants. The study measured the recreational benefits of improved water quality in terms of swimming and shellfishing in the same study area. Contingent valuation surveys revealed that aggregate annual benefits for swimmable waters were between $30 and $60 million, while "shellfishable" water was worth between $30 and $70 million.

Notes: Applicable to estuaries adjacent to urban and suburban

31. Study: Jaworski, E., Raphael, C.N. 1978. Fish, Wildlife, and Recreational Values of Michigan's Coastal Wetlands. Prepared for Great Lakes Shorelands Section, Division Land Resources Program, Michigan Department of Natural Resources.
Land Cover: Herbaceous emergent Wetlands
Ecosystem Service: Recreation (Fishing)
Valuation Method: Direct Market Price
Location: Lake Saint Claire, Michigan
Site Description: Lake Saint Claire is on the western shore of Lake Eerie, where recreational activities are more frequent and economically important.
Description: The authors analyzed the recreational and food provisioning services of Michigan's coastal regions. These calculations were based exclusively on market price methodologies, specifically the expenditure data related to fishing and hunting activities. The only values from this study used for the SC3 project benefit transfer were those related to fishing. Other hunting values were not included in benefit transfer calculations but may be applicable upon review if similar waterfowl species exist across the regions.
Notes: Applicable to wetlands connected to lakes and bay

32. Study: Jenkins, W.A., Murray, B.C., Kramer, R.A., Faulkner, S.P. 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. Ecological Economics. 69. 1051-1061.
Land Cover: Woody wetlands
Ecosystem Service: Waste treatment (nitrogen mitigation), recreation (waterfowl), climate stability
Valuation Method: Benefit transfer, biophysical modelling, avoided cost
Location: Arkansas, Mississippi, and Louisiana
Site Description: Mississippi Alluvial Valley (MAV), the largest floodplain in the US, located below the confluence of the Mississippi and Ohio Rivers. Once containing nearly 10 million hectares of bottomland hardwood forest, it had only 2.8 Mha by the 1980s. The major land use is now agriculture, dominated by cultivation of corn, cotton, rice, and soybeans.
Description: This study combines field data with secondary data to model changes in land cover and ecosystem service production in wetlands and agricultural lands. Economic values are adjusted to be site-specific through benefit transfer methods. They generate county-level values based on the mix of services present and aggregate to arrive to regional values. It is concluded that restoring wetlands in MAV has a social value well above the alternative use in agriculture. The largest benefits are found with flows from nitrogen mitigation, followed by GHG mitigation.
Notes: Applicable to wetlands adjacent to agricultural land

33. Study: 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.
Land Cover: Open water (estuary)
Ecosystem Service: Recreation (Fishing, bird watching, hunting, swimming, boating, scenic attributes) nursery and habitat.
Valuation Method: Hedonic cost, travel cost, productivity value, and contingent valuation.

Location: Peconic Estuary, Suffolk County, New York
Site Description: The Peconic Estuary system is made up of connected watershed lands along the east end of Long Island, NY. The PES comprises 5 communities and about 38 percent of the land area and 8 percent of the year-round population of Suffolk County. It contains valuable fisheries, beaches, parks, open space, and wildlife habitat, which are currently under threat.
Description: The authors coordinated four studies to find the value of estuarine resource services in the Peconic Estuary System in Suffolk County. The four studies used separate methodologies, with one hedonic model, one travel cost study, a wetlands productivity value study, and a contingent valuation survey. The wetlands productivity analysis used the commercial value of the fin fish and shell fish, the viewing value of birds, and the hunting value of waterfowl. Suffolk County is an affluent, suburban area. Used to assess nonmarket economic values in a coastal management context.
Notes:

34. Study: Kahn, J. R., Buerger, R.B. 1994. Valuation and the consequences of multiple sources of environmental deterioration - the case of the New-York Striped Bass fishery. Journal of Environmental Management 40, 257-273.
Land Cover: Open water (estuary, bay)
Ecosystem Service: Habitat and nursery, food provisioning
Valuation Method: Travel cost
Location: Long Island Sound, Lake Montauk, New York
Site Description: Lake Montauk is a 900-acre embayment that is home to the largest commercial and sporting fish fleets in the state of New York.
Description: This study examines two sources of environmental degradation in the New York striped bass fishery: the decline in environmental quality in Chesapeake Bay and the PCB contamination of striped bass from the Hudson River. The estimated loss in economic value from contamination ranges from $2.3 to $7.7 million annually due to Chesapeake Bay contamination, while the loss is $0.745 to $3.7 million for PCB contamination of the Hudson striped bass. PCB contamination has been found in sport fish in the San Francisco Bay since testing began in the 1990s, highlighting the applicability of this benefit transfer. Data is from 1985.
Notes:

35. Study: Kazmierczak, R.F. 2001. Economic linkages between coastal wetlands and habitat/species protection: a review of value estimates reported in the published literature. LSU Agricultural Economics and Agribusiness Staff Paper. http://www.agecon.lsu.edu/faculty.
Land Cover: Emergent herbaceous wetlands, woody wetlands
Ecosystem Service: Habitat and biodiversity
Valuation Method: Benefit transfer (meta-analysis)
Location: Global
Site Description: Various coastal and non-coastal wetlands all over the US and the world.
Description: This manuscript summarizes a total of 8 peer-reviewed studies, published from 1975 to 2001, reporting 24 separate estimates for the disaggregated value of habitat and species protection services provided by coastal and non-coastal wetlands. Studies conducted for wetlands in other regions of the U.S. reported habitat and species protection service values that ranged from a low of

$168.96/acre/year to a high of $403.16/acre/year. Geographic location and type of wetland appeared to have a relatively minor impact on the estimated values.
Notes:

36. Study: Kealy, M. J., Bishop, R.C. 1986. Theoretical and empirical specifications issues in travel cost demand studies. American Journal of Agricultural Economics 68, 660-667.
Land Cover: Open water (lake)
Ecosystem Service: Fishing
Valuation Method: Travel cost
Location: Wisconsin
Site Description: The study accounts for about half of the water surface area (about 7,165,900 acres) of Lake Michigan in the Wisconsin part. It has large beaches, fish, and fishing.
Description: A travel cost demand model is used to estimate the welfare that anglers derive from fishing in Lake Michigan, accounting for the differences in on-site time among recreationists, among many other variables. The value of recreational fishing in the Great Lakes is found to be $19.54 per day. The authors found that the demand for recreation was largely independent of users' income and leisure time.
Notes: Applicable to large lakes with fishing

37. Study: Kline, J. D., Swallow, S.K. 1998. The demand for local access to coastal recreation in southern New England. Coastal Management 26, 177-190.
Land Cover: Open water (beaches)
Ecosystem Service: Swimming, Fishing, Boating, and Bird Watching
Valuation Method: Contingent Valuation
Location: Gooseberry Island, Massachusetts
Site Description: Gooseberry Island is located in southeastern Massachusetts. It is undeveloped coastlines and beaches. There are no facilities or services provided on the island, and public access to the island currently is free. It attracts an estimated 72,000 visitors in an average summer season although it may be as much as 10°F cooler than other nearby locations. Visitors fish from shore or launch small watercraft or walk on the beach.
Description: The literature on recreational demand typically focuses on heavily-used beaches, which are not characteristic of most of the New England coastline. Therefore, this article examines the recreational demand for coastal access to a local, free-access site in southern New England. On-site interviews were conducted at Gooseberry Island, Massachusetts. The estimated average value of a visitor-day during the summer season is $3.06 for weekdays and $4.18 for weekends and holidays. This study includes useful values that may apply to the less-frequented coastal areas of the San Francisco Bay Area. The values are somewhat comparable to the low end of values presented in existing literature for beach recreation.
Notes: Applicable to undeveloped beaches

38. Study: Knowler, D.J., MacGregor, B.W., Bradford, M.J., Peterman, R.M. 2003. Valuing freshwater salmon habitat on the west coast of Canada. Journal of Environmental Management 69, 261–273.
Land Cover: Emergent herbaceous wetlands (Inland wetlands)
Ecosystem Service: Supporting habitat and biodiversity for fishing
Valuation Method: Production Function

Location: Strait of Georgia coho salmon fishery in southern British Columbia, Canada
Site Description: Coho salmon spawning and rearing habitat calculated with data from 16 stream sites the Thompson River, which contribute to fisheries populations in the Strait of Georgia. These streams comprise 503.2 km of habitat accessible to coho salmon and drain an area of approximately 7,130 km2. In portions of the river's catchment areas, coho salmon stocks had declined by as much as 90% in the last decade.
Description: In this paper, the authors present a framework for valuing benefits for fisheries from protecting areas from degradation, using the Strait of Georgia coho salmon fishery in southern British Columbia, Canada. Specifically, they use a bioeconomic model of the coho fishery to derive estimates of value consistent with economic theory. In addition, they estimate the value of changing the quality of fish habitat by using empirical analyses to link fish population dynamics with indices of land use in surrounding watersheds. The estimated value of protecting habitat ecosystem services is C$0.93 to C$2.63 per hectare of drainage basin, or about C$1322 to C$7010 per km of salmon stream length.
Notes:

39. Study: Kreutzwiser, R. 1981. The economic significance of the long point marsh, Lake Erie, as a recreational resource. Journal of Great Lakes Resources 7, 105-110.
Land Cover: Open water (Lake, Inland wetlands)
Ecosystem Service: Recreation (Fishing, Bird Watching, and Waterfowl Hunting)
Valuation Method: Travel cost
Location: Lake Erie, Ontario, Canada
Site Description: Long Point marsh, 750 hectares, and Point Peele, 710 hectares, mostly designated as National Parks in the north shore of Lake Erie.
Description: During 1978, the authors collected data from 703 users of a public marsh at Long Point and Point Pelee on the north shore of Lake Erie, in order to assess the economic significance of wetlands for recreation. The Long Point marsh provided various recreational opportunities, including nature viewing, fishing, and waterfowl hunting, for over 17,000 users. Those users placed a willingness to pay on recreation at over $213,000 and generated directly and indirectly almost $225,000 in local spending on food, travel, accommodation, and other items.
Notes: Applicable to inland wetlands and lakes

40. Study: Kulshreshtha, S. N., Gillies, J.A. 1993. Economic-evaluation of aesthetic amenities - a case-study of river view. Water Resources Bulletin 29, 257-266.
Land Cover: River
Ecosystem Service: Aesthetic information (amenity values in real estate)
Valuation Method: Hedonic
Location: Saskatchewan, Canada
Site Description: Major river in Canada which originates from glaciers in the Rockies, experiencing high flow reductions (70%) from climate change, agricultural and urban water use.
Description: The authors used hedonic price analysis to find the value of the South Saskatchewan River to the City of Saskatoon residents, based on willingness to pay for property taxes or higher rents. The study focuses specifically on rivers with urban access. Aesthetic values such as parks, trails, and vegetation are considered. It is found that it has high value in terms of its aesthetic environment within

the city. This study helps estimate the value of those rivers in urban settings, which are visited more frequently by residents.
Notes: Applicable to large rivers

41. Study: Lant, C. L., Roberts, R.S. 1990. Greenbelts in the corn-belt - riparian wetlands, intrinsic values, and market failure. Environment and Planning 22, 1375-1388.
Land Cover: Riparian buffer
Ecosystem Service: Recreation
Valuation Method: Contingent Valuation
Location: Iowa and Illinois
Site Description: Greenbelts—corridors of riparian wetland forest and meandering channels in an agricultural watershed. Fourteen towns from Iowa and Illinois were chosen so that communities of various sizes and many of the major river basins within the study area were represented.
Description: On the basis of an explicitly spatial market-failure model of land use in the riparian zone, contingent valuation was used to estimate the recreational and intrinsic benefits of improved "river quality" (a subjective measure based on aesthetics and amenities) in selected Iowa and Illinois river basins. Willingness to pay for river quality was most related to income and recreational participation, but not to other spatial or socioeconomic variables. Intrinsic values are found to be expressible as economic values similar to that of other public goods. Together with recreational values, they are larger on a per-acre basis, in many instances, than the production of agricultural commodities. The study took place in a rural setting with low population density.
Notes:

42. Study: Lant, C. L., Tobin, G. 1989. The economic value of riparian corridors in cornbelt floodplains: a research framework. Professional Geographer 41, 337-349.
Land Cover: Riparian Corridor
Ecosystem Service: Waste Treatment
Valuation Method: Contingent Valuation
Location: Iowa and Illinois
Site Description: Riparian buffers adjacent to cropland on the Cornbelt floodplains – corn and soy cultivation. The study looks at three drainage basins in the agricultural Midwest: 1) The Edwards River of west-central Illinois (poorly managed rivers with high sediment concentrations, little riparian wetland, high drainage density, and about half the length of the main river channelized). 2)The Wapsipinicon River of northeast Iowa (substantial riparian forests and swamps, covering 50% of the floodplain of the main river; completely natural, meandering channel; low sediment load). 3) The South Skunk River at Ames, IA (uncontrolled, and riparian forests can be found intermittently along the floodplain, average sediment concentration).
Description: Lant and Tobin develop a new research framework to determine the economic value of riparian corridors in floodplains of the agricultural Midwest. The authors address certain market failures associated with inefficient allocation of incentives, with regard to agricultural decision-making. A spatial economic model based on willingness-to-pay procedures assesses the apposite mix of agricultural and wetland uses that compares the marginal value of natural riparian vegetation and agricultural production on rural Cornbelt floodplains. An application is illustrated using willingness to pay estimates, which were between $117 and $282 per person for three drainage basins.

Notes: Applicable to forest and wetland, within riparian corridor, adjacent to cultivated and pasture/hay.

43. Study: Leschine, T. M., Wellman, K.F., Green, T.H. 1997. Wetlands' Role in Flood Protection. October 1997. Report prepared for: Washington State Department of Ecology Publication No. 97-100. http://www.ecy.wa.gov/pubs/97100.pdf
Land Cover: Wetland (urban)
Ecosystem Service: Moderation of extreme events (flood protection)
Valuation Method: Avoided Cost
Location: Washington
Site Description: Scriber Creek in Lynwood (5.1 miles long emptying into a wetland of about 6.8 square miles in a highly urbanized and developing community that contains 18 major drainage areas covering an area of approximately 7 square miles) and Springbrook Creek (with similar characteristics) in Renton. Flooding along rivers and streams in the lowlands of Western Washington have been increasingly frequent.
Description: The importance of flood-mitigating wetlands in Western Washington is highlighted. The authors use cost estimates for engineered hydrologic enhancements to wetlands currently providing flood protection as proxies for the value of the flood protection these same wetlands currently provide. The argument is illustrated by estimating the dollar-per-acre values of wetlands systems for flood protection in two Western Washington communities currently experiencing frequent flooding, including Renton and Lynnwood.
Notes: Applicable to urban wetlands

44. Study: Loomis, J.B. 2002. Quantifying Recreation Use Values from Removing Dams and Restoring Free-Flowing Rivers: A Contingent Behavior Travel Cost Demand Model for the Lower Snake River. Water Resources Research 38 (6), 21-28.
Land Cover: River
Ecosystem Service: Recreation (boating, camping, and fishing)
Valuation Method: Travel Cost
Location: Washington
Site Description: Lower Snake River in Washington, where 4 dams were to be removed. Minimum river depths are 4-6 feet. Small islands inside the river will reappear (wildlife habitat) when dam is removed. Generally there is no fee for access to the river.
Description: The authors present a travel cost demand model, using intended trips contingent upon dams being removed and the river being restored. This model is used as a tool for evaluating the potential recreational benefits of dam removal. The model is applied to the Lower Snake River in Washington using data from mail surveys of households in the Pacific Northwest region. Five years after dam removal, about 1.5 million visitor days are estimated, with this number growing to 2.5 million annually during years 20-100. If four dams are removed and 225 km of river are restored, the annualized benefits at a 6.875% discount rate would be $310 million.
Notes: Applicable to large rivers

45. Study: Mahan, B. L. 1997. Valuing urban wetlands: a property pricing approach. Portland, Oregon: U.S. Army Corps of Engineers. Institute for Water Resources.

Land Cover: Inland wetlands and marshes (urban)
Ecosystem Service: Amenity value in real estate
Valuation Method: Hedonic price
Location: Portland, Oregon
Site Description: Residential homes within the urban portion of Multnomah County, Oregon – which lies within the Portland urban growth boundary, encompassing it. Multnomah is the smallest Oregon county and has the largest population. The county's population in 1990 was 583,900. There were 187,300 occupied houses in Portland in 1990; about 53 percent of these were owner occupied. Being located in the maritime Pacific Northwest, the area enjoys significant water resources including two major rivers, several lakes, numerous streams and many wetlands.
Description: This report, prepared for the U.S. Army Corps of Engineers, explores several central questions relating to wetlands policy, especially regarding differences among heterogeneous wetlands. The authors set out to value wetland environmental amenities in the Portland, Oregon metropolitan area using the hedonic model. The findings show that wetlands have a significant influence on nearby residential property values; different types of wetlands have significantly different marginal implicit prices; and wetlands and non-wetland greenspaces (e.g. public parks, lakes, or rivers) have significantly different marginal implicit prices. This study helps quantify the value of wetlands in metropolitan regions.
Notes: Applicable to urban wetlands

46. Study: Mathews, L. G., Homans, F.R., Easter, K.W. 2002. Estimating the benefits of phosphorus pollution reductions: an application in the Minnesota River. Journal of the American Water Resources Association 38, 1217-1223.
Land Cover: River
Ecosystem Service: Recreation (visits)
Valuation Method: Contingent Valuation
Location: Minnesota River, Minnesota
Site Description: The Minnesota River is 335 miles long. The main pollutants are sediments, phosphorus, nitrogen, bacteria and oxygen demanding material.
Description: This paper estimates the benefits of a 40 percent reduction in phosphorus pollution in the Minnesota River, using contingent valuation. Data on recreational use was also collected for the Minnesota Valley National Wildlife Refuge. The model estimates annual household willingness to pay for phosphorus reduction at $140.
Notes: Applicable to rivers adjacent to agricultural activity

47. Study: Mazzotta, M. 1996. Measuing Public Values and Priorities for Natural Resources: An Application to the Peconic Estuary System. University of Rhode Island.
Land Cover: Bay (Estuary, coastal eelgrass beds), wetlands, grasslands (open space) and cultivated land
Ecosystem Service: Fishing (Shellfish gathering), habitat nursery, aesthetic, recreation
Valuation Method: Contingent valuation
Location: New York
Site Description: The Peconic Estuary System in Suffolk County, New York comprises over 100 bays, harbors, and tributaties covering and area of over 100,000 acres. Its watersheds drain an area of around

110,000 acres. Five communities surround it along with farms and historical sites, making it a very popular recreational destination.
Description: This PhD dissertation attempts to measure public values and priorities for protecting and enhancing natural resources of the Peconic Estuary system. A contingent valuation survey (contingent choice survey) allowed residents to value five specific natural resources: farmland, undeveloped land, wetlands, shellfishing areas, and eelgrass. Given a discount rate of 7.625%, ranges of present values for all five natural resources are derived.
Notes: Applicable to bays with high tourism and recreational activities

48. Study: McPherson, E. G. 1992. Accounting for benefits and costs of urban greenspace. Landscape and Urban Planning 22, 41-51.
Land Cover: Developed open space (urban canopy)
Ecosystem Service: Water regulation, gas regulation, climate regulation
Valuation Method: Avoided cost
Location: Tucson, Arizona
Site Description: The Trees for Tucson/Global ReLeaf is a volunteer-based program with the goal of planting 500,000 desert adapted trees throughout the city. The city has about 500,000 people and an area of 226.71 square miles. It has hot summers and temperate winters. It has a desert climate, relatively high precipitation but also high evapotranspiration.
Description: Costs and benefits to urban vegetation are given based on a proposed tree-planting project in Tucson, Arizona. Services such as heating/cooling energy savings, interception of particulates, and stormwater runoff reduction are analyzed. Air-conditioning energy savings are projected to be the tree-planting program's greatest benefit. Average annual cooling savings are about US$21 per tree (288 kW).
Notes:

49. Study: 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, 75-84.
Land Cover: Developed open space (urban green space)
Ecosystem Service: Air quality (Removal of air pollution CO, O3, NO2, Particulate Matter, SO2)
Valuation Method: Avoided Cost
Location: Sacramento, California.
Site Description: Sacramento has an estimated population of about 470,000 and covers an area of 100.1 square miles. It has a Mediterranean climate, characterized by damp to wet, mild winters and hot, dry summers. Sacramento's Shade program will result in the planting of 500,000 trees.
Description: A cost analysis is conducted to determine if shade trees planted in residential yards can be a cost effective means to improve air quality. The authors used deterministic models to estimate pollutant deposition and biogenic hydrocarbon emissions estimated annually for 30 years in California. Sampling a wide variety of plots throughout urban regions in Sacramento, the authors estimated the pollution mitigation benefit of urban trees.
Notes: Can also apply to low/medium intensity developed open space

50. Study: McPherson, E.G., Simpson, J.R. 2002. A comparison of municipal forest benefits and costs in Modesto and Santa Monica, California, USA. Urban Forestry & Urban Greening 1, 61-74.

Land Cover: Developed open space (urban canopy)
Ecosystem Service: Gas regulation (air pollution), climate regulation (carbon sequestration), storm protection, energy savings, aesthetic amenities in real estate
Valuation Method: Avoided Cost and Hedonic Price
Location: Modesto and Santa Monica, California.
Site Description: Modesto and Santa Monica have extensive tree planting programs. Modesto is in a central valley and has a population of 182,000 within 9,000 ha. Santa Monica is on the Pacific Ocean, has a population of 92,000 within 2,000 ha. Climates are Mediterranean.
Description: The authors compare functions and values of urban tree populations in Modesto and Santa Monica, California. The annual benefits from urban trees were estimated at $2.2 million in Modesto and $805,732 in Santa Monica. For every $1 invested in park management, there was a $1.85 and $1.52 benefit in Modesto and Santa Monica, respectively. Most benefits were from the aesthetic value of trees, while the majority of costs were from pruning trees and foliage. Benefits and costs were unevenly distributed throughout each city, largely because of variation in tree sizes and growth rates, prices, residential property values, and climate.
Notes: Can also apply to low/medium intensity developed open space

51. Study: Mullen, J. K., Menz, F.C. 1985. The effect of acidification damages on the economic value of the Adirondack Fishery to New-York anglers. American Journal of Agricultural Economics 67 (1), 112-119.
Land Cover: Open water (Rivers and Lakes)
Ecosystem Service: Fishing (recreation)
Valuation Method: Travel Cost
Location: New York
Site Description: The Adirondack mountainous region contains 2,877 lakes and ponds with a surface area of 282,154 acres and an additional 31,805 miles in streams. Most of this is open to public fishing. The Adirondack Park is 6 million acres, undeveloped with only 115,000 permanent residents (1970's). It is a recreational destination for many people in surrounding areas.
Description: A travel cost model is used to estimate losses in net economic value of the Adirondack recreational fishery resulting from damages caused by acidic deposition. Annual losses to New York resident anglers are estimated to be approximately $1 million per year in 1976 dollars.
Notes: Applicable to lakes and ponds with fishing activity

52. Study: Nowak, D.J., Crane, D.E., Dwyer, J.F. 2002. Compensatory Value of Urban Trees in the United States. Journal of Arboriculture, 28 (4), 194-199.
Land Cover: Forest (urban temperate and boreal trees)
Ecosystem Service: Aesthetic, amenity values
Valuation Method: Replacement Cost
Location: United States
Site Description: The study includes values for all of the USA as well as for individual cities. It included the entire urban forest structure of Atlanta, Georgia; Baltimore, Maryland; Boston, Massachusetts; Jersey City, New Jersey; New York, NewYork; Oakland, California; Philadelphia, Pennsylvania; and Syracuse, New York.

Description: Using field data from eight U.S. cities, the authors estimated the total compensatory value of tree populations to range from $101 million in Jersey City, NJ, to $5.2 billion in New York, NY. Compensatory value is defined as the compensation to owners for the loss of an individual tree, and can be seen as a valuation of trees as a property asset. The authors estimate the total compensatory value for urban forests in the contiguous United States at $2.4 trillion. This study also provides values for California.
Notes: Applicable within urban boundary

53. Study: Nunes, P.A., Van den Bergh, J.C. 2004. Can people value protection against invasive marine species? Evidence from a joint TC-CV survey in the Netherlands. Environmental and Resource Economics 28, 517-532.
Land Cover: Open water (bay)
Ecosystem Service: Recreation, human health and habitat.
Valuation Method: Contingent Valuation and Travel Cost
Location: Netherlands
Site Description: The open sea along the North-Holland beaches with the questionnaire being distributed at Zandvoort, a famous Dutch beach resort. The algal blooms create thick foams with repellent odors and repulsive coloration of the beach water ("red tides").
Description: A joint travel cost and contingent valuation survey was administered in order to find the benefit of a marine protection program which prevents overgrowth of harmful algal blooms (HABs). Algae are primarily introduced in North European waters through ballast water of ships. The present valuation is an assessment of the non-market benefits associated with the introduction of ballast water standards. These authors report to be the first to use these valuation techniques in relation to harmful algal blooms. They use the travel-cost method to measure recreation benefits derived from the prevention of HABs. Then they use the contingent valuation to measure bio-ecological benefits derived from the prevention of red tides in the marine ecosystem.
Notes:

54. Study: Opaluch, J., Grigalunas, T., Mazzotta, M., Johnston, R., Diamantedes, J. 1999. Recreational and Resource Economic Values for the Peconic Estuary, prepared for the Peconic Estuary Program. Peace Dale, RI: Economic Analysis Inc.
Land Cover: Open water (bay,estuary), wetlands, farmland, urban green space, grasslands
Ecosystem Service: Recreation (swimming, boating, fishing, wildlife viewing), Habitat and nursery (food and habitat for fish, birds and other species of value), and aesthetic (amenity values for real estate).
Valuation Method: Contingent valuation, travel cost, productivity value, and hedonic price.
Location: Peconic Estuary, New York.
Site Description: The Peconic Estuary System in Suffolk County, New York comprises over 100 bays, harbors, and tributaties covering and area of over 100,000 acres. Its watersheds drain an area of around 110,000 acres. Five communities surround it along with farms and historical sites, making it a very popular recreational destination. The water quality is high and tourism is an important part of the local economy.
Description: The authors present the results of four non-market valuation studies carried out by Economic Analysis Inc. to estimate the uses and economic value that the public holds for the natural assets. They provided estimates of (1) outdoor recreational uses and of the non-market economic values

of key recreational activities, and (2) other resource values provided by the natural assets. The study was conducted in the New York Peconic Estuary System, near the Chesapeake Bay region. Demographically, the surveyed public represents much of NY's Long Island.
Notes: Applicable to open space areas (parks, wildlife preserves, wetlands, and institutional space)

55. Study: Pimentel, D. 1998. Benefits of biological diversity in the state of Maryland. Cornell University, College of Agricultural and Life Sciences. Ithaca, New York.
Land Cover: Pasture, Forest
Ecosystem Service: Soil formation, crop productivity, pollination, biological pest control, food, pharmaceuticals, waste treatment, nutrient cycling, nitrogen fixation, bioremediation, biotechnology productivity
Valuation Method: Replacement cost
Location: Maryland
Site Description: The values apply to whole state of Maryland, which had 5 million people in 1996 and a land cover of 6 million acres. About 18% of the land had been developed with housing, industry, and highways; 36% was devoted to agriculture and 38% was forest land.
Description: Pimentel values the biological diversity of plant species in the State of Maryland, assessing their contribution to agriculture, fishing, hunting, and outdoor recreation, among others. The total economic benefit of biological diversity is found to be approximately $1.8 billion per year.
Notes:

56. Study: Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Sphpritz, P., Fitton, L., Saffouri, R., Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science 267, 1117-1123.
Land Cover: Cultivated Pastures
Ecosystem Service: Nutrient regulation, crop productivity, soil formation
Valuation Method: Replacement cost
Location: United States
Site Description: United States – average values are derived for the whole country based on general estimates.
Description: This article describes the environmental and agricultural issues related to soil erosion. Erosion reduces fertility and water availability for crops. A reduction of soil depth of 2.8 cm results in a reduction in productivity of about 7%. It takes hundreds of years to replace a single centimeter of lost topsoil. On and off site costs are added to productivity losses to arrive to the total cost of erosion.
Notes: Applicable to general cultivated

57. Study: Piper, S. 1997. Regional impacts and benefits of water-based activities: an application in the Black Hills region of South Dakota and Wyoming. Impact Assessment 15, 335-359.
Land Cover: Open water (Reservoir)
Ecosystem Service: Water supply, recreation (boating, swimming, and fishing)
Valuation Method: Direct expenditures (travel cost, WTP for water supply, irrigation costs)
Location: South Dakota and Wyoming

Site Description: Black Hills is a region that includes six counties in western South Dakota, three adjacent counties in Wyoming, and the city of Gillette, Wyoming – with a population of about 189,000 people. The dominant agricultural activities in the region are livestock, hay, and wheat production.
Description: A framework for evaluating water management scenarios at the regional level is presented. The regional impacts from agricultural production, recreational expenditures, and residential water service expenditures are analyzed. Water demand is presented a function of population size, the number of commercial establishments in the area, and the size and type of businesses and industry in the area. According to their estimates, irrigated agriculture generates the greatest regional economic impacts in the Black Hills and water-based recreation generates the greatest benefit to the nation.
Notes: Applicable to areas with irrigated agriculture and water based recreation

58. Study: Pompe, J., Rinehart, J.R. 1995. Beach quality and the enhancement of recreational property-values. Journal of Leisure Research 27, 143-154.
Land Cover: Open water (beach)
Ecosystem Service: Amenity and storm protection values to real estate
Valuation Method: Hedonic price
Location: South Carolina
Site Description: Surfside beach and Garden City, which are in close proximity in South Carolina. Garden City is about 1 mile inland from Surfside beach. Surfside Beach has a total area of 2.0 square miles and a population of 4,425. Garden City has an area of 5.5 square miles and population of about 9,357.
Description: The hedonic method is used to find the effect of beach quality on property values in two South Carolina towns. Beach width is used as a proxy measurement for beach quality. Marginal values for beach width vary along the supply curve: additional beach width is worth more for slimmer beaches, relative to the same addition to an already wide beach. Vacant lots increase in price more than developed land with greater beach front. WTP is said to reflect values for storm protection and recreation.
Notes: Applicable to beach homes at risk of flood.

59. Study: Prince, R., Ahmed, E. 1989. Estimating individual recreation benefits under congestion and uncertainty. Journal of Leisure Research 21, 61-76.
Land Cover: Forest
Ecosystem Service: Recreation (hiking)
Valuation Method: Contingent Valuation
Location: West Virginia
Site Description: Ramsey's Draft Wilderness is a designated wilderness area in the North River Ranger District of the George Washington and Jefferson National Forests of Virginia. It comprises 6,518 acres. An estimated 15,496 individuals were expected to engage in day hiking annually.
Description: The authors discuss the appropriate method to analyze consumer decision making under uncertainty of congestion at recreational sites. They focus on all day hikers (excluding camping). They argue that a recursive system is the most appropriate method when users cannot predict congestion in order to avoid downward biases in WTP. Using contingent valuation, the benefit of forestland in terms of hiking opportunities is estimated to be between \$19.04 and \$24.18 per acre per year.
Notes: Applicable to medium to large forests with hiking opportunities

60. Study: 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.
Land Cover: Urban green space, grassland riparian
Ecosystem Service: Amenity values and flood risk values for real estate
Valuation Method: Hedonic price and contingent valuation
Location: Missouri
Site Description: Dardenne Creek watershed, a suburban watershed of the St. Louis metropolitan area. It covers about 415 km2. The watershed has experienced environmental degradation such as flooding, soil erosion, and losses of wetland, aquatic stream habitat, and water quality due to rapid population growth and urban development.
Description: This study finds the economic value of riparian buffers and open space in a suburban watershed using both contingent valuation and hedonic pricing. The contingent valuation survey was distributed in the area surrounding the Dardenne Creek watershed to find residents' willingness to pay for adopting riparian buffers and preserving farmland in a hypothetical real estate market. The hedonic pricing model assessed actual sale prices of homes in the watershed, which was used to find the value of open space, flood risk, and stream proximity. Residents' willingness to pay estimates were consistent with the values derived from hedonic pricing; in other words, stated preference was the same as observed preference.
Notes:

61. Study: Rein, F.A. 1999. An Economic Analysis of Vegetative Buffer Strip Implementation. Case Study: Elkhorn Slough, Monterey Bay, California. Coastal Management, 27 (4), 377-390.
Land Cover: Grasslands (Native perennial grasses), Should also have Riparian buffer, emergent herbaceous wetlands; adjacent to agriculture.
Ecosystem Service: Waste treatment, soil retention, recreation, disturbance prevention, biological control, productivity costs
Valuation Method: Avoided cost
Location: California
Site Description: Elkhorn Slough in Monterey County is one of the last remaining salt marsh wetlands in California. Approximately 26% of the watershed is in agricultural production, primarily intensive row crops like strawberries and flowers. The surrounding uplands have steep slopes and sandy loam topsoil, which are particularly susceptible to erosion (Mountjoy, 1996). It has great biodiversity but it is under threat by high nutrient concentrations from agricultural runoff and erosion.
Description: This study investigates the economics of implementing vegetative buffer strips as a tool to protect water quality from nonpoint pollution. It evaluates environmental costs and benefits of implementing vegetative buffer strips, both to the grower and to society as a whole, as a means of capturing nonmarket ecosystem values and informing decision making. Results indicate a net economic benefit to the grower for installing vegetative buffer strips within the first year, if the economic costs of erosion are considered. The installation of vegetative buffer strips also has extensive economic benefits to society in areas such as tourism, commercial fisheries, long-term road maintenance, and harbor protection. These results support installing vegetative buffer strips as a management strategy in an erosion-prone watershed to protect water quality and preserve soil fertility, as well as to protect economic interests.
Notes:

62. Study: Ribaudo, M., Epp, D.J. 1984. The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. Land Economics 60, 397-403.
Land Cover: Open water (Lakes)
Ecosystem Service: Recreation
Valuation Method: Travel Cost
Location: Vermont
Site Description: St. Albans Bay is located on the northeastern portion of Lake Champlain about 30 miles north of Burlington, Vermont. It is approximately 1,700 acres with a maximum depth of 40 feet and a mean depth of 27 feet. The bay had been a major recreational site, providing swimming, boating, fishing, and other recreation opportunities. Over the past 10-15 years, however, there has been an increasing problem with phosphorus loading in the bay, resulting in extensive floating plant growth. As a result of environmental problems, recreational use of the bay has declined. In 1960 total attendance for the park was 27,456, which declined to a total of 3,261 in 1979.
Description: The authors identify several methodological issues associated with the travel cost method. Specifically, most travel cost analyses do not account for changes in recreational behavior due to site quality and availability of substitutes. The authors account for these dynamic factors by using contingent behavior analysis of current and former users at St. Albans Bay in Vermont. Improved water quality was found to be desirable for recreationists. In the regression, income and other demographic factors did not have a significant effect on decisions for recreation, suggesting a good fit for transfer in California.
Notes: The results apply especially to large lakes with recreational activities.

63. **Study:** Rosenberger, R. S. and Walsh, R.G. 1997. Nonmarket Value of Western Valley Ranchland Using Contingent Valuation. Journal of Agricultural and Resource Economics.
Land Cover: Rangeland
Ecosystem Service: Aesthetic and information (heritage, landscape, aesthetics).
Valuation Method: Contingent valuation
Location: Colorado
Site Description: Yampa River Valley in Routt County, with an area of 50,000 acres and about 6000 households. It is characterized by open valley and currently under threat of conversion to development.
Description: Ranchland and farmland in this area is currently under threat as development grows. It has been an important cultural identity of the region. Environmental and cultural values however are said to not be properly accounted in land prices. Values were dependent on the amount of ranchland being protected, on the income of individuals, and on the level of development pressure.
Notes:

64. Study: Sanders, L. D., Walsh, R.G., Loomis, J.B. 1990. Toward empirical estimation of the total value of protecting rivers. Water Resources Research 26, 1345-1357.
Land Cover: Open Water (rivers)
Ecosystem Service: Recreation (fishing, boating, camping, hunting, sight-seeing, information, cultural)
Valuation Method: Contingent Valuation
Location: Colorado

Site Description: Rivers in the Rocky Mountains of Colorado: Sections of the Cache la Poudre; Colorado; Conejos; Dolores; Elk; Encampment; Green; Gunnison; Los Pinos; Piedra; Yampa Rivers totaling about 905 kilometers in length.
Description: This paper develops and applies a procedure to estimate a statistical demand function for the protection of rivers in the Rocky Mountains of Colorado. In addition to direct consumption benefits of onsite recreation, total value includes offsite consumption of the flow of information about these activities and resources consumed as preservation benefits. The authors recommend that offsite benefits be included when determining the total value of rivers to society. Because demographic factors like household income and education had minimal or no effects on willingness to pay, the model provides a good range of estimates for benefit transfer.
Notes: Applicable to general rivers

65. Study: Shafer, E. L., Carline, R., Guldin, R.W., Cordell, H.K. 1993. Economic amenity values of wildlife - 6 case-studies in Pennsylvania. Environmental Management 17, 669-682.
Land Cover: Open water (Rivers), Forests (mountain, game lands)
Ecosystem Service: Recreation (fishing and wildlife viewing)
Valuation Method: Contingent valuation and travel cost
Location: Pennsylvania
Site Description: Different sites where activities can be carried out: Fisherman's Paradise (8mile stream of Spring Creek), Spring Creek (21 mile of Spring Creek), Hawk Mountain Sanctuary (200 acres in the Appalachian Mountains), Middle Creek Wildlife, Management Area (5200 acres of state game lands), Elk viewing areas (144-square-mile area of state forest and state game lands), Shaver's Creek Environmental Center (education center).
Description: Both travel cost method and contingent valuation are used to evaluate the economic value of six distinct ecotourism activities in Pennsylvania. The six activities were: catch-and-release trout fishing; catch-and-release trout fishing with fly-fishing equipment; waterfowl viewing; elk viewing; observing migration flights of raptors; and viewing live wildlife in an environmental education setting. The estimated consumer surplus was twice the out-of-pocket payments spent to visit the sites.
Notes: Applicable to rivers with fishing and/or mountainous forests and game lands.

66. Study: Smith, W.N., Desjardins, R.L., Grant, B. 2001. Estimated changes in soil carbon associated with agricultural practices in Canada. Canadian Journal of Soil Science 81, 221-227.
Land Cover: Cultivated land
Ecosystem Service: Carbon sequestration
Valuation Method: Biophysical measurement
Location: Canada
Site Description: Agricultural soils in Canada are examined, with laboratory testing for different types of soils and modelling for different management regimes such as reduced tillage, better selection of crops and crop rotations, reduction in summer fallowing frequency, and nutrient management. Three soil textures (sandy loam, loam, and clay loam) were examined in each of seven soil groups.
Description: The Century model was used to estimate the influence of changing agricultural practices on C levels in seven major soil groups in Canada between 2000 and 2010. The Century model is a computer simulation model that uses relationships of soil-plant-climate interactions to describe the dynamics of soil C and N in grasslands, crops, and forests. Conversion of arable land to permanent cover would result

in the greatest sequestration of C, averaging 0.62 Mg C ha-1 yr-1. Other agricultural practices are assessed for their potential to sequester C. This study indicates that there are several feasible techniques that could be adopted by agricultural producers in Canada that would significantly increase CO_2 uptake from the atmosphere. Although monetary values are not provided, they can be inferred based on the economic value of CO_2 sequestration.
Notes: Applicable to general agricultural land

67. Study: Soderqvist, T., Scharin, H. 2000. The regional willingness to pay for a reduced eutrophication in the Stockholm archipelago. In: Beijer Discussion paper No. 128, Stockholm, Sweden.
Land Cover: Open water (Marine archipelago)
Ecosystem Service: Waste treatment (water quality)
Valuation Method: Contingent valuation
Location: Sweden
Site Description: The Stockholm Archipelago is one of the most important recreational areas along the Swedish Baltic Sea coast. It consists of a cluster of approximately 24,000 islands.
Description: By applying the contingent valuation method, the benefits of reduced eutrophication effects in the Stockholm archipelago are estimated. Eutrophication effects include water turbidity, algal blooms, anoxic situations, disturbed cod reproduction. The mean willingness to pay per adult resident in the counties of Stockholm and Uppsala is estimated to be SEK 436-725 per year. This corresponds to a population estimate of SEK 506-842 million per year.
Notes: Applicable to bay

68. Study: Thibodeau, F. R., Ostro, B.D. 1981. An economic analysis of wetland protection. Journal of Environmental Management 19, 72-79
Land Cover: Wetland
Ecosystem Service: Flood control, land value, pollution reduction, water supply, recreation, aesthetics, preservation and research, vicarious consumption, option demand, and undiscovered benefits.
Valuation Method: Hedonic price, benefit transfer, replacement cost
Location: Massachusetts
Site Description: Wetlands in the Charles River Basin in Massachusetts – comprising 8,535 acres of marsh and wooded swamp, draining 196,000 acres of urban and suburban land around the Boston area. These are wetlands around dense urban populations, where there are few park and green recreational areas.
Description: In response to several policies that offer payments for wetland preservation, this paper quantifies the economic benefits of wetlands in the Charles River Basin. It uses a combination of methods to evaluate different services. Values are provided in the event that the entire resource is lost – with a range of between $150,000 and $190,000 per acre (one-time value). The paper also analyzes the legal issues associated with wetland preservation.
Notes: Most relevant to wetlands near urban areas

69. Study: 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.
Land Cover: Urban green space (parks and open space)

Ecosystem Service: Water regulation
Valuation Method: Benefit transfer, direct expenditures, contingent valuation
Location: New York
Site Description: Nassau and Suffolk Counties on Long Island. The government structure on Long Island is highly complex. In Nassau and Suffolk Counties there are two cities, 13 towns, 96 villages, 125 school districts, and 132 fire districts.
Description: The Trust for Public Land (TPL) conducted an analysis of the economic benefits and fiscal impact of parks and open space in Nassau and Suffolk Counties on Long Island. Several calculations are made, including reduced cost of government services (property tax revenues); recreation and tourism; agriculture industry; government cost savings; and additional non-market benefits, which are discussed qualitatively. When both property tax revenues and expenditures for services are taken into account, it is argued that residential development is more costly to local governments than are parks and open space. The method used in this analysis is the average cost approach at the county, city, and town level; where estimates for the costs of government services (e.g., transportation, education, and public safety) are based on the existing average cost of providing services per acre.
Notes:

70. Study: 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
Land Cover: Urban green space (parks and open space)
Ecosystem Service: Water regulation
Valuation Method: Benefit transfer, direct expenditures, hedonic price, contingent valuation
Location: Washington
Site Description: Seattle, Washington with more than 5,400 acres of city parks —26 recreation centers, 114 ball fields, 165 tennis courts, trails for bike commuters, and a mountain bike course.
Description: This study assesses seven major factors to determine the value of Seattle parks: property value, tourism, direct use, health, community cohesion, clean water, and clean air. Property tax and tourists' sales tax provide direct income to the city's treasury. Some value is derived from increased property values for Seattleites. Finally, direct savings are provided to Seattle residents because recreation on public lands yields consumer surplus; in addition, health benefits are derived from recreation and cleaner air.
Notes:

71. Study: Tyrvainen, L. 2001. Economic valuation of urban forest benefits in Finland. Journal of Environmental Management 62, 75-92.
Land Cover: Urban green space (forest)
Ecosystem Service: Amenity values, habitat, forest resources
Valuation Method: Contingent valuation
Location: Finland
Site Description: Mediums sized towns of Joensuu and Salo in Finland with differing amounts of green areas. Joensuu has a flat landscape with abundant urban forests and water bodies (34% of town area is forest). Salo has 23,000 people and is an old commercial centre in a large river valley. It has much less forests and most of the housing is in old agricultural land.

Description: Contingent valuation is used to find the value of urban forests in two different urban environments, which are Joensuu and Salo, Finland. More than two thirds of respondents were willing to pay for the use of recreation areas. Proximity to forests and better land management increased willingness to pay. Half of all respondents exhibited positive willingness to pay for preventing construction in urban forests. Responses between the two towns were similar. Architectural values were slightly higher in Salo and use of the forest was more active in Joensuu.
Notes:

72. Study: Van Kooten, G.C., Schmitz, A. 1992. Preserving Waterfowl Habitat on the Canadian Prairies: Economic Incentives Versus Moral Suasion. American Journal of Agricultural Economics 74, 79-89.
Land Cover: Farmland, wetland and pasture (grass, shrubs)
Ecosystem Service: Habitat (for waterfowl)
Valuation Method: Contingent valuation
Location: Canada
Site Description: Prairie pothole region of western Canada, Saskatchewan, accounts for 20% of duck production. The area is characterized by a mix of wetlands and uplands that serve as breeding grounds. These have been under threat as grain prices increase and farmers have incentive to convert habitats to agricultural production.
Description: This paper examines a pilot project of the North American Waterfowl Management Plan that encourages farmers to create or maintain waterfowl habitat by relying not only on economic incentives but on awareness, education, and moral persuasion. A regression analysis examines attitudes, economic incentives, and willingness to pay and willingness to accept compensation for modifying land use in order to conserve waterfowl habitat. Results indicate that current economic incentives offered to agricultural producers are inadequate because they ignore nonmarket costs, and that a positive attitude toward habitat preservation cannot be used as a substitute for monetary incentives. Because demographic factors like age and education did not significantly impact willingness to pay or willingness to accept, it is appropriate for a benefit transfer.
Notes:

73. Study: Wade, W.W., McCollister, G.M., McCann, R.J., Johns, G.M. 1989. Recreation Benefits for California Reservoirs: A Multisite Facilities-Augmented Gravity Travel Cost Model. Spectrum Economics, Inc. 32 p.
Land Cover: Open water (Lakes and reservoirs)
Ecosystem Service: Boating, fishing and swimming
Valuation Method: Travel cost
Location: California
Site Description: 83 freshwater lakes and reservoirs in California, including waterflows of California's Sacramento-San joaquin Rivers within the Delta, and reservoirs upstream and downstream of the Delta supplied by these same waterflows. Flows from the Delta watershed are impounded throughout California at dozens of reservoirs engineered to distribute the water throughout the state. 58 counties are used as destination spots with different substitute options for each.
Description: This paper uses a gravity travel cost model, which allows for non-linearity in its calculations. The authors calculate the recreational benefit of 83 fresh lakes and reservoirs in California using the new model, accounting for boating, fishing, and swimming. A comparison is provided for various locations

and activities. Site visits are proportionally related to the size of the reservoir. Values change depending on availability of substitutes and the population using the sites. Marginal freshwater recreation benefits per visitor day are found to be higher in Southern California than in Northern California, largely because of fewer substitutes and greater scarcity in the south.
Notes: Applicable for general lakes and reservoirs

74. Study: Ward, F.A., Roach, B.A., Henderson, J.E. 1996. The economic value of water in recreation: Evidence from the California drought. Water Resources Research, 32 (4), 1075-1081.
Land Cover: Open water (Lakes and reservoirs)
Ecosystem Service: Recreation (water-related)
Valuation Method: Travel cost
Location: California
Site Description: 12 Corps of Engineer reservoirs in the Sacramento, California District, which commonly experience drawdowns during the summer. These drawdowns reduce recreational visits because of aesthetics, expanded mud flats, reduced water for fish habitat, and facilities such as boat ramps being inoperative.
Description: This paper looks at how recreational values change with reservoir levels, i.e. in response to drought. The study uses a travel cost model containing water level as a visit predictor. Data on visitors were collected by origin and destination before and during the early part of the 1985-1991 California drought. Because lake levels varied widely during the sample period, water's effect on visits was isolated from price and other effects. For the range of the lake levels seen, annual recreational values per acre-foot of water vary from $6 at Pine Flat Reservoir to more than $600 at Success Lake. Variations were a function of size of the reservoir, proximity to urban centers, and recreational opportunities. These findings are limited to use values of visitors who travel to the reservoirs and do not reflect passive use values to people who value the reservoirs but never visit them. If this study is used for function transfer it is recommended that four factors are considered: current visitor use multiplied by average benefits per visit (for this study, benefits per visit ranged from $1 to $3 for day users), the elasticity of "percent full" to the reservoir's actual percent full measured in surface area, the reservoir's recreational capacity in surface area, and the surface acres produced by adding 1 acre-foot of water to the reservoir.
Notes: Applicable to lakes or reservoirs with recreational opportunities

75. Study: Whitehead, J. C., Groothuis, P. A., Southwick, R., Foster-Turley, P. 2009. Measuring the economic benefits of Saginaw Bay coastal marsh with revealed and stated preference methods. Journal of Great Lakes Research, 35 (3), 430–437.
Land Cover: Coastal wetlands
Ecosystem Service: Recreation
Valuation Method: Travel cost and contingent valuation
Location: Michigan
Site Description: Saginaw Bay coastal marsh in the Great Lakes Region. Typical plants are cattails, rushes, grasses and shrubs. The average amount of wetland acres in each county is 46,000. The number of households in the five-county Saginaw Bay region is 50,191.
Description: The authors estimate the economic benefits of Saginaw Bay coastal marsh using the travel cost and contingent valuation methods. The travel cost method uses actual recreation behavior. An analysis of Michigan residents, as well as Michigan residents with hunting and fishing licenses, finds that

site selection is negatively related to travel cost and positively correlated to wetland acreage. The contingent valuation finds that willingness to pay is negatively related to marsh protection cost and positively related to income and environmental organization membership.
Notes:

76. Study: Whitehead, J. C., Hoban, T.L., Clifford, W.B. 1997. Economic analysis of an estuarine quality improvement program: The Albemarle-Pamlico system. Coastal Management 25, 43-57.
Land Cover: Open water (estuary)
Ecosystem Service: Water quality, habitat, recreation
Valuation Method: Contingent valuation and travel cost
Location: North Carolina and Virginia
Site Description: Albemarle-Pamlico Estuaries – the second largest estuarine complex in the United States, which comprises over 30,000 square miles in northeastern North Carolina and southeastern Virginia. The system is composed of seven sounds.
Description: This paper bases its analysis on a 5-year study of the Albemarle-Pamlico Estuaries. This article presents an economic efficiency analysis of the management plans proposed in that study. Under plausible conditions and reasonable data for benefits and costs, it appears that the management plan would be an efficient government program if the negative externalities associated with economic growth of the Albermarle-Pamlico region are controlled.
Notes:

77. Study: Willis, K.G. 1991. The recreational value of the forestry commission estate in Great Britain - a Clawson-Knetsch travel cost analysis. Scottish Journal of Political Economy 38, 58-75.
Land Cover: Forest
Ecosystem Service: Recreation
Valuation Method: Travel cost
Location: Great Britain
Site Description: In order to be representative of all forest types in Great Britain, they were clustered into 15 categories based on age, diversity of plantations, climate, topography, exposure, geographical location, recreational facilities and forest uses.
Description: The recreational value of several types of forest in Great Britain is assessed within the context of a larger ROI calculation for public investments. To estimate environmental benefits, a travel cost model is used. The impact on the internal rate of return (IRR) of forestry operations from including consumer surplus on non-priced recreation is variable. In some cases such as the New Forest, Cheshire and Dean, where the consumer surplus from recreation per hectare is high, the impact on the IRR is substantial. However, in many of the remoter Scottish forests the impact is negligible. In intermediate cases, the planting model chosen makes a difference. Based on observed behavior, the Cheshire forest had the highest consumer surplus per hectare per visit.
Notes: Applicable to general forests by type

78. Study: Willis, K.G., Garrod, G.D. 1991. An individual travel-cost method of evaluating forest recreation. Journal of Agricultural Economics 42, 33-42.
Land Cover: Forest
Ecosystem Service: Recreation

Valuation Method: Travel cost
Location: Great Britain
Site Description: In order to be representative, six forests in Great Britain were studied, sharing similar characteristics in terms of tree variety, maturity and recreational use.
Description: This paper uses an alternative travel cost method for calculating consumer surplus for outdoor recreation. Zonal consumer-surplus estimates are compared to individual visitor observations. The data was collected in 1988 and included forests within the Forestry Commission. Considerable variation was found between the methods.
Notes: Applicable to general forests by type.

79. Study: Wilson, S.J. 2008. Ontario's wealth, Canada's future: Appreciating the value of the Greenbelt's eco-services. David Suzuki Foundation, Vancouver, Canada. Http://www.davidsuzuki.org/Publications/Ontarios_Wealth_Canadas_Future.asp.
Land Cover: Urban forest, wetlands, pasture/hay, grasslands, cultivated, open water (rivers)
Ecosystem Service: Air quality, pollination, water regulation, waste treatment, habitat, recreation, climate regulation (stored carbon and carbon sequestration), food provision
Valuation Method: Benefit transfer, direct pricing, avoided cost, replacement cost
Location: Ontario, Canada
Site Description: Greenbelt in Southern Ontario, which covers over 1.8 million acres and includes green space, farmland, communities, forests, wetlands, and watersheds, including habitat for more than one-third of Ontario's species at risk. It surrounds dense urban population centers, including the Greater Toronto Area.
Description: This document assesses the value of ecosystem services in Ontario's Greenbelt. Values per hectare are given for all types of land cover in the Greenbelt, as well as for each type of ecosystem service provided by these lands. The annual value of the region's measurable non-market ecosystem services is estimated at $2.6 billion annually; an average value of $3,487 per hectare. Wetlands have the greatest values, worth an estimated $1.3 billion per year ($14,153/hectare) because of their high value for water regulation, water filtration, flood control, waste treatment, recreation, and wildlife habitat.
Notes: Appropriate for greenbelts surrounding urban populations.

80. Study: Wilson, S.J. 2010. Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature.Http://www.davidsuzuki.org/Publications/Ontarios_Wealth_Canadas_Future.asp.
Land Cover: Urban forest, wetlands, grasslands, cultivated, rivers, watersheds, coastal.
Ecosystem Service: Air quality, pollination, water regulation, water supply, waste treatment, salmon habitat, recreation, climate regulation, food provision, coastal protection.
Valuation Method: Direct pricing, avoided cost, replacement cost, production functions, travel cost, benefit transfer.
Location: British Columbia, Canada
Site Description: B.C.'s Lower Mainland and its watershed - including the Lower Fraser Valley which contains some of Canada's best agricultural lands, wetlands and forests. The population of the region including the Greater Vancouver Regional District and the Fraser Valley District is now over 2.5 million people. The dominant ecosystem type is forests at 61%.
Description: This paper examines the ecosystem services derived from British Columbia's lower mainland. Values per hectare are provided for ten different ecosystem services, both on a per-person

level and in aggregate. The top three benefit values provided by the study area's ecosystem services are: (1) climate regulation, (2) water supply due to water filtration services by forests and wetlands; and (3) flood protection and water regulation provided by forest land cover.
Notes: Many of the per-acre values are especially appropriate for west coast ecosystems that are relatively similar to the coastal areas of California.

81. Study: Winfree, R., Gross, B., Kremen, C. 2011. Valuing pollination services to agriculture. Ecological Economics 71, 80-88.
Land Cover: Cultivated
Ecosystem Service: Pollination
Valuation Method: Attributable net income, replacement cost, production value
Location: Pennsylvania and New Jersey
Site Description: 23 watermelon farms located in central New Jersey and east-central Pennsylvania. They produce less than 2% of the fruit in the region.
Description: The authors use replacement cost, production value, and attributable net income to estimate pollination services provided by bees to watermelon production. The attributable net income method modifies the production value to subtract the costs of inputs to production. It also accounts for the pollination requirements of the plant, and the pollination already provided by other pollinator taxa, thereby better relating the measured service (pollination) to the marketable good (fruit production). The attributable net income method produces valuations that are intermediate between those obtained with the replacement value and the production value approaches.
Notes:

82. Study: Woodward, R., Wui, Y. 2001. The economic value of wetland services: a meta-analysis. Ecological Economics 37, 257-270.
Land Cover: Emergent herbaceous wetlands, woody wetland
Ecosystem Service: Water supply, waste treatment, recreation, habitat, disturbance prevention, food provisioning
Valuation Method: Meta-analysis
Location: Global
Site Description: N/A
Description: Using results from 39 studies, the authors evaluate the relative value of different wetland services, the sources of bias in wetland valuation, and the returns to scale exhibited in wetland values. To do so, meta-analysis is used. They assume that a wetland's value is a function of the system's ecological characteristics and its socio-economic environment. They find evidence that CV studies tend to yield greater values than any other method, but no visible relationship between value per acre and either the number of services or the size of the wetland. Strong econometric foundations give more precise values. Bird watching and fishing opportunities are the most valued services. The authors conclude that the value of wetlands is highly dependent on site-specific traits.
Notes:

83. Study: Wu, J., Skelton-Groth, K. 2002. Targeting conservation efforts in the presence of threshold effects and ecosystem linkages. Ecological Economics 42, 313-331.
Land Cover: Open water (rivers)

Ecosystem Service: Habitat for salmon
Valuation Method: Direct market price
Location: Oregon
Site Description: 13 streams within the John Day River watershed. The River Basin is part of the mid-Columbia river drainage system and is located in northeastern Oregon. The entire drainage area is approximately 20,979 km2. The general climate of this region is arid to semi-arid with low precipitation. Summer streamflows are small and under stress by increased demand for water by farmers, threatening cold-water fish populations.
Description: An empirical investigation is conducted for Pacific Northwest riparian habitat investments for salmon restoration. The authors show that conservation benefits are lost when correlated environmental benefits and thresholds are ignored in federal conservation policies. The empirical analysis focuses on riparian habitat improvement for salmonid restoration in the thirteen streams in the John Day River Basin. The results point towards upper elevation streams being targeted for conservation first. The temperatures in these streams are close to threshold levels.
Notes: Applicable to rivers with salmon

84. Study: Young, C.E., Shortle, J.S. 1989. Benefits and costs of agricultural nonpoint-source pollution controls: the case of St. Albans Bay. Journal of Soil and Water Conservation 44, 64-67.
Land Cover: Open Water (Rivers)
Ecosystem Service: Value in real estate, recreation
Valuation Method: Direct market price, hedonic, travel cost
Location: Vermont
Site Description: St. Albans Bay watershed in Lake Champlain. Algal blooms and other nutrient overload problems had impaired recreation in the bay because of surrounding water treatment plants and uncontrolled dairy manure storage.
Description: A cost-benefit analysis is conducted for a combined program to control agricultural runoff and upgrade municipal wastewater treatment in the St. Albans Bay watershed of Lake Champlain in Vermont. Benefits are estimated to exceed costs by $1.7 million for the period 1981 to 2030. Benefits were calculated using appreciation in property values and enhanced recreational experiences. Costs for manure control and waste water were also calculated.
Notes: Applicable to rivers or lakes with water quality problems

85. Study: Zavaleta, E. 2000. The Economic Value of Controlling an Invasive Shrub. AMBIO: A Journal of the Human Environment, 29 (8), 462-467.
Land Cover: Open water (riparian buffer)
Ecosystem Service: Water Supply, Flood Protection
Valuation Method: Avoided cost
Location: United States
Site Description: Arid and Semi-Arid regions of western USA (the 23 states which have been invaded by Tamarisk, including California, Nevada, Arizona and Colorado). In this region almost all agriculture is dependent on irrigation. Tamarisk has replaced native riparian forest and scrub communities in 470,000–650,000 ha of riparian floodplain habitat in the 23 states, from sea level to 2,500 m.
Description: This study values the economic impacts of an invasive woody shrub on ecosystem services. Tamarisk, the invasive species, consumes more water than native vegetation, increases sedimentation,

and flood risks - with significant economic implications for a region in which water is scarce. The focus is on riparian areas and surface waters, which harbor a disproportionate amount of the region's biological diversity and provide stopover habitat and water sources for wildlife. The value of the absence of invasive species was derived by calculating the avoided cost of having to remove and control for them. Four species of tamarisk are found in California, including the Bay Area and Central Coast regions.
Notes: Applicable to forest, shrub and wetland within riparian corridor (not containing Tamarisk)

86. Study: Zhongwei, L. 2006. Water Quality Simulation and Economic Valuation of Riparian Land Use Changes. Dissertation for the University of Cincinnati. 257 p.
Land Cover: Riparian buffer, forest and grass filter strip
Ecosystem Service: Waste treatment
Valuation Method: Replacement cost
Location: Ohio
Site Description: Little Miami River watershed - a major tributary of the Ohio River. The watershed occupies 1,757 square miles of land area and eleven counties. It contains the longest Exceptional Warmwater Habitat segment in Ohio, flowing through several steep forested gorges. Agriculture dominates land use.
Description: This dissertation quantifies the ecological and economic impacts of land-use changes in riparian buffer zones on the hydrology and water quality in the Little Miami River watershed in Ohio. Based on an integrated GIS modeling approach, this study quantifies the impacts of riparian land-use changes on the hydrology and water of the watershed. Replacement costs were used to estimate the value of nitrogen and phosphorus removal through wastewater treatment plants. Different configurations of riparian strips are examined.
Notes: Applicable to general riparian buffer adjacent to agriculture

87. Study: Zhou, X., Al-Kaisi, M., Helmers, M.J., 2009. Cost effectiveness of conservation practices in controlling water erosion in Iowa. Soil & Tillage Research 106, 71-78.
Land Cover: Grass riparian buffer (adjacent to agriculture)
Ecosystem Service: Soil retention (erosion control)
Valuation Method: Avoided cost
Location: Iowa
Site Description: Diverse cultivated areas with grassed buffers or terrace systems or watershed areas that may prevent erosion. Corn and soy are main crops cultivated.
Description: The objective of this study was to determine the effectiveness and economic benefits of selected conservation practices in sediment reduction by water erosion in major soil areas of Iowa. One farm was selected to represent the typical soil and slope gradient in each of the eight Major Land Resource Areas (MLRAs) in Iowa. Three tillage systems [no-tillage (NT), strip-tillage (ST), and chiselplow tillage (CP)] and three conservation structures [grassed waterways (GS), grass filter strips (FS), and terrace systems (TS)] were investigated under a corn–soybean rotation using the Water Erosion Prediction Project (WEPP) model.
Notes:

Appendix D: Value Transfer Studies Used by Land Cover

Due to space considerations, Appendix D has been made available online here:

http://www.eartheconomics.org/FileLibrary/file/California/Sonoma_ESV_Appendix_Values_by_Land_Cover.pdf

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