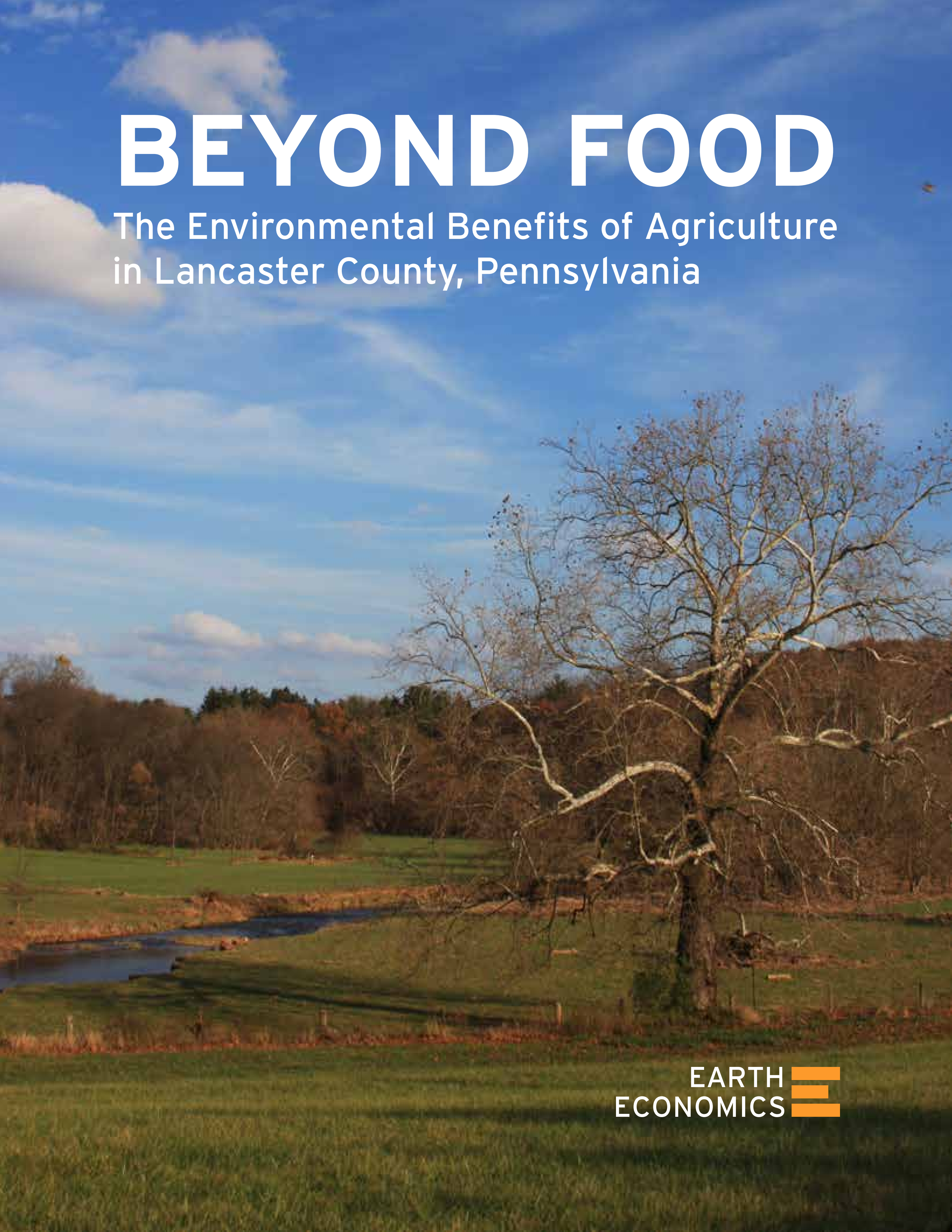
BEYOND FOOD

The Environmental Benefits of Agriculture in Lancaster County, Pennsylvania



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CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

Economies need nature. Any farmer will tell you fertile soil, clean water and a stable climate is as crucial to the business as a tractor. These natural services can be viewed as capital assets—just like the land or the tractor. Lancaster County's natural capital provides a robust flow of essential economic goods and service benefits, including food, water, clean air, natural beauty, climatic stability, storm and flood protection, and recreation.

This study estimates that Lancaster County's natural capital provides an estimated $676 million in economic benefits on an annual basis. Of 21 economically valuable ecosystem services present in the County, 13 were valued across 7 Lancaster County land cover types.

If the natural capital that generates this annual benefit stream were regarded as a short-lived economic asset, **Lancaster County's natural capital asset value would be roughly $17.5 billion** (4% discount rate over 100 years). In truth, open space, pastures, forests, fertile soils, wetlands and aquifers are not short-lived and do not depreciate or fall apart like bridges, cars, and power plants.

Because natural capital assets are renewable, selfsustaining, and long-lived, there is good reason not to discount the value of future ecosystem services like water and food provisioning or flood protection. Recognizing the long lifespan of natural assets and using a zero discount rate over a 100-year period (this counts no value after 100-years), **Lancaster County's natural capital asset value would be as high as $114 billion.** This figure still omits many valuable natural asset benefits.

Agricultural lands make up over 65% Lancaster County's ecosystem and form a key part of the region's economic foundation. In addition to a robust agricultural sector that provides the livelihoods for much of Lancaster County's population, agricultural lands generate key ecosystem services. When viewed in fiscal terms, **cultivated, pasture, and associated agricultural lands were estimated to provide a stream of $483 million in annual ecosystem service benefits.**

A federally-accepted Benefit Transfer Methodology was applied to the study area utilizing peer-reviewed primary valuation studies based on market pricing, cost avoidance, replacement cost, travel cost, hedonic values, and contingent valuation. The calculated value represents the average of the low and high estimates across all values for the given ecosystem services.

RECOMMENDATIONS

The following steps are recommended based on the study findings:

- **Invest in natural capital.** Lancaster County ecosystems should be viewed as essential assets and investment opportunities for promoting economic prosperity. Continuing to invest in the agricultural sector, farmland preservation, and natural resource conservation will increase the value of these assets.

- **Develop more comprehensive valuations, maps, and models of key ecosystem services.** This study provides a baseline valuation of ecosystem services in Lancaster County and identifies key local benefits provided. More detailed valuation studies on these benefits can be used to make more cost-effective investments across the landscape. Value can be mapped and modeled at higher resolutions incorporating new primary data or local knowledge for specific ecosystem services of interest.

- **Include ecosystem services in rural economic development planning.** Recognizing the links between healthy ecosystems, agriculture, tourism, cultural cohesion, and real estate values provides a quantifiable perspective of the value of rural regions. Ecosystem services can help inform the creation of incentive structures to provide landowners and farmers direct financial benefits for best stewardship practices. Ultimately, an ecosystem service perspective helps identify, quantify, and secure jobs that are sustainable in the long-term.

- **Include ecosystem service valuation in policy, accounting, and decision-making tools.** Ecosystem service valuation can provide governments, organizations, and private landowners with a way to calculate the Return on Investment of past or hypothetical preservation and restoration investments. Ecosystem services also provide an objective means for quantifying trade-offs in development decisions.

CHAPTER 1
INTRODUCTION

Lancaster County sits in south central Pennsylvania and is widely known as Pennsylvania Dutch Country after the many German people who settled there. When the first Europeans arrived to the region, Native Americans were utilizing the fertile soils to grow squash, sunflower, maize and beans. The Swiss Mennonites arrived in 1711 and were soon joined by several other groups looking for a new life. Over 90% of these settlers became farmers. This agricultural heritage continued developing as the meat and dairy industries took hold. Today, Lancaster County is the number one non-irrigated county in the United States for crop production (Blue Ribbon Report, 2005).

Situated adjacent to the Susquehanna River, which flows into Chesapeake Bay, Lancaster County is primarily composed of fertile agricultural lands that have led the region to national recognition for its agricultural products and cultural heritage. As a result, Lancaster County has become a popular tourist destination, receiving over 10 million visitors per year, who travel to the area to experience "Amish Country" and the scenic countryside. The region has capitalized on this foundation by providing lodging, dining, shopping, and recreational opportunities.

LANCASTER COUNTY'S ECONOMY

Although Lancaster County is mostly known for its unique cultural heritage, agriculture, and tourism, in actually boasts a diversified economic base. Economic output is dominated by two traditional sectors—agriculture and manufacturing. Over the last 15 years, growth in employment has been dominated by the retail and hospitality industries. Lancaster County is also growing as a logistics and transportation hub as well as a substantial provider of health care services. The strong link between two key industries, tourism and agriculture, is discussed in Box 1.

Lancaster County's transportation, arts, recreation, and health care infrastructure have been improving over the past decade, but are still limiting, especially in terms of attracting younger workers. The County has made progress in upgrading its industrial, commercial, and residential infrastructure, while also preserving farmland and regulating growth. However, development pressures continue on municipalities around the County.

BOX 1. THE COMBINED POWER OF AGRICULTURE AND TOURISM

Lancaster County inspires nostalgia for America's rich agricultural heritage. According to the Pennsylvania Dutch Convention and Visitors Bureau, roughly half of tourism revenues in Lancaster County are related to agriculture. The annual value of tourism in the County is estimated at $1.19 billion, with around $580 million attributable to agriculture. Three of the top six reasons that people cite for visiting the area are the Amish, food and drink, and the area's history. Additional research would help further define the role of agriculture and tourism.

Local residents also appreciate and support places that celebrate agriculture. The Landis Valley Museum, which features the Pennsylvania Dutch agricultural history; the Turkey Hill Experience, which features the history of the dairy industry in the region; and Family Farm Days at Oregon Dairy, which open a thriving dairy farm to the public, are examples of places and events that draw locals and tourists alike.

All economic sectors depend in some way on the natural assets of Lancaster County. The fertile farmland, temperate climate, and picturesque countryside attract both residents and visitors. Ecosystem functions, including water supply, soil formation, and pollination support the economy in fundamental ways. This report takes a closer look at the natural capital of Lancaster County to better understand its value.

A NATIONAL LEADER IN AGRICULTURE

The importance of agriculture to Lancaster County's economy cannot be overstated. Research from the Lancaster County Workforce Investment Board and EMSI estimate the total economic contribution from the Agriculture Sector at roughly $6.9 billion, around 18% of the total Gross Regional Product. The County is number one in the state for several product categories, including wheat, broiler chickens, milk production, dry hay, and corn. With over 5,000 farms, it is no wonder that Lancaster County is an economic and infrastructure hub for agricultural activity. Equipment dealers, fertilizer supplies, seed companies, and feed centers all call Lancaster County home.

To protect its agricultural character and economic base, the Lancaster County Agricultural Preservation Board and the Lancaster Farmland Trust have worked in concert to preserve farmland. To do this, Lancaster County has strategically leveraged investments of its own local resources with State and other available farmland preservation funds. In total, Lancaster County has invested $113 million of its own funds, which have been nearly matched by more than $90 million in State funds and $10 million in Federal funds. In addition, the Lancaster Farmland Trust has invested nearly $13 million of private funds in farmland preservation.

In 2013, Lancaster County became the first county in the nation to reach 100,000 acres in farmland preservation. This milestone was the result of four decades of strategic efforts between the County of Lancaster and the Lancaster Farmland Trust that began nearly forty years ago. This history of farmland preservation has led to the protection of critical natural capital assets, whose value is quantified in this report. Please see Appendix D for a detailed history of farmland preservation in Lancaster County.

HOW TO USE THIS STUDY

This study provides a primer on critical natural capital concepts and estimates dollar values for a selection of key ecosystem services in Lancaster County. This study is the first county-wide analysis of natural capital in Lancaster County including:

- Identification of ecosystem services present in Lancaster County,
- Valuation of ecosystem services with a special focus on farmland,
- Valuation of land area by type of ecosystem.

Many economically valuable services were identified as present in Lancaster County, but could not be valued because primary valuation or transferable studies are lacking. As a result, this study estimates only a fraction of the total potential natural capital value.

The conceptual framework of natural capital and the dollar values estimated can be used immediately in many practical applications including the following:

- **Performing Benefit-Cost Analyses (BCA):** The values in this study can be used to inform decision-making. For example, when doing a Benefit-Cost Analysis (BCA) of a proposed land use decision, the values would give additional perspective to the analysis.
- **Calculating rates of return on conservation projects:** By looking at the differences in ecosystem services produced by agricultural lands and developed areas, we can calculate ecosystems services lost to development as well as the Return on Investment (ROI) of both past and potential land preservation work. This methodology also works for restoration, conservation, public lands, and parks.
- **Enhancing/establishing funding and investment mechanisms:** By understanding the economic benefits of different land-use practices, we can justify funding mechanisms for Best Management Practices (BMPs). These practices can lead to better environmental outcomes and provide landowners with additional support for stewardship.

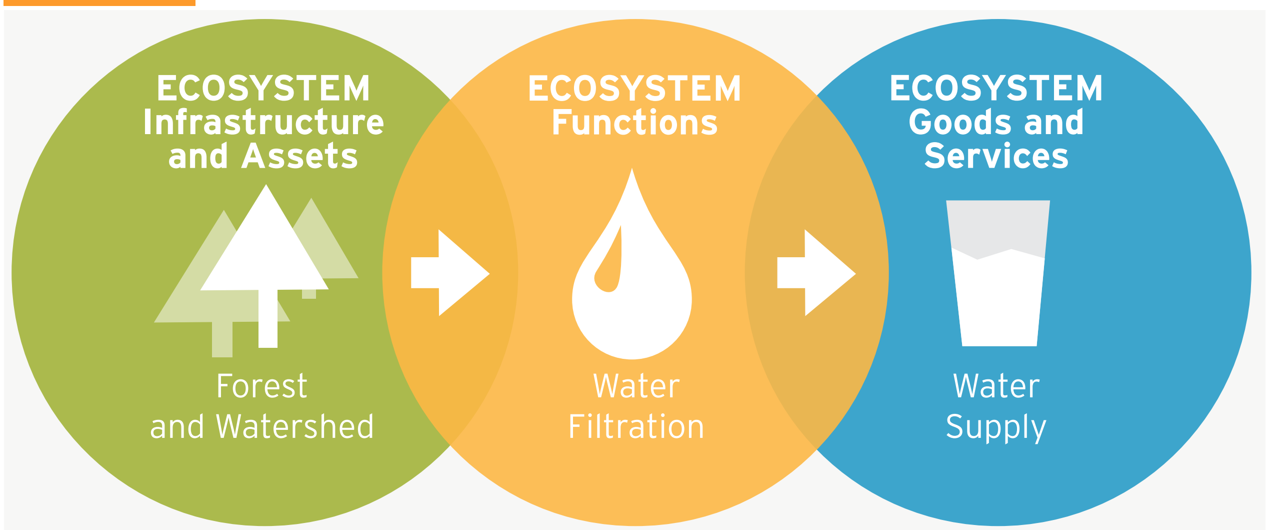
CHAPTER 2
ECOSYSTEM GOODS AND SERVICES IN LANCASTER COUNTY

Ecosystem goods and services are defined as the benefits people derive from ecosystems.

Humans need ecosystem services to survive; breathable air, drinkable water, nourishing food, flood protection, waste treatment, and stable atmospheric conditions are all examples of nature's services which we often take for granted. Ecosystem services are also the basis of all economic activity. In Lancaster County, the natural capital of healthy ecosystems and productive lands allows crops to grow, supports habitat for livestock and wildlife, and improves quality of life.

Healthy, functioning natural capital is critical to the production of ecosystem goods and services. The natural capital of an ecosystem consists of its structural components, such as trees, forests, soil, and hill slopes. Forest ecosystems, for example, absorb and filter rainfall to slow down flood flows while also providing water filtration functionality for water supply. Figure 1 shows the relationship between natural capital and the production of ecosystem services.

FIGURE 1. NATURAL CAPITAL, ECOSYSTEM FUNCTIONS, AND ECOSYSTEM SERVICES



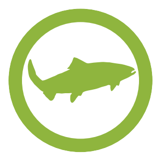
The benefits of ecosystem goods and services are similar to the economic benefits typically provided by economic activity, such as the services and outputs of skilled workers, buildings, infrastructure, and machines. Many ecosystem goods, such as livestock, vegetables, fiber, and water, are valued through supply and demand through their sale in markets. However, many ecosystem services, such as flood protection and pollination, are not amenable to markets because they are non-rival and non-exclusive, meaning they cannot practically be owned. For example, when the flood protection services of a watershed are lost to deforestation, economic impacts can include costs of new infrastructure (e.g. levees), flood damages, increased insurance costs, and appropriation of public emergency funds.

In 2001, an international coalition of over 1,360 scientists and experts from the World Bank, the United Nations Environmental Program, and the World Resources Institute initiated an assessment of the effects of ecosystem change on human wellbeing. They produced the landmark Millennium Ecosystem Assessment (MEA), which classifies ecosystem services into four broad categories, as seen on the right. (Millennium Ecosystem Assessment; UNEP, 2005a).

All of the 21 services identified in Table 1 are provided by nature in Lancaster County. Many of these services provide direct benefits to residents, while others have more dispersed beneficiaries. We provide more detailed descriptions for some of the key ecosystem services provided by natural capital in Lancaster County in the following pages.

Provisioning services provide physical materials that society uses. Forest trees are used for lumber and paper. Agricultural lands provide food. Natural systems yield wild berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food (Farber et al., 2006).

Regulating services are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water quality and delivery timing, soil erosion or accumulation, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health (UNEP, 2005a).



Supporting services include primary productivity (natural plant growth), nutrient cycling (nitrogen, phosphorus, and carbon cycles) such as and the fixing of CO_2 by plants to produce food. 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 scientific research and educational opportunities.

TABLE 1. ECOSYSTEM GOODS AND SERVICES

Provisioning Services	
ENERGY AND RAW MATERIALS	Providing fuel, fiber, fertilizer, minerals, and energy
FOOD	Producing crops, fish, game, and fruits
MEDICINAL RESOURCES	Providing traditional medicines, pharmaceuticals, and assay organisms
ORNAMENTAL RESOURCES	Providing resources for clothing, jewelry, handicraft, worship, and decoration
WATER SUPPLY	Provisioning surface and groundwater for drinking, irrigation, and industrial use

Information Services	
AESTHETIC INFORMATION	Enjoying and appreciating the presence, 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 natural ecosystems 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

Regulating Services	
AIR QUALITY	Providing clean, breathable air
BIOLOGICAL CONTROL	Providing pest and disease control
CLIMATE STABILITY	Supporting a stable climate through carbon sequestration and other processes
MODERATION OF EXTREME EVENTS	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
POLLINATION	Pollinating wild and domestic plant species
SOIL FORMATION	Creating soils for agricultural use and ecosystems integrity; maintaining 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	
GENETIC RESOURCES	Improving crop and livestock resistance to pathogens and pests
HABITAT AND NURSERY	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species

Adapted from de Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description, and valuation of ecosystem functions, goods, and services. Ecological Economics 41, 393-408.74 and TEEB, 2009.

PROVISIONING SERVICES

Water Supply

Ecosystems capture precipitation in the form of rain and snow. Water is filtered through forests and other vegetation into ground water structures like aquifers and surface water reservoirs, lakes, and rivers for use by urban areas, industry, and agriculture. The hydrologic cycle is affected by the structural elements of a watershed, such as forests, wetlands and geology, as well as by processes such as evapotranspiration and climate. More than 60% of the world's population gets its drinking water from forested watersheds (UNEP, 2005b; United Nations Environmental Program, 2005). Increasing loss of forest cover around the world has decreased water supply, due to lower ground water recharge and lower flow reliability (Syvitski, 2005).

One way to understand the economic value of intact watersheds is to compare it to the cost of building and maintaining water supply and treatment facilities. To the extent that loss of ecological systems results in reduced supply, value can also be ascertained through the cost of having to import water from elsewhere. These are examples of what economists refer to as replacement costs.

Lancaster County has more than 1400 miles of streams in the Chesapeake Bay Watershed, and the Susquehanna and Conestoga rivers flow through the County's borders. About 61% of the County's water supply is groundwater with the other 39% as surface water. While Lancaster County has the distinction of being home to some of the most productive non-irrigated farmland in the United States, droughts do occur, such as the 2002 drought. With population continuing to grow at a rapid pace, ensuring a stable water and clean water supply is essential to meeting the needs of citizens going forward. Because farmland allows rainwater to penetrate the surface and enter groundwater supplies, protecting farmland is an excellent form of water conservation. The following example illustrates how farmland can contribute to the water supply.

BOX 2. WATER SUPPLY FACTS IN LANCASTER COUNTY

- *Farmland collects 34 million gallons of ground water from rain*
- *Cows & family use 1 million gallons of water*

RESULT: NEARLY 33 MILLION GALLONS OF GROUND WATER CONTRIBUTED

If 300 houses are built on this 85 acre farm:

- *The housing development collects at least 1/3 less ground water from rain*
- *300 families use over 16 million gallons of water*

RESULT: 26 MILLION FEWER GALLONS OF GROUND WATER CONTRIBUTED

Source: Keep Lancaster County Farming Blue Ribbon Commission Report 2005

Food

Providing food is one of the most important functions of ecosystems. Agricultural lands are the primary source of food for humans. Farms are considered modified ecosystems and food is considered an ecosystem good with labor, built, and natural capital inputs. In traditional economic analyses, agricultural value is measured by the total market value of crops produced. This amount exceeds $1 billion in Lancaster County annually. A 2005 report estimated the number of people Lancaster County feeds each year (Table 2). These consumers can be viewed as beneficiaries of the Lancaster County food supply ecosystem service.

TABLE 2. NUMBER OF PEOPLE FED BY LANCASTER COUNTY ANNUALLY

Food Supply Item	Number of People Fed
Eggs	11,900,000
Milk	10,200,000
Chicken	3,300,000
Pork	4,600,000
Beef	727,000

While these measures are useful, market value is only a small portion of the total value agricultural lands provide through pollination, carbon sequestration, aesthetic value and other services. The Lancaster Farmland Trust is enhancing these ecosystem service values through their Smart Farms program, described in Box 3.

BOX 3. SMART FARMS - MANAGING AGRICULTURAL LANDSCAPES FOR ENHANCED ECOSYSTEM SERVICES

Lancaster Farmland Trust's Smart Farms program is an agricultural and environmentally conscious program that assists local producers in managing their operations sustainably. With a host of soil and water conservation practices available to farmers, Lancaster Farmland Trust staff helps tailor a selection of working land practices with the objective of balancing farm profitability with environmental impacts.

Working with its partners in the agricultural community, Smart Farms offers free on-farm consultation with experts in agricultural and environmental engineering. Participating farmers can receive expert input on optimizing soil fertility and improving operations. The program's goal is to prevent productive soils from degradation and exhaustion. This work will ensure that Lancaster County can continue to provide fresh food and fiber to the residents of the County and beyond.

More recently, the program has begun focusing on optimizing the benefits of a more complete set of farmland ecosystem services.

Source: Jeff Swinehart, Lancaster Farmland Trust

REGULATING SERVICES

Climate Stability

Climate regulation refers to the roles that ecosystems play in regulating the gaseous phase of organic and inorganic compounds that affect atmospheric composition and climate.

Atmospheric oxygen is a product of photosynthesis from marine plankton and terrestrial plants. The regulation of climate is dependent on the composition of the atmosphere. “Greenhouse gases” such as CO_2 are transparent to light but trap heat, warming the planet like a greenhouse. Trees or other plants play an important role in regulating air quality by removing pollutants from the atmosphere. Carbon dioxide is removed through carbon sequestration as plants absorb CO_2 to grow.

Biological Control

Healthy ecosystems limit the population of invasive plant species, pests and diseases, thereby protecting human health, crops and livestock. A number of natural predators help control pest species, limiting potential damage. For example, birds consume insects that would otherwise infest trees and damage forests.

Many exotic species have been introduced to areas beyond their natural range. The evolving field of integrated pest management is researching crop management techniques that enhance biological control services. These techniques include crop diversification and genetic diversity, crop rotation and promoting an abundance of smaller patches of fields (Lichtfouse et al., 2009; Lichtfouse E. et al., 2009; Risch et al., 1983).

Pollination

Pollination is essential to agricultural crops, trees, and flowers. Insects, birds, mammals and the wind transport pollen grains to fertilize plants. People depend on pollination directly for food and fiber (such as wood, paper and cloth), and indirectly as part of ecosystem productivity. Many plant species would go extinct without animal- and insect-mediated pollination. Pollination services by wild animals are also crucial for crop productivity for many types of cultivated foods, enhancing the basic productivity and economic value of agriculture.

Notably, some plants have only a single pollinator species. The importance of wild pollinators to food crops means that wild habitats near croplands are necessary in order to provide sufficient habitat to keep populations of pollinators intact.

Water Regulation

Water regulation includes regulation of water flows through the ground and along terrestrial surfaces, and regulation of temperature, dissolved minerals and oxygen. Many ecosystems absorb water during rains and release it in dry times, and also regulate water temperature and flow for plant and animal species. Forest cover, riparian vegetation, and wetlands all contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed. In undeveloped areas of a watershed, typically less than 15% of precipitation reaches streams or rivers as surface runoff, compared with 55 to 70% in a developed watershed. See Figure 2 and Figure 3 for a graphic illustration.

When forested basins are heavily harvested, the ground’s capacity to absorb water is reduced, and surface water runoff is increased and conveyed into streams and rivers. This contributes to higher peak flows, more frequent flood events, and erosion and landslide issues. A result of this may be lower low flows in summer months, because the water is not retained in soils and aquifers.

FIGURE 2. THE MOVEMENT OF WATER IN A DEVELOPED WATERSHED

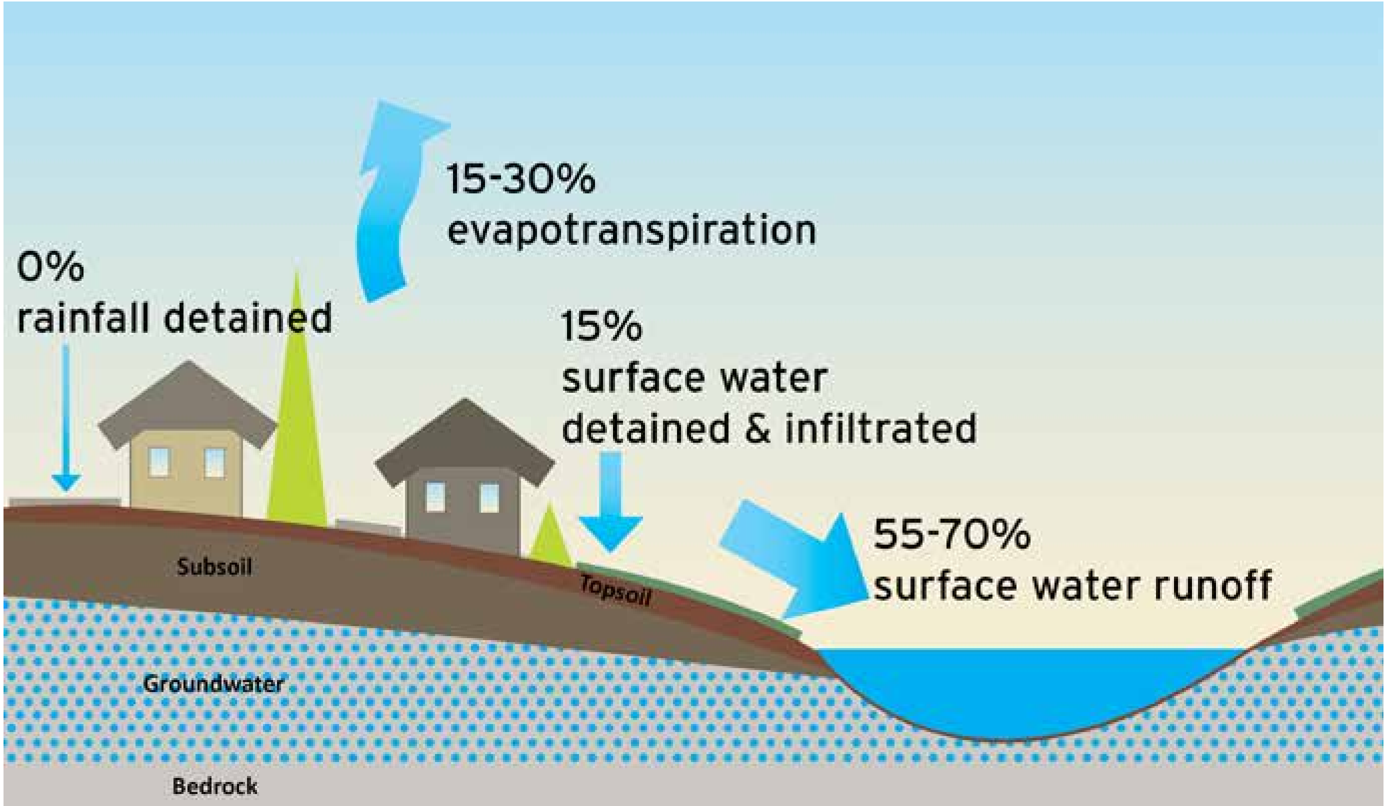
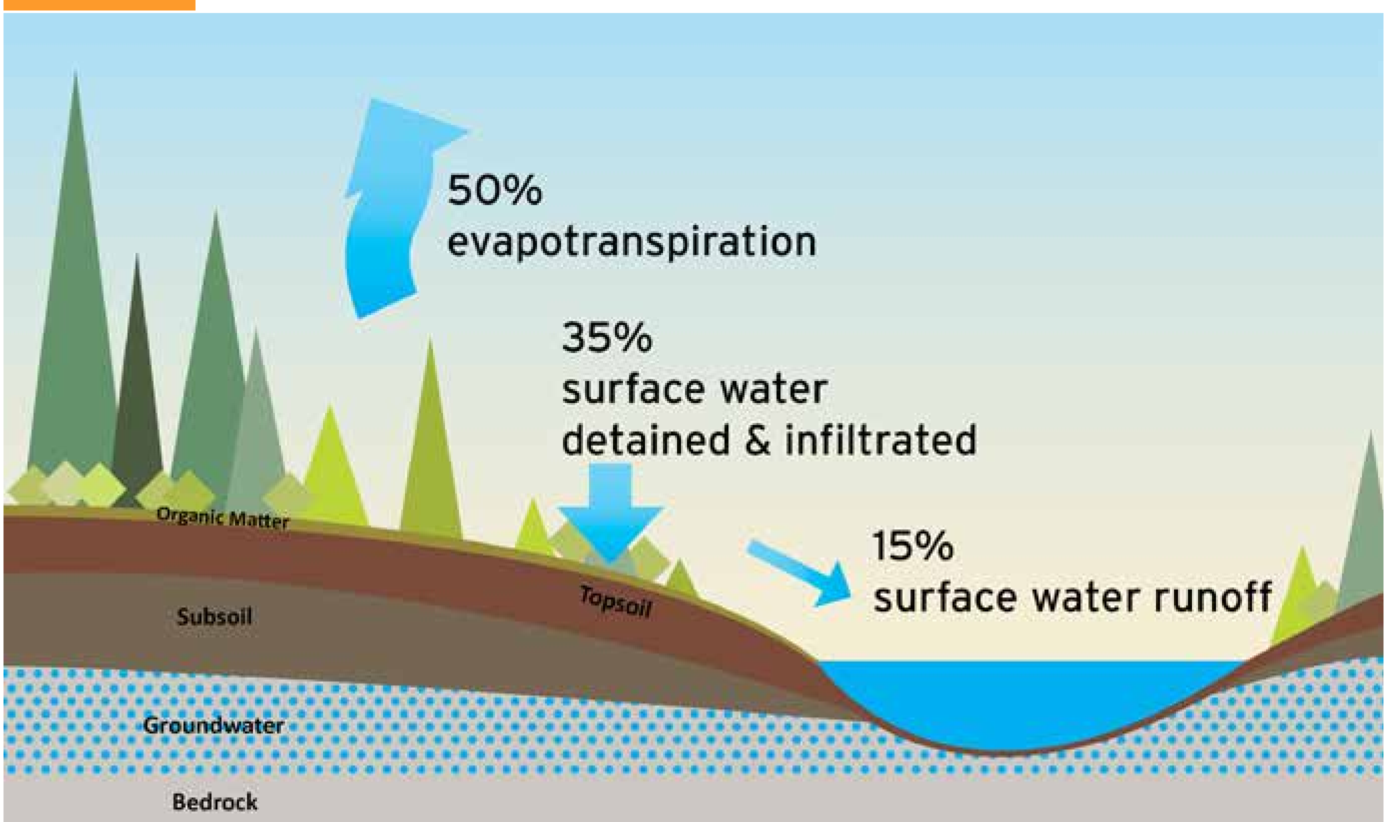


FIGURE 3. THE MOVEMENT OF WATER IN A FORESTED WATERSHED



Soil Retention

The soil retention properties of ecosystems determine the soil's rate of erosion. The susceptibility of a given slope to erosion is determined by factors such as grain size, soil cohesion, slope gradient, rainfall frequency and intensity, surface composition and permeability and type of land cover. Soil retention is closely linked with prevention of disturbances such as landslides, which are often caused by excessive erosion and can frequently be attributed to human changes in land use. A healthy forest's organic layers act as a natural sponge, absorbing water during periods of heavy precipitation and preventing erosion. In areas where active forest harvesting occurs, the upper layers of soil are often removed or degraded.

Many Lancaster County farmers are adopting no-till techniques to improve soil retention on their land. According to agronomists at Pennsylvania State University, No-Till agriculture increases farm efficiency and profits while preventing social erosion and runoff. Environmental improvements also include increased water infiltration, soil organic matter, and biological activity in the soil (Duiker and Myers, 2006). Some Lancaster County farmers are members of the PA No-Till Alliance, a group of like-minded producers that have used no-till systems in their operations and know the many benefits it has to offer. Visit http://www.panotill.org for more information.

Soil related ecosystem services along with water quality and nutrient cycling are being targeted by the Lancaster County Conservation District. They are described in Box 4.

BOX 4. ENHANCING SOIL REGULATING ECOSYSTEM SERVICES WITH LOW-COST BEST MANAGEMENT PRACTICES

Ecosystem Services can be enhanced and protected by stewardship work on a variety of land cover types. The Lancaster County Conservation District works to promote the implementation of agricultural Best Management Practices (BMPs). A BMP is defined as an agronomic practice or a structure that will conserve and protect soil health and water quality. Structural BMPs, which are often expensive, include manure storage facilities, streambank fencing & crossings, and grassed waterways. These structures aim to enhance ecosystem services including water quality, nutrient cycling, and erosion. Agronomic BMPs include crop rotation, conservation tillage or no-till practice, contour farming, cover crops, and pasture management. These management strategies are lower cost; however, they still work to enhance ecosystem services such as soil quality and quantity, water quality, pollination, and carbon sequestration.

Source: Dennis Eby, Lancaster County Conservation District

Soil Formation

Soil serves a vital function in nature, providing a medium for plant growth as well as nutrients for plants and habitat for millions of micro- and macro-organisms. Healthy soils store water and nutrients, regulate water flow and neutralize pollutants more efficiently than degraded soils (Marx, 1999). Soil retention contributes to a number of other ecosystem services, including disturbance prevention, salmon habitat, and provisioning of raw materials such as timber. Soil quality and abundance is critical for human survival. However, many human actions can negatively affect natural formation of high-quality soils. Soil is formed over thousands of years through a process that involves parent material, climate, topography, organisms, and time (United States Department of Agriculture, 1983).

CULTURAL SERVICES

Recreation and Tourism

Ecosystem features like biological diversity, clean water, and intact forest areas attract people to engage in recreational activities and can also increase property values or attractiveness for business. Recreation provides joy, health, and happiness to people. Tourism and recreation are related to, but not totally encompassed by, aesthetic attributes. Citizens travel to beautiful places local or distant to engage in activities they enjoy. These include camping, hiking, biking, hunting, ATV riding, fishing, swimming, kayaking, bird watching, and enjoying local foods and communities.

Degraded ecosystems reduce access, enjoyment, and participation in these activities. Storm protection and waste treatment are also important ecological services associated with recreation and tourism because they help keep tourists safe and protect both private and public infrastructure needed for the tourist industry.

As explained in Chapter 1, tourism is a key industry in Lancaster County. Estimates put the impact of tourism in Lancaster County at around $1.19 billion, with $580 million attributable to agriculture-related tourism. Rural landscapes, agricultural activities, and well-developed tourism infrastructure complement each other to great economic impact in Lancaster County.

CHAPTER 3
NATURE'S VALUE IN LANCASTER COUNTY

Lancaster County's economy cannot be fully appreciated without a consideration of the significant contributions of natural capital to the flow of ecosystem services that benefit human well-being.

Our communities and the economy that connects us reside within the environmental landscape. Because our economic system developed during a time of abundant stocks of natural capital, economic decisions were made without considering the explicit contribution (or scarcity) of functioning ecosystems to economic activity and output Ecosystem services build a bridge between what we have discovered about how nature functions with economic theory, which help us quantify the utility of assets, trade-offs implicit in decisions, and investment alternatives.

To estimate the value of ecosystem services produced in Lancaster, Earth Economics first identified the land covers present across the watershed using Geographical Information Systems (GIS) data provided by the GIS Division of Lancaster County. Earth Economics selected location-specific ecosystem service valuation studies based on these land-covers from its database of peer-reviewed literature.

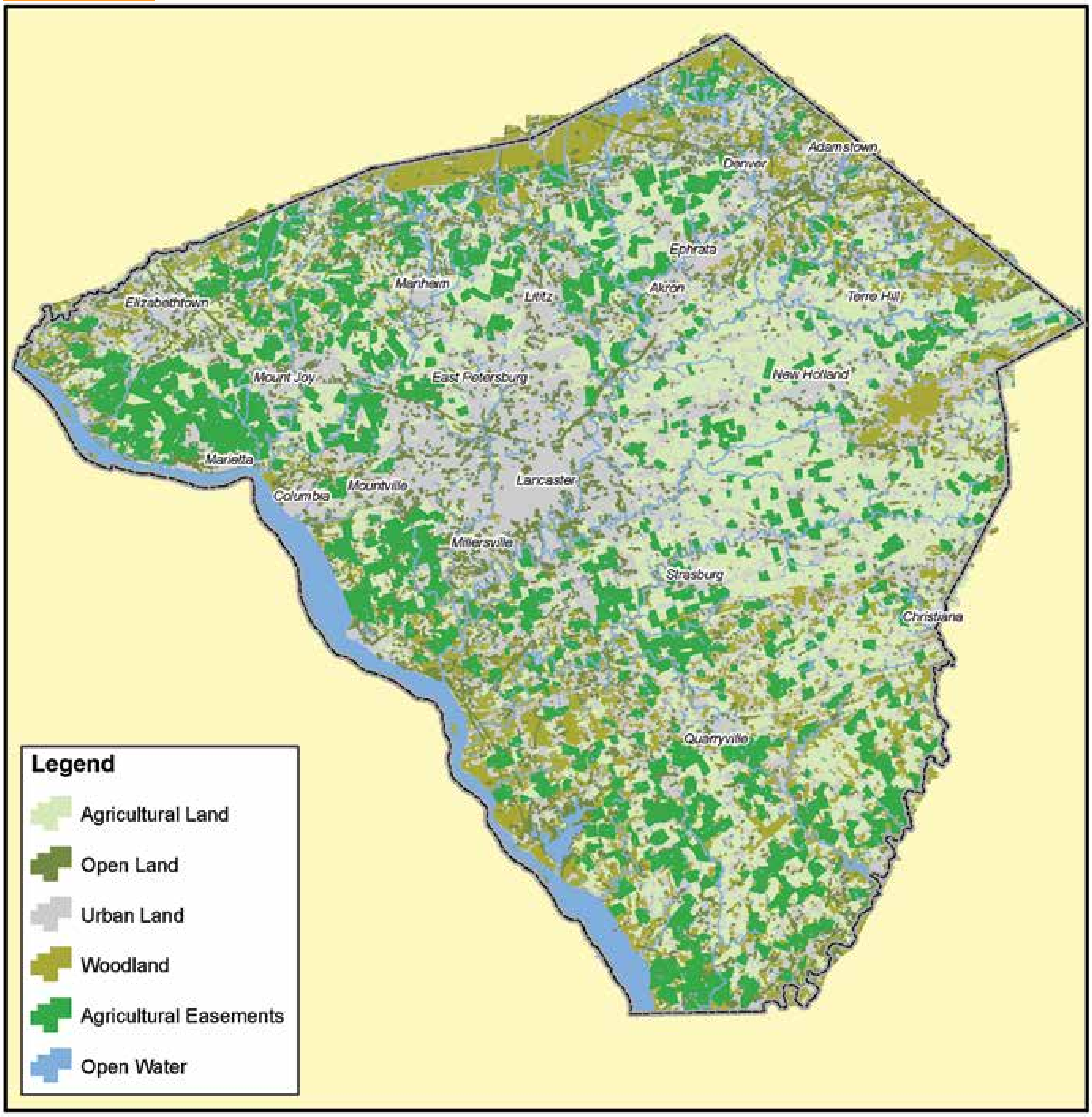
These studies were aggregated and sorted to derive low and high range annual per-acre dollar values. Values were summed across all land covers, resulting in a total annual flow of value for the natural capital in Lancaster County.

LAND COVER IN LANCASTER COUNTY

Mapping goods and services provided by factories, restaurants, schools and businesses provides a view of the region's economy. Retail, residential and industrial areas command different economic functions and their appraisal values are based on their location and perceived value derived from recent sales, market dynamics, and economic outlook. The distribution of landcovers, ecosystems, and ecosystem functions and services can be perceived in the same way. Each land cover, from wetlands to forests to agricultural lands, provides a suite of ecosystem services.

Land Use Land Cover (LULC) classifications occurring in Lancaster County are listed in Table 3. Farmland in Lancaster County is often estimated at around 400,000 acres and is measured by the sum of farmland properties. GIS analysis allows us to look past parcel ownership, recognizing ecosystems that span across property boundaries. Clearly, forests within or adjacent to a stream have provide different ecosystem services than crop or pastureland and are valued accordingly. Figure 4 shows land cover across Lancaster County.

FIGURE 4. LANCASTER COUNTY LAND USE AND LAND COVER, 2012



Source:
Lancaster County GIS, Copyright (c) 2014. This map to be used for reference or illustrative purposes only. This map is not a legally recorded plan, survey, or engineering schematic and it is not intended to be used as such.

For complete disclaimer see http://www.co.lancaster.pa.us/gisdisclaimer.

Updated March 2014

1 inch = approximately 6 miles

TABLE 3. TOTAL ACREAGES BY LAND COVER CLASS IN LANCASTER COUNTY

Land Cover Class	Description	2012 Total Acreage	% Of Land Cover
Forest	Deciduous Forest	95,646	19.0%
	Coniferous Forest	1,254	0.2%
	Mixed Forest	3,736	0.7%
Herbaceous Wetlands	Forested wetlands	1,170	0.2%
Woody Wetlands	Non-forested wetlands	2,423	0.5%
Rivers/Lakes	Open water	25,632	5.1%
Shrub/Scrub	Shrub/brush	5,126	1.0%
	Mixed cover	6,350	1.3%
Grassland/herb	Herbaceous	17,150	3.4%
Agriculture	Cropland	281,589	56.1%
	Cropland and pasture	791	0.2%
	Orchards/groves/vinyards/nurseries	2,959	0.6%
	Large confined feeding operations	2,800	0.6%
	Other agriculture	258	0.1%
Pasture	Pasture	46,812	9.3%
Urban green space	Recreational (park, campground)	8,392	1.7%

Source: Lancaster County Land Use/Land Cover Data; Based on Aerial Photography Captured Spring 2012

BENEFIT TRANSFER METHODOLOGY

Benefit Transfer Methodology (BTM) was used to estimate the value of ecosystem services produced by each land cover in Lancaster County. BTM is a widely accepted economic methodology in which the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations. BTM is used when the cost of conducting original valuation studies on every site for every vegetation type is prohibitive.

The “transfer” refers to the application of derived values and other information from the original study site to a new but sufficiently similar site, like a house or business “comp.” A business comparable or “comp” completes a valuation using aggregate data of recent comparable transactions. As the “bedrock of practical policy analysis” (Desvousges et al., 1992), BTM 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 (Wilson and Hoehn, 2006).

Earth Economics maintains, and is continually expanding, a database of published, peer-reviewed ecosystem service valuation studies for use in benefit transfer studies. The valuation techniques used to derive the values in the database studies are well accepted among academics in both economics and ecology. Valuation methods have been developed within environmental and natural resource economics over the last 40 years.

As Table 4 indicates, these techniques include market pricing, replacement cost, avoided cost, production approaches, travel cost, hedonic pricing and contingent valuation .

TABLE 4. VALUATION METHODS USED TO VALUE ECOSYSTEM SERVICES IN PRIMARY STUDIES

Revealed-Preference Approaches	
Travel Cost	Uses variations in visitor travel costs and number of trips taken to trace out a demand curve for recreation at a particular site. *Example: The value of the recreation ecosystem service as the consumer surplus or the additional amount visitors will pay over and above their costs.*
Hedonic Pricing	The value of a service is implied by what people will be willing to pay for the service through purchases in related markets. *Example: Housing prices along the coastline tend to exceed the prices of inland homes.*
Market-Based 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 is often sold in a private market.*
Replacement Cost	Cost of replacing ecosystem services with man-made systems. *Example: the cost of replacing a watershed's natural filtration services with a man-made water filtration plant.*
Avoidance Cost	Value of costs avoided or mitigated by ecosystem services that would have been incurred in the absence of those services. *Example: Wetlands buffer the storm surge of a hurricane, reducing damage along the coast.*
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.*
Stated-Preference Approaches	
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. *Example: People are willing to pay for preservation of wilderness for aesthetic and other reasons.*
Group Valuation	Discourse-based contingent valuation, which is arrived at by bringing together a group of stakeholders to discuss values to depict 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 service scenarios or ecological conditions that differ in the mix of those conditions. *Example: Choosing between wetlands scenarios with differing levels of flood protection and fishery yields.*

Adapted from Farber et al., 2006. Linking Ecology and Economics for Ecosystem Management. Bioscience 56, 121-133.

VALUATION GAPS

Due to limitations in the range of primary valuation studies conducted on ecosystem services, not all ecosystem services identified on each land cover could be assigned a known value from the database. Therefore, some land cover classes could not be valued.

Table 5 provides a matrix that summarizes the suite of ecosystem services valued on each land cover in Lancaster County. Thirteen of the 21 ecosystem services were valued across 7 land cover types. Not every land cover type produces all 21 ecosystem services, but only 19 combinations were valued in this report due to a lack of data. For example, science and education was not valued for cultivated lands. However, we know there are significant workshop, education, and outreach activities taking place on Lancaster County farms through the work of the Conservation District and Ag Extension programs among others. As with market-based valuations, the information for ecosystem valuations is often imperfect or incomplete.

TABLE 5. ECOSYSTEM SERVICES VALUED IN LANCASTER COUNTY

Ecosystem Service	Cultivated	Forests	Fresh Water	Inland Wetlands	Pastures [cultivated]	Shrub	Urban
Aesthetic Information	x						
Biological Control	x						
Climate Regulation	x			x			
Pollination	x				x		
Raw Materials	x						
Recreation	x	x	x	x			
Soil Formation	x						
Soil Retention	x						
Waste Treatment			x	x			
Water Regulation	x						x
Water Supply	x						
Science and Education		x					
Habitat and Nursery	x		x	x		x	

ANNUAL VALUE OF DIFFERENT LAND COVERS IN LANCASTER COUNTY

Combining the available ecosystem service values for one land cover yields a ecosystem service dollar value/acre/year provided by that land cover. The totals for agricultural lands, for example, were $311 on the low end, and $2,904 per acre per year at the high end, as shown in Table 6 below. An average value of these low and high values is a useful approximation for discussing the scale and scope of ecosystem services in Lancaster County. We estimate that annually, Lancaster County ecosystems provide between $22 million and $1.1 billion annually in benefits. An average of these values, $676 million, is a good approximation for general discussion about the size and scope of these benefits.

Uncertainty exists for all valuation appraisals. A house appraisal will have several comparables, and a range of values. However, appraisers typically pick a single appraisal value based on professional judgment. In some cases, such as the FEMA application of ecosystem service values, single values are selected. In this valuation, the range and average of values are provided to reflect different perspectives of utility and the uncertainties inherent in ecosystem service valuation.

TABLE 6. ECOSYSTEM SERVICE VALUES BY LAND COVER CLASS IN LANCASTER COUNTY

Land Cover Class	Area (Acres)	Low Value ($/Acre/Year)	High Value ($/Acre/Year)	Low Value ($/Year)	High Value ($/Year)
Agriculture	288,397	$311	$2,904	$89,723,220	$837,594,738
Forest	100,637	$563	$1,073	$56,635,082	$107,988,912
Rivers/Lakes	25,632	$1,747	$5,793	$44,775,368	$148,486,142
Herbaceous & Woody Wetlands	3,593	$2,870	$4,278	$10,310,170	$15,371,546
Pasture	46,812	$420	$420	$19,670,594	$19,670,594
Shrub/Scrub	11,476	$3	$3	$38,788	$38,794
Urban green space	8,392	$141	$192	$1,184,648	$1,607,635
Total	***484,938***	***$6,055***	***$14,664***	***$222,337,870***	***$1,130,758,361***

Most of the peer-reviewed studies are conducted within healthy ecosystems and by way of BTM, the assumption is inherent that Lancaster County ecosystems are of equal health at the time of valuation. This assumption may not be correct, as this study did not examine the extent of soil or land degradation in Lancaster County, so benefit transfer may overestimate or underestimate the value of particular services provided on some land cover types.

Some ecosystem services are spatially independent. A ton of carbon sequestered, for example, has basically the same atmospheric carbon reduction value wherever it is sequestered. However, different species and forests of different stand ages sequester carbon at different rates. It is important to know how many tons of carbon are sequestered in a predominantly Douglas Fir forest and the age and elevation of that forest. Once the local carbon data is known, the value range can be derived from local, national or international data sources.

Flood protection value, however, is specific to the watershed. If no local estimated value exists, then neighboring and similar watersheds are better for estimating the value than a more distant watershed.

Most of the studies utilized here were conducted in the United States. All estimates are based on studies conducted in temperate ecosystems. In the very few cases where no local or national figures were available, international values were utilized where appropriate and were derived from high-income temperate countries. In this way, estimates from ecosystem types with very different ecologies or very different income demographics to Lancaster County were excluded. All values were standardized to 2012 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator (United States Department of Labor Bureau of Labor Statistics, 2014). Appendix A lists the studies used for the value transfer estimates.

SUBSET CALCULATIONS OF PRESERVED LANDS

Lancaster County has preserved the most agricultural land in the country. We can separate out the subset of preserved lands using additional GIS data provided by Lancaster County and calculate ecosystem service values. This analysis generates a measure of the intangible benefits the people of Lancaster County have received from farmland preservation. It is important to note while the preserved lands are all located in agricultural regions, that GIS data does not classify all of this land as agricultural. Regardless, we are able to calculate the ecosystem service values for these acres separately. A significant portion of the total value can be attributed to preserved lands. Between $33 million and $231 million are attributable to preserved acres on an annual basis.

TABLE 7. ECOSYSTEM SERVICE VALUES OF PRESERVED LANDS IN LANCASTER COUNTY

Land Cover Class	Area (Acres)	Low Value ($/Acre/Year)	High Value ($/Acre/Year)	Low Value ($/Year)	High Value ($/Year)
Agriculture	74,131	$311	$2,904	$23,062,961	$215,300,058
Forest	7,411	$563	$1,073	$4,170,383	$7,951,875
Rivers/Lakes	419	$1,747	$5,793	$731,630	$2,426,265
Herbaceous & Woody Wetlands	344	$2,870	$4,278	$988,166	$1,473,268
Pasture	10,386	$420	$420	$4,364,357	$4,364,357
Shrub/Scrub	894	$3	$3	$3,021	$3,022
Urban green space	33	$141	$192	$4,619	$6,268
Total	***93,618***	***$6,055***	***$14,664***	***$33,325,136***	***$231,525,112***

ASSET VALUE OF NATURAL CAPITAL IN LANCASTER COUNTY

An ecosystem produces a flow of valuable services across time, like a traditional capital asset. As long as the natural infrastructure of the watershed is not degraded or depleted, this flow of value will likely continue into the future. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a capital asset (such as a power plant or bridge) can be calculated as the net present value of its expected future benefits.

Asset values are also established in market transactions. Thus, the asset value of an apartment building can be calculated from either the net present value of the expected income, or when an apartment building is sold, the sales value is taken as the asset value. Many built assets such as bridges, roads, airports, watersheds are not sold on in markets. This calculation is an estimate of asset value without a potential for sale. However, it is useful for revealing the scope and scale of the economic value that Lancaster County's natural systems hold.

When the value of wetlands, forests and natural systems is more clearly apparent, it shows that wise investments in restoration and conservation can provide good rates of return over vast periods of time. Effectively maintaining an aquifer's health, for example, provides value to every resident, farm, and business in the county across centuries.

Calculating the net present value of an asset implies the use of a discount rate. The net present value of Lancaster County's natural capital was calculated using two discount rates: zero and 4%. Benefit-Cost Analysis and Return on Investment (ROI) calculations were initiated after the 1930s to examine investments in built capital assets, like roads, power plants, factories, and dams.

Built capital investments were expected to be productive for a few decades and afterward they would require replacement. Natural capital, however, does not necessarily depreciate or fall apart like built capital assets, provided it is given some level of stewardship and protection.

Using a 0% discount rate recognizes the renewable nature of natural capital and also assumes that people 100 years from now will enjoy the same level of benefits we enjoy today. If the availability of natural capital decreases in other areas, then Lancaster's natural assets may have an even higher value in the future. Discounting assumes that someone 100 years from now would register virtually no benefit (as measured in present value). Federal agencies like the Army Corps of Engineers use a 4% discount rate (2012 discount rate) for water resource projects, a rate that lowers the value of the benefits by 4% every year into the future (U.S. Army Corps of Engineers, October 17, 2013). The private sector tends to use even higher discount rates. Discounting can be adjusted for different types of assets and is designed to reflect the following:

- **Pure time preference of money.** This is the rate at which people value what they can have now, compared with putting off consumption or income until later.
- **Opportunity cost of investment.** A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a positive return in one year.
- **Depreciation.** Built assets such as roads, bridges and levees deteriorate and lose value due to wear and tear. Eventually, they must be replaced.

Discounting has limitations that may result in under- or over-estimates when applied to natural capital. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations, or even to this generation in just a few years into the future. Natural capital assets should be treated with lower discount rates than built capital assets because they tend to appreciate over time, rather than depreciate. Additionally, most of the benefits that natural assets in Lancaster County provide reside in the distant future, whereas most of the benefits of built capital reside in the near-term, with few or no benefits provided into the distant future. Both types of assets are important to maintain a high quality of life, but each operates on a different time scale. It would be unwise to treat human time preference for a forest like it was a building or that of a building as if it was a disposable coffee cup. Thus, a lower discount rate better reflects the asset value of Lancaster County's natural capital.

The cut-off date of 100 years is arbitrary. Clearly, far greater value yet resides for the many generations who will benefit from Lancaster County's natural capital well beyond the 100-year point, assuming the watershed is adequately protected. Currently, the value of economic assets is generally not considered beyond 100 years. This study follows that tradition. With no cut-off for value, any renewable resource would register an infinite value. The value of natural capital can, and should extend far beyond a 100-year period.

These values are analogous to an asset value for the natural capital of Lancaster County. There are large differences in asset value depending on which discount rate is used. For agricultural lands that are becoming scarcer over time, the zero percentage discount rate is probably a better approximation. The values are underestimates because not all ecosystem services were valued.

Yet by any measure Lancaster County's natural capital is worth a lot. Treated with a 4% discount rate like a built capital bridge or factory, which falls apart, the value of natural capital in Lancaster County is in the range of $5.5 billion to $28 billion. Treated as an asset that persistently provides the same value across time, using a zero discount rate for 100 years only yields a natural capital asset value range of $22 billion to $114 billion (Table 8).

We also calculate an asset value for preserved farmland in Lancaster County. There is more certainty that these assets will be maintained with the legal protections provided to protected farmlands. As more land is developed in surrounding areas, the services provided by protected farmlands will only increase in value. Table 9 estimates preserved farmland asset value for both 0% and 4% discount rates.

If these assets fall apart, it will be at great cost to people living today and in the future. If these assets are enhanced, they can be a basis for clean air, clean water, vibrant agriculture and industry, employment, rising real wages and a high quality of life, for generations.

TABLE 8. NET PRESENT VALUE OF LANCASTER COUNTY'S NATURAL CAPITAL

Discount Rate	Low Estimate	High Estimate	Average
0% (100 years)	$22,675,704,807	$114,492,539,338	$68,584,122,073
4% (100 years)	$5,556,681,235	$28,056,395,616	$16,806,538,426

TABLE 9. NET PRESENT VALUE OF PRESERVED FARMLAND IN LANCASTER COUNTY

Discount Rate	Low Estimate	High Estimate	Average
0% (100 years)	$3,332,513,643	$23,152,511,223	$13,242,512,433
4% (100 years)	$816,632,435	$5,673,522,643	$3,245,077,539

CHAPTER 4
AGRICULTURAL PRESERVATION: CULTURAL IDENTITY AND ECONOMIC FUTURE

This report provides an appraisal valuation of ecosystem services in Lancaster County by quantifying the economic value supplied by nature every year. Through provisioning food, assuring a clean drinking water supply, buffering floods, and supporting several other critical services, Lancaster County ecosystems provide roughly $676 million in economic value every year. If treated like an asset, the value of Lancaster County ecosystems is $17.5 billion at a 4% discount rate.

Cultivated and Pasture lands were estimated to provide between $109 and $857 million annually in ecosystem service benefits. To put these numbers in perspective, compare this range to the $1.2 billion in total value of cash receipts for all crops, livestock products, and USDA government payments calculated for production agriculture in Lancaster County in 2011. Farms in Lancaster County are thus producing similar values in ecosystem services to total economic production.

For preserved lands, the County has invested a combined total of roughly $100 million in state and federal funding and $13 million in private funds from the Lancaster Farmland Trust. This total invested farmland preservation of $226 million total is at the low end of the estimated annual ecosystem service value. If this farmland were to be developed, many of the ecosystem services would be lost forever. This is an excellent Return on Investment.

Future enhancements to this value can be achieved with investment in technology and stewardship. The Lancaster County Conservation District is working to enhance these values through the implementation of Best Management Practices as discussed below in Box 5.

BOX 5. SPATIALLY LOCATING BMPS FOR OPTIMAL INVESTMENT AND ENHANCED ECOSYSTEM SERVICES

The Lancaster County Conservation District's Planning and Tracking Portal is a geo-spatial database application that tracks and manages conservation and nutrient management plans, as well as their related Best Management Practices (BMPs). Stream projects can also be tracked, and a module for the Erosion & Sediment department is in development. This application was built by WorldView Solutions in Richmond, VA to assist the Lancaster County Conservation District with better management of its heavy workload. In January 2012, the application went live and has since entered over 800 conservation plans and 10,000 BMPs.

The system was initially developed to assist staff with their daily tasks to compile accurate reports that are required by the PA Department of Environmental Protection. This information, once provided to the EPA, can be included in Chesapeake Bay Model to document the achievements of the farmers in Lancaster County in meeting both the Watershed Implementation Plan (WIP) and the Total Maximum Daily Loads (TMDL). It has since evolved into a tool that enables the District to implement a targeted approach to improving water and soil quality by identifying locations of concern in the county. By spatially locating plans and BMPs, we are able to manipulate and report data in many ways, for example, queries based on proximity to streams and identifying watersheds in need of BMP implementation.

Source: Andrew Hake, Lancaster County Conservation District

This initial estimate of natural capital value shows the economic benefits provided by ecosystems to be on par with the total economic impact of agriculture and tourism in Lancaster County. The ecosystems provide goods and services across vast spans of time and well beyond their boundaries, at little or no cost. The loss of "free" services like flood risk reduction and drinking water quality has real local and regional economic costs. Some ecosystem services can be protected and enhanced through the innovative use of technology. Using manure to produce energy simultaneously enhances waste treatment and water quality ecosystem services while lowering carbon emissions. This project is discussed in greater detail in Box 6.

Protecting and restoring natural capital is critical to maintaining a sustainable quality of life, equity and economic progress in the region. Though only a snapshot in time, these appraisal values are defensible and applicable to decision-making at every jurisdictional level.

Because this is a meta-study, utilizing many valuation studies, we do not know the cumulative shape of the error for these results. However, both the low and high values established are likely underestimates of the full value of ecosystem services provided within Lancaster County because values for most ecosystem services have not been estimated. In addition, many ecosystem services have only been valued for one vegetation type. Sparse data and omission of existing value is still the greatest hurdle to such studies, and the greatest source of error in this valuation.

BOX 6. MANURE-TO-ENERGY AND LANCASTER COUNTY FARMING: A WIN-WIN

With the heavy concentration of animal-related (dairy, poultry, swine) farming in the Lancaster County agriculture economy, the ability to process manure is a very important issue in preserving water quality. As part of the Chesapeake Bay watershed, Lancaster County plays a key role in the wider efforts to restore the Bay.

Farmers in Lancaster County have discovered that manure can be used in a number of ways as an alternative energy source, not only disposing of the waste but also saving in electric and other costs for the farming operation. Some farmers have even generated additional revenue by selling electricity back to the grid.

Currently, there are close to 30 manure-to-energy projects which include anaerobic digesters, composting, and manure burners. These projects occur on a variety of farm sizes. Some of these energy systems are very sophisticated and are operated by technology companies while others are much more basic with the farmer doing most of the labor in designing, building, and operating of the system.

Below are some examples of energy projects in Lancaster County:

- *Wanner's Pride-N-Joy Farm has a 600 cow dairy herd. Their anaerobic digester generates in excess of $40,000 in income by selling electricity back to the grid. It also produces savings in the cost of bedding for cows through the use of the digested solids.*
- *Brubaker Farms uses manure from 700+ cows and 500+ heifers to generate electricity for use on the farm as well as to sell back to the grid. This project generates over $150,000 per year in income.*
- *Oregon Dairy and Graywood Farms use manure from their two large dairy herds, additional waste from horse farms in the area, and food waste from the Oregon Dairy supermarket to generate compost or "manufactured topsoil" which is used primarily in the landscape, turf, horticulture, and highway and mine reclamation areas. The two farms work in collaboration with Terra-Gro, Inc. to operate the compost business as a separate revenue-generating company from their traditional farming operations.*

Source: Scott Sheely, Lancaster Agricultural Council

While this report provides a valuation of ecosystem services in Lancaster County, it is only a first step in the process of developing policies, measures, and indicators that support discussions about the tradeoffs in investments of public and private money that ultimately shape the regional economy. Recommended next steps include:

- **Invest in natural capital.** Lancaster County ecosystems should be viewed as essential assets and investment opportunities for promoting economic prosperity. Continuing to invest in the agricultural sector, farmland preservation, and natural resource conservation will increase the value of these assets.

- **Develop more comprehensive valuations, maps, and models of key ecosystem services.** This study provides a baseline valuation of ecosystem services in Lancaster County and identifies key local benefits provided. More detailed valuation studies on these benefits can be used to make more cost-effective investments across the landscape. Value can be mapped and modeled at higher resolutions incorporating new primary data or local knowledge for specific ecosystem services of interest.

- **Include ecosystem services in rural economic development planning.** Recognizing the links between healthy ecosystems, agriculture, tourism, cultural cohesion, and real estate values provides a quantifiable perspective of the value of rural regions. Ecosystem services can help inform the creation of incentive structures to provide landowners and farmers direct financial benefits for best stewardship practices. Ultimately, an ecosystem service perspective helps identify, quantify, and secure jobs that are sustainable in the long-term.

- **Include ecosystem service valuation in policy, accounting, and decision-making tools.** Ecosystem service valuation can provide governments, organizations, and private landowners with a way to calculate the Return on Investment of past or hypothetical preservation and restoration investments. Ecosystem services also provide an objective means for quantifying trade-offs in development decisions.

APPENDIX A
VALUE TRANSFER STUDIES USED: FULL REFERENCES

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APPENDIX B
STUDY LIMITATIONS

This first ecosystem services valuation produced by Lancaster County has significant implications regarding the conservation, management, and restoration of natural capital.

Though valuation exercises have notable limitations, these shortcomings should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type from other locations. Like any approach to economic analysis, this methodology has strengths and weaknesses.

Some arguments against benefit transfer include:

- Every ecosystem is unique. Per-acre values derived from another location may be irrelevant to the ecosystems being studied.
- Even within a single ecosystem, the value per acre depends on the contiguous 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).
- 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.
- 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 (Howarth & Farber, 2002). 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. However, 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 Lancaster County would make this approach to valuation extremely difficult and costly.

Responses to these critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

- 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 Lancaster 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.

- The results of the spatial modeling analysis that are 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.

- 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.

- 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 of, 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 extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, on the other hand, assuming they have infinite value. Pragmatically speaking, in estimating the value of ecosystem services, it is better to be approximately right than precisely wrong.

The estimated value of the world's ecosystems presented in Costanza et al. (1997), 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. Human life, like ecosystems is priceless, yet people's time is valued 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 "infinity" 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 to people exceeds the value of the gross world product—and oxygen production is only a single ecosystem service and good.

GENERAL LIMITATIONS

- **Static Analysis.** This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics. Though new dynamic models are being developed, it is difficult to assess how they would affect valuations.
- **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 would increase the total values.
- **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 Lancaster 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.
- **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 political 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.
  - Resolution: The National Landcover Database utilizes pixels of 30 meters by 30 meters, which necessitates spatial approximation in categorization.
- **Ecosystem Health.** Health of ecosystems varies between studies and within study areas. 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. Addressing 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.** The most serious issue resulting in the significant underestimation of the value of ecosystem services is that not all ecosystems have been thoroughly studied or valued. . 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. Table 4 illustrates which ecosystem services were identified in Lancaster County for each land cover type and which of those were valued.
- **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.** Most 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 C
ANNOTATED BIBLIOGRAPHY

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.

Contingent valuation is applied to find the value of environmental amenities for areas that would have been agricultural lands in Greenville County, South Carolina. Marginal household benefits were estimated at $0.06 per thousand acres, or $60 per acre.

Bouwes, N. W., Scheider, R. 1979. Procedures in estimating benefits of water quality change. American Journal of Agricultural Economics 61, 635-639.

The authors calculate the avoided cost of maintaining water quality in Wisconsin's Pike Lake, finding a $74.64/acre/year value of water quality.

Everard, M., Jevons, S. 2010. Ecosystem services assessment of buffer zone installation on the upper Bristol Avon, Wiltshire. Report to The Environment Agency, United Kingdom, 24 p.

This report outlines the background, methods, findings, and learning following an assessment of the changes in ecosystem services stemming from the installation of a buffer zone on 330 meters of one bank of the upper Bristol Avon catchment, North Wiltshire. With a capital cost of £4,700, the buffer zone was completed in 2008; however, gross lifetime benefits from the buffer zoning project are estimated at £144,860, representing a benefit-to-cost ratio of 31:1. Fishery benefits were found to have an annual benefit of £828, and a lifetime benefit of £13,989.

Hauser, A., Cornelis van Kooten, G. 1993. Benefits of Improving Water Quality in the Abbotsford aquifer: An application of contingent valuation methods.

Contingent valuation is conducted to find the benefits of improved water quality in the Abbotsford Aquifer in British Columbia. The estimate of off-farm benefits for improving water quality is found to be about $1.8 million annually.

Jenkins, W. A., Murray, B. C., Kramer, R. A., and Faulkner, S. P. 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. Ecological Economics, 695 1051-1061.

This study attempts to quantify the value of restoring forested wetlands in the Mississippi Alluvial Valley, based on the value of ecosystem services. The ecosystem services assessed are greenhouse gas mitigation, nitrogen mitigation, and waterfowl recreation. Social welfare value is found to be between $1435 and $1486 per hectare per year, with greenhouse gas mitigation valued between $171 and $222, nitrogen mitigation valued at $1248, and waterfowl recreation at $16.

Knoche, S. and Lupi, F. 2007. Valuing deer hunting ecosystem services from farm landscapes. Ecological Economics 64, 313-320.

Knoche and Lupi use a random utility travel cost model to find the potential value of white-tailed deer provisioning and recreational services, specifically for agricultural lands. In addition, the authors find the value of providing deer hunters public access to a percentage of agricultural land.

Mazzotta, M. 1996. Measuing Public Values and Priorities for Natural Resources: An Application to the Peconic Estuary System. University of Rhode Island.

In a PhD dissertation, Mazzotta attempts to measure values and priorities for protecting and enhancing natural resources in the Peconic Estuary system. A contingent valuation 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.

Sandhu, H.S., Wratten, S.D., Cullen, R., and Case, B. 2008. The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. Ecological Economics 64, 835-848.

The authors estimate the value of ecosystem services associated with organic and conventional agricultural landscapes in Canterbury, New Zealand. There were significant differences between the ecosystem services provided by conventional and organic agriculture. The results are presented in annual US$ per hectare.

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.

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.

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.

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. 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.

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.

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; recreation and tourism; agriculture industry; government cost savings; and additional non-market benefits, which are discussed qualitatively.

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.

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 document provides a large number of ecosystem service value estimates.

Winfree, R., Gross, B., Kremen, C. 2011. Valuing pollination services to agriculture. Ecological Economics 71, 80-88.

The authors attempt to apply two existing valuation methods to pollination services, as well as develop a new one. They demonstrate all three methods using a data set on watermelon pollination by native bees and honey bees in New Jersey and Pennsylvania. Some discussion is devoted to explaining why different methods produce disparate values.

Wu, J., Skelton-Groth, K. 2002. Targeting conservation efforts in the presence of threshold effects and ecosystem linkages. Ecological Economics 42, 313-331.

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 are ignored in federal conservation policies. Several use values for fish are discussed, as well as correlated nonuse values and social benefits.

APPENDIX D
HISTORY OF FARMLAND PRESERVATION IN LANCASTER COUNTY

Over the past 40 years, Lancaster County's farmland has faced increasing development pressures. Farmland preservation became a critical national issue in the 1980s when unplanned and uncontrolled land use threatened productive farmland in nearly every urban center in the United States, including Lancaster County. Between 1980 and 1990, Lancaster County added roughly 60,000 people — about the population of the city of Lancaster. Ironically, the scenic farmland that acted as a "magnet" to the area was quickly disappearing as more and more farms were sold to make way for housing developments and commercial centers.

Lancaster County's farmland preservation efforts began in 1975 with the adoption of a Comprehensive Plan that presented several techniques for the preservation of agricultural lands as an appropriate use of Lancaster County's high quality soils. Within a few years, the County Commissioners appointed an Agricultural Preservation Task Force to investigate the feasibility of a deed restriction program as a way to preserve County farmland. In 1979, the Task Force completed its report and recommended creation of a County Agricultural Preserve Board and the establishment of a deed restriction program to protect County farmland.

In 1980, the County Commissioners appointed a nine-member Agricultural Preserve Board, which was considered an agricultural advisory group. The purpose of this group was to advise the County on criteria and procedures for implementation of a deed restriction program. In 1982, the first perpetual conservation easements were donated to the County and a year later the Agricultural Preserve Board was established as County Department. The Agricultural Preserve Board adopted its first official Program Guidelines in 1984, and began purchasing agricultural conservation easements for an initial amount of $250/acre.

By the late 1980's, Pennsylvania was making progress towards establishing a statewide farmland preservation program. Efforts were led by State Senator Noah Wenger and Chester County Representative Samuel Morris, who sponsored PA Act 149, which established the state farmland preservation program. Lancaster County was the first county authorized under the state farmland preservation program and preserved the first farm through the state program in 1989.

It became apparent that Lancaster's farmland preservation program was not effectively reaching Plain Sect farmers and a new organization was needed to serve Amish and Mennonite farmers who were hesitant to participate in the county/state preservation program due to religious beliefs. In 1988, Lancaster Farmland Trust, a private, non-profit organization, was formed specifically to fill this need. The organization continues to be an important support arm of the Lancaster County Agricultural Preserve Board and the two organizations work hand in hand as partners to preserve Lancaster County's treasured farmland.

Throughout the 1990s, Lancaster County made significant progress in farmland preservation through the work of the two complimentary organizations. Utilizing a combination of county, state and private funding, in 1996 Lancaster County achieved the milestone of preserving 20,000 acres of farmland. The same year, Pennsylvania authorized a cigarette tax to create what is still the only significant dedicated source of revenue for farmland preservation. Originally $0.02/ pack and later capped at $20.85 million annually, this dedicated funding served as a reliable and predictable source of funds, against which Lancaster could leverage its own local funds.

In 1999, more significant funding was made available through a new line item in the State budget. Lancaster County appropriated an additional $2 million that year and leveraged $7 million in State funding as a result.

In 1999, again taking advantage of an opportunity to leverage significant State funds, the County Commissioners approved a $25 million bond for farmland preservation. This influx of County funds was timed to coincide with the State's Growing Greener bond issue, which made $100 million available for farmland preservation over five years. Lancaster County's aggressive local funding allowed it to maximize its match of State funds and these significant additional resources enabled the preservation of 500 farms in 2001 and 50,000 acres in 2002, making Lancaster County the national leader in farmland preservation.

With the State's original Growing Greener resources exhausted, another initiative for funding the preservation of farmland, open space and environmental resources was announced in 2006 in the form of Growing Greener II. This initiative made $80 million available for farmland preservation statewide and Lancaster County again took advantage of this opportunity to leverage State funds by authorizing $25 million of bond funds to be used for farmland and natural lands preservation and urban enhancement. With a local match of $9 million, Lancaster County received a record $9.3 million of state funds the same year and, by 2008, Lancaster County preserved its 1,000th farm, a joint project with Lancaster Farmland Trust.

The same year, Lancaster began funding the Lancaster Farmland Trust through an annual challenge grant. Initially $1 million, this County grant funding allowed the Lancaster Farmland Trust to match funding from its donors dollar for dollar, up to $1 million each year. The challenge grant remains in place today, although at a reduced amount. It continues to be an important source of revenue for the Lancaster Farmland Trust and has attracted additional out of county grant funds because of the cooperative nature of preservation efforts it represents between Lancaster County and the Lancaster Farmland Trust.

APPENDIX E
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