Nature's Value in the Térraba-Sierpe National Wetlands: The Essential Economics of Ecosystem Services

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EARTH ECONOMICS

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Earth Economics project team members for this study included Dave Batker, Maya Kocian, Jennifer Harrison-Cox, Patrick Miller, Zac Christin, Rowan Schmidt, Tedi Dickinson, Jennifer McFadden, Kellen Hawley and Jim Pittman.

Earth Economics is responsible for the content of this report.

Prepared For:

THE UNIVERSITY OF VERMONT

617 Main Street
Burlington, VT 05405
(802) 656-2906

Prepared By:

EARTH ECONOMICS

1211 Tacoma Avenue South
Tacoma, WA 98402 USA
01 (253) 539-4801
www.eartheconomics.org
info@eartheconomics.org

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ACOSA	Área de Conservación Osa
CENAT	Centro Nacional de Alta Tecnología
ECOTICOS	Education, Communication, Technical, Institutional and Conceptual Solutions
EE	Earth Economics
ESV	Ecosystem Service Valuation
GIEE	Gund Institute for Ecological Economics
GIS	Geographic Information System
PES	Payments for Ecosystem Services
PRIAS	Programa National de Investigaciones Aerotransportadas y Sensores Remotos
PV	Present Value
MINAE	Ministerio de Ambiente y Energía
SINAC	Sistema Nacional de Áreas de Conservación
HNTS	Humedal Nacional Térraba Sierpe

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Executive Summary

The Térraba-Sierpe National Wetlands (HNTS) is located in the Osa Peninsula of Costa Rica. The annual values of the HNTS are **$302,334,177** on the low estimation and **$1,929,804,914** as the high estimation. Two discount rates were used in this report, 0% and 3%. With natural assets providing a suite of highly valuable ***ecosystem goods and services***, the HNTS provides storm protection, natural drought mitigation, nutrient flows, biodiversity, mussel (piangua) habitat, aesthetic value, and many other public goods and services. Most of these highly valuable services are public services, which are non-excludable, benefiting everyone.

Although rendered for free, ecological goods and services are valuable both to the local economy and the global community. If these valuable goods and services are lost, people sustain costs, like loss of clean drinking water, critical fish and wildlife habitat, and storm protection. The services previously provided by natural systems for free must be replaced by costly, built structures. In some cases, once lost, ecosystem goods and services cannot be recovered.

Natural capital is comprised of geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continual return of valuable benefits (Daly and Farley, 2004). It contributes to our economy and quality of life in many ways that are not currently included in policy considerations. This includes provision of water, natural water filtration, energy production, storm protection and flood control, recreation, water management, biodiversity, and education.

Many economic measures were developed when natural capital was abundant and built capital scarce. With the goal of providing more manufactured goods and services, human beings developed a blind spot to the economic importance of natural systems. Built and financial capital, along with labor, are considered primary factors of production for economic development. Until very recently, land and natural systems were frequently excluded in economic analysis. Today, economics recognizes the many things important to human well-being beyond manufactured products. Consideration of the Térraba-Sierpe mangroves and other ecosystems as natural capital helps provide a more complete view of ecosystem health and the production of valuable benefits.

Methods

In long-term partnership with the Gund Institute for Ecological Economics, Earth Economics maintains a database of ecosystem valuation studies to derive value estimates. This ecosystem service valuation (ESV) provides the best available scientific method for quantitative analysis of the relationships between ecosystem health and economic benefit in the Térraba-Sierpe to date.

Hectares of vegetation types in Geographic Information System (GIS) data, provided by Programa Nacional de Investigaciones Aerotransportadas y Sensores Remotos – Centro Nacional de Alta Tecnología (PRIAS-CENAT), an NGO based in San Jose, were used with a benefit transfer methodology. This methodology uses the findings of peer reviewed academic journal articles in order to estimate the high and low dollar value range of a list of 17 ecosystem services produced within a hectare of each vegetation type. These values were then summed for an initial rough-cut total valuation of ecosystem goods and services provided annually by each area. After this, values were modified according to the particular area of Térraba-Sierpe being examined. To get a sense of value over time, the present value (PV) was calculated over different time horizons from the estimates of the annual flow of ecosystem benefits. Several discount rates were used for comparison.

This analysis supports the Térraba-Sierpe National Wetlands Management Plan that was completed by stakeholders in the Térraba-Sierpe community in 2008. Understanding the value of the HNTS in economic terms is a critical first step to ensuring appropriate management of this incredible and international asset. Conservation programs and activities that clearly provide extensive economic benefits to the local community are typically easier to secure local and international funding for, and are longer lasting and self-sustaining.

Recommendations

The following is a list of recommendations resulting from our research of the Térraba-Sierpe wetlands.

1. Convert ESV study results into local currency.
2. Perform additional ESV studies on specific watersheds in the Osa Peninsula.
3. Initiate mapping and modeling of ecosystem services in the region.
4. Use ESV data to fund further region specific service value transfer studies through local universities and implement broad changes in asset accounting practices.
5. Perform an initial analysis of restoration and conservation funding mechanism and work with local and regional stakeholders to further refine the sustainable plan to ensure ongoing funding and policy support for basin-scale restoration and conservation efforts.

Part 1: Introduction

Study Location

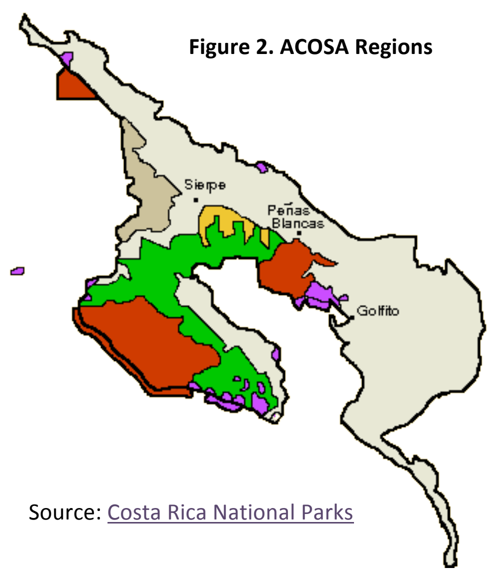
Overview

Figure 1. Costa Rica Map showing location of ACOSA

Named after the Térraba and Sierpe rivers, the Humedales National Térraba-Siepre (HNTS) was established on March 17, 1994 and became one of the 17 protected wildlife areas of Área de Conservación Osa (ACOSA).[1] Nationally designated as a Forest Reserve in 1977 and registered as a Wetlands International RAMSAR site in 1995, the HNTS is located on the Pacific Coast of Costa Rica, north of Drake Bay, in Puntarenas Province approximately 10 miles south of Palmar Sur. The HNTS encompass 30,654 hectares (66,850 acres) and is entirely state-owned and managed by the Ministry for the Environment and Energy (Ministerio de Ambiente y Energía or MINAE). Few people live in the region and the main human settlements are in the surrounding communities of Sierpe, Palmar and Cortes.

The HNTS protects the extensive river mouth delta systems, estuaries and wetlands between the Terraba River and the Sierpe River, and contains the largest and most important mangrove reserve in Central America. The eight species of mangrove include red, black, grey and tea mangroves. These mangroves provide an invaluable coastal ecosystem to an abundance of avian, mammalian, reptilian and aquatic species.

Figure 2. ACOSA Regions



Source: Costa Rica National Parks

Within the Térraba- Sierpe mangroves, many products are extracted for sale or recreation. The main income generating activity in the area comes from the harvesting of the clam *Anadara tuberculosa*, commonly referred to as "piangua". Limited line fishing is permitted in the estuary of the Terraba Sierpe. The Térraba-Sierpe wetlands

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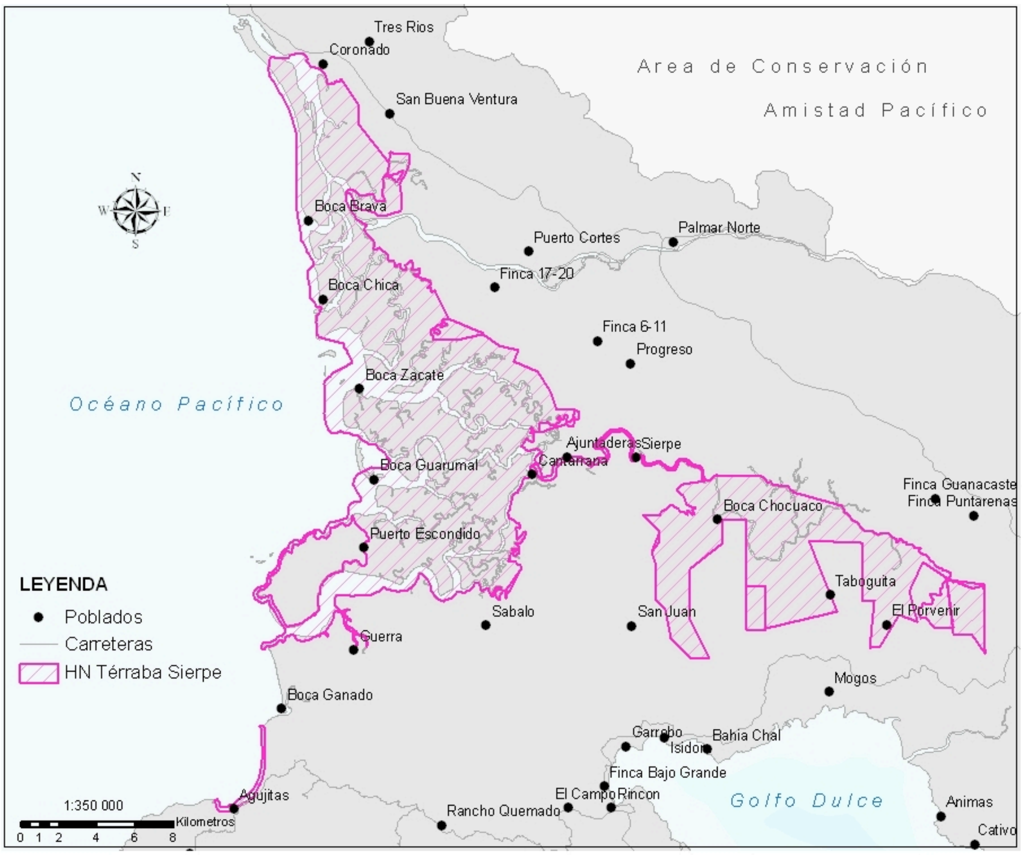
[1] Responding to the new policies of the Ministerio de Ambiente y Energía or MINAE, eleven conservation areas were established by this department in 1998 to oversee and manage the public lands of Costa Rica. These conservation areas are known as the Sistema Nacional de Areas de Conservacion (SINAC). ACOSA is one of these eleven Conservation Areas and includes large areas of the Osa Peninsula and its surroundings along the Pacific coast of Costa Rica.

generate approximately $1,130/day, in terms of shellfish extraction (Reyes et al., 2004). The wetland is also regional and international tourism destination and provides income to tour operators.

Figure 3. Térraba-Sierpe National Wetlands Region



Source: Térraba-Sierpe Management Plan, 2008

Characteristics

The HNTS is characterized by a woodland ecosystem with periodically flooded swamps and mangrove forest, palm swamp forest, sandy beaches and cliffs. The area includes the mouths of the Térraba and Sierpe Rivers and adjacent lagoons of Sierpe and Porvenir. The Térraba River is the main source of freshwater into the estuarine system, draining a basin of approximately 5,000 square kilometers. The main tributaries are the General River and the Sierpe River. The Sierpe forms the border of the mangrove woodland. The mangrove vegetation provides erosion protection, both from run-off and wind erosion, and maintains water quality. The area is periodically flooded by tides with an average total tidal fluctuation of approximately 2 meters. The climate is very hot and humid. The average annual rainfall is 3,638 mm, with the rainy season from April to November (Kappelle, 2002).

The Térraba- Sierpe region is geologically formed by volcanic, erosive and alluvial materials. Soils have a high water content, variable salt quantities and low levels of oxygen. These soils tend to be semi fluid, poorly consolidated, and grey or black in color reflecting high sulphate content. The alluvial soils, with good to poor drainage, derive from sediments and volcanic ash.

Objectives of this Study

The objective of this basic ecosystem service valuation (ESV) study is to support the ability of Térraba-Sierpe stakeholders to make a clear course towards the implementation of green business portfolios while shying away from unsustainable practices. To meet that objective, this report:

- Provides a brief discussion of the economy within HNTS;
- Identifies ecosystem services within the region and highlights the importance of these services to sustained economic development;
- Assigns value to these ecosystem services within an economic framework of built and natural assets for long-term sustainable management;
- Discusses this valuation within an economic framework that illuminates the necessity and value of natural capital, and the importance of the conservation and restoration of natural capital as a long-term economic asset; and,
- Provides an economic justification Térraba-Sierpe's management plan.

Value Transfer in Economic Valuation

The methodology of value transfer was used to conduct this economic valuation. Conducting original studies for every ecological service on every site for every vegetation type is cost and time prohibitive; researchers developed a technique called benefit or value transfer which is a widely accepted economic methodology wherein 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.

This valuation is similar to a house appraisal where an appraiser considers the values (sales) of houses in different locations, the similar and different attributes, and specific aspects of the house and property being appraised. The number of bedrooms, condition of the roof, unfinished basement, and view are additive values for estimating the full value of the house. These additive values provide different services and contribute to the total value of a house.

Earth Economics manages a database of published, peer-reviewed ecological service valuation studies. Originally developed by the Gund Institute for Ecological Economics (GIEE), the database provides value transfer estimates based on land cover types and is updated as new literature becomes available.

The value of the ecosystem services described above is additive. A hectare of forestland provides water regulation and filtration services and aesthetic, flood protection, and refugium benefits. One study may establish the value per hectare of a watershed in water filtration for a drinking water supply.

Another study may examine the value per hectare of refugium for wildlife. To determine the full per hectare value provided by a vegetation type, ecosystem service values are summed up and multiplied by the total area.

The valuation techniques utilized to derive the values in the database were developed primarily within environmental and natural resource economics. As Table 1 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing and contingent valuation.

> ***Direct use value*** involves interaction with the ecosystem itself rather than via the services it provides. It may be consumptive use such as the harvesting of trees or fish, or it may be non-consumptive such as hiking, bird watching or educational activities.
>
> ***Indirect use value*** is derived from services provided by the ecosystem when direct values are not available. This may include the removal of nutrients, providing cleaner water downstream (water filtration) or the prevention of downstream flooding. Studies may derive values from associated market prices such as property values or travel costs. Values can also be derived from substitute costs like the cost of building a water filtration plant when natural ecosystem filtration services are disturbed and fail. Contingent valuation is an additional method that entails asking individuals or groups what they are willing to pay for a good or service.

Table 1. Methods for Primary Research in Ecosystem Service Valuation

Direct Use Values	
Market Price	Prices set in the marketplace appropriately reflect the value to the "marginal buyer." The price of a good tells us how much society would gain (or lose) if a little more (or less) of the good were made available. *Example: Rainforest products such as coffee and cacao.*
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services. *Example: Hurricane protection provided by barrier islands avoids property damages along the coast.*
Replacement Cost	Cost of replacing ecosystem services with man-made systems. *Example: Nutrient cycling waste treatment replaced with costly manmade treatment systems.*
Factor Income	The enhancement of income by ecosystem service provision. *Example: Water quality improvements increase commercial fisheries catch and incomes of fishermen.*
Travel Cost	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 whose value placed on that area must be at least what they were willing to pay to travel to it.*
Hedonic Pricing	The reflection of service demand in the prices people will pay for associated goods. *Example: Housing prices along the coastline tend to exceed the prices of inland homes.*
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. *Example: People would be willing to pay for increased preservation of beaches and shoreline.*
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, businesses come together to determine the value of an area and the services it provides.*

How to Use this Report

This basic ESV report is organized into four sections:

1. ***Introduction to Térraba-Sierpe National Wetlands*** provides an overview of the geography, population and economy of the region.
2. ***Key Concepts*** defines fundamental elements and definitions necessary for an understanding of an ecological economics approach.
3. ***The Value of Natural Capital*** describes four broad categories of ecosystem goods and services and provides a few specific examples in the HNTS.
4. ***Valuation of the Térraba-Sierpe National Wetlands*** puts ecological economics into action, determining dollar values based on concepts developed in the previous two sections.
5. ***Conclusion*** stresses the importance of conservation and restoration of the HNTS.

Part 2: Key Concepts

The scientific field of Economics has advanced significantly in recent years in ways that improve our ability to quantify the value and impacts of resource management strategies. A great deal of research since 1985 has focused on developing and refining methods, tools, and techniques for measuring the value produced by natural systems. These include new concepts such as "natural capital" and new techniques including ecosystem service valuation.

Natural Capital and Asset Management

Ecosystems and natural resources, or natural capital, have previously been viewed as virtually limitless compared to human-built capital. In the past, they were considered as "free" and therefore of no value. Given the increasing scarcity of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives, and make effective and efficient management decisions. Excluding natural capital in asset management can result in significant losses, increased costs, and decreases in efficiency and community benefit.

Understanding Natural Capital

Natural capital is comprised of geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continual return of valuable benefits (Daly and Farley, 2004). It contributes to our economy and quality of life in many ways that are not currently included in policy considerations. This includes provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity and education. Consideration of the Térraba-Sierpe mangroves and other ecosystems as natural capital helps provide a more complete view of ecosystem health and the production of valuable benefits.

Economics of Natural Capital

Healthy ecosystems are self-maintaining; they have the potential to provide an ongoing output of valuable goods and services in perpetuity and to appreciate in value over time. In contrast, built structures and other man-made capital have a tendency to depreciate in value over time and require significant financial inputs for operations and maintenance. By incorporating natural capital within Térraba-Sierpe's management plan, MINAE can enhance the capacity of ecosystems to produce economic value and community benefit. It shows how minimal investment through support for proper management of these assets would continually bring large returns by way of ecological goods and services.

Public and private landowners have a unique opportunity to understand the full economic importance of ecosystems in services. The provision and filtration of water is a good example. The city of New York accepted in 1997 the importance of ecosystem service valuation when considering long-term supply options for a city that demanded more than 3.8 million liters of water daily. Facing degraded drinking water quality, New York City weighed the options of building a water filtration plant costing over $7 billion or of investing $1.5 billion to restore the health of the watershed and allow natural processes to filter the water and meet drinking water standards. The City decided to invest in watershed restoration that had a far higher rate of return—a less costly and less risky method for meeting standards.

Ecosystems in the Térraba-Sierpe can be managed in a way that optimizes the aggregate value of goods and services with potential to benefit current and future generations.

Ecosystems and Value Production

Ecosystem goods and services depend on ecosystem structure and processes. **Structural components** in ecosystems include trees, wetland plants, soil, topography and animals. **Ecosystem processes** include the flow of water, animal life cycles, photosynthesis, nutrient cycles and others. These structural components and ecosystem processes support **ecosystem functions** such as water catchment, soil accumulation, habitat creation and buffers to flooding. Ecosystem functions generate benefits to people called **ecosystem goods and services**.

Ecosystems are comprised of individual structural components (trees, forests, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, etc.) that generate ecological goods and services (salmon, timber, flood protection, recreation, etc.). Figure 4 below summarizes these relationships in a simplified diagram. Ecosystem infrastructure has particular physical components within given boundaries of the ecosystem. The infrastructure itself is dynamic, as biotic structures migrate and abiotic components flow through the watershed, often via air or water. These functions vary widely in spatial boundaries (oxygen migrates globally, while spawning habitat is locally confined). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes and functions combine to produce economically valuable goods and services.

Figure 4. Relationship of Ecosystems to the Goods and Services Produced

Ecosystem service valuation assigns a dollar value to goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce the full diversity of valuable ecosystem goods and services. In this particular case, the management plan protects and reestablishes not only the ecological processes necessary for narrow interests, for example, White mullet (*Mugil curema*) spawning or water filtration but also for the production of a larger basket of valuable ecosystem goods and services. This study will give a lower range estimate for the low and high values of ecological goods and services resulting from support for the proper management of Térraba-Sierpe. Restoring these ecological processes within a natural range of variability maintains structure and the ecological goods and services that follow. Further study will show the value of ecological goods and services contributed by all restoration sites, thereby showing the low estimate of the cumulative value brought in by these restorations sites to present and future generations.

Ecosystem Goods

Ecosystems provide a variety of useful goods like water, timber and fish. Most goods are excludable; if one individual owns or uses a particular good, that individual can exclude others from owning or using the same, i.e., if one person eats a mango, another person cannot eat that same mango. Excludable goods can be traded and valued in markets. The production of goods can be measured by the physical quantity produced by an ecosystem over time, such as the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of ecosystem goods over time.

Ecosystem Services

Ecological services are defined as "the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life" (Daily et al., 1997). Ecosystems provide a variety of services that individuals and communities use and rely upon, not only for their quality of life, but also for economic production (Daily, 1997; Costanza et al., 1997). Ecosystem services are measurable benefits that people receive from ecosystems. Table 2 lists some ecosystem services.

Unlike ecosystem goods, ecosystem services are not tangible items that you can hold. Some services, such as flood protection, are not measurable in physical quantity. Some services, such as human labor, can be valued (wages), measured (time or work accomplished) and traded in markets (labor market). Ecosystem services are often difficult to value, measure and trade because they have no labor component. Hurricane protection, flood protection, recreational value, aesthetic value and water filtration are a few of the services that many ecosystems provide. Many services are not easily measured in terms of market value—many are fundamentally "public goods". Because of their physical nature, no one can privately own them, and they cannot be traded in markets, just as no one can own or trade natural flood protection (though built infrastructure that provides flood protection, like levees, *can* be owned).

This stream of services provided by an ecosystem is referred to as a ***service flux***. A flow of goods can be measured in quantitative productivity over time while a service flux is generally more difficult to measure and value.

Many ecosystem services are non-excludable: When one person enjoys a view of the sunset, it does not prevent another person from enjoying the same sunset, unless congestion develops. Similarly, all downstream residents benefit from the flood protection provided by forested land or dams upstream. Many ecosystem services, such as oxygen production, soil regulation and storm protection are not, or cannot, be sold in markets. However, markets for some ecosystem services are possible and slowly growing; water temperature trading and carbon sequestration markets are examples.

Typically, in an ecosystem service market, beneficiaries of an ecosystem service pay those who offer to provide the ecosystem service. In Costa Rica, flood protection services, drinking water supply and water quality were being lost as forests were cut down. San Jose, the capital, was experiencing floods, drinking water shortages, and silt laden water by the early 1990's because upland landowners had cleared 79% of original forest cover, primarily for cattle ranching, greatly decreasing the ability of forestland to provide ecosystem services (Tidwell, 2006). In 1996, Costa Rica adopted a new system using a gasoline tax and slightly increased water fees to pay upland landowners for increasing forest cover and recovering the hydrological ecosystem services, giving them incentive to keep trees on their land. Forest cover rose from 21% to 42% in 12 years, flooding was greatly reduced, and San Jose's water supply became clean and sufficient. By understanding the provisioning of flood control and drinking water on the landscape, identifying beneficiaries, and setting up a payment mechanism, flood protection and drinking water were restored and both upland and downstream residents were better off.

Table 2. Examples of Ecosystem Services

Examples of Ecosystem Services
Supply and filtration of drinking water
Purification of the air
Mitigation of floods and droughts
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun's harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures
Provision of aesthetic beauty and recreation

Source: Daily et al., 1997

The Value of Ecosystem Services Relative to Ecosystem Goods

While the value of a service flux may be more difficult to measure, its value may, in many cases, significantly exceed the value of the flow of goods. A study of Philippine mangroves showed that the services of storm protection and nursery functions (85% of commercial fish species are dependent on the mangroves for a period of time within their lifecycle) produced several times the value of shrimp aquaculture operations that replaced the mangrove ecosystems (Boumans et al., 2004).

Process, Function, Structure and Value Production

The quality, quantity, reliability and combination of goods and services provided by the ecosystems within a watershed depend highly on the structure and health of the ecosystems within the watershed. Structure refers to a specific arrangement of ecosystem components. The importance of ecosystem structure can be understood by using the car as a metaphor. The steel, glass, plastic and gasoline that comprise a car must retain a very particular structure to provide transportation service. Having a pile of the same constituent materials but absent a car's structure, this "car" cannot provide transportation service. Fish and animal species require certain processes, structures and conditions. Ecological service production is more dependent on structure than the flows of goods. A coffee plantation may yield a flow of goods (coffee beans) but it cannot provide the same service fluxes (biodiversity, recreation and flood protection) as an intact natural forest.

Integrated Ecosystems

A heart or lungs cannot function outside the body. Neither can the human body cannot function without a heart and lungs. Good health requires organs to work as part of a coordinated system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. Each of the physical and biological components of the watershed, if they existed separately, would not be capable of generating the same goods and services provided by the processes and functions of an intact watershed system (EPA, 2004). Ecosystem services are systems of enormous complexity. Individual services influence and interact with each other, often in nonlinear ways (Limburg et al., 2002).

Value Production "In Perpetuity"

Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity" and without cost to humans. A forest provides water control, flood protection, aesthetic and recreational values, slope stability, biodiversity, and other services, without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, dissipate, may depreciate, and usually end up discarded, requiring further energy inputs for disposal or recycling. Destruction of ecosystem functions disrupts an ongoing flux of valuable ecological services. Building houses and shopping centers in flood plains increases flooding. When an ecosystem's free natural flood prevention functions are destroyed, flood damage will exact continuing costs on individuals and communities who must either suffer flood damage or pay for engineered structures and storm water infrastructure to compensate for the loss. Without healthy ecosystems, taxpayers, businesses and governments incur damage or costs to repair or replace these ecosystem services. When ecological services are restored, the reverse dynamic can occur.

Part 3: The Value of Natural Capital

In 2001, an international coalition of scientists within NASA, the World Bank, the United Nations Environmental Program, the World Resources Institute and others initiated an assessment of the effects of ecosystem change on human wellbeing. The product of this collaboration was the Millennium Ecosystem Assessment, which classifies ecosystem services into four broad categories describing their ecological role (MEA, 2003). Ecological economists generally use these same categories.

- **Provisioning services** provide basic materials; mostly ecosystem service goods. Forests grow trees that can be used for lumber and paper, berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The waters of the Térraba-Sierpe provide fish and shellfish. Provisioning of these goods is a familiar service provided by nature, and is easiest to quantify in monetary terms (Farber et al., 2006).

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

- **Supporting services** include primary productivity, nutrient cycling 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 those that provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas. Humans use natural places for recreation, and for learning about the planet through science and education.

Within each category, there are many more specific ecosystems services. Table 3 is specific to mangrove ecosystems.

Table 3. Table of Ecosystem Services provided by Mangrove Ecosystems

Ecosystem Service	Provision by Mangrove Ecosystems
Gas Regulation	CO^2 storage. Growing mangroves create O^2 and absorb CO^2 and SO^2.
Climate Regulation	Global climate can sequester up to 1.5 tons of carbon/ha/year (Ong 1993). Regional climate: evapotranspiration and cloud formation affect both rainfall and transport of stored heat energy to other regions by wind. Microclimate: shade and insulation affect local humidity and temperature extremes.
Disturbance Regulation	Buffer adjacent terrestrial communities and ecosystems against storms and tsunamis. Slow the rate of water flow and allow silt to settle out, reducing the impact of flooding on adjacent marine ecosystems such as sea grass beds and coral reefs.
Supply of Raw Materials	Building materials (durable, water resistant timber and thatch); energy (charcoal and firewood); food resources (crabs, mangrove worms, fish, honey, sugar, fruits, alcohol, vinegar, animal fodder); traditional medicines; fur; aquarium industry products; tannins; dyes from bark; lime; etc.
Water Supply	Evapotranspiration can increase local rainfall, also involved in water catchment and groundwater recharge.
Waste Absorption Capacity	Capture and absorb large amounts of waste flowing from land, including nutrients and industrial waste, protecting marine habitats.
Erosion Control & Sediment Retention	Stabilize land against the erosive forces of the sea. Slow water flow allowing sediments and pollutants flowing from land to settle.
Nutrient Cycling	Capture and reuse nutrients that might otherwise pollute marine ecosystems. Remineralize organic and inorganic matter. Export organic matter to other ecosystems.
Pollination	Provide habitat and food for insects and bats, thus helping support the wild populations of these highly valuable pollinators.
Biological Control	Provide habitat and food for insect, bat and bird species that prey on pest species.
Biodiversity and Habitat	Provide vital habitat and create conditions essential to reproduction for a wide range of terrestrial and aquatic species. Support a vast variety of marine life in complicated food webs supported by the detritus they generate. Estimates of commercial seafood species that depend on mangroves for at least some stage of their life cycle range from 67% in eastern Australia (Untawale, 1986) to 80% in Florida (Hamilton and Snedaker, 1984), and nearly 100% of the shrimp catch in ASEAN countries (Singh et al., 1994; cited in Ronnback, 1999). Provide habitat for indigenous people.
Genetic Resources	Contain unique biological materials, many of which have medicinal uses.
Scientific and Educational	Benefit people through direct knowledge gained for subsistence, safety, and commercial purposes. The study of natural systems is also an important intellectual pursuit for helping people understand how complex systems work.
Recreation	Boating, birdwatching, fishing, etc.
Cultural	Aesthetic, artistic, educational, spiritual and scientific values.

Source: Farley et al., 2009

These are the primary categories of ecosystem services, and are discussed below. It should be kept in mind that these can be further broken down into sub-categories. For example, recreation contains boating, fishing, birding, hiking, swimming and other activities. Every year, ecosystem services are added to the more detailed categories.

The following sections provide an overview of provisioning, regulating, supporting and cultural ecosystem services. For this basic ESV report, three specific examples for Térraba-Sierpe are provided in special "Spotlight on Térraba-Sierpe" sections within orange boxes.

Provisioning Services

Water Supply

Watersheds provide fresh water for human consumption and agriculture; including surface water and ground water for large metropolitan areas, wells, industry and irrigation. The hydrological cycle is affected by structural elements of a watershed such as forests, wetlands and geology, as well as processes such as evapotranspiration and climate. Over 60% of the world's population gets their drinking water from forested watersheds (UNEP, 2005). Some Térraba-Sierpe residents are among these. Increasing loss of forest cover around the world has decreased water supply, due to lower ground water recharge and to lower flow reliability (Syvitski, 2005).

Raw Materials

Raw Materials include biological materials used for medicines, fuel, art and building, as well as geological materials used for construction or other purposes.

Regulating Services

Gas and Climate Regulation

Ecosystems help to regulate the gaseous portion of nutrient cycles that effect atmospheric composition, air quality and climate regulation. This process is facilitated by the capture and long-term storage of carbon as a part of the global carbon cycle. Forests and individual trees play an important role in regulating the amount of oxygen in the atmosphere and in filtering pollutants out of the air, including removal of tropospheric ozone, ammonia, sulfur dioxide, nitrogen oxide compounds (NOx), carbon monoxide and methane.

Carbon sequestration is a specific and important type of gas regulation. Forests, agricultural lands, wetlands and marine ecosystems all play a role in carbon sequestration. Undisturbed old growth forests have very large carbon stocks that have accumulated over thousands of years. Replacing old growth forests with new trees results in net carbon emissions caused by the loss of hundreds of years of carbon accumulation in soil carbon pools and large trees (Harmon, 1990).

Maintaining a climate within a stable range is increasingly a priority for local, federal and international jurisdictions. The role of forests and other ecosystems in controlling Greenhouse Gases (GHGs) – those that contribute to global warming – is essential to the continuation of life on earth. However, carbon sequestration is not the only value provided by gas and climate regulation.

Managed forests have the potential to sequester nearly as much carbon as old growth forests, but this requires longer rotations than current industrial standards and other changes (Harmon and Marks, 2002). Agricultural soils can also sequester more carbon when certain techniques are used, including crop rotations, livestock waste disposal, and conservation tillage, especially no-till (West and Post, 2002; Tweeten et al., 1998). Because these types of practices could provide significant global value - $8 to $59 per ton by some estimates – there is increased interest in including agricultural lands in carbon trading markets, with farmers receiving payments for their sequestration. The potential of this market and others related to agricultural lands will be discussed in the section on funding mechanisms.

Disturbance Regulation

Estuaries and bays, coastal wetlands, headlands, intertidal mudflats, seagrass beds, rock reefs and kelp forests provide storm protection. These areas are able to absorb and store large amounts of rainwater or water runoff during a storm, in addition to providing a buffer against coastal waves. Estuaries, bays, and wetlands are particularly important for absorbing floodwaters (Costanza et al., 2008; UNEP, 2005).

Today, changes in land use, combined with the potential for higher frequency storm events due to climate change, make this service one of the most important for the future of economic development in Térraba-Sierpe. In order to have productive agricultural and forested lands, protected built capital and high value, productive ecosystems, flood protection must be effective and efficient. Given that significant infrastructure can be damaged during large storm events, tourism and recreation could be harmed as well.

One of the most significant factors in an ecosystem's ability to prevent flooding is the absorption capacity of the land. This is determined by land cover type (forest vs. pavement), soil quality, and other hydrological and geological dynamics within the watershed.

The retention of forest cover and restoration of floodplains and wetlands provides a tangible and valuable ecosystem service. Most notably, it reduces the devastating effects of floods, which include property damage, lost work time, injury and loss of life.

Erosion Control

Natural erosion and landslides provide sand and gravel to streams, creating habitat for fish and other species but too much erosion can be harmful.

Natural erosion protection is provided by plant roots and tree cover. Soil erosion control is closely linked with disturbance prevention. While the absorption capacity of the land will largely determine floodwater levels, the retention of this water can play a significant role in preventing landslides and other damaging forms of erosion. Sedimentation from a large number of landslides can harm aquatic habitat.

On the other hand, human alteration of shoreline and stream corridors can prevent the type of natural erosion upon which many aquatic species depend. Forested and vegetated areas naturally provide stability and erosion control, while impermeable built surfaces or deforested areas cannot retain soil well. Human activities may not only affect an area's ability to retain soil, but can also increase the flow of water that may mobilize soil particles. Accidental surface-water discharges or increased storms related to climate change can both increase erosion risk.

> ***Erosion Control in the Térraba-Sierpe***
>
> Natural systems both create and enrich soil, and mangrove trees in particular hold soil in place; forest canopies diminish impact of torrential rainstorms on soils, and diminish wind erosion.
>
> Soil erosion is immediately noticeable along in the delta near the town of Sierpe where palm oil plantations have replaced natural systems.

Water Absorption Capacity

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.

Agricultural and urban development often results in lost forest cover or riparian vegetation. This shift in land cover is among the most important causes of a reduced fresh water flow to coastal wetlands and bays. When forested basins are heavily harvested, they become dominated by recently clear-cut or young stands, causing the remaining vegetation and litter layer on the forest floor to absorb less water. More water then flows over land into streams and rivers, contributing to higher peak flows, flood events, erosion and landslide issues (Moore and Wondzell, 2005). Heavy harvesting also reduces the ability of forests to slowly release water during dry summer months and moderate stream temperatures. These cumulative effects can damage built and natural capital.

Coastal freshwater wetlands form a salinity gradient with saltwater marshes and the ocean. These freshwater wetlands keep salt water from intruding on coastal freshwater supplies, both at the surface and in aquifers (UNEP, 2005). Alteration of hydrology by diverting water from estuaries is considered to be a major threat to coastal areas (Pringle, 2000). Hypersalinization can occur when too much fresh water is prevented from reaching estuaries, threatening fresh water supplies, habitat and other services.

As was discussed in the section on Water Supply, ecosystems are able to naturally both supply and then filter clean water for human use. 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 call replacement costs (see section on Valuation Methods).

A wide variety of stream-flow augmentation techniques have been adopted in the United States, Great Britain and elsewhere. In order to balance human desire to maximize water supply with other services such as water regulation and habitat, these types of management techniques must be carefully evaluated regarding their impact on water flows elsewhere in the watershed. Many of the processes behind stream-aquifer relationships and other hydrologic relationships within the watershed are still not fully understood, though they greatly impact our ability to protect ecosystem services other than freshwater provision.

Pollination

Pollination supports wild and cultivated plants, which are an important supply of food for people. Pollination also 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 are also crucial for crop productivity for many types of cultivated foods, enhancing the basic productivity and economic value of agriculture (Nabhan and Buchmann, 1997). Wild habitats near croplands are necessary in order to provide sufficient habitat to keep populations of pollinators, so vital to crop production, intact. The loss of forestlands and native shrubby riparian areas in suburbanizing rural areas has a negative impact on the ability of wild pollinators to perform this service.

Biological Control

Biological Control is the ability of ecosystems to limit the prevalence of crop and livestock pests and diseases. A wide variety of pest species destroy human agricultural crops, reducing worldwide harvest by an estimated 42%, thereby causing a loss of $244 billion each year (Pimentel et al., 1997). A number of natural predators for pest species contribute to natural control of damages. These predators also play a role in protecting forests from pests. Birds, for example, are a natural predator of some harmful insects. Unfortunately, many exotic pests, for which no natural predators exist, have been introduced to areas beyond their natural range. These new pests have caused annual damage ranging from $1.1 to $134 million in the United States alone (Chapin et al., 2000).

In recent years, humans have turned increasingly towards pesticides to control crop losses. While pesticides can reduce the risk of specific pest attacks, they can also harm natural predator populations and lead to resistance among pests, making pests even more difficult to control in the future. Overuse of pesticides is also known to reduce provisioning of some other ecosystem services, particularly water quality. While there may be a role for pesticide control in agricultural practice, there are also ways to manage crops so as to enhance biological control services. These techniques include crop diversification and genetic diversity, crop rotation, and promotion of an abundance of smaller patches of fields (Dordas, 2009; Risch et al., 1983).

Supporting Services

Nutrient Cycling

There are 22 elements essential to the growth and maintenance of living organisms. While some of these elements are needed only by a small number of organisms, or in small amounts in specific circumstances, all living things depend on the nutrient cycles of carbon, nitrogen, phosphorous and sulfur, in relatively large quantities. These are the cycles that human actions have most affected. Silicon and iron are also important elements in ocean nutrient cycles because they affect phytoplankton community composition and productivity. It is living things that facilitate the movement of nutrients between and within ecosystems and which turn them from biologically unavailable forms, such as rocks or the atmosphere, into forms that can be used by others. Without functioning nutrient cycles, life on the planet would cease to exist.

As plants and plant parts die, they contribute to the pool of organic matter that feeds the microbial, fungal and micro-invertebrate communities in soils. These communities facilitate the transformation of nutrients from one form to another. Larger animals play a crucial role in nutrient cycles by moving nutrients from one place to another in the form of excrement, and through the decomposition of their bodies after they die. Forests also play a significant role in global nutrient cycles; they hold large volumes of basic nutrients and keep them within the system, buffering global flows. Deforestation has played a large part in altering global carbon and nitrogen cycles (Vitousek et al., 1997).

The marine environment plays a central role in all major global nutrient cycles. Marine organisms fix nitrogen and take up carbon, phosphorous and sulfur from the water or from other organisms. Much of the mass of these macronutrients is deposited in sediments where it is either stored for the long term or taken back up to surface waters by upwelling. The ability of marine environments to cycle nutrients can be negatively affected by nutrient overloads, which result largely from human actions that cause water pollution such as fertilizer runoff.

The removal of forests, riparian areas and wetlands has had a significant effect on nutrient cycles. These ecosystems trap and retain nutrients that would otherwise run off into streams and rivers, and eventually end up in the ocean. A combination of increased use of fertilizers and the loss of the buffering capacity of these ecosystems has led to fresh water, estuarine and ocean systems suffering nutrient overloads which lead to large blooms of phytoplankton. Loss of commercially, recreationally and culturally important fish species has occurred as a result. The number of marine dead zones in the world has doubled every decade since the advent of nitrogen fertilizers after World War II (UNEP, 2005). The presence of these dead zones is a clear indication that global nutrient cycles have been severely altered by human actions.

Nutrient cycling is a supporting service because many other services depend on it. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered. Nutrient cycling is a fundamental precursor to ecosystem and economic productivity. This fundamental role cannot be fully substituted by human-made solutions, and operates at multiple, overlapping scales, so it is difficult to arrive at an accurate economic value for these services, and they are often undervalued (Farber et al., 2006). Given that nutrient cycling is fundamental to the operation of life on the planet, it is important that biological science inform policy that will protect this critical service.

Biodiversity and Habitat

Biological diversity is defined as the number and types of species and the ecosystems they comprise. It is measured at gene, population, species, ecosystem and regional levels (Magurran, 1988). For all ecosystems, biodiversity is both a precondition of the flow of ecosystem services and an ecosystem service in itself (UNEP, 2006). It is a precondition because ecosystems, with their full native complement of species, tend to be more productive and more resilient to change in environmental conditions or external shocks. Biodiversity is also an ecosystem service in itself because novel products have been derived from genetic and chemical properties of species, it provides a secure food base (multiple sources of food with different seasonal availability) and people ascribe value to it simply for its existence. Likely one of the more diverse areas in Térraba-Sierpe is home to a rich diversity of species and ecosystems.

Biodiversity and Habitat of Térraba-Sierpe

ACOSA is extremely rich in species diversity of plants, animals, fungi and microorganisms. According to INBio's database, there are at least 2659 vascular plant species in ACOSA, distributed over 203 families and 1029 genera (Kappelle, 2002).

The wetland reserve is an important habitat of many species of birds, fish (55 species), shellfish (10 commercially exploited species), mammals and reptiles. Resident and migratory bird species often found in Térraba Sierpe include Herons, Egrets, Cotingas and Pandion haliaetus. Common mammals include Agouti paca and Lutra annectens. Reptiles include Caiman crocodilus, Crocodvlus acutus and Tree Boas.

Habitat is the biophysical space and process in which wild species meet their needs – a healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators. Habitat may provide refugium and nursery functions; a refugium refers to general living space for organisms, while nursery habitat is specifically habitat where all the requirements for successful reproduction occur (De Groot et al., 2002). In addition to the physical structure provided to species, food web relationships are important components of habitats that support all species.

At a global scale, the loss of biodiversity in all ecosystems through habitat degradation and loss has been substantial in marine and coastal ecosystems, forests, grasslands and agricultural systems. This has large implications for maintenance of ecosystem services (UNEP, 2005; 2006).

Habitat contributes significantly to other ecosystem services, namely fisheries, recreation through wildlife watching, and cultural or spiritual values, which are often expressed though people's willingness to pay for protection of natural areas and through public or private expenditures on acquiring and protecting habitat.

Nutrient Cycling

Primary productivity is another supporting service upon which all other ecosystem services depend. It refers to the conversion of energy from sunlight into forms that living organisms use. Marine and land plants perform this function, using the sugars that are products of photosynthesis for their own respiration. Human life depends directly on primary productivity through consumption of crops, wild plants, seaweed, fish and seafood, and livestock.

In the past, we depended mainly on the direct energy flow from food consumption to conduct the work of survival. Then we used the help of draft animals and simple machines. At the onset of the industrial age, humans increasingly depended on fossil fuels, which is ancient stored energy from photosynthesis. Since humans started to perform work with the use of fossil fuels, the number of people and amount of consumption has far exceeded what would have been possible just by operating on current energy flows. Humans appropriate over 40% of the planet's terrestrial primary productivity. This share is increasing – with massive ecological implications for the rest of planet's organisms and energy budget (Vitousek, 1986). One likely consequence is a loss of biological diversity, which, as discussed above, would have severe consequences on the delivery of many other ecosystem services.

About 8% of total primary productivity of ocean ecosystems supports human fisheries. However, when the calculation is confined to parts of the ocean where most primary productivity and fish catches occur, the number approaches the productivity of terrestrial systems, 25-30% (Pauly and Christensen, 1995; Pimm, 2001). Again, if humans consume most ocean primary productivity in the form of fish and seafood, not much will be left to fuel the remainder of the food web and all the ecological processes that it drives (Pimm, 2001).

Terrestrial primary productivity comes mainly from forests, but ecosystem types such as grasslands and meadows also contribute, although at a much lower rate. Loss of forests to development decreases primary productivity.

Marine primary productivity comes from wetland plants, macroalgae, and sea grasses in the coastal and near shore environment, and from phytoplankton in the continental shelf and deep-sea waters. Most marine primary productivity occurs in the coastal zone out to the farthest extent of the continental shelf. Due to changes in currents, upwelling, and changes in water chemistry, which may affect the ability of diatomaceous phytoplankton to form calcereous shells, climate change has large implications for ocean productivity (Orr et al., 2005).

Cultural Services

Aesthetic

Aesthetic value, as an ecosystem service, refers to the appreciation of and attraction to beautiful natural land and seascapes (De Groot et al., 2002). The existence of National Seashores, State and National Parks, Scenic Areas, and officially designated scenic roads and pullouts attest to the social importance of this service. There is also substantial evidence demonstrating the economic value of environmental aesthetics through analysis of data on housing markets, wages and relocation decisions (Palmquist, 2002). There is also evidence substantiating the view that degraded landscapes are associated with economic decline and stagnation (Power, 1996).

Recreation Value in the Térraba-Sierpe

There are no public facilities in the park, but guided tours can be arranged in the town of Sierpe. Tours include bird watching, boat tours of the mangroves, fishing and kayaking. Also in the region is the Diquis Valley, known for archaeological finds including the mysterious stone spheres from Pre-Columbian times.

Bird and Wildlife Watching: Bird watching in the Térraba-Sierpe Wetlands is a year-round activity. Herons (boat-billed, green-backed, tiger-throated, great blue and little blue), egrets, pelicans, osprey, roseate spoonbills, black-necked stilts and mangrove black hawks are just a few commonly spotted species.

Hiking: Hiking excursions to an 800-foot waterfall can be arranged in Sierpe. Tourists can arrange guided tours through local outfits to see poison dart frogs, monkeys, crocodiles and a multitude of birds.

Mangrove Tours: Motorized boat outings run up and down the Térraba and Sierpe Rivers in search of wildlife. Guided kayak excursions are also an option.

Recreation and Tourism

Ecosystem features like biological diversity and clean water attract people to engage in recreational activities, and can also increase property values or attractiveness for business. Tourism and recreation are related to, but not totally encompassed by, aesthetic values. People travel to beautiful places for vacation, but they also engage in specific activities associated with the ecosystems in those places. Recreational fishing, scuba diving, surfing, kayaking, whale and bird watching, hunting, enjoying local seafood, and beachcombing are all activities that would not occur or be thoroughly enjoyed without intact shorelines, healthy fish and wildlife populations, clean water, and without the aesthetic quality of the area. Storm protection, shoreline stabilization 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.

Tourism and recreation, significant parts of nearly all coastal economies throughout the world, are both a blessing and a curse. Development designed to attract tourists has been a major source of degradation in coastal environments causing water quality decline and habitat degradation (UNEP, 2006). Too much recreational fishing pressure and too many whale-watching boats can also put excessive pressure on the species that attract people in the first place. The concept of ecotourism has arisen in part to deal with these issues. It is, however, an incomplete solution to date (UNEP, 2005; 2006).

While teasing out the direct monetary contribution of the ecosystems themselves to the recreation and tourism economy, there is no doubt that attractive landscapes, clean water, and healthy fish and wildlife populations provide a necessary underpinning to this sector of the economy. Several studies of nature-related recreation are included in the ecosystem service value analysis described below.

Scientific and Educational

Ecosystems are the subject of much scientific study for both basic knowledge and for understanding the contribution of functioning ecosystems to human wellbeing.

The number of educational and research institutions devoted to studying marine and terrestrial environments shows the scientific and educational importance of ecosystems. Government, academic and private resources are devoted to formal study of ecosystems in the HNTS. Such pursuits benefit people through direct knowledge gained for subsistence, safety and commercial purposes. The study of natural systems is also an important intellectual pursuit for helping people understand how complex systems work. Scientific and educational institutions devoted to both marine and terrestrial environments also provide locally significant employment.

Cultural

Ecosystems and their components play a role in the spiritual beliefs of people. These values do not lend themselves well to economic quantification. Other aspects of the linkage between ecosystem and culture include the spiritual significance that individuals and societies place on nature, and the scientific and educational value derived from studying natural systems.

Individuals of non-native origin also express the spiritual value of nature through various means. One important aspect of attempting to ascribe economic value to spiritual significance should be noted here. The use of willingness to pay surveys (see below for definitions) for things like saving sea turtles reveals that many people are unwilling to trade money or tangible goods for the loss of species or places; they rank the protection of nature above many aspects of material well-being. Some respondents to such survey instruments give “protest bids” which indicates that they are not willing to put a price on saving wildlife or wild places (see Spash, 2005 for a review).

Part 4: Results of Ecosystem Service Valuation Analysis of Térraba-Sierpe

The methodology for valuing ecosystem services involves the identification and categorization of ecological services, Geographic Information System (GIS) data, and peer-reviewed studies of market and non-market values using direct use and indirect use valuation methods. Analysis for this study began with GIS data on land-use and vegetation landcover compiled for the study site. Economic valuation data from peer reviewed academic journal articles were aggregated using a value transfer methodology to estimate a high and low dollar value range for a list of 17 ecosystem services (water purification, flood control, climate regulation, etc.). Economic modeling was used to integrate data on the health, age and species diversity of the ecosystems on the study site. Initial analysis resulted in a rough-cut total valuation of ecosystem goods and services provided annually by each area. The next sections discuss the analysis process in more detail.

Valuation of Térraba-Sierpe by Land Cover Class

The total estimated value generated on the 150,000 hectares of Térraba-Sierpe in ecosystem services is estimated to be in the range of $302 million to $1.9 billion, annually. All values in this report are in US currency and have been adjusted for inflation to 2009 dollars. The following sections and tables discuss this in more detail.

These estimates are based on the range of values for these land covers as found by studies conducted outside Térraba-Sierpe. As cursory estimates based on the benefit transfer methodology, they provide a range of values. A specific study or set of studies can be conducted to narrow the range in values.

Total Acreage of Térraba-Sierpe by Landcover Class

Table 4 shows the acreages of GIS classification types that characterize Térraba-Sierpe and were used as geo-spatial estimates for calculating ecosystem service valuation.

Table 4. Acreage of Térraba-Sierpe by Landcover Class (2005)

GIS Classification	Hectares
Lakes and Ponds	182
Tropical Forest	45,420
First Succession (Native Palm Tree Oil)	5,811
Annual Crops	14165
Permanent Crops (Plantations)	6,060
Wetland	6,751
Mangrove	13,328
Pasture	18,164
Urban	621
Marine	31,111
Islets	204
Beach	863
Exposed Land	317
No Data	14,313
Aquaculture	371
Total Acreage	**157,681**

Valuation of Térraba-Sierpe by Landcover Class

Tables 5a-5e show the estimates of ecological services produced by each GIS vegetation type within Térraba-Sierpe. These estimates are all presented in 2009 US dollars. The land area may vary slightly from actual area depending on the extent to which source GIS data is accurate and current. Mangrove forests in Térraba-Sierpe provide more value than any other landcover type. There are eight different types of mangroves in the region including Red and White Mangroves (*Rhizophora mangle* and *Laguncularia racemosa* respectively) (Sierra et al., 2007). Food production, flood protection, waste treatment and tourism provide the largest contributions of benefits to people in the region.

Table 5a. Valuation of Térraba-Sierpe Mangroves and Tropical Forests

	Mangrove		Tropical Forest	
	Low	High	Low	High
Food Production	$2.49	$4,939.23	$8.91	$117.19
Recreation & Aesthetic	$37.44	$3,233.13	$0.42	$980.29
Habitat & Refugium	$313.31	$332.12		
Raw Materials	$22.41	$1,973.13	$64.01	$1,502.10
Disturbance Regulation	$2.39	$12,675.09	$5.32	$5.32
Waste Treatment	$10,776.39	$10,776.39	$92.58	$92.58
Biological Control				
Gas & Climate Regulation			$32.81	$58.58
Refugium & Nursery				
Refugium & Wildlife Conservation				
Water Supply			$11.26	$11.26
Water Regulation			$0.15	$25.04
Pollination				
Soil-Formation			$10.64	$10.64
Erosion Control			$7.26	$1,020.39
Nutrient Cycling			$1,433.01	$1,433.01
Genetic Resources			$2.25	$254.14
Total	**$11,154.43**	**$33,929.08**	**$1,668.60**	**$5,510.54**

Table 5b. Valuation of Térraba-Sierpe Wetlands and Lakes & Ponds

	Wetland		Lakes and Ponds	
	Low	High	Low	High
Food Production				
Recreation & Aesthetic	$13.55	$6,057.99	$1.80	$20,962.49
Habitat & Refugium				
Raw Materials				
Disturbance Regulation				
Waste Treatment	$1,262.43	$4,224.21		
Biological Control				
Gas & Climate Regulation	$12.09	$12.09		
Refugium & Nursery	$2.55	$8,125.20		
Refugium & Wildlife Conservation			$62.67	$1,574.76
Water Supply	$0.19	$20,352.99	$18.23	$887.96
Water Regulation	$440.64	$3,754.75		
Pollination				

Soil-Formation				
Erosion Control				
Nutrient Cycling				
Genetic Resources				
Total	**$1,731.45**	**$42,527.22**	**$82.69**	**$23,425.21**

Table 5c. Valuation of Térraba-Sierpe Cropland and Plantations

	Cropland		Plantation	
	Low	High	Low	High
Food Production				
Recreation & Aesthetic	$11.10	$23.24		
Habitat & Refugium				
Raw Materials				
Disturbance Regulation				
Waste Treatment				
Biological Control				
Gas & Climate Regulation			$8.19	$14.64
Refugium & Nursery				
Refugium & Wildlife Conservation				
Water Supply				
Water Regulation				
Pollination	$0.97	$5.21		
Soil-Formation				
Erosion Control				
Nutrient Cycling				
Genetic Resources				
Total	**$12.07**	**$28.45**	**$8.19**	**$14.64**

Table 5d. Valuation of Térraba-Sierpe's Pastures and Urban Areas

	Pastures		Urban	
	Low	High	Low	High
Food Production	$15.04	$15.04		
Recreation & Aesthetic	$0.01	$11.10	$508.95	$1,587.96
Habitat & Refugium				
Raw Materials				
Disturbance Regulation				
Waste Treatment				
Biological Control	$5.84	$5.84		
Gas & Climate Regulation			$10.82	$569.76
Refugium & Nursery				
Refugium & Wildlife Conservation				
Water Supply				
Water Regulation			$2.42	$73.59
Pollination	$0.97	$4.88		
Soil-Formation	$0.24	$2.68		
Erosion Control				
Nutrient Cycling				
Genetic Resources				
Total	**$22.10**	**$39.54**	**$522.20**	**$2,231.31**

Table 5e. Valuation of Térraba-Sierpe's Beach and First Succession

	Beach		First Succession	
	Low	High	Low	High
Food Production				
Recreation & Aesthetic	$368.41	$119,607.47		
Habitat & Refugium				
Raw Materials				
Disturbance Regulation	$58,365.09	$94,607.88		
Waste Treatment				
Biological Control				
Gas & Climate Regulation			$6.60	$66.30
Refugium & Nursery				
Refugium & Wildlife Conservation				
Water Supply				
Water Regulation				
Pollination				
Soil-Formation				
Erosion Control				
Nutrient Cycling				
Genetic Resources				
Total	**$58,733.49**	**$214,215.35**	**$6.60**	**$66.30**

Table 6. Annual Ecosystem Service Valuation for Térraba-Sierpe

Ecosystem Category	Low Value	High Value
Lakes and Ponds	$15,027	$4,256,839
Tropical Forests	$75,785,201	$250,279,704
First Succession	$38,337	$385,229
Annual Crops	$170,919	$402,959
Permanent Crops (Plantations)	$49,654	$88,733
Wetland	$11,688,694	$287,094,728
Mangrove	$148,656,176	$452,176,084
Pastures	$401,456	$718,252
Urban	$324,524	$1,386,668
Beach	$50,705,404	$184,934,953
Ocean	n/a	n/a
Exposed Land	$0	$0
No Data	$0	$0
Total Value	**$302,334,177**	**$1,929,804,914**

Per hectare values were summed up for each land cover type across ecosystem services. Table 6 shows the acreage of each vegetation type within the watershed, the total $/hectare for that vegetation type across the ecosystem services where values exist.

Present Value of Térraba-Sierpe Over Time

The present values of Térraba-Sierpe ecosystem services are presented below in Table 7. Under any calculation of PV, the ecosystem services provided by Térraba-Sierpe are enormous and highly significant, ranging from a low of $9.6 billion for the lower value estimate at a 3% discount rate to $60 192 billion for the higher value estimate at a 0% discount rate.

Table 7. Present Value over 100 years with Various Discount Rates

Discount Rate	Low Estimate	High Estimate
0 %	$30 billion	$192 billion
3%	$9.6 billion	$61 billion

For a non-discounted, generation-neutral estimation of ecosystem services in Térraba-Sierpe over time, Earth Economics calculated present values at a zero discount rate.

Preservation of Present Values

Sustainable management of Térraba-Sierpe would preserve critical ecosystem processes and ecological services while preventing future land conversion and the loss of these valuable processes and services.

While sustainable management of HNTS redounds to the long-term interest of the public and communities of Térraba-Sierpe may well prevent the necessity for further restoration, this shift in land ownership/management does not confer any increased "net" value on the ecosystem services provided without a projected land use change for HNTS. Self-interested actions of private land owners could result in vegetation destruction or ecological process changes that would degrade the ecological services provided. This would likely result in a substantial loss of benefits and potentially substantial costs incurred by the public. In comparison to a project that involves restoration or enhancement of ecosystems, this study calculates a present value specifically for the preservation of the annual range of values that exist in present condition.

Part 5: Conclusion

The annual value provided by Térraba-Sierpe ecosystem services is between $302,334,177 and $1,929,804,914 using data collected by PRIAS-CENAT on vegetation types over these 150,000 hectares. Calculation of the present value does not capture a full picture of the benefits for people in the future, and so calculations of values generated by the watershed and by the project were also calculated with a zero discount rate.

Estimated ecosystem service benefits provided by Térraba-Sierpe total between $30 billion and $193 billion over 100 years at a zero discount rate. This represents the summation of the flow of annual benefits to recipients across a century, treating all recipients equally and assuming there is no appreciation in value or inflation. A 3% discount rate, more commonly used for renewable, self-sustaining ecosystem services, provides a range of $9.6 billion – $61 billion. These numbers are likely underestimates for both the low and high ends of the ranges.

Both the high and low estimates of ecosystem services are likely underestimates of their true value. Some identified services could not be valued. Other services that were valued are likely higher in Térraba-Sierpe than in studied watersheds. For example, water purification and non-market valuations only captured partial values. Also, the values of ecosystem services are rising rapidly due to increasing scarcity. In the case of recreation, the upper watershed is overvalued and lower watershed likely undervalued, with an ambiguous net result. The large ranges of value reflect the fact that benefit transfer methodology allows for uncertainty and variability. The ranges for these estimates will close with ongoing research.

A clear understanding of the relationships between watershed ecosystem health and the provision and economic value of these goods and services is critical information for asset management decisions. A scenario where further degradation of Costa Rica's watersheds is allowed might result in catastrophic long-term economic cost, species loss and negative impacts to quality of life for local residents. In a scenario where the full suite of benefits provided by healthy watershed ecosystems and floodplain processes are examined and accounted for in asset management, long-term economic gains may be understood and maximized, currently threatened species populations might recover and local residents and communities can develop and thrive in an environment that supports the local and global community and is mutually sustaining.

Most of the value provided by restoring healthy ecological processes in Térraba-Sierpe will be garnered by future generations. The annual values calculated for Térraba-Sierpe correspond to thin slices of the benefits that future generations will gain if Térraba-Sierpe is maintained in an ecologically healthy condition. Unlike human-built capital, like cars and buildings, ecological capital appreciates and can be self-maintaining.

Initial Recommendations

1. **In planning, land managers should consider a more detailed analysis of the ecosystem goods and services that Térraba-Sierpe provides, as well as the distribution of these services to beneficiaries.** The natural assets of Térraba-Sierpe are large and highly valuable.

2. **Térraba-Sierpe supplies sufficient ecosystem service benefits to justify several million dollars of investment.** Because most of the benefits are held in the future, the estimate of value depends on how future value is weighted; including what discount rate is used.

3. **The public should continue to be involved and informed of Térraba-Sierpe ecosystem services and their value**. Stakeholders should partner with other organizations and agencies to increase the understanding of ACOSA and SINAC ecosystem goods and services and their value to the local and global communities.

Longer Term Recommendations

This study is an initial first step in understanding the true value of the Térraba-Sierpe. With further investments in mapping, detailed scenario analysis, accounting improvements and policy research, further innovations can be made to ensure HNTS, other SINAC assets and the surrounding regions are managed well for generations to come.

1. **Develop further modeling and mapping capacity.** General, basin-wide investigation including hydrological studies should be coupled with further development of ecosystem service and scenario tools. Leading edge tools are available for identifying, mapping, and valuing carbon sequestration, biodiversity, flood protection, etc. Maps of ecosystem services can include:
    - **Provisioning maps** to show where ecosystem services and goods are produced;
    - **Beneficiary maps** to show who is benefiting from existing ecosystem services;
    - **Flood source maps** to show how flooding is created, and where provisioning of flood protection and other ecosystem services are being impaired, such as a bridge that might restrict the floodway causing increased flooding upstream, or a steep and unstable slope that could slide to block river flows;
    - **Critical path maps** to show how the ecosystem services are transferred to beneficiaries and identify critical areas for service provisioning.
2. **Develop scenario analysis.** Create scenario analysis with modeling to help judge project and investment proposals against established criteria.
3. **Develop project prioritization and reporting methodology.** Investigate robust reporting options to keep stakeholders and the community informed of project and investment status, location and performance.

4. **Develop funding mechanisms.** Examine improved cross-disciplinary funding mechanisms for storm protection and other ecosystem services to ensure the sustainability of ecosystem project investments and outcomes.
5. **Develop innovative funding sources.** Create complementary funding sources. Conservation in Costa Rica has generally been funded by government through local taxes and fees. There are other funding mechanisms, such as a watershed investment district or carbon trading regime, which could provide complementary funding mechanisms to supplement these traditional approaches. ECOTICOS should consider design options of an "environmental utility" or "watershed utility". Such a utility can better fund MINAE in managing SINAC natural assets and the goods and services they provide to the public.
6. **Seek cross-jurisdictional partnerships.** Develop funding mechanisms with a wide consideration of a combination of complementary international, federal, provincial and local funding mechanisms.
7. **Improve Comprehensive Planning.** Continue to advance land use planning, such as building standards, and examine ecosystem services within the watershed, in light of economic development planning.

This analysis supports a triple bottom line approach. The range of 17 identified categories of ecological goods and services provided by Térraba-Sierpe should be more closely examined. This can be done in a collaborative arrangement with other agencies and organizations to conduct a set of ecosystem service studies. For example, if each protected area jurisdiction conducted one ecosystem service study with a full research agenda in their jurisdiction, the compilation of these studies would contribute greatly to better defining and narrowing the range of value produced by Costa Rica's ecosystems. This approach would reduce the cost of the studies and all jurisdictions would benefit.

Overall ECOTICOS has initiated a path-breaking step of valuing the full range of ecosystem services provided on Térraba-Sierpe. ECOTICOS should continue with the inclusion of ecosystem services in the project analysis, and proceed with informing the public of the full range and value of benefits that ecosystems provide.

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Appendix A: List of Value-Transfer Studies Used

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Appendix B: Table of Value Transfer Studies

Land Cover	Ecosystem Service	Author(s)	Low ($/hectare)	High ($/hectare)	Single Value ($/hectare)	Lowest	Highest
Mangrove							
	Food Production					$2.49	$4,939.05
		Foster, J.H.	$2.49	$4,939.05			
		Lahman	$16.90	$2,938.58			
	Total Ecosystem					$2,469.86	$75,619.88
		Hickman, C.	$2,590.93	$75,619.88			
		Lugo & Brinson	$2,469.86	$16,096.90			
	Recreation					$37.44	$3,233.02
		Bell, F.W.	$37.44	$3,233.02			
		Hamilton, L.S. & Snedaker, S.C.	$619.95	$1,976.97			
	Habitat/Refuge					$313.30	$332.11
		Christensen, L.	$332.11	$332.11			
		De Groot, R.S.	$313.30	$314.86			
	Raw Materials					$22.41	$1,973.06
		Costanza et al.	$78.95	$264.29			
		Dugan, P.J.	$22.41	$1,973.06			
	Disturbance Regulation					$2.39	$12,674.64
		Christensen, L.	$3,960.39	$3,960.39			
		Dugan, P.J.	$2.39	$12,674.64			
	Waste Treatment					$10,776.01	$10,776.01
		De Groot, R.S.	$10,776.01	$10,776.01			

Tropical Forests						
	Erosion Control				$7.26	$1,020.36
		Chopra	$7.26	$1,020.36		
	Nutrient Cycling				$1,432.96	$1,432.96
		Chopra	$1,432.96	$1,432.96		
	Genetic Resources				$2.25	$254.13
		Farnworth et al.	$2.25	$254.13		
	Food Production				$8.91	$117.19
		Godoy et al.	$8.91	$117.19		
	Water Regualtion				$0.15	$25.04
		Kramer et al.	$0.15	$25.04		
	Water Supply				$11.26	$11.26
		Kumari	$11.26	$11.26		
	Recreation				$0.41	$980.25
		Lampietti & Dixon	$0.41	$980.25		
	Raw Materials				$64.01	$1,502.04
		Lampietti & Dixon	$64.01	$1,502.04		
	Soil Formation				$10.64	$10.64
		Pimentel et al.	$10.64	$10.64		
	Waste Treatment				$92.58	$92.58
		Pimentel et al.	$92.58	$92.58		
	Disturbance Regulation				$5.32	$5.32
		Ruitenbeck	$5.32	$5.32		
	Climate Regulation				$81.00	$144.64
		Adger et al.	$81.00	$144.64		
Beach						
	Disturbance Regulation				$58,363.04	$94,604.55

		Parson, G.R.			$58,363.04		
		Pompe, J.J.			$94,604.55		
	Recreation					$368.39	$119,603.27
		Taylor, L.O. and V.K. Smith			$368.39		
		Kline, J.D. and S.K. Swallow			$119,603.27		
Wetland							
	Water Regulation					$440.63	$3,754.62
		Thibodeau, F.R. & Ostro, B.D.			$3,010.93		
		Ernst, C., Gullick, R., & Nixon, K.			$440.63		
		Thibodeau, F.R. & Ostro, B.D.			$2,737.80		
		Wilson, S.J.			$3,754.62		
	Water Supply					$.19	$20,352.28
		Lant, C.L. & Tobin, G.			$78.47		
		Hayes, K. M., Tyrrell, T.J. & Anderson, G.	$838.75	$1,303.78			
		Allen, J. et al.	$6,796.93	$20,352.28			
		Creel, M. & Loomis, J.			$233.68		
		Lant, C.L. & Tobin, G.			$85.74		
		Lant, C.L. & Tobin, G.			$944.22		
		Lant, C.L. & Roberts, R.S.	$.19	$.24			
		Pate, J. & Loomis, J.			$1,549.52		
	Aesthetic and Recreational					$13.55	$6,057.77
		Allen, J. et al.	$66.98	$6,057.77			
		Doss, C.R. & Taff, S.J.			$1,992.39		
		Doss, C.R. & Taff, S.J.			$1,803.42		

		Hayes, K. M., Tyrrell, T.J. & Anderson, G.	$789.91	$1,509.75			
		Mahan, B.L., Polasky, S. & Adams, R.M.			$14.96		
		Thibodeau, F.R. & Ostro, B.D.			$282.63		
		Thibodeau, F.R. & Ostro, B.D.	$13.55	$43.36			
		Whitehead, J.C.	$449.86	$904.48			
		Wilson, S.J.			$311.41		
	Refugium & Nursery					$2.55	$8,124.92
		Allen, J. et al.	$3,335.73	$8,124.92			
		Vankooten, G.C. & Schmitz, A.			$2.55		
		IJC Study Board			$5,419.51		
	Climate Regulation					$12.08	$12.08
		Wilson, S.J.			$12.08		
	Waste Treatment					$1,262.38	$4,224.06
		Wilson, S.J.	$1,262.38	$3,537	0		
		Wilson, S.J.	$1,385.09	$4,224	0		
Pastures							
	Aesthetic & Recreational					$0.01	$11.10
		Boxall, P.C.			$.01		
		New Jersey Type A		$11.10	$11.10		
	Soil-Formation					$.25	$2.68
		Pimentel, D.			$2.51		
		Pimentel, D.		$2.68			
		Costanza et al.	$.25	$.25			
	Biological Control					$5.84	$5.84
		Costanza et al.	$5.84	$5.84			
	Food Production					$15.03	$15.03

		Costanza et al.	$15.03	$15.03			
	Pollination					$.97	$4.88
		New Jersey Type A		$.97	$4.88		
Urban							
	Gas & Climate Regulation					$2.42	$569.74
		McPherson, E.G.			$352.98		
		McPherson, E.G.			$70.76		
		McPherson, E.G.		$569.74			
		McPherson, E.G.		$114.22			
		McPherson, E.G., Scott, K.I. & Simpson, J.R.			$10.82		
		McPherson, E.G., Scott, K.I. & Simpson, J.R.		$15.03			
		American Forests		$87.61			
	Water Regualtion					$2.42	$73.59
		McPherson, E.G.			$2.42		
		McPherson, E.G.		$3.72			
		American Forests		$73.59			
	Aesthetic & Recreational					$508.94	$1,587.90
		Tyrvainen,L.			$1,491.91		
		Tyrvainen,L.			$751.63		
		Tyrvainen,L.			$508.94		
		Tyrvainen,L.		$1,587.90			
		Tyrvainen,L.		$543.15			

		Tyrvainen,L.		$802.16			
Cropland							
	Aesthetic & Recreational					$11.10	$23.24
		Bergstrom, J., Dillman, B.L. & Stoll, J.R.			$11.10		
		Bergstrom, J., Dillman, B.L. & Stoll, J.R.		$23.24			
	Pollination					$.97	$5.21
		Robinson, W.S., Nowogrodzki, R., & Morse, R.A.			$4.88		
		Robinson, W.S., Nowogrodzki, R., & Morse, R.A.		$5.21			
		Southwick, E.E. & Southwick, L.	$.97	$3.46			

Appendix C: Study Limitations

This study provides a best-possible first estimate of the economic value of the ecological goods and services generated within Térraba-Sierpe. The study, based primarily on value transfer and not on original research of each ecosystem service within Térraba-Sierpe, should be regarded as the best first estimate. It also has the potential for improved accuracy from further research.

While a number of study limitations should be kept in mind when considering the results, these limitations do not detract from the fact that ecosystem services provide high value. Térraba-Sierpe's management plan is better informed with fact-based estimates rather than an implicit assumption of zero value for the following reasons:

1. ***Limited ecosystem service studies.*** Not all ecosystems have been well studied or valued. This results in a serious underestimate of the value of ecosystem services. Also, the approach does not fully include the "existence" value of ecosystems.
2. ***Uncertainty and service identification.*** Some ecological services may not yet be identified. The dollar estimates of the value produced by natural systems are inherently underestimates. For example, while we may be able to place a dollar value on the water filtration services provided by a forest, we cannot fully capture the aesthetic pleasure that people gain from looking at the forest, nor every aspect of the forest's role in supporting the intricate web of life. Thus, most ecological service valuations serve as base markers somewhere below the minimum value of the true social, ecological and economic value of an ecological service.
3. ***Lack of appropriate valuation studies.*** Medicinal, historic and spiritual values were identified but eliminated from the study because existing studies were inappropriate for this area. However, assuming that Térraba-Sierpe produces no value in these categories is incorrect and reduces its true value. Historical values are site specific and resources were insufficient for a specific study of Térraba-Sierpe. Also, there is no accepted method for monetizing spiritual value.
4. ***Static analysis.*** The values of goods and services, natural capital or otherwise, are dynamic. The current analysis provides a "snapshot" of value in Térraba-Sierpe and for the project site. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al., 2002). This could give rise to a general tendency for value transfer based on studies performed over the past ten years to underestimate the value of ecological services produced by ecosystems today. Dynamic models are being developed but are outside the scope of this study.
5. ***GIS information.*** The GIS vegetation cover data used is fairly coarse. For instance, it does not differentiate the quality of different wetlands. An assumption was made that ecosystems identified in the GIS analysis are fully functioning. As fewer and fewer ecosystems are fully intact due to human impact, this may result in an over-estimate of current value. This method assumes spatial homogeneity of services within ecosystems. Every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease value depends on the spatial patterns and services involved. Solving this difficulty requires spatial

dynamic analysis which is outside the scope of a basic ESV study.

6. ***Process.*** Since this methodology is based on ecosystem services provided per hectare of vegetation type, it does not pick up the full value of process changes. The valuation assumes smooth responses to changes. If ecosystems approach thresholds of collapse higher values for affected services would be produced.
7. ***Irreversibility.*** If a threshold is passed, valuation is out of the "normal" sphere of marginal change
8. ***Endangered species status.*** This report does not incorporate adequate analysis appropriate for consideration of endangered species as an element of critical natural capital. In particular, it overlooks any non-incremental impacts such as the potential for land management to contribute to a radical decline or even extinction in populations of endangered species.
9. ***Bias.*** Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.
10. ***Sustainability.*** The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values.

If these problems and limitations were addressed, the result would most likely be significantly higher values. At this point, however, it is impossible to know how much higher the low and high values would be.

Appendix D: Summary of October 2009 Sierpe Workshop

As part of our project work in Costa Rica, the ECOTICOS team held a 3-day workshop in which residents of the Sierpe region were asked to describe the ecosystems of their surroundings and the services provided by these ecosystems. They were also asked to name the beneficiaries of the land's services and to identify the threats to the ecosystems' existences.

Identified Goods and Services

A total of 17 ecosystem services that directly benefit the quality of life for the Sierpe community were identified. Examples include food production, medicinal resources, fish habitat and reproduction, wildlife habitat, culturally significant sites, recreation areas, aesthetic value, educational resources, raw material, and climate regulation. People identified local villages and the tourism industry as the primary beneficiaries of these ecosystem services. Many services that benefit the community most aided the agricultural industry such as the many regional rice and banana plantations. These services include soil retention and formation, water regulation, genetic diversity, waste treatment, pollination and biological population control. Many of these services, for example water and gas regulation, local climate regulation, and recreation, are provided by different ecosystems. Some of the ecosystems to which services were most commonly attributed were mangrove forests, tropical forests, lakes and riparian areas.

Identified Threats

The participants at the workshop also pointed to a myriad of threats to these important ecosystem services. Some threats, such as deforestation, sedimentation, cattle grazing, habitat destruction and even excessive shrimp farming were cited as having wide-reaching impacts. These problems were included as threatening almost all of the ecosystem services that were mentioned. Other threats, especially those against cultural heritage, were more unique. For example, the influence of foreign culture as well as increasing amounts of archeological work were both pointed to as threats to cultural and spiritual information contained in locals' surroundings.

Identified Beneficiaries

Another group of services that Sierpe community members identified is those that benefit the global population. Services like nutrient and gas regulation, cultural and artistic value, historical sites, genetic diversity, recreation, education and research opportunities, and ornamental objects were categorized as benefiting all of humanity. These assets are also described as being threatened, often by sources similar to those previously mentioned. Some other commonly portrayed dangers include loss of biodiversity, introduction of toxins and waste products, infrastructural development, invasive species, and the effects of ozone depletion.

Some of the ecosystem services that were mentioned by local people could be categorized as most benefiting the ecosystem itself. For example, pollination was described as a necessary process for improving the health of forests and other ecosystems, although this service does not directly benefit the community. Other such services included wildlife habitat, water regulation, climate regulation, waste treatment and disturbance prevention. While climate regulation was cited as benefiting humanity, it was also categorized as beneficial for the health of the land. In this way, descriptions of ecosystem services seem to have a positive feedback effect on the heartiness of mangrove forests, forests and other types of land. As with the previous two categories, these goods and services are being pressured by deforestation, sedimentation and many other processes.

Conclusions

The evidence presented by the local residents of the Sierpe region, who undoubtedly have an intricate understanding of the land from which they originate, suggests that the ecosystem goods and services provided by their land are vast and complex. Furthermore, many services have come under threat by human-caused influences. The people of the Sierpe communities, their accounts and immense local knowledge, are invaluable and should be included in any analysis of the ecosystem services in the region.

Workshop participants identified that further workshops on the Sierpe in additional locations would benefit local residents, government agencies and non-governmental organizations (NGOs) residing and working in the area.

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