Nature's Value in **Qinghai Province**

The Essential Economics of Ecosystem Services

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The Essential Economics of Ecosystem Services
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CI	Conservation International
ESV	Ecosystem Service Valuation
FDI	Foreign Direct Investment
GIS	Geographic Information System
Ha	Hectares
NFPP	Natural Forest Protection Program
NPV	Net Present Value
PES	Payments for Ecosystem Services
rESV	Earth Economics Rapid Ecosystem Service Valuation
RMB	Renminbei (principle currency for the People's Republic of China)
SLCP	Sloping Land Conversion Program

Executive Summary

China is developing rapidly. Understanding the economic value of natural systems in areas like the Qinghai Province is essential to promote development and a high quality of life in both rural and urban communities. Many economic measures were developed when natural capital was abundant and built (man-made) capital was scarce. Today the goods and services of nature, like water, food, energy, flood protection and climate stability, are becoming scarce and more valuable. It is increasingly apparent that not only built capital, financial capital and labor are primary factors of production for economic development, but natural systems are as well. Until recently, land and natural systems were frequently excluded in economic analysis. Today, economics recognizes that most things important to human well-being and survival are bound to the health of natural systems.

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, storm protection and wildlife habitat. 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.

Conservation International (CI) is building upon their solid foundation of previous work with communities in China to implement a Freshwater Initiative in the Qinghai Province. CI has been at the forefront in the development of freshwater Payment for Ecosystem Service (PES) projects in China. From a pioneering freshwater PES project at the world heritage site of Lijiang, to ongoing work with officials and policy-makers to integrate PES concepts into national law, CI has led the charge for a system that creates development opportunities for rural communities, reinforces traditional cultures of conservation, and secures freshwater resources for future generations. CI's experience with field models and the policy community will be critical to ensuring the success of the Freshwater Initiative in China.

The findings of this report document the economic importance of natural systems of Qinghai Province. All built capital is literally built out of and with natural capital from the materials, water, energy and services, such as flood control and climate stability. Freshwater ecosystem goods and services in particular are crucial to economic development from the highest elevation human habitation in the Province all the way down to Shanghai at the delta.

Freshwater systems are essential to human development and quality of life. Natural systems that produce water and water regulation provide water for human consumption, irrigation and industrial uses. Flood protection is increasingly important to communities along rivers including major metropolitan areas in China, Laos, Myanmar, Thailand, Cambodia and Vietnam. This brings new potential for funding conservation. Identifying, valuing, mapping and modeling ecosystem services provides the scientific and economic baseline for changing policy and vast amounts of investment.

Currently, billions of dollars are invested in the downstream watersheds from Qinghai Province in flood protection alone. Restoring and protecting natural systems has not been included in flood protection analysis. As a result, investment is inefficient. Greater flood protection could be provided by including the health of natural systems and the importance of conservation areas into flood protection planning.

A solid economic case for the benefits of conservation can be made by presenting the full suite of economic benefits that conservation provides to both local and distant populations. This can be accomplished by identifying ecosystem goods and services provided, placing an economic value on these goods and services, mapping the provisioning areas, beneficiaries and impairments to ecosystem services, modeling ecosystem services and setting up funding mechanisms for conserving and restoring areas that provide ecosystem services including payments for ecosystem service.

Study Results

The annual value of 12 of 23 identified ecosystem goods and services provided by the forests, grasslands, scrub/shrub lands, wetlands, lakes, ice and snow, urban green space and bare lands in the Qinghai Province is between **$12 billion and $123 billion.** One ecosystem good provided is water; one ecosystem service is flood protection. This includes water for drinking, irrigation and industry along three crucial rivers, the Yangtze, Yellow and Mekong. It also includes flood protection locally and as far away as Shanghai and Vietnam. If the natural systems of Qinghai Province providing this stream of benefits down these three major waterways over time were valued as an economic asset the value of the natural areas of the Province would be between **$385 billion and $3.9 trillion** (net present value, NPV) over a span of 100 years using a 3% discount rates. This demonstrates the tremendous value of this absolutely critical upper watershed area in China.

Understanding the value of the Qinghai Province to people, both within the Province and in downstream communities, is a critical first step to ensuring appropriate management of this irreplaceable economic asset. It also shows that China provides significant ecosystem service benefits to other countries. Conservation programs can provide solid economic benefits; conservation is often the least-cost path to providing water, flood control and other vital economic values tied to economic development and human well-being.

Recommendations

The following is a list of recommendations resulting from our research of the Qinghai region. Some of the recommendations CI may already be pursuing while others may be new approaches.

1. **Cultivate local and regional knowledge and support by working on the ground through pilot projects and workshops.** CI has a great track record of developing in-country programs that empower local residents to take action in their own community, utilize local knowledge, networks and systems and engage the broader international community. Because the

conservation impacts of this particular region affect critical economic areas, such as Shanghai, setting out a plan for continued cooperation and expanded outreach with local and regional jurisdictions, universities and residents is imperative to securing appropriate attention and commitment to the environmental problems of Qinghai. Impacted residents must be part of the solution identification process. Reports like this are valuable because, once released, they will receive extensive press and initiate many levels of dialog.

2. **Convert rESV study results into local currency.** To accurately reflect value in local terms, figures in this report should be provided in both US dollars and RMB currency using currency conversion rates and socio-economic indicators.

3. **Conduct supplemental research and analysis on additional ecosystem service areas in Qinghai Province, including: disturbance regulation, water regulation, biodiversity and habitat, and the economic value of recreation and tourism.** This rESV report provides a cursory look at the economy of Qinghai Province and the value of natural capital within that economy. Any restoration or conservation practice in one area can negatively or positively impact other areas; it is important to have as comprehensive understanding of the different services and interdependencies as possible. In this report, three ecosystem service areas, (fresh water provisioning, raw materials and soil erosion control), are described in detail. Due to funding and time limitations inherent in a rESV, some services particularly important to the Qinghai region were not examined. These include flood protection, water regulation, biodiversity and habitat, and the economic value of recreation and tourism.

4. **Perform additional ESV or rESV studies on specific drainage basins including the Qaidam, Yangtze and the Mekong River basins.** When designing restoration and conservation strategies, such as the establishment of new protected areas, it is crucial to get the geographic scale right. Earth Economics has been doing policy and funding mechanism work with governmental jurisdictions that ensures land and natural resource management occurs at the appropriate scale. For the Qinghai region, we believe that a basin-wide watershed scale focus is the superior approach to both analysis and the resulting policy work. To support further work advancing the restoration and conservation of Qinghai, Earth Economics strongly encourages CI to conduct additional valuation studies in of the three drainage basins fed from the Qinghai plateau.

5. **Initiate mapping and modeling of fresh water ecosystem services.** This provides spatial detail of the provisioning areas, impairments and beneficiary areas for ecosystem services. Modeling will allow for better policy decisions and the capacity to justify far larger investments. Current flood protection analysis, for example, does not include the value of forests, rivers, lakes, wetlands and grasslands for storing, delaying and infiltrating floodwaters. As a result within the basins downstream of Qinghai Province, billions of dollars are spent on “built” solutions only,

including levees and dams, when by investing in greater conservation and restoration more resilient, robust and long-lasting flood protection could be secured. The inclusion of natural systems in flood analysis in China and elsewhere could open up far larger resources for conservation.

6. **Use ESV data to fund further region specific service value transfer studies through local universities and implement broad changes in asset accounting practices.** Two areas that should be considered for further development include glacier provisioning of freshwater systems and ecosystem valuation of the Qinghai region's alpine meadows and marshes. Once these local values are identified, ensure the natural resources are tracked as jurisdictional assets in local accounting systems.

7. **Perform an initial analysis of restoration and conservation funding mechanisms and work with local and regional stakeholders to further refine and develop an implementable, sustainable plan to ensure ongoing funding and policy support for basin-scale restoration and conservation efforts.** As local and international government based funding mechanisms and markets for habitat, climate control (carbon), and water quality develop, the effectiveness of funding mechanisms to correct inefficiency and secure valuable ecosystem services is rapidly improving. Still, a number of factors make ecosystem service markets more challenging than markets for goods. Payments for ecosystem services (PES) policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, carbon sequestration, soil conservation, biodiversity or flood protection.

8. **Review existing PES schemes for implementation challenges, on-the-ground success factors and political resiliency.** PES schemes rely on financial incentives to encourage behavioral and land management changes that restore and conserve natural resources. In the last decade, hundreds of new PES initiatives have emerged around the globe with varying degrees of success. Before designing PES schemes specific to the Qinghai, it is will be critical to perform a social and economic review of existing PES in China and to glean best practices.

CI brings local presence, sophisticated policy tools, monitoring and tracking expertise and international attention to the 'Greater Asia Watershed' which serves the largest number of people (over 2 billion), and the largest number of humanity's poorest people. Earth Economics is committed to partnering with CI to ensure success of its programs in the Qinghai Province, in the People's Republic of China and across Asia.

This Document

Rapid ESV elements in this document are as follows:

Part 1: Introduction to Qinghai Province provides an overview of the geography, population and economy of the region.

Part 2: Key Concepts provides fundamental elements and definitions necessary for understanding 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.

Part 3: The Value of Natural Capital describes four broad categories of ecosystem goods and services and provides several specific examples in the Qinghai Province.

Part 4: Valuation Analysis of Qinghai Province puts ecological economics into action, determining dollar values based on concepts developed in the previous two sections.

Part 5: Conclusion discusses an economics approach to sustainable development, stresses the importance of conservation and restoration in Qinghai and provides an economic justification and next steps for implementing PES in Qinghai.

Part 1: Introduction to Qinghai Province

Overview

Named after its largest inland plateau lake, Qinghai Lake, Qinghai Province (pronounced Ching-hai) is located in China's southwestern region (Figure 1). The Province is 737,129 square kilometers, constituting one eighth of the country's total area. It is the fourth largest Province in area after Xinjiang, Tibet and Inner Mongolia Autonomous Regions.

Figure 1. Qinghai Province

Important ecological status and abundant natural resources are distinctive features of Qinghai. Described the "Water Tower of China", Qinghai is the origin of some of the world's major rivers including the Yangtze River, Yellow River and Mekong River. In addition, it is rich in minerals and supports thriving industries in hydropower, agro-husbandry and tourism.

Population

The provincial population, estimated at 5,570,000 in 2007, has a growth rate of 1.3%. The province is China's second lowest in population density after Tibet. Approximately 50% of the population of Qinghai Province is Han Chinese, with the remainder made up of Tibetan (20%) and other minority ethnic groups. The people of Qinghai are largely spread out; however, there are a few urban centers. The most notable densely populated area is in the eastern part of the Province, Xining, the region's capital.

Government

The Qinghai Province operates its government through a provincial committee that is responsible for most of the economic planning.

Geography

Qinghai is at the high average altitude of 2990 meters (9800 feet) and has many of the characteristics associated with mountainous, plateau regions. It houses many of the tributaries to the Yellow, Yangtze, Chang and Mekong rivers. Much of the stagnant waters of Qinghai are high in salinity. For example, the Qaidam basin is a salty marsh region within the borders of Qinghai. Perhaps the best example is the salty waters of Qinghai Hu, the largest lake in China. Formerly high-altitude meadows and grass lands, the land of Qinghai is increasingly baron and desolate; the region's desert areas are rapidly expanding partially as a result of poor land management practices.

Industry

The people of Qinghai traditionally practiced an agricultural way of life, planting crops and raising livestock. This way of life is still practiced, especially in the southern portion of the Province. During the 1950s, however, the northwest began to see a large amount of emigration as Han Chinese came into the Province to find work in the newly growing metal ore and mineral industries. Today, the metal industry generates much of the Province's income. Agriculture is another large sector of Qinghai's economy. In recent years, the oil and gas industry has begun operations in the Province, passing the metallurgy industry in contribution to the region's GDP. The region also has a productive salt industry, as well as a hydropower sector. In 2007, the petroleum and natural gas industries, hydropower generating industry, nonferrous metal industry and saline chemical industry combined contributed to 81.7% of the total added value of industrial output (Qinghai Statistical Yearbook, 2009).

Major export items include aluminum and rolled aluminum, silicon, yarn and woolen fiber with primary markets in Japan, the US and Korea. Major imports include aluminum oxide, medical instruments and equipment, automobiles and automobile parts. The smelting, manufacturing and water processing industries account for most of the Province's foreign investments, which has increased dramatically after the 2006 completion of the Qinghai-Tibet railway. In 2007, foreign investments in Qinghai were mainly engaged in manufacturing industries (40.1% of the contracted amount), and the production of electricity, gas and water.

In 2007, retail sales of consumer goods rose by 15.7% to RMB 20.8 billion and annual per capita disposal income of urban households was RMB 10,276 (+14.2%). Major consumer markets are located in Xining, which accounted for 66.7% of Qinghai's total retail sales. Major department stores and shopping centers in Qinghai include Xining Department Store, Xining Xidan Malls, and the Hualian Commercial Building (Qinghai Statistical Yearbook, 2009).

Regional Hydrology

Qinghai-Tibetan Plateau used to possess 36,000 glaciers covering an area of 50,000 square kilometers, but their area has shrunk by 30 percent over the past century. Studies performed between 1950 and 1970 indicated that 53.4% of glaciers on the Qinghai-Tibetan Plateau were retreating; today, 95% of these glaciers are retreating (Yao et al, 2007).

The Yangtze, Yellow and Mekong rivers originate in Qinghai Province (Figure 2). These three rivers are of critical international and regional importance as described below.

Figure 2. China map showing the Yangtze, Yellow and Mekong Rivers.

Source: CIA, 2010

Yangtze River

The Yangtze River is China's longest and widest river, with an annual flow of 951.3 billion cubic meters, or one-third of China's annual freshwater supply (Varis and Vakkilainen, 2001). Yet this supply is in danger, since about one third of the lake area in the mid and lower Yangtze basin has been converted to cropland (Yin and Li, 2001), and wetlands in the middle and lower reaches of the Yangtze River decreased by almost two thirds since 1980 (Wang et. al, 2008). The resulting ecological systems have a low capacity to store floodwater, which is critical because the glaciers feeding the Yangtze are rapidly declining.

Yellow River

China's second longest river, the Yellow River, is 5,464 kilometers long, running through nine provinces and autonomous regions, passing through the city of Dongying in Shandong Province and leading into the Bohai Sea's estuary. The upper and middle reaches of the Yellow River flow through some of the most impoverished regions in China. Since 1972, the Yellow River has been dramatically affected by human impacts such as climate change, damage to vegetation, and water withdrawals for irrigation. Warming from climate change has increased evaporation of freshwater. Destruction of vegetation and overuse of groundwater in the Loess Plateau region has led to the gradual desertification of land with increasingly arid land conditions, and even faster evaporation of remaining water. A lack of water-saving irrigation technology and capital for flood protection leads to both a loss of natural systems and an inefficient economic utilization of the Yellow River.

Mekong River

The Mekong River is perhaps Asia's most important cross-border river system. Beginning in China's Tibetan Autonomous Prefecture of Yushu in Qinghai Province, the Mekong runs through China, Laos, Myanmar, Thailand, Cambodia and Vietnam. From Vietnam it flows into the South China Sea. Currently, the Mekong River basin countries are experiencing serious environmental degradation from deforestation, soil erosion and river siltation, water pollution, habitat destruction and encroachment, climate change, and biodiversity loss. Toxic emissions and hazardous waste accumulation threaten human health. The loss and degradation of Thai and Vietnamese wetlands and their biodiversity pose a serious threat to the six countries of the Mekong River basin. Loss of habitat has already led to the extinction of several species. Large-scale drainage of wetlands for farming and aquaculture is the most serious threat. The development of both large and small scale dams pose the second greatest threat. If efforts are not made to protect and restore the Mekong River basin wetlands, their reduced size will lead to both global and localized species extinctions.

Qinghai Ecosystems in Peril

Qinghai Province can be characterized by its three major ecosystems: grassland ecosystem, forest ecosystem and wetland ecosystem, which are crucial in maintaining the ecological stability. Changes in these ecosystems could influence sustainable development in the region.

Overall, alpine step meadows and alpine frigid meadows have been seriously degraded. Degeneration of vegetation and grassland has led to desertification and frequently induced dust storms. With the continuous increase in cultivated land area, grassland area in the region has dropped significantly since the 1960s. At present, degraded grassland occupies about 83% of total usable grassland area. As the number of livestock have increased, range condition has deteriorated and the carrying capacity has fallen. The forest area in the northeastern margin of the Qinghai–Tibetan Plateau has decreased by 20%, and the local ecosystem has become very fragile. To avoid further deterioration of the environment and ecosystems, it is important to establish and implement ecosystem protection planning including funding mechanisms for restoration. New effective measures and technical improvements are essential to securing both the ecological and economic potential of the Province (Wang et al., 2008).

Part 2: Key Concepts

Economics has advanced significantly in recent years in ways that improve our ability to quantify the value and impacts of resource management strategies. Since 1985, a great deal of research has focused on developing and refining methods, tools and techniques for measuring the value produced by natural systems in the discipline of *ecological economics*. These include new concepts such as *natural capital* and new techniques including *ecosystem service valuation (ESV)*. Earth Economics has perhaps the world's largest database of ecosystem service valuation studies. In addition, a recent National Science Foundation grant implemented by the University of Vermont, Conservation International and Earth Economics has helped advance the most sophisticated and comprehensive tools for valuing, mapping and understanding ecosystem services.

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 little or no value. Yet they provide essential economic benefits including water for drinking, irrigation and industry, flood protection, storm protection, recreation and other benefits. Given the increasing scarcity of healthy ecosystems, and the economic services they provide (such as storm water conveyance) the valuation of natural capital presents value not previously seen and 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, development, jobs 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, natural storm water management, biodiversity, and education. Consideration of the Qinghai Province in terms of natural capital provides a more complete view of local and regional economies, and ecosystem health and the production of valuable benefits.

Economics of Natural Capital

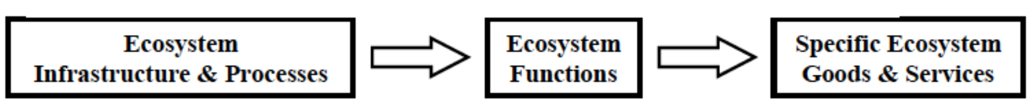
Healthy ecosystems are self-maintaining; they have the potential to provide an ongoing output of valuable goods and services in perpetuity and to appreciate in value over time. In contrast, built structures and other man-made capital have a tendency to depreciate in value over time and require significant financial inputs for operations and maintenance. By incorporating natural capital within a comprehensive planning and management process, the China can increase the capacity of ecosystems to produce significant national, regional and local benefits of economic value. Minimal investment through support for proper management of these assets would continually bring large returns by way of ecological goods and services.

Ecosystems and Value Production

Ecosystem functions generate benefits to people called *ecosystem goods and services*. 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.

Ecosystems are comprised of individual structural components (trees, forests, soils, 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 3 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, 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 3. Relationship of Ecosystems to the Goods and Services Produced



Ecosystem service valuation (ESV) 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. A management plan protects and reestablishes not only the ecological processes necessary for narrow interests, for example, a single food fishery or water filtration.

This study provides a conservative estimate for both the low and high values of ecological goods and services resulting from support for the proper management of Qinghai Province. Conserving and restoring these ecological processes within a natural range of variability maintains structure and the ecological goods and services that follow. This study is a baseline current ecosystem service value analysis. Scenarios for ecological goods and services enhanced by conservation and restoration sites can also be provided, as well as mapping of the beneficiaries and cumulative value brought in by healthy systems 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 possesses or uses a particular good, that individual can exclude others from possessing or using the same. For example if one person eats an apple, another person cannot eat that same apple. 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 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.

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. Furthermore, many services are not easily measured in terms of market value--many are fundamentally *public goods* such as flood protection or clean air; because of their physical nature, no one can privately possess or own them, and they cannot be traded in markets.

The 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 whether they pay for that benefit or not. 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 are slowly growing; water temperature trading and carbon sequestration markets are examples.

Table 1. 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 significantly exceed the value of the flow of goods. Biao et al. (2010) performed a study that estimated the value of forest ecosystems provided in Beijing Province, China, in terms of water conservation. Water conservation in this case referred to the water supply service that the Province's forests provides, and was broken down into three ecological processes for analysis: rainfall interception, soil water storage, and fresh water provision. It was found that, at their maximum potential capacity, forest ecosystems in Beijing Province could provide interception, storage, and supply services to a value of 5.23 billion RMB ($US770 million), at an average value of 5,704 RMB ($US840) per hectare ($US340/acre). These services are provided for free, and contribute greatly to the sustainable development of Beijing's economy (Biao et al., 2010).

This is also the case in the US. The value of the wetlands in the Mississippi Delta is estimated to be over $20 billion. The largest share of this value is the function of the wetlands for providing hurricane protection (Earth Economics, 2010).

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 flow of goods. A timber plantation may yield a flow of goods (wood) 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; 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 engineering structures and storm water infrastructure to compensate for the loss. Without healthy ecosystems, residents, 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.

Payment for Ecosystem Services (PES)

Typically, in an ecosystem service market, beneficiaries of an ecosystem service pay those who offer to provide the ecosystem service. In China, payments for ecosystem services are being used to address a number of environmental crises and improve human well-being. Planned ecosystem service payments in China today exceed 700 billion RMB (~$US100 billion) (Liu et al., 2008). China is currently undertaking two of the world's largest ecological rehabilitation projects, the Natural Forest Protection Program (NFPP) and the Sloping Land Conversion Program (SLCP, also known as the "Grain to Green Program"), both involving payments that aim to increase ecosystem service provisioning (Forest and Grassland Taskforce of China, 2003). These programs as described below, aim to increase ecosystem services such as water regulation, erosion prevention and carbon sequestration, thereby reducing threats to humans and the environment, which include soil erosion, landslides and desertification. To date, they have both shown much success socially and ecologically, but many challenges remain (Liu et al., 2008).

Natural Forest Protection Program (NFPP)

The NFPP aims to ban logging in China's southwest, and substantially reduce logging in other areas. To achieve this, the central government has spent large sums on tasks such as forest protection, regeneration, and reallocation of forest workers (State Forest Administration, 2002; Xu et al., 2006). Much of the payments subsidize the state forest bureaus to plant, seed and protect tracts of forest (Xu et al., 2006). To date, the NFPP has been largely successful at meeting reforestation and protection targets; between 1998 and 2002 for example, 3.05 million ha (~7.5 million acres) was afforested, and by 2005, 11 million ha (~27 million acres) of land had been reforested due to mountain closure and planting of trees (Liu et al., 2008).

Sloping Land Conversion Program (SLCP)

The SLCP was introduced to complement to the NFPP, and aims to convert 32 million ha of marginal croplands on steep hillsides and slopes to forest and grass coverage between 2002 and 2011. This is to be achieved by subsidizing farmers with 2.55 tons of grain per year for each hectare of cropland retired in the upper reaches of the Yangtze River and 1.50 tons for each hectare in the upper and middle reaches of the Yellow River. In addition, farmers are eligible for one-time cash subsidies to cover the costs of reseeding and maintaining trees or grass. By the end of 2006, the SLCP had converted almost 9 million ha (~22 million acres) of cropland to grassland or forest and had afforested 11.7 million ha (~29 million acres) of barren land, exceeding the targets set by the central government (Liu et al., 2008). Note that ecological health in many areas has been vastly improved, including reductions in water runoff and soil erosion, less need for irrigation, and a general increase in land fertility. In Hunan Province, for instance, soil erosion declined by 30% between 2000 and 2005. The program has also alleviated poverty, directly benefiting more than 120 million farmers nationwide (Liu et al., 2008).

Rural Provisioners and Urban Beneficiaries

Decision makers and local communities have a unique opportunity to understand the full economic importance of ecosystem services. The provision and filtration of water is a good example. In 1997, the city of New York accepted the importance of ecosystem service valuation when considering long-term supply options for a city that demanded a daily supply of more than 3.8 billion liters (1 billion gallons) of water. 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, and a less costly and less risky method for meeting standards.

Without a funding mechanism linking New York and moving funding into rural areas to restore ecosystem services, the city would have far more costly and polluted water and rural areas would have less income and investment. Payments for ecosystem services are important because they get the economics right, providing investment and income in rural provisioning areas from urban beneficiary areas. Both gain.

Downstream urban cities, such as New York or Shanghai, benefit from several important rural ecosystem services, such as water provisioning, water filtration and flood protection. China has been a leader in experimenting with payment for ecosystem services systems. Importantly, science provides the foundation of tracking the physical production and consumption of ecosystem services. Economics provides the valuation and a framework for funding mechanisms, such as payments for ecosystem services where the beneficiaries pay for the provisioning of ecosystem services.

Ecosystems in the Qinghai Province can be managed in a way that provides significant development opportunities from the aggregate value of goods and services with the potential to benefit both current and future generations.

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):

- **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 Puget Sound provide fish, shellfish and seaweed. 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, 2006).

- **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, enjoying natural places for recreation, and learning about the planet through science and education.

Within each category, there are many more specific ecosystems services. These services are identified in Table 2.

Table 2. Categories and Definitions of Ecosystem Services

Service	Definition
Provisioning	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building. Geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
Regulating	
Gas and Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Waste Treatment	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil from through natural processes
Supporting	
Nutrient Cycling	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms
Biodiversity and Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
Pollination	Fertilization of plants and crops through natural systems
Cultural	
Aesthetic	The role which natural beauty plays in attracting people to live, work and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for education and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)

Based on Daly and Farley 2004 and de Groot 2005

While these are the primary categories of ecosystem services, 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.

The following sections provide an overview of provisioning, regulating, supporting and cultural ecosystem services. For this rapid ESV report, three specific examples for Qinghai Province are provided in special "Spotlight on Qinghai" sections within orange boxes. Should a full ESV report be done by Earth Economics, each service would contain regional analysis.

Provisioning Services

Fresh Water

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 2006). Qinghai Province residents are among these, as are residents down the lengths of the Yangtze, Yellow and Mekong rivers. Forest cover loss globally has reduced water supply and ground water recharge, lowering flow reliability (Syvitski, 2005).

Fresh Water in Qinghai

The northeastern margin of the Qinghai–Tibetan Plateau was the most important water reservation area and ecological shelter for the Yellow River Basin, where rivers and swampland supply the Yellow River with large quantities of water. During the past 40 years, due to the climate changes and irrigational water use, the surface water area in the region has decreased and water areas of most lakes and rivers were reduced. The lake water area shrank by 0.54% from the 1970s to the 1980s, and by 9.25% from the 1980s to the 1990s (Wang et al., 2008). At the beginning of 1980s, the wetland area was 6,400,000 ha. However, at the end of 2004, the wetland area was only 1,900,000 ha, a decrease of 70.4% (Statistics yearbook of Ganan 2005; Gannan Recorder Compilation Committee, 1998; Gannan Statistics Yearbook Compilation Committee, 2005, both cited in Wang et al., 2008). In addition, the swampland drained away gradually in the northeastern margin of the Qinghai–Tibetan Plateau. Since the 1970s, the swampland vegetation was gradually replaced by meadow species, mesophytes and xerophytes (Wang et al., 2008). Swampland was 1,200,000 ha in the 1980s and shrank to a mere 300,000 ha at the end of 2004, a reduction of 75.0% (Gannan Statistics Yearbook Compilation Committee, 2005).

Qinghai Province has a burgeoning mineral water industry touting pure sources in the towering Kunlun Mountains to the vast lakes and swamps, far away from populated areas. The Qinghai Provincial Government appears to lack a unified development or management plan with regard to bottling water. However, industry statistics show that China's mineral water production has reached more than 1,200 enterprises (Quili Temple Mineral Water, 2010).

Raw Materials

Raw Materials include biological materials used for medicines, fuel, art and building; 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.

Raw Materials in Qinghai

Natural resource development, especially in oil and gas, is growing in the region. Between three and five billion dollars is expected to be invested in natural gas and oil extraction over the next five years (People's Daily Online, June 12, 2010). Natural gas hydrate exploration and development is also expected to be a major economic contributor in the future (English.news.cn, March 6, 2010; Zyga, March 12, 2010).

Qinghai Salt Lake Potash Company Ltd mines salt in the Qinghai Kunlun Development Zone. Net profits of the company were 3.10937 billion yuan in 2009 (ReportLinker, 2008). Qinghai Lithium Co., Ltd. is mining lithium carbonate, potassium sulphate and boric acid in the region. Lithium is used in hi-tech batteries (MyiStop, January 18, 2010).

There are five aluminum smelter companies in Qinghai Province: Chalco, Qingtongxia, Qinghai Qiaotou, Qinghai Changqing and Qinghai Baihe (AME Mineral Economics website, 2010).

Yihui Metallurgy Group Company Ltd mines chrome, nickel and manganese raw materials in the region (Global Internet Casting Industry, December 16, 2008).

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 et al, 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 should be explored in a subsequent funding mechanisms study.

Disturbance Regulation

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.

Soil Erosion Control

Natural erosion and landslides provide sand and gravel to streams, creating habitat for fish and other species.

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 fish habitat.

Soil Erosion Control in Qinghai

With the continuous increase in cultivated land area and number of livestock, the area of degraded grasslands in the northeastern margin of the Qinghai–Tibetan Plateau had increased significantly since the 1950s. In this region, there were approximately 2,960,000 ha of natural rangeland, and degraded grassland occupied about 83.20% of total usable grassland area, in which severe and moderately degraded grassland area was 814,000 ha and 1,370,000 ha, respectively; desertified grassland was 53,300 ha and salt affected grassland was 5,500 ha (Wang et al., 2008).

On the other hand, human alteration of shoreline and stream corridors can prevent the type of natural erosion upon which many 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.

Water Regulation

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 smaller 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.

As was discussed in the section on drinking water, 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.

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. Much of the science behind stream-aquifer relationships and other hydrologic relationships within the watershed are still not fully understood, and will greatly impact our ability to protect other ecosystem services as we utilize this valuable one.

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.

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 them 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 promoting an abundance of smaller patches of fields (Dordas, 2009; Risch et al., 1983).

Waste Treatment

Microorganisms in sediments and mudflats of estuaries, bays and nearshore areas break down human and other animal wastes (Weslawski et al., 2004). They can also detoxify petroleum products. The physical destruction of habitat, alteration of food webs, or overload of nutrients and waste products disrupts disease regulation and waste processing services. Changes to ecosystems can also create breeding sites for disease vectors where they were previously non-existent. People can be exposed to disease in coastal areas through direct contact with bacterial or viral agents while swimming or washing in fresh or saltwater, and by ingesting contaminated fish, seafood or water. The recent rise of cholera outbreaks in the southern hemisphere is associated with degradation of coastal ecosystems (UNEP, 2006).

Additionally, wetlands, estuarine macroalgae and nearshore sedimentary biota play a crucial role in removing nitrogen and phosphorous from water (Garber et al., 1992; Weslawski et al., 2004).

Supporting Services

Soil Formation

Soil is formed over thousands of years through a process that involves parent material, climate, topography, organisms and time. Soil quality and abundance is critical for human survival, yet human actions can also affect nature’s ability to provide high quality soils.

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 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, 2006). 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 this service, and it is 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.

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 over-harvest, 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

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.

Primary Productivity
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 are 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 et al., 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.

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. Such loss is an issue in the Qinghai Province.

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 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. 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 tourism industry.

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 in Part 4 of this report.

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 scientific and educational importance of ecosystems. 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 and Spiritual

Ecosystems and their components play a role in the passing of traditions and 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.

In 2005, CI began the “Sacred Lands” conservation program in Tibetan communities that sought to promote traditional Tibetan resource management systems and introduce these sustainability values to the broader Chinese society. Tibetan culture and Buddhism emphasize a reverence for life and nature and, traditionally, every Tibetan village and monastery designates its own sacred sites—nearby mountains, lakes and rivers. These voluntary indigenous practices result in an effective and harmonious way to manage the land and play an important role in conservation.

Part 4: Valuation Analysis of the Qinghai Province

Study Objectives

This Rapid Ecosystem Service Valuation (rESV) study of the Qinghai Province provides initial values for ecosystem services using benefit transfer analysis, cursory research of the project site and other resources provided by the CI. Due to data, timing and financial limitations, the results of this valuation are characterized as a range of high and low values, based on the summation of 12 ecosystem service values across vegetation types.

This study provides a first analysis in support of CI’s initiative to create PES projects to Tibetan communities in Qinghai Province.

Study Method

Hectares of vegetation types in Geographic Information System (GIS) data, provided by CI, were used with a benefit transfer methodology. This methodology, based on peer reviewed academic journal articles, estimates the high and low dollar value range of 12 of 23 identified ecosystem services produced within the project area. Per hectare values were estimated for each vegetation type and each ecosystem service. These values were then summed for an initial rough-cut total valuation of ecosystem goods and services provided annually. The net present value (NPV) was then calculated from the annual value flow of ecosystem services. Revealing the economic value of natural systems is critical to inform conservation and investment decisions. The NPV is analogous to the asset value for a factory or house that provides marketable goods and services. Several discount rates were used for comparison.

Appendices A-C provide additional information about benefit transfer methodology and its application in this study.

Area of Study and GIS Data

The ecological goods and services produced by each land cover type in Qinghai Province were estimated utilizing the methodological approach outlined in the introduction of this report. **The total estimated value generated on the 74 million hectares of Qinghai Province in ecosystem services is estimated to be in the range of US$12-123 billion annually.** The following sections and tables discuss this in more detail.

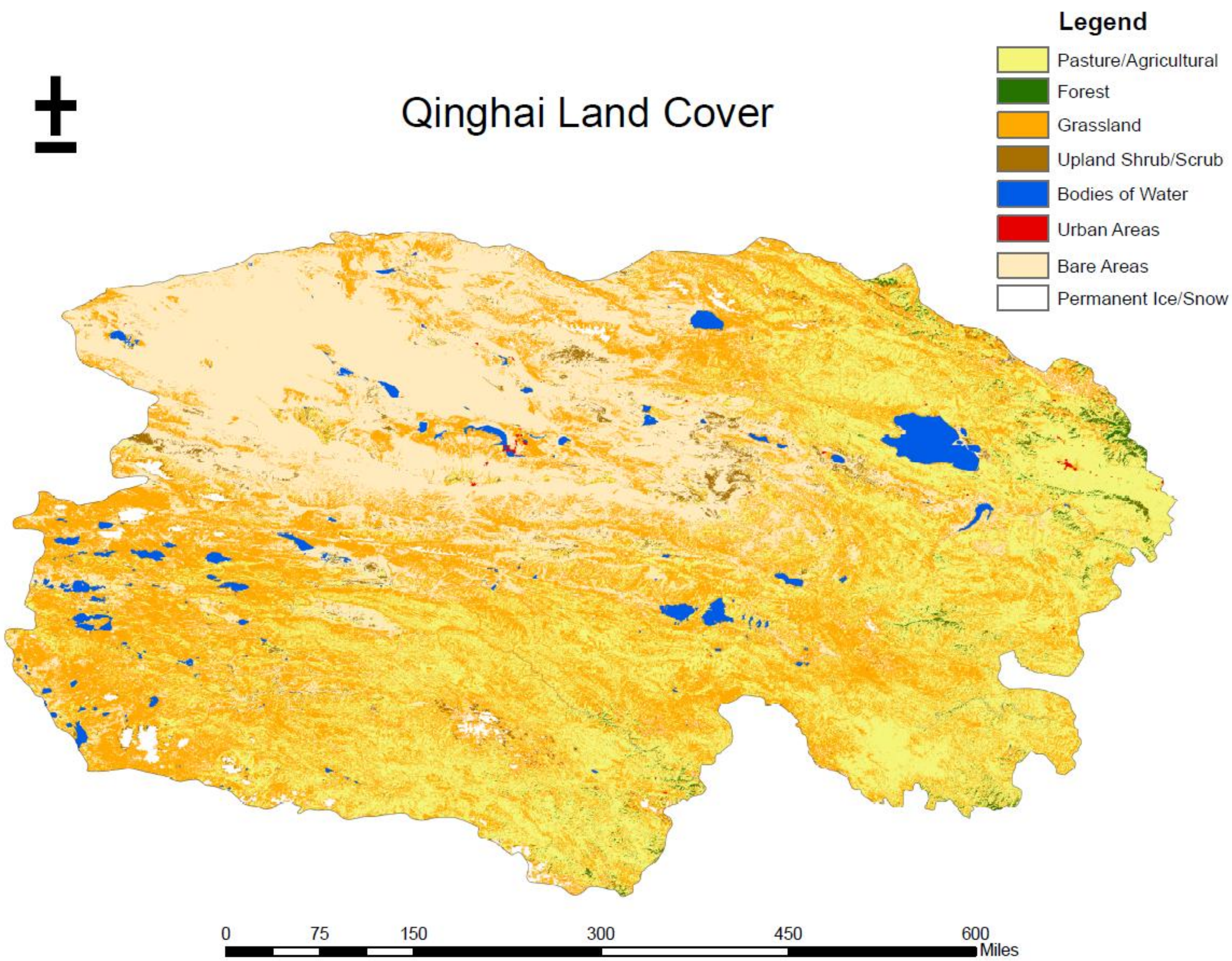
Land cover data derived from the GlobCover database reflects the best available geographic information system (GIS) data for the Qinghai Province. Table 3 shows GIS land cover type and area for each class in the region.

Table 3. Qinghai Province Land Cover Summary

Cover Type	Hectares
Temperate Forest	457,836
Forest	1,569
Grassland	25,517,667
Swamps/Floodplains	20,472
Agricultural Lands	23,033,572
Urban Green Space	42,680
Lakes/Rivers	1,338,512
Brackish Marsh	8
Upland Shrub/Scrub	1,012,273
Permanent Ice/Snow	1,305,801
Bare Lands	20,982,369
Totals	**73,712,759**

Figure 5 shows the geographic boundary of the study site. Grassland and agricultural lands mainly cover Qinghai Province. The red cluster on the eastern side of the Province is the city of Xining.

Figure 5. Qinghai Province Land Cover Map



Valuation Results

Earth Economics maintains a database of ecosystem service valuation studies. The following tables show the US dollar values for the low and high boundaries for ecosystem service values after a peer literature review.

The following tables show land cover type, ecosystem services, valuation study authors, and low and high values. Values are in 2009 US dollar per hectare per year units.

Table 4. Temperate Forest Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Temperate Forest			
Gas & Climate Regulation	Adger et al. 1995	$102.76	$157.30
Raw Materials	Sharma 1992	$26.30	$26.30
Aesthetic & Recreational	Walsh et al. 1978	$15.75	$60.98
Waste Treatment	Pimentel et al. 1997	$92.59	$92.59
Soil Formation	Pimentel et al. 1997	$10.65	$10.65
Biological control	Pimentel et al. 1997	$4.26	$4.26
Temperate Forest Total		**$252.31**	**$352.07**

Table 5. Forest Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Forest			
Gas & Climate Regulation	In-house estimate	$134.90	$2,603.25
Water Regulation	Loomis, J.B. 1988	$25.27	$25.27
Aesthetic & Recreational	Boxall, P.C., et al. 1996; Bishop, K. 1992	$0.47	$1,677.15
Habitat Refugium & Nursery	Haener, M. K. 2000; Kenyon, W., et al. 2001	$4.00	$1,315.40
Water Supply	Ribaudo, M. and Epp, D. J. 1984	$1,749.07	$2,217.87
Soil erosion control	Dodds, W. K., et al. 2008	$273.71	$719.73

Pollination	Hougner, C. 2006	$165.58	$743.69
Forest Total		**$2,353.00**	**$9,302.36**

Table 6. Grasslands Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Grasslands			
Gas & Climate Regulation	Fankhauser and Pearce 1994; Costanza et al. 1997	$10.02	$10.12
Water Regulation	Costanza et al. 1997; Jones et al. 1985	$4.34	$5.34
Waste Treatment	Pimentel et al. 1997	$125.98	$125.98
Soil Formation	Sala and Paruelo 1997; Costanza et al. 1997	$1.29	$1.45
Biological control	Pimentel et al. 1995; Pimentel et al. 1997	$24.06	$33.29
Soil erosion control	Costanza et al. 1997; Barrlow 1991	$41.99	$47.04
Pollination	Pimentel et al. 1995; Pimentel et al. 1997	$26.61	$36.21
Grasslands Total		**$234.29**	**$259.43**

Table 7. Swamps/Floodplains Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Swamps/Floodplains			
Gas & Climate Regulation	Kumari 1995	$393.12	$393.12
Water Regulation	Kumari 1995; Costanza et al. 1997	$44.33	$4,677.57
Raw Materials	Gren and Soderqvist 1994	$9.36	$312.10
Aesthetic & Recreational	Gupta and Foster 1975; Gren and Soderqvist 1994	$24.77	$2,969.05
Water Supply	Gupta and Foster 1975	$437.74	$63,355.02
Disturbance Regulation	Thibodeau and Ostro 1981	$11,852.11	$11,852.11
Waste Treatment	Gren and Soderqvist 1994	$400.03	$8,571.51

Swamps/Floodplains Total		**$13,161.46**	**$92,130.47**

Table 8. Agricultural Land Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Agricultural lands			
Aesthetic & Recreational	Bergstrom, J., Dillman, B. L. and Stoll, J.R. 1985	$72.31	$72.31
Pollination	Southwick, E. E. and Southwick, L., 1992; Robinson, W. S. et al. 1989	$6.31	$31.82
Agricultural lands Total		**$78.62**	**$104.13**

Table 9. Urban Green Space Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Urban Green Space			
Gas & Climate Regulation	McPherson, E. G. 1992; McPherson, E. G., et al. 1998	$70.50	$2,300.30
Water Regulation	McPherson, E. G. 1992; Birdsey, R. A. 1996	$15.04	$449.36
Aesthetic & Recreational	Tyrvainen, L. 2001	$3,316.67	$9,722.54
Urban Green Space Total		**$3,402.21**	**$12,472.21**

Table 10. Lakes and Rivers Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Lakes/Rivers			
Water Regulation	Gibbons 1986	$2,389.89	$9,229.89
Aesthetic & Recreational	Patrick, R., et al. 1991; Loomis J. B. 2002	$4.44	$51,799.45
Habitat Refugium & Nursery	Loomis, J. B. 1996; Streiner and Loomis, J. B. 1995	$45.04	$3,891.31
Water Supply	Piper, S. 1997; Howe and Easter 1971	$85.04	$15,580.96
Waste Treatment	Gibbons 1986	$195.72	$2,544.40

Lakes/Rivers Total		$2,720.14	$83,046.02

Table 11. Brackish Marsh Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Brackish Marsh			
Gas & Climate Regulation	Costanza et al. 1997; In-house estimate	$84.17	$916.34
Water Regulation	Woodward and Wui, 2001	$338.42	$1,466.39
Waste Treatment	In-house estimate	$738.90	$2,812.46
Brackish Marsh Total		**$1,161.50**	**$5,195.20**

Table 12. Upland Shrub/Scrub Values

Land Cover/Ecosystem Service	Valuation Study Author	Minimum Value	Maximum Value
Upland Shrub/Scrub			
Gas & Climate Regulation	Costanza et al. 1997	$10.62	$10.62
Water Regulation	Costanza et al. 1997	$4.55	$4.55
Waste Treatment	Costanza et al. 1997	$131.95	$131.95
Soil Formation	Costanza et al. 1997	$1.50	$1.50
Biological control	Costanza et al. 1997	$35.66	$35.66
Soil erosion control	Costanza et al. 1997	$43.97	$43.97
Upland Shrub/Scrub Total		**$228.24**	**$228.24**

Table 13 shows the land cover types, hectares of land cover type, low and high value estimates per hectare, and the low and high value estimates for each land cover type in Qinghai. The sum of ranges in value these vegetation types provide are the annual benefits produced in the region.

Table 13. Estimate of Summed Ecosystem Value Flows for the Qinghai Province Region

		Low & High Values per Hectare		Total Low & High Values	
Land Cover Type	**Hectares**	***Low***	***High***	***Low***	***High***
Temperate Forest	457,836	$252.31	$352.07	$115,514,338	$161,190,356
Forest	1,569	$2,353.00	$9,302.36	$3,691,853	$14,595,406
Grassland	25,517,667	$234.29	$259.43	$5,978,602,012	$6,620,077,155
Swamps/Floodplains	20,472	$13,161.46	$92,130.47	$269,441,457	$1,886,095,044
Agricultural Lands	23,033,572	$78.62	$104.13	$1,810,979,171	$2,398,487,464
Urban Green Space	42,680	$3,402.21	$12,472.21	$145,206,467	$532,313,727
Lakes/Rivers	1,338,512	$2,720.14	$83,046.02	$3,640,933,503	$111,158,092,300
Brackish Marsh	8	$1,161.50	$5,195.20	$9,292	$41,562
Upland Shrub/Scrub	1,012,273	$228.24	$228.24	$231,045,946	$231,045,946
Permanent Ice/Snow	1,305,801	n/a	n/a	n/a	n/a
Bare Lands	20,982,369	n/a	n/a	n/a	n/a
Totals				**$12,195,424,038**	**$123,001,938,959**

Although the values provided here are underestimates of the true value Qinghai ecosystems provide, they meet the same basic standard of accepted economic measures. **Based on available data, the value of the services examined here provided by Qinghai is estimated between $12-123 billion annually.** The low and high estimates are both underestimated for many reasons, which are described in Appendix C.

These estimates are based on the range of values for these land covers types outside the region. As cursory estimates based on benefit transfer methodology, they provide an estimated range. A specific study or set of studies should be conducted to narrow the range in values. Appendix B contains all of the references for the value transfer studies that were used in the analysis.

Water bodies (rivers and lakes) at $2,700 - $83,000 and floodplains at $13,200 - $92,100 provide the highest values per hectare. All natural systems provide economic benefits. For some systems, there is far more valuation data available than for others systems. For example, glaciers in the Himalayas store vast amounts of water and influences the lives of nearly half the world's population, although economists have yet to value this critical ecosystem (IPCC, 2007). Generally, brackish marsh and shrub/scrub systems are far less studied than wetlands and forested systems. In Qinghai, water regulation, disturbance prevention and water supply ecosystem services have the highest values per hectare.

A carbon sequestration calculation was made in-house based on carbon sequestration rates described in Birdsey 1996 and using the Chicago Climate Exchange figures for the low estimate ($4.40/ton) and high estimates of $85/ton based on the 2006 Stern report, which would include the social cost of carbon.

Preservation of Present Values

Calculations of the present value of the flow of ecosystem services do show that intact natural systems provide enormous value to society in the short and long term. We enjoy (require) some of this value now, such as the supply of drinking water, but through time future generations will cumulatively receive very large economic benefits from functioning natural capital.

Self-interested actions of private landowners could result in vegetative 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.

Table 14. Present Value of Ecosystem Services in Qinghai over 100 Years

Discount Rate	Low Estimate	High Estimate
0% (100 years)	$1.2 trillion	$12.3 trillion
3% (100 years)	$385 billion	$3.9 trillion

The differences between these values depend on the discount rate chosen as shown by Table 11. For simplicity, we used two discount rate, 0 and 3 percent. A zero percent discount rate implies that we in the present hold future flows of ecosystem services to be just as important to people living in the future as the value of those assets are to us today. A 3 percent discount rate implies that people today have a positive time preference so that what remains in the future is less important than what we have today to meet current needs.

Part 5: Conclusion

The findings of this report document the economic importance of natural systems of Qinghai Province. All built capital is literally built out of and with natural capital from the materials, water, energy and services, such as flood control and climate stability. Freshwater ecosystem goods and services in particular are crucial to economic development from the highest elevation human habitation in the Province all the way down to Shanghai at the delta.

Freshwater systems are essential to human development and quality of life. Conservation areas and natural systems that produce water and water regulation provide water for human consumption, irrigation and industrial uses. Flood protection is increasingly important to communities along rivers including major metropolitan areas in China, Laos, Myanmar, Thailand, Cambodia and Vietnam. This brings new potential for funding conservation. Identifying, valuing, mapping and modeling ecosystem services provide the scientific and economic baseline for changing policy and vast amounts of investment. Currently, billions of dollars are invested in the downstream watersheds from Qinghai Province in flood protection alone. Restoring and protecting natural systems has not been included in flood protection analysis. As a result, investment is inefficient. Greater flood protection could be provided by including the health of natural systems and the importance of conservation areas into flood protection planning.

A solid economic case for the benefits of conservation can be made by presenting the full suite of economic benefits that conservation provides to both local and distant populations. This can be accomplished by identifying ecosystem goods and services provided, placing an economic value on these goods and services, mapping the provisioning areas, beneficiaries and impairments to ecosystem services, modeling ecosystem services and setting up funding mechanisms for conserving and restoring areas that provide ecosystem services including payments for ecosystem service.

Study Results

The annual value of 12 of 23 identified ecosystem goods and services provided by the forests, grasslands, scrub/shrub lands, wetlands, lakes, ice and snow, urban green space and bare lands in the Qinghai Province is between **$12 billion and $123 billion.** One ecosystem good provided is water; one ecosystem service is flood protection. This includes water for drinking, irrigation and industry along three crucial rivers, the Yangtze, Yellow and Mekong. It also includes flood protection locally and as far away as Shanghai and Vietnam. If the natural systems of Qinghai Province providing this stream of benefits down these three major waterways over time were valued as an economic asset the value of the natural areas of the Province would be between **$385 billion and $3.9 trillion** (net present value, NPV) over a span of 100 years using a 3% discount rates. This demonstrates the tremendous value of this absolutely critical upper watershed area in China.

Understanding the value of the Qinghai Province to people, both within the Province and in downstream communities, is a critical first step to ensuring appropriate management of this irreplaceable economic asset. It also shows that China provides significant ecosystem service benefits to other countries. Conservation programs can provide solid economic benefits; conservation is often the least-cost path to providing water, flood control and other vital economic values tied to economic development and human well-being.

Recommendations

The following is a list of recommendations resulting from our research of the Qinghai region. Some of the recommendations CI may already be pursuing while others may be new approaches.

1. **Cultivate local and regional knowledge and support by working on the ground through pilot projects and workshops.** CI has a great track record of developing in-country programs that empower local residents to take action in their own community, utilize local knowledge, networks and systems and engage the broader international community. Because the conservation impacts of this particular region affect critical economic areas, such as Shanghai, setting out a plan for continued cooperation and expanded outreach with local and regional jurisdictions, universities and residents is imperative to securing appropriate attention and commitment to the environmental problems of Qinghai. Impacted residents must be part of the solution identification process. Reports like this are valuable because, once released, they will receive extensive press and initiate many levels of dialog.

2. **Convert rESV study results into local currency.** To accurately reflect value in local terms, figures in this report should be provided in both US dollars and RMB currency using currency conversion rates and socio-economic indicators.

3. **Conduct supplemental research and analysis on additional ecosystem service areas in Qinghai Province, including: disturbance regulation, water regulation, biodiversity and habitat, and the economic value of recreation and tourism.** This rESV report provides a cursory look at the economy of Qinghai Province and the value of natural capital within that economy. Any restoration or conservation practice in one area can negatively or positively impact other areas; it is important to have as comprehensive understanding of the different services and interdependencies as possible. In this report, three ecosystem service areas, (fresh water provisioning, raw materials and soil erosion control), are described in detail. Due to funding and time limitations inherent in a rESV, some services particularly important to the Qinghai region were not examined. These include flood protection, water regulation, biodiversity and habitat, and the economic value of recreation and tourism.

4. **Perform additional ESV or rESV studies on specific drainage basins including the Qaidam, Yangtze and the Mekong River basins.** When designing restoration and conservation strategies, such as the establishment of new protected areas, it is crucial to get the geographic scale right. Earth Economics has been doing policy and funding mechanism work with governmental jurisdictions that ensures land and natural resource management occurs at the appropriate scale. For the Qinghai region, we believe that a basin-wide watershed scale focus is the superior approach to both analysis and the resulting policy work. To support further work advancing the restoration and conservation of Qinghai, Earth Economics strongly encourages CI to conduct additional valuation studies in of the three drainage basins fed from the Qinghai

plateau.

5. **Initiate mapping and modeling of fresh water ecosystem services.** This provides spatial detail of the provisioning areas, impairments and beneficiary areas for ecosystem services. Modeling will allow for better policy decisions and the capacity to justify far larger investments. Current flood protection analysis, for example, does not include the value of forests, rivers, lakes, wetlands and grasslands for storing, delaying and infiltrating floodwaters. As a result within the basins downstream of Qinghai Province, billions of dollars are spent on "built" solutions only, including levees and dams, when by investing in greater conservation and restoration more resilient, robust and long-lasting flood protection could be secured. The inclusion of natural systems in flood analysis in China and elsewhere could open up far larger resources for conservation.

6. **Use ESV data to fund further region specific service value transfer studies through local universities and implement broad changes in asset accounting practices.** Two areas that should be considered for further development include glacier provisioning of freshwater systems and ecosystem valuation of the Qinghai region's alpine meadows and marshes. Once these local values are identified, ensure the natural resources are tracked as jurisdictional assets in local accounting systems.

7. **Perform an initial analysis of restoration and conservation funding mechanisms and work with local and regional stakeholders to further refine and develop an implementable, sustainable plan to ensure ongoing funding and policy support for basin-scale restoration and conservation efforts.** As local and international government based funding mechanisms and markets for habitat, climate control (carbon), and water quality develop, the effectiveness of funding mechanisms to correct inefficiency and secure valuable ecosystem services is rapidly improving. Still, a number of factors make ecosystem service markets more challenging than markets for goods. Payments for ecosystem services (PES) policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, carbon sequestration, soil conservation, biodiversity or flood protection.

8. **Review existing PES schemes for implementation challenges, on-the-ground success factors and political resiliency.** PES schemes rely on financial incentives to encourage behavioral and land management changes that restore and conserve natural resources. In the last decade, hundreds of new PES initiatives have emerged around the globe with varying degrees of success. Before designing PES schemes specific to the Qinghai, it is will be critical to perform a social and economic review of existing PES in China and to glean best practices.

CI brings local presence, sophisticated policy tools, monitoring and tracking expertise and international attention to the 'Greater Asia Watershed' which serves the largest number of people (over 2 billion), and the largest number of humanity's poorest people. Earth Economics is committed to partnering with CI to ensure success of its programs in the Qinghai Province, in the People's Republic of China and across Asia.

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Appendix A: Benefit 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 akin to a house appraisal where an appraiser considers the valuations (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 acreage.

The valuation techniques utilized to derive the values in the database were developed primarily within environmental and natural resource economics. As the table below 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.

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: Lithium from salt mining.*
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services. *Example: Flood and mudslide protection provided by intact Alpine meadows.*
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 culturally significant areas.*
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.*

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 Qinghai Province to date.

Appendix B: List of Value-Transfer Studies Used

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Appendix C: Study Limitations

This study provides a best-possible first estimate of the economic value of the ecological goods and services generated within the Qinghai Province. The study, based primarily on value transfer and not on original research of each ecosystem service within Qinghai, should be regarded as the best first estimate but also have 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. Project decisions are 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 the Qinghai Province 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 the region. Similarly, 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 the Qinghai Province 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. That every hectare of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis, 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.