

VALUATION OF ECOSYSTEM SERVICES IN TRINITY COUNTY, CALIFORNIA

by

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This study considers the role of the forest ecosystem in Trinity County, California's economy. I seek to better understand the natural resource-based economy of a national forest-proximate community by creating a framework that describes the resource flows into and out of Trinity County and guides ecosystem services valuation within the County. Thus, this study examines the monetary benefits that ecosystem functions create through delivery of goods such as water, energy, and timber and also estimates the value of services, such as recreation, carbon sequestration, and amenity value. Finally, this study examines how money is spent to maintain the ecosystem functions that create these goods and services, such as who pays to maintain water

collection and filtration capacity or habitat. Ultimately, this study offers insight into opportunities and limitations for ecosystem services valuation at the county level, and considerations for future attempts to value ecosystem services.

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CHAPTER I

INTRODUCTION

This project seeks to broaden understanding of the forest ecosystem's role in the economy of Trinity County, California by valuing the services this ecosystem provides. Many rural communities across the United States face pressures to transition away from economies based on natural resource extraction. Researchers, government officials, and environmental and community advocates have suggested that payments for ecosystem services could help form a new economic base. Ecosystem services valuation attempts to put prices on benefits provided by the ecosystem that are often undervalued, or valued at zero, in the marketplace. Determining an economic value for forest ecosystem services will provide necessary information and rationale for protecting and managing the forest in Trinity County and ecosystems in counties across the United States. This analysis has particular relevance for communities like Trinity County that are dominated by public land. The conclusions of this study could inform pricing, cost sharing, and land use policies in Trinity County and could help to change the balance between who pays and who benefits.

Creating mechanisms to pay for ecosystem services requires an understanding of the ecological and economic flows into and out of the community. Currently, those who benefit from the ecosystem services provided by the forest ecosystem in Trinity County generally do not pay for the upkeep of the services. Changing the relationships between

these groups is balance could be an opportunity for the economic development of Trinity County and could help address long-term equity issues necessary for sustainable development. This project uses innovative techniques within natural resource planning to address issues of community economic sustainability. By combining approaches from economics, regional and land use planning, and natural resource management, this project will help inform the understanding and development of markets for ecosystem services.

Trinity County, located in northern California, both contains and is surrounded by a significant portion of Shasta-Trinity National Forest. Trinity County has an area of 3,200 square miles and a population of approximately 13,000. Until recently, Trinity County's economy relied largely on the timber industry. In the past twenty years, the economy has shifted towards tourism and depends more heavily on other natural resources besides timber, particularly water for both hydropower and to export for consumption in central California. Although its economic focus has changed, the county still relies on its natural resource base for most of its economic activity.

To better understand the dynamics of a National Forest-proximate community with a natural resource-based economy, this project creates a framework that describes the resource flows into and out of Trinity County. The goal is to better understand the monetary benefit that ecosystem functions currently create through delivery of water, energy (through hydropower), timber, and fish. It also investigates services with other types of value that currently have a price on the market: recreation, carbon sequestration, and amenity value. Simultaneously, the project seeks to better understand how money is

spent to maintain ecosystem functions that create these services: who pays to maintain water collection and filtration capacity, habitat, stand structure, and other important ecosystem functions. Finally, the project investigates characteristics of mechanisms that link those who benefit from ecosystem services with the maintenance of ecosystem function.

I am working on this project in conjunction with the Watershed Research and Training Center in Trinity County, which promotes land stewardship and economic development in part through jobs based on restoration. This project will allow the Watershed Center to make better-informed policy decisions in the future and better understand the economic flows upon which its communities depend by recognizing the economic, social, and environmental facets of sustainability.

Purpose of the Research

This project represents a model for valuing ecosystem services in local communities, particularly those dominated by federally managed land. Because it relies upon publicly available data, other communities could replicate the project's framework and approach. Other valuations of ecosystem services occur at much larger geographic scales or focus on single services, despite the fact that indicators for other types of social, health, and economic services are often valued at the county level. Many budgetary decisions and much spending to maintain ecosystem functions are carried out at a county level. This study values ecosystem services at the county level, where many land use decisions are made. It thus puts ecosystem indicators on a similar footing with other services and gives them practical applications for existing institutional frameworks.

Through its scope, approach, and framework, this project promotes the development of sustainable communities.

The purpose of this project is not simply to calculate the economic production based on natural resources in Trinity County. Instead, the purpose of this project is to investigate how these values fit into the ecosystem. In addition, the goal is to understand how much of the value can, already is, and could be expressed in economic terms. The purpose of this project is to provide context for these values and map out who pays and who benefits.

Worldwide, payments for ecosystem services are seen as an opportunity for economic development, particularly in rural- and natural resource-based communities (Pagiola et al. 2005; Tallis et al. 2008; Swallow et al. 2009). Ecosystem services valuation is a first step towards creating markets that could provide those payments, and in understanding the economic and environmental systems within which these payments would operate.

In addition, researchers have called for work to make the concepts of ecosystem services and the indicators used to assess them more standardized (Layke 2009). The hope is that this work would aid policy makers in using ecosystem services in their decision making. This project both helps decision makers within Trinity County understand what data and indicators are available locally because it assesses ecosystem services at a countywide level. This project also provides a model for ecosystem services valuation elsewhere.

Research Questions

- What is the ecological and economic framework within which ecosystem goods and services exist in Trinity County?
- What are the values of ecosystem goods and services in Trinity County?
- Who pays to ensure ecosystem functions in Trinity County?

Trinity County

This project examines ecosystem services in Trinity County because of its historically natural resources-based economy, the composition of institutions in Trinity County that provide data relevant to valuation, and the interest of local organizations and residents in ecosystem services valuation.

Three-fourths of Trinity County's 2,052,980 acres are federally owned: 71% are managed by the Forest Service, 4% by the Bureau of Land Management, and 1% by the Bureau of Reclamation (The Sierra Institute 2002: 3). This composition should allow more access to information about the outputs of this ecosystem compared with counties that are dominated by private landownership. Data are collected about water, forest cover, and other aspects of the ecosystem by public entities and these data are publicly available.

In addition to being publicly managed, the resources and institutions in Trinity County together form an instructive set for ecosystem services valuation. Trinity County has federal agencies, community based organizations, and county government all interacting to manage its natural resource base. The county also has a wide variety of the ecosystem goods and services types that are often discussed in the ecosystem services

valuation literature, such as cultural, provisioning, supporting, and regulating services (Layke 2009). This broad scope of services and availability of data make Trinity County a practical place to study ecosystem services valuation.

The county's economy is also largely based on its natural resources, especially natural resources extracted on public land. Since the 1950s, Trinity County's largest legal cash crop has been timber (The Sierra Institute 2002: 3). Both the amount of timber harvested and the value of that timber have decreased significantly due to the restrictions of the Northwest Forest Plan, mechanization and consolidation of mills, global competition, and a degraded land base (The Sierra Institute 2002: 3). Some of the economic base has shifted to recreation and tourism. In addition, local wood processing and valued-added wood products are seen as increasingly important sectors of the local economy. However, because of the drops in timber harvest and prices, residents of the county are looking to other sources to diversify their economy. Markets for ecosystem services could provide an opportunity to diversify the county's economic base while maintaining its natural resources. Local organizations and residents are interested in learning more about these markets.

Understanding the value of the ecosystem services in the county also provides residents and organizations with a more complete picture of the economic flows in and out of the county. The benefits the ecosystem provides do not go to only one entity and identifying these benefits comprehensively is not straightforward. In addition, numerous public, private, and non-profit organizations work to restore, improve, and protect ecosystem functions. These inputs are also not comprehensively understood or described.

Valuing ecosystem services in the county provides another large-scale perspective on a fundamental but little-understood aspect of the local economy.

CHAPTER II

LITERATURE REVIEW

Definition of Ecosystem Services

The literature contains extensive discussion as to the definition of ecosystem services and functions. Often they are described as “naturally occurring goods and services” (Brown et al. 2007: 334), which some researchers understand to mean services produced with no human input (Brown et al. 2007: 337), or “those that exist without human action” (Brown et al. 2007: 334). This definition excludes agriculture, which is included in the Millennium Ecosystem Assessments (Capistrano 2005). In addition, this definition takes a rather simplistic view of ecosystems, which are maintained through labor inputs including management, restoration, and protection through regulation. Human input cannot be a characteristic that excludes a service from the category of ecosystem services because it would exclude nearly all goods and services. Other definitions, such as that of the Millennium Ecosystem Assessment, suggest that goods and services without human benefit should be included (Millennium Ecosystem Assessment 2003: 53). Other definitions limit ecosystem goods and services to those that are renewable; as a result, forests are considered an ecosystem good only if they are managed sustainably (de Groot et al. 2002: 397). Ecosystem services are different from other natural resource goods because they have both economic impact and social benefit.

The Importance of Ecosystem Services Valuation

Determining the economic value of ecosystem services provides additional information and rationales for protection and management of ecosystems. Ecosystem services valuation recognizes that these ecosystems have value even though the price of these goods and services has often been unvalued, or valued at zero. Enumerating this value is useful to both public and private landowners. While it would be easy to dismiss this value as infinite because all goods ultimately come from ecosystems, society relates to many systems through their economic values and so capturing the economic value of the ecosystem is important. In addition, while total value of an ecosystem can be very large, the marginal value, which determines how participants are paid, can be small. Understanding the relationship between total value and marginal value is an important aspect of ecosystem services valuation.

Ecosystem services valuations are carried out for several reasons. Some valuations are done "to show that natural systems are indisputably linked to human welfare, even when they are priced at zero" (Pritchard et al. 2000: 36). In these valuations "the focus is not on a single number that describes the worth of an ecosystem but on the myriad ways in which human systems and natural systems influence and undergird one another" (Pritchard et al. 2000: 36). This ensures that nature is represented in decision making processes and notes "that its role in the economy is not merely aesthetic" (Pritchard et al. 2000: 36). Other valuations try to prioritize land use and ecosystem types (Pritchard et al. 2000: 36). This information is used as additional support for ecological reasons to protect particular land use and ecosystem types. Finally, some valuations are

used "to justify or critique a particular decision in a particular place" (Pritchard et al. 2000: 37). While this type of rationale for ecosystem services valuation can be problematic due to measurement issues, it can also be used conjunction with other decision-making tools to target and prioritize natural resource management.

There is a government role for ecosystem services valuation. To avoid the underproduction of these ecosystem services, often considered public goods, "governments generally take on the responsibility for producing public goods on behalf of society with public financing through taxation" (Kline 2007: 4). Valuing ecosystem services enumerates the extent of public goods, which can help avoiding the tragedy of the commons (Hardin 1968). These economic justifications are often called for by policymakers: "With limited budgets and demands for fiscal accountability, policy makers and managers often must describe economic rationales for their decisions to justify public expenditures and programs, weigh public preferences and support, and compare the benefits of different policy and management alternatives" (Kline 2007: 1). Ecosystem services valuation is one approach to articulating these economic rationales.

There are other conceivable roles for government in ecosystem services valuation as well. Through policies and incentives encouraging ecosystem services provision on private lands, government can work to encourage both the concept and the services themselves (Kline 2007: 4). Increasingly, ecosystem services are being looked to by the Forest Service and other federal agencies as a useful approach for management (Collins and Larry 2007: 9)

In addition, as natural resource dependent communities (especially those dominated by federal land) seek economic activities not dependent on extraction, markets for ecosystem services may provide a non-extractive economic base. Currently, those who benefit from the ecosystem services provided by the forest ecosystem in Trinity County do not pay for their upkeep. Changing this balance could be an opportunity for the economic development of Trinity County and could help address long-term equity issues necessary for sustainable local development.

Also, monitoring these services and functions could provide jobs that employ some or all of the skills of the local workforce, who are knowledgeable about the ecology, management, and functions of the forest ecosystem (Gutman 2007). Each market for ecosystem services will have particular rules for valuing these services (such as methods to determine baseline conditions and additionality standards). This study cannot provide an exact analysis of how much money could be made through these potential markets. This study also does not employ the methodologies these potential markets may employ, both because many of these markets do not exist yet and because these methodologies for evaluating these services have not been established. However, determining the magnitude of ecosystem services and comparing this magnitude to values in proposed and existing ecosystem services markets could inform the potential viability of ecosystem services markets as a engine for economic development.

In addition, some have suggested that ecosystem services markets could provide both income for residents of natural resource dependent communities and a revenue source for rural governments. Historically, the federal government has provided

payments to counties in compensation for non-taxable federal lands. These payments were tied to commodity production, such as timber, on federal land. As timber sales decreased, these payments decreased, and increasingly counties looked to other types of contracting and other sources for county income. The payments were separated from commodity production through the Secure Rural Schools Act and the Payments in Lieu of Taxes program. The topic of whether and how federal land should participate in markets for ecosystem services is controversial. However, if federal land participated in markets for ecosystem services, there could be opportunities to create new systems of payments to counties. These systems could be based on the valuation or the provision of ecosystem services.

Currently, many payments for ecosystems are payments for practices that protect function, rather than for changes in environmental quality as measured by environmental goods or services. Landowners are paid for land that is not farmed and is put into riparian or other land uses through the Conservation Reserve Program. The federal government gives money to create fish habitat, rather than for the increase in fish population. Payments for ecosystem services, rather than payments for ecosystem structure or function, are a fundamentally different approach to conservation (Palmer and Filoso 2009). Payments for ecosystem services focus on outcomes not means, which is why it so important that many ecosystem goods and services are examined (and maintained) simultaneously through bundled payments, best practices requirements, or payments for one good dependent on maintenance of other goods and services. These approaches would allow ecological functions to be maintained.

Finally, ecosystem services valuation is not simply a method for creating new ways of paying for ecosystem maintenance. Valuing ecosystem services can also map who is currently maintaining ecosystems and who is benefiting from that maintenance. Ecosystems services valuation can act as a large-scale benefit cost analysis for agencies and other organizations that are working to maintain and improve ecosystem structures and functions.

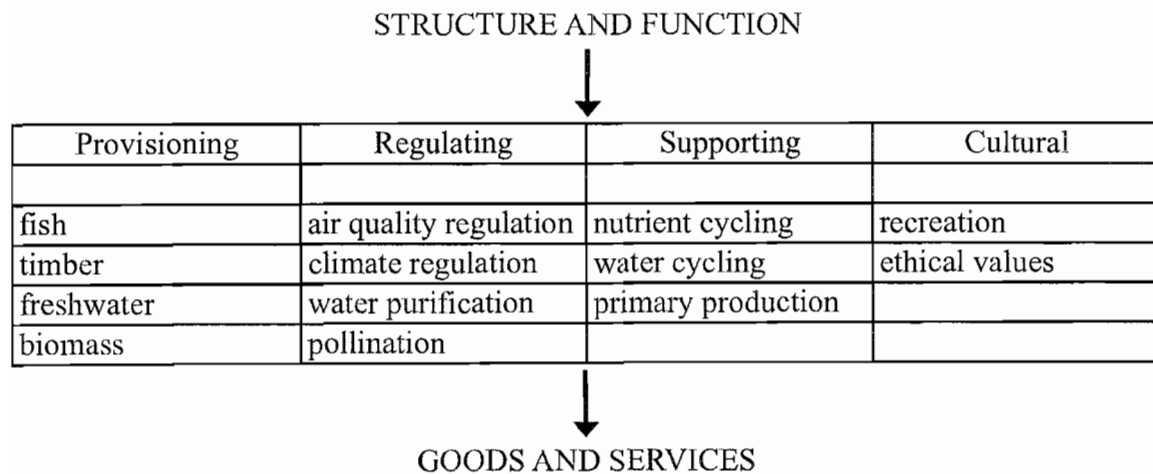
Ecosystem Services Types

Early discussions of ecosystem services examined the concept quite broadly, and discussed ecosystem services and functions as one idea (Daily 1997: 3). Increasingly other researchers have examined ecosystem goods and services separately from ecosystem structure and functions (Brown et al. 2007). Ecosystem functions describe the capacity of an ecosystem (Ansink et al. 2008: 490). Ecosystem services are the benefits that the capacity produces (Ansink et al. 2008: 490). One way to understand the services and functions of ecosystems is to think of ecosystem function as the stock of natural capital, while ecosystem services are the flows produced by that stock (Ansink et al. 2008: 495).

The literature often categorizes ecosystem services and functions into different types. One system discussed in a variety of research (Capistrano et al. 2005; Chan et al. 2006; Brown et al. 2007; Layke 2009) classifies goods and services as provisioning, regulating, cultural, or supporting. Provisioning goods and services are obtained directly from ecosystems, such as fish or timber. Regulating services are benefits obtained from an ecosystem's control of natural processes, such as air quality and pollination. Cultural

services are nonmaterial benefits obtained from ecosystems, such as recreation and spiritual value. Supporting services are the natural processes that maintain other services, such as nutrient cycling and primary production (Layke 2009: 1, 6-7). Thus far, society has generally put more value on provisioning services than other types of services. In the context of the goods and functions classification, provisioning and cultural services are generally considered goods, while supporting and regulating services are generally considered functions.

Figure 1: Classification of Ecosystem Goods and Services



Source: Layke 2009

Valuing Particular Goods and Services

Some goods and services have observable values because they are traded directly or indirectly in markets. For example, timber (measured in board feet) has a price in the market, though this price does not necessarily also reflect the values of erosion control, carbon sequestration, and habitat that many be lost when trees are removed from the

ecosystem due to timber harvest. The price of timber may not account for the services that are lost due to logging.

Due to undefined property rights or property rights attributed to the public at large, many valuable services are not traded directly or indirectly through markets (Brander et al. 2006: 227). There are several methods of valuation frequently used to determine the indirect use and passive use values of ecosystem services. These include household revealed preference methods (including travel cost and hedonic pricing methods), stated preference methods (like contingent valuation), production function methods, and replacement cost methods (Brown et al. 2007: 346). These other valuation methods try to correct for the problems inherent in how we value ecosystems. They recognize the externalities ignored in the current market, overestimating producer surplus because other costs are ignored (Brander et al. 2006: 229).

- Travel cost methods estimate demand (through willingness to pay) using the travel costs required to visit a site (Brander et al. 2006: 228). This method is can be used to indicate the value of recreation.
- The contingent valuation method uses hypothetical questions to obtain actors' willingness to pay (Brander et al. 2006: 228). This method is can be used to indicate the value of biodiversity and water quality improvements.
- Hedonic pricing estimates willingness to pay using price differentials and characteristics of related products (Brander et al. 2006: 228). This method can be used to indicate the amenity value of an area.
- Replacement costs estimate how much it would cost to substitute a service,

often using manmade structures instead (Heal 2000: 27). For example, this method can be used to indicate the value of the function of water purification by estimating the cost of building a water filtration plant to replace the ecosystem function that purifies the water.

There are difficulties associated with each valuation method. Replacement cost, opportunity cost, and market prices "do not have a sound basis in welfare theory and may be expected to over- or underestimate values" (Brander et al. 2006: 229). The travel cost method has limited abilities to deal with marginal prices; the good or service exists or it does not, otherwise someone would not travel there (Heal 2000: 28). However, hedonic cost methods are able to address marginal values. Contingent valuation is not actually based on transactions, unlike other methods. Instead, contingent valuation is a survey methodology (Heal 2000: 28). This method often requires participants to imagine what they would pay or spend, which can be inaccurate. About travel cost and contingent valuation methods, Kline points out that "these methods can be expensive and require specialized expertise to implement. Such demands often place benefits valuation beyond the reach of public agencies for routine policy and management decisions." (Kline 2007: 13). Using methods that do not require extensive research may be a useful goal for ecosystem services valuation methodologies. Values of ecosystem services also change over time. Monitoring these changes requires extensive research to avoid inaccurate valuation (Kline 2007: 13).

Replacement cost methods often only measure the replacement of one of the ecosystem services provided by the ecosystem, not all of them (Heal 2000: 27). Brander

points out that the replacement cost "approach is based on the assumption that if individuals incur costs to replace ecosystem functions, then the lost services must be worth at least what people are willing to pay to replace them" (Brander et al. 2006: 230). Brander suggests this method is flawed because "replacement costs are not based on social preferences for ecosystem services, or individuals' behavior in the absence of those services, and are unlikely to approximate consumer and producer surpluses." (Brander et al. 2006: 230).

While most valuations of ecosystem services that employ these methods have been performed since the late 1990s, the origins of these methods stem from methods developed much earlier in economics and environmental economics. Hotelling's work valuing parks using the travel cost method is frequently used as part of recent valuations of ecosystem services (1949). Krutilla did work on willingness to pay for existence value of natural wonders, which he suggested advocated good government stewardship of land (1967). Methods that value goods that are not in the market were proposed (Costanza et al. 2006: 63): travel cost (Hotelling 1949), contingent valuation (Davis 1963), and hedonic pricing (Ridker and Henning 1967). The management motivations for ecosystem services valuation also have origins in multi-use management, which historically has been an important approach to managing public forest lands (Bowes and Krutilla 1989).

The value of ecosystem services is determined by using data-based indicators. Layke (2009) extensively reviews the indicators available for ecosystem services and points out that "up to now most indicators used for ecosystem services have been adopted from narrower environmental fields such as biodiversity, ecology, and climatology, and

from economic sectors such as agriculture, forestry, and fisheries" (Layke 2009: 4). While these existing indicators are a "necessary starting point," they "should be seen as an interim strategy" because they often measure other things besides the service itself (Layke 2009: 4). This characterization accurately describes the indicators used in this study to value ecosystem services in Trinity County as well; the data were collected for other purposes and the units and measurements were chosen to achieve those ends. In time, more appropriate indicators need to be developed and data should be collected to describe ecosystem functions and services in particular. Layke also points out that particularly for sub-global ecosystem services valuations, "the topics covered appeared to be shaped by the data available to the authors from national statistic accounts and other locally accessible data compilations" (Layke 2009: 3). This focus is understandable, since most current day valuations, including this one, work from existing data.

Valuing and Pricing

According to economists, natural ecosystems are assets that produce a flow of goods and services over time, like any other asset in an economy (Barbier 2006: 4). Barbier points out that whether or not a market exists for ecosystem goods and services, their social value equals the discounted net present value of the flow of goods and services (Barbier 2006: 4). If B_t is the social benefits from ecosystem services in any time period t , then the social value of these flows is shown in Equation 1, where r is the social rate of discount.

Equation 1: Social Value of Flows

$$V_0 = \sum_t \frac{B_t}{(1+r)^t}$$

Barbier suggests that B_t can be measured by the aggregate willingness to pay by the individuals who benefit in each period (Barbier 2006: 5). These individuals are usually ignorant of the costs of maintaining what they are paying for, or unaware of the origin of that good or service. Additionally, because sometimes there are no substitutes for that environmental good or service, aggregate willingness to pay can be a problematic measure of value. Barbier points out that “the benefits arising from the regulatory and habitat functions of natural ecosystems generally are not [marketed]. If the aggregate willingness to pay for these benefits, B_t , is not revealed through market outcomes, then efficient management of such ecosystem services requires explicit methods to measure this social value” (Barbier 2006: 5). Additionally, Barbier points out that many ecosystem assets and services are nonrenewable resources with renewable service flows. This means that if managed, the flows can be used at a sustainable rate. However, while the asset can decrease (through land degradation, land use conversion, etc.) it cannot increase.

Heal points out that while valuation of ecosystem services through development of market prices or deriving price from other market transactions would be ideal, “there are relatively few cases in which this can be done” (2000: 28). When this is possible, these prices may “not reflect the social importance of the services or the extent of the losses that we would suffer if these services were removed” (Heal 2000: 28).

That valuation exists should not suggest that it is always an accurate reporting of societal need. Services are valued more when they are rare. Distribution of income also affects demand and prices for goods and services (Heal 2000: 25). The market price of a good reflects the value of having slightly more or less of a good, not losing the good entirely (Heal 2000: 25). However, many decisions made about environmental goods and services do not have small impacts on a good or service, they have large impacts. Market prices do not reflect this risk very well. Still, market prices for ecosystem goods and services “provide an obvious basis for valuing them” (Heal 2000: 25).

Similarly, decisions that are made that effectively protect or improve ecosystem services can have a negative effect on prices. Because value and scarcity are inversely related, when these principles are applied to conservation, “species recovery and relative abundance can paradoxically result in reduced support for conservation” (Vira and Adams 2009: 160).

Valuing Ecosystem Services Comprehensively: Approaches and Scales

Decision-making about framing ecosystem services valuations has important outcomes for the valuations. Choices about what goods and services to include affect the total value of the ecosystem. These choices are made based on data availability and accuracy, but are also based on what is relevant to that ecosystem, economy, and society.

There are two key dimensions to different types of ecosystem services valuation: scale and method. The value of ecosystem services is can be calculated for ecosystem types at the parcel level (Kaufman and Dayton 1997), or they can be calculated at a larger ecological or geographic scales (Wilcox and Harte 1997; Capistrano 2005; Costanza et al.

2006). The scale at which valuations are done affects the outcomes of those valuations due to data availability, data accuracy, and other factors. Because of the measurement difficulties inherent at working at a larger scale, large-scale studies often are enumerations of services rather than quantitative valuations. There are practical difficulties with valuation of ecosystem services at a broad scale (Costanza et al. 1997). For example, when ecosystem services are valued at a very large scale, changes in land use are often not accounted for (Nelson et al. 2009: 4). But more local assessments, which tend to examine one service in a small area, limit comprehensive understanding of resource flows in a region. "Although these [small scale] methods are superior to the habitat assessment benefits transfer approach, these studies lack both the scope (number of services) and the scale (geographic and temporal) to be relevant for most policy questions" (Nelson et al. 2009: 4).

To create valuations that are useful for policy questions, it is helpful to examine ecosystem services at a more comprehensive scope and scale than a single parcel. Examining ecosystem services at a larger scale allows better understanding of the inputs into and flows out from an area. This information improves knowledge of the area's regional economics. Understanding who pays what prices for the outputs of a region's ecosystem and who pays money to protect the sources of those outputs reveals a more thorough understanding of those outputs. "Site-specific case studies... can be used to translate the abstract information embodied in more general studies of ecosystem services into tangible and convincing terms that show how ecosystem services affect human economies" (Wilcox and Harte 1997: 311). While site-specific case studies demonstrating

the effects of ecosystem services on human economies have been identified as useful, few have been done quantitatively. This analysis of Trinity County seeks to fill this hole in the literature. In analyzing ecosystem goods and services at the county level, this analysis seeks to match data availability and spending and decision making power.

The methods that are used to combine valuations of particular goods, services, and functions are also important. Benefit or value transfer is the method of adapting other ecosystem service valuation studies to areas that have limited or no data on ecosystem services valuation. These studies have been conducted on similar goods and services in similar locations. This method can be problematic because these studies were often not designed for application to other locations. Often these studies are simply illustrative new methods, and rarely are results verified through repetition. However, benefits transfer is often seen as the only option available because primary research would be too time consuming or costly (Costanza et al. 2006: 74). To improve the ability to compare and compile value transfer studies, the Environmental Valuation Reference Inventory was developed by Environment Canada, the U.S. Environmental Protection Agency, and others (McComb et al. 2006). This inventory aggregates many studies of ecosystem services for use in value transfer.

One approach to ecosystem services valuation is to understand the social benefit by applying a value to land type and then estimating the amount of that land type in the study area, often using GIS. Usually, a value of ecosystem goods and services is associated with a land use type on a per acre basis. The acreage of land in each land use type is determined using GIS, and the value of ecosystem goods and services on that land

is calculated. GIS analyses also rely on benefit transfer, but are able to address issues related to scale with more facility. GIS analysis allows researchers to examine services at a variety of scales relevant to policy- and decision-making. This land use analysis is not the approach this study takes. This study looks at the known impact that the ecosystem has on the economy of Trinity County. This impact serves as a lower bound to the value of ecosystem services in Trinity County.

Other examinations of ecosystem goods and services focus on assessing these ecosystems rather than valuing them. One example of this approach is the subglobal assessments in the Millennium Ecosystem Assessment, which focuses on the state of the global ecosystem rather than its value. This allows a more qualitative analysis, and also allows more focus on describing ecosystems rather than assigning economic values (Capistrano 2005).

Some ecosystem services valuations also examine an ecosystem in terms of its capacity to supply services now and in the future. These flows are valued, which reflects “the value of the ecosystem based on current and expected future flows of services” (Ansink et al. 2008: 495). This study’s valuation focuses on current values for these flows, not future markets or future flows.

Economic Impact Versus Social Benefit

Activities can have both local economic impact and broader social benefit. While economists tend to maximize social benefit, local communities care more about the economic impact to that community. Phrased differently, economists seek to maximize overall consumer surplus, while local communities seek to maximize the consumer

surplus within a community. Economic models recognize the equivalency of substitutes of environmental goods, while local communities see economic benefit not from a broad societal perspective that sees all benefits to individuals as equal, but instead sees economic benefit as place-based. This fundamental difference suggests the need to evaluate local economic impact separately from social benefit. Researchers should choose which valuation to focus on depending on the goal of the analysis. Social benefits of environmental goods benefit many more people than local economic impacts. Understanding the broader social benefits of environmental goods is important to understanding their value to society. Spending on ecosystem function maintenance and restoration is usually local and place based, while the social benefits of that restoration benefit a broader, sometimes global community. Assessing the social benefit of both sides of this equation would overlook questions about the balance of who is paying for these improvements to ecological function.

Other Inputs to the Model

Ecosystem functions are not the only elements that create ecosystem goods and services. Many other factors, such as societal demand and societal choices external to the ecosystems are also important. Communities choose to maintain particular ecosystem functions because they provide products for society (ecosystem services). In fact, ecosystem services can be described as ecosystem functions that have societal demand (Chan et al. 2006; Ansink et al. 2008). However, communities also take many actions that impact the landscape for other reasons, such as to ensure societal function, but do not necessarily improve ecological function.

In addition, spending money on ecosystem function does not create particular ecosystem services. There are many other non-ecological inputs to maintain some of these services. To attribute too much of the value of these services to the money spent on ensuring ecological function that provides those services is incorrect. To continue to use Ansink et al.'s description of ecosystem structure and function as natural capital, other kinds of capital like human capital also contribute to creating ecosystem services (2008). Some researchers minimize this contribution, asserting that "production of ecosystem goods and services requires no inputs of built capital, except in the sense that in today's complex world ecosystem processes are often damaged by human endeavors and are left to do their work relatively unimpeded by human enterprise only through conscious decisions to protect the ecosystem" (Brown et al. 2007: 337). However, this definition minimizes the human capital of various types such as such as environmental restoration, laws, and enforcement along with regular management.

For example, water catchment yields from forests depend on a wide variety of ecological factors such as rainfall amount, stand structure, and rainfall seasonality. In addition to these factors, the value of the water caught by forests is not only determined by their ecological function (Vira and Adams 2009: 159). As Vira and Adams describe, "if any change in these factors (e.g., pollution, dam construction, channelization) affects the value of water to downstream users, the conservation case for forest preservation is undermined, without any change in the characteristics of the forest itself. The provision of water services from an upstream forested catchment might support the case for

conservation of the natural capital in the biodiversity of the forest, but only if these services are actually delivered to the downstream end user" (2009: 159).

While assessing the full value of these human capital inputs to ensure ecosystem function would be difficult, some of this value can be assessed through examining the budgets of governmental and non-governmental organizations. While it is impossible to directly connect the actions of these entities to improve ecosystem function with the services created, their goal is the creation of ecosystem services. Similarly to determining the value of a place based on how much someone would pay to travel there (travel cost method), the value of a function can at least partially determined by the amount someone will pay to preserve or restore that function.

In addition, work to enhance ecosystem function often has long-term benefits. The current amount of a good or service results not just from disturbances to the system, such as restoration, but historical work as well. For this reason, the value of the ecosystem services enhanced by these efforts to improve ecosystem function should be examined over the course of many years. Along with long-term benefits, efforts to improve one area of ecosystem function often have effects on many different services. These effects emphasize the importance of an integrated ecosystem services approach.

Other Valuations of Ecosystem Services

In addition to reviewing the literature that addresses methods and types of ecosystem services valuation, this chapter also reviews the literature of other valuations themselves.

The term ecosystem services, first used by Ehrlich and Ehrlich in (1981), was “an attempt to build a common language for discussing linked ecological and economic systems” (Costanza et al. 2006: 68). The term is useful for synthesizing economic and ecological concepts and for evaluating tradeoffs in landscape and conservation policy decision-making (Costanza et al. 2006: 68).

An early valuation, which both legitimized the concept of valuing nature and created the largest scale estimate of the value of ecosystem services, was Robert Costanza’s valuation of global ecosystem services (Costanza et al. 1997). That study found the value of global ecosystem services (marketed and non-marketed) to be \$33 trillion, using a meta-analysis approach. The average total value of 17 services in 16 biomes was examined, and then the world’s land cover of that biome was multiplied by that average value. This value was twice the value of the world’s gross domestic product at that time.

Nature’s Services was the first book written on ecosystem services and it examined their characteristics and implications (Daily 1997). Although most chapters focused on characteristics of the concept, one chapter in this book examined the ecosystem services in Gunnison County, Colorado. While this study did not carry out a cost-benefit analysis of environmental protection versus development, it described the importance of ecosystem services to the local public lands-dominated economy (Wilcox and Harte 1997).

Between 2001 and 2005, 1,360 researchers carried out the Millennium Ecosystem Assessment, which was called for by the United Nations. It examined the state of both the

global ecosystem and sub-global ecosystems using studies that had already been carried out (a meta-analytic approach). While this study did not value these ecosystems, it enumerated their services and assessed their state of health (Capistrano 2005). The degradation of these services was determined to be a barrier to achieving the Millennium Development Goals. The study also found that there are significant, problematic gaps in knowledge about ecosystem services at the local and national scale.

In 2006 researchers estimated the value of ecosystem services of the state of New Jersey (Liu et al. 2010). They used a spatially explicit benefit transfer approach, evaluating twelve ecosystem services types across eleven land use/land cover categories by using other studies that determined the value of the ecosystem services. The study found that the value of ecosystem services in New Jersey was somewhere between \$11.6 and \$19.6 billion per year.

The studies that value ecosystem services across a spatial scale all rely on benefits transfer. These studies do not rely on primary research. Most of these studies that they are transferring from are usually investigating one service at a time. These studies tend to discuss the social benefits, the benefits to broader society, of ecosystem goods and services. While social benefit is important, these studies often do not address the economic impact to the local community.

There are also examples of very research that examine the value of ecosystem services related to a particular species, not a place or ecosystem. Martin and Blossey refuted research that the high value of habitat provision that the aquatic invasive plant *Phragmites* provides was sufficient to avoid management for eradication (2008). Martin

and Blossey suggest that any ecosystem service must be considered within the broader framework of other ecosystem services. While their point that the high value of an individual ecosystem service does not matter if other ecosystem services are so low as to render the ecosystem dysfunctional is very relevant to the current emphasis on carbon markets, this single species scale differs significantly from this study.

Ecosystem services valuation has also been used by the government through cost benefit analysis and, more narrowly, in Natural Resource Benefit Analysis after hazardous substance or oil releases (Costanza et al. 2006: 72). These processes have relied on many methods and concepts also used in academic ecosystem services valuations, such as contingent valuation and passive use value.

Inherent Limitations of Ecosystem Services Valuation

Researchers recognize numerous limitations to ecosystem services valuations and these valuations are often couched with significant caveats. As Brown et al. suggest, "a focus on ecosystem services may turn out, through hubris or ignorance, to have been shortsighted, but, on the other hand, this focus is a vast improvement over business as usual and provides an opening for an even greater consideration of ecosystem processes as our understanding of the natural world improves" (Brown et al. 2007: 332).

Many criticize ecosystem services valuation for being immoral, because it seeks to quantify something invaluable, and inaccurate (Heal 2000). However, many people including Costanza (1997) argue that valuation is inevitable:

"Although ecosystem valuation is certainly difficult and fraught with uncertainties, one choice we do not have is whether or not to do it. Rather, the decisions we make as a society about ecosystems imply valuations (although not necessarily expressed in monetary terms). We can choose to make these valuations explicit or not; we can do them with an explicit acknowledgement of the huge uncertainties involved or not; but as long as we are forced to make choices, we are going through the process of valuation" (Costanza et al. 1997: 255).

Services can be undervalued because valuations disregard social importance, oversimplify, are based on inaccurate data, or they give undue weight to one decision-making mechanism. These criticisms are important to keep in mind when undertaking valuation projects. In theory, services can also be overvalued. This overvaluation can happen in two ways. The first is that the information the price is based on could be inaccurate, or for some other information-based reason could be inflated. The second reason is more abstract. Estimates of social benefit are not overvaluations, but sometimes these value estimates do not have practical utility in the local market. For example, while the climate regulation service that forests provides has value through carbon credits, there are geographic, knowledge-based, legal, and other barriers to entry into the markets that provide payments for this service. Examining non-local values for carbon credits might suggest that the value of that service in Trinity County is quite high, Trinity County might not be able to participate because it is not local to the market organization, Trinity County's public land cannot currently participate, or people in Trinity County have used different methodologies to evaluate the amount of climate regulation taking place on the land.

While economic markets value ecosystem services inaccurately or not at all, there are also problems with the accuracy of ecosystem services valuation. When ecosystem

services are not valued, most of the time they will be undervalued or their values will be set at zero, but the valuation could also simply be uneven. Some services are valued, while others are not. Often, which services are valued reflects the priorities of either the local or more often the broader national or global society. Non-uniform valuation is also a problem, where different methods unintentionally give different weights to different services, suggesting that some services are more valuable than others. Uneven and non-uniform values are fair criticisms of valuations of ecosystem services, and this study (which does not value many ecosystem services, and uses different methods to value each service) definitely leaves out many services.

Most assessments of ecosystem services have simplifying assumptions. Some assessments recognize these assumptions as limitations. Still, some researchers believe that these assumptions are too substantial for the assessments to be functional. Pritchard et al. (2000) identified the myth of objectivity, the belief in commensurability, and a normative premise as the most difficult assumptions inherent in valuations of ecosystem services. The myth of objectivity suggests that a set of correct values exists that should be used to make decisions (Pritchard et al. 2000: 37). This assumption takes different forms for ecologists and economists, but both make this assumption. Economists think that people have measurable, unexpressed preferences between different states of nature. Ecologists assume that nature can be judged using scientific measures of ecosystem function, which are somehow intrinsic. Both economists and ecologists also believe in commensurability; they believe that things can be valued using either money or energy. Finally they also have a normative premise that ecosystem services should be valued in a

prescribed way (either by individuals in a market or by an expert on behalf of the system)(Pritchard et al. 2000: 37).

This project recognizes that objectivity cannot be achieved, but instead tries to use values most relevant to Trinity County. These include both valuing economic impact and indirect methods of valuation. This project emphasizes that while resources are not exchangeable, decisions still need to be made about how to use scarce resources to maintain ecosystem function. Valuation provides some way to compare carbon storage in forests to the forests' recreational value to their board foot value as timber. Monetary value provides a single measuring stick.

Along with simplifying assumptions, each measurement in an ecosystem services valuation has a degree of inaccuracy. These arise both because valuing methods have flaws and because valuing methods are inaccurate. Some researchers find these inaccuracies too problematic to give the valuation any merit (Ludwig 2000). However, some researchers believe while recognition of these flaws is important, it is still worthwhile to undertake ecosystem services valuation. Brown et al. point out that "monetary estimates of the values of ecosystem goods or services, even if inexact, may be far better than a complete lack of such estimates, especially if the direction of the error in estimation- whether the value estimate is taken to be a lower bound or an upper bound of the actual value, for example- is known" (Brown et al. 2007: 344). Most important is that these valuations are transparent and their methods, even when problematic, are subject to examination.

Just as human systems are not static, some researchers claim that ecosystem services valuations do not recognize the complex and dynamic nature of natural systems. This study tries to place these values within an ecological context; however, this criticism is still relevant. Ecology is the study of connectedness, so suggesting that there are simple mechanisms that can describe trade-offs between goods makes no sense (Pritchard et al. 2000). Flexible systems frameworks, such as the one used in this study, allow new relationships, functions, goods, and services to be added to the model. Other types of ecosystem services valuations may suggest that some dollar value can substitute for these systems, by using concepts like willingness to pay and tradeoffs at the margins: "currently used modes of valuing ecosystem services do not take into account the inherent complexities and resulting uncertainties associated with dynamics of these coupled systems of people and nature" (Pritchard et al. 2000: 36). However, understanding these tradeoffs at the margins, and putting them into economic terms, can help make the valuation more accurate. Doing so acknowledges an important point made by Pritchard et al.: "in a world of human dominance, complex systems, and true uncertainty, it becomes increasingly difficult to assume that there will be only negligible feedbacks of marginal change" (Pritchard et al. 2000: 38). Recognizing this complexity and these feedbacks is difficult. As a field, ecological economics has sought to recognize that substitutability of natural systems is imperfect. Ecosystem services valuation seeks to make models of this feedback that are more dynamic and reflective of complex realities. While ecosystem services valuation is not perfect, it is a useful tool.

Others point out that ecosystem services valuation is difficult because unlike other goods that participate in markets, many ecosystem goods and services are not excludable. One person's use of a good does not limit another person's use of the good. In addition, many ecosystem goods and services do not have clear property rights associated with them (Fisher et al. 2008).

Limitations to the Application of Ecosystem Services Valuation

Another objection to ecosystem services valuations concerns how they are used. Some of this fear is broad: "the danger is that hasty and uncritical adopters of new paradigms overload them with hope, leading to disillusionment and premature abandonment" (Vira and Adams 2009: 158). Other aspects of this fear are more specific and pointed; researchers believe ecosystem services valuation can be misused to promote certain uses by inflating their value. This criticism can be directed at non-quantitative approaches to valuation as well.

Similarly to the objection that ecosystem services valuation puts too much emphasis on economic bases for decision making over ethical, ecological, or other bases, some researchers suggest that ecosystem services valuation views preferences too narrowly. They point out that economic preferences arise in the context of other institutions. These institutions create context within which "the commodification of nature, and of political space, are not found to be as inevitable as previously thought by economists" (Pritchard et al. 2000: 39). These institutions are also constantly evolving, thus changing preferences and values (Pritchard et al. 2000: 39). Valuations are a snapshot in time. To suggest that human preferences are static, or even to suggest that the

bases of human decision-making are static (or centered around economics) is inaccurate. That said, ecosystem services valuation attempts to provide pragmatic opportunities for policymaking while still pushing the traditional boundaries and conceptions of valuation and economics.

Ecosystem services valuation is criticized because it puts emphasis on economic value. Ludwig (2000) argues that personal and social values matter more than economic values in decision making. While many of the same types of appeals to values and authority are made at the national scale as at the individual level, some argue that the economic costs and benefits of ecosystems have not yet been included in decision making because they have not been valued. Kline points out that valuation of ecosystem services can result in poor decision making: “it is easy for benefits information to be misused in ways that undermine public support for natural resource decisions” (2007: 2). Again, however, all types of information can be misused.

While social and personal values have not always been translated into institutional values that are relevant to policy, ecosystem services valuation is an attempt to make personal and social values related to ecosystems applicable in an institutional setting. Currently, making them applicable in an institutional setting means assigning them an economic value. These economic valuations also make explicit the economic tradeoffs inherent in decisions. One limitation of non-economic value based decision-making is that it sometimes lacks a context for compromise. While participants may disagree with the economic values assigned to different services, they at least provide a starting point for comparison and discussions. Tradeoffs are necessary in most natural resource

decision making, so beginning those discussions is important.

All of these limitations to the use of valuation of ecosystem services show that economic valuation of ecosystem services cannot be the only basis for management decisions. Most broadly, decision-making should also consider equity, sustainability, and other factors. In addition, the limits, thresholds, and other characteristics of these natural systems must be well understood if their value or their management is going to be subject to their value in a market. Once ecosystem function had degraded to a particular level, it cannot recover, no matter how high the demand for it. Pritchard et al. point out, "the presence of threshold effects and irreversibilities in life-support systems is a warning against relying solely on consumer preferences as the basis for value" (2000: 38). However, economic valuation adds an important additional basis for decision-making.

Specific Limitations to the Trinity County Model

This analysis is not intended as a suggestion for management of particular good or service over another. Nor does this study suggest that inputs and outputs should be equal, or inputs to the system should be completely paid for by those who benefit. Particular benefit cost ratios are not inherently better than others, nor should ecosystem services values be the only motivator in management decisions. This model is intended to reveal in a comprehensive way where value is being put into the system, what benefits come from the system, and who is accruing the value of those benefits.

"Linking those metrics to forest policy and management actions, disturbances (for example, fire, forest-land development), and other factors whose effects forest policy makers and managers would like researchers to examine, is another challenge altogether. In evaluating forest benefits, economists generally have focused on estimating values for specific benefits. They largely have sought information from ecologists and other biophysical scientists that describes ecosystem attributes and how they change over time in response to forest policy and management actions- what many economics sometimes call ecosystem "production functions." Although both types of information are useful in evaluating ecosystem services, those production relationships are absolutely critical but all too frequently lacking or missing altogether" (Kline 2007: 10).

These results are not a quantitative examination of future possibilities for participation in ecosystem services markets. However, it describes the framework within which participation in these markets would take place. It is important to be aware of the broader ecological and economic framework within which any individual ecological good or service has value. This study takes a different approach from many other valuations of ecosystem services, due to its focus on economic impact. But it is this economic impact that has the most obvious effects on local development. Prioritizing the values of different ecosystem services reflect the implications for local communities rather than simply scalar understandings of value. Economic impact, along with social benefit, is important to this analysis.

CHAPTER III

METHODS

This analysis examines the current prices received for ecosystem goods and services and the amount of money being spent to ensure some level of ecosystem function that allows these services to be created. The goal of this analysis is not to examine the value that ecosystem services or ecosystem functions should have if the total social benefit were included. This model attempts to examine current value, not future value, theoretical value, or willingness to pay. Heal points out that valuations based on market prices are likely to be incomplete: “there are usually services provided by natural ecosystems for which there are no markets and so no market prices. These therefore will be omitted from the calculations. At best therefore we will compute lower bounds for the values of these natural systems. However, even these lower bounds can be strikingly high, high enough to generate action for conservation” (Heal 2000: 26). This valuation of Trinity County analyzes current economic activity, and thus is probably also a lower bound.

Introduction

To develop this framework and evaluate ecosystem services, this project draws on information from the ecological and economics literature, the Watershed Center, public agencies, and other organizations. Because Trinity County is largely public land, using publicly available data about public land allows us to create a general framework and a

rough estimate of the value of the services flowing from the county. Each ecosystem function and service has different measures and indicators for its value. As a result, each service will be evaluated differently. To determine measures and indicators to use for each function and service, I examined the literature to see what methods other valuations have used. I compared these methods to the data that are available in Trinity County to determine what method to use for this valuation. When data are available, the value of ecosystem services is examined over time.

This project differentiates between the local economic impact of the ecosystem good or service and the broader social value of that good or service. The local economic impact is important because it influences the local economy of Trinity County. However, it is the social impact that measures the value of that good or service to society as a whole. If the forest ecosystem in Trinity County is degraded and that degradation decreases the local economic impact through a decrease in recreation income or other effects, this will be detrimental to the local economy of Trinity County but could often be substituted by a supply of this good or service elsewhere, transferring the local economic impact outside of the county. However, the value of this economic impact to the local community cannot be replaced.

Many manmade disturbances to the system that maintain or improve ecosystem function have the goal of improving ecosystem services. However, these efforts usually have the goal of maintaining or increasing the social value of these goods and services, not necessarily the local economic impacts of the goods and services. The Forest Service budget is not always seeking to increase or maintain local economic impact, it is seeking

to increase social value. Measuring this social value can be difficult. The Forest Service's use of their budget is evaluated based on certain performance measures, but these performance measures are not always tied to the local economy. In addition, these measures may not identify the benefits that are accrued to private parties due to their maintenance of ecosystem function. Understanding these connections between maintenance and restoration of ecosystem function and distribution of benefits of ecosystem goods and services is also complicated because budgets for maintenance and restoration come from multiple sources, both governmental and non-governmental.

Services and Functions

To understand the value of the Trinity County ecosystem, I created a model that included both the functions of the ecosystem and the services produced by these functions. Although there is debate within the literature about whether to value ecosystem services or ecosystem functions (Ansink et al. 2008), I believe it is important to examine both functions and services and to understand the system as a whole. Although valuing ecosystem services is what creates economic impact and social benefit, if their relationships with ecosystem functions are ignored, the production of these goods and services cannot be maintained. Fitting ecosystem goods and services into their ecological context is essential for their maintenance. Unlike other types of goods and services, the origin of ecosystem goods and services was not developed by society and so less well understood. Just as it seems intuitive that because a manmade product comes from an assembly line at a factory, the factory must exist for the product to exist, understanding

and maintaining ecosystem functions is needed to ensure the production of ecosystem services.

Much of the literature supports this approach: “successful application requires a precise differentiation between the descriptive realm of ecosystem functions and the evaluative realm of ecosystem services” (Barkmann et al. 2008: 48) Barkmann goes on to explain in more detail:

“Because ecosystem services relevant to local respondents are valued rather than scientifically described ecosystem functions, typical 'basic science' models that represent ecosystem functioning cannot be used for the analysis of valuation scenarios with direct policy relevance. Engineering-type models that embody technical and, in our case study, agronomic knowledge are necessary to bridge the gap between ecosystem functioning and their practical implications. A lack of this kind of information also hinders a meaningful application of alternative valuation approaches.” (Barkmann et al. 2008: 48)

Both differentiating what these functions and services are and being careful about the language we use to describe them are important: “the shorthand labels we attach to processes and services must not be allowed to blur the distinction between process and the services they perform” (Brown et al. 2007: 332) The model of ecosystem services and functions I use emulates other input and output models of forests. As Kline suggests, “the only real difference between the ecosystem services concept and economists' traditional conceptualization of multiple forest benefits is the emphasis on ecosystems as an organizing structure of benefits” (2007: 2). This allows policymakers and managers to examine many parts of the ecosystem simultaneously. Increasingly, the ecological basis of the inputs is being included in models.

This model examines the services produced by the system. In this model, we only examine services that currently have prices. This model also examines the inputs into the system to maintain the function of the ecosystem. Ansink et al. suggest that “valuation of ecosystem functions gives a better estimate of the total economic value of the ecosystem under consideration” (2008: 494). A more complete understanding of the total value of the system could be examined through understanding the ecosystem structures’ replacement values.

More generally, this model uses the production function approach, also referred to as valuing the environment as input (Barbier 2006: 1). Barbier points out that this approach requires both understanding of “the ecological processes, components, and functions that generate useful services” and the way in which these services create economic benefit (Barbier 2006: 1). Ecological and economic relationships must be well understood. The understanding of these ecological relationships is facilitated by intensively studied and managed public lands, such as those in Trinity County. The economic relationships implied by those ecological relationships are less well understood and must be extrapolated from both publicly available data on sales from public lands and newly emerging markets for ecosystem services such as carbon markets. Connecting functions and services is a challenge; as mentioned by the National Academy of Science, “the fundamental challenge of valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structure and functions of natural systems, the benefits (i.e., goods and services) derived by humanity, and their subsequent values” (Heal et al. 2006: 2). However, understanding these relationships is

important for understanding the changes in value of services caused by changes in function. Using an analogy Smail and Lewis describe that degradation of ecosystem function “reduces both the product coming off the assembly line, and the assembly line itself” (2009: 8).

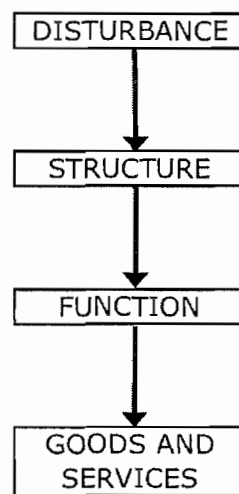
Model for Trinity County

This project’s model describes a framework for what sorts of data should be collected to understand both the inputs and outputs of the system for key ecosystem functions and services in Trinity County, California. The goal of this framework is to assess the major components of this ecological and economic system. Although the particular units of this model could not be used to understand the economy and ecology of a different county, the model itself is intended to be transferable.

The model used to describe ecosystem functions and services in Trinity is modeled on the framework described in Ansink et al. (2008: 497). Layke also describes a model that includes both functions, which he calls processes, and services, which he refers to as benefits (2009). “In this framework, benefits primarily consist of provisioning, and cultural and aesthetic services, while beneficial ecosystem processes primarily consist of regulating services”(Layke 2009: 19). Barbier includes a table of ecosystem functions, ecosystem processes and components, and ecosystem services (benefits), which relate to the ecosystem functions, structure, and goods and services discussed here (2006: 4). Even early valuations of ecosystem services discuss input-output models as a basis for valuating ecosystems (Wilcox and Harte 1997: 323).

The framework developed by this project uses a four-layer model, illustrating the key components of the Trinity County ecosystem (Figure 2). This model suggests that many of these ecological components have economic values that can be estimated, an assertion based on the theoretical reasoning for valuing ecosystem services. More importantly, this model suggests that, as in the ecological system, there are economic effects of changes in one layer of the diagram on other layers.

Figure 2: Four-Layer Model



The structure of an ecosystem generates the functions of that ecosystem. In turn, those functions generate goods and services. For example, one function that forests, an ecosystem structure, generate is filtering air. This air filtration creates an ecosystem service: air quality. Valuing the economic impact and social use values of these goods and services created by ecosystem functions addresses difficulties with double counting. Often, ecosystems are described based on their structures, such as forests, wetlands, streams, or lakes. As a result, ecosystems are often valued this way. This approach can

result in double counting because particular structures produce multiple ecosystem goods and services (Boyd and Banzhaf 2007). To avoid this problem, this model examines the structures that make up the ecosystem, the ecological functions of those structures, and the goods and services that are created from those functions. These goods and services are quantified, not the structures or functions themselves.

Disturbance, both natural and manmade, affects ecosystem structure. It is an input to the ecosystem. Disturbance can destroy or improve ecosystem structures. This disturbance itself generally has both social values and economic impact, in addition to its effects on ecosystem goods and services. For example, forest fires have economic impacts (the cost of fighting the fire) and social values (the damage done to the fire and the side effects of the fire). Similarly, stream restoration has both economic impacts (the cost of the labor to do the work) and social value (the side effects of that restoration on other ecosystem structures).

Studies of ecosystem functions do not tend to acknowledge a minimum level of structure needed to deliver services (Fisher et al. 2008: 2062-3). This can be problematic for both valuation and on a more practical level for policymakers. Acknowledging some minimum level of structure using both economics and the regulatory standards that exist for some functions could provide a useful baseline from which ecosystem services valuation becomes applicable.

Figure 3 illustrates the relationships between ecosystem structure and functions and the ecosystem goods and services these structures and functions produce. The diagram only shows the ecosystem structure, functions, goods and services discussed in

this project. This framework integrates many different ecosystem services. In doing so, it encourages integrated valuations rather than valuations of single ecosystem services. This approach avoids the common problem of valuing only on one good or service, which can have negative environmental consequences. In ecosystems, components are integrated and their valuations should acknowledge this integration, rather than fostering the management of one service over all others. For example, if only climate regulation is valued and forests are managed to maximize carbon sequestration, this management can have negative effects on other ecosystem services such as biodiversity or water quality. This approach is dangerous, because it could suggest that other ecosystem functions do not need to be maintained because the future value of carbon sequestration may be high.

Spatial Scope

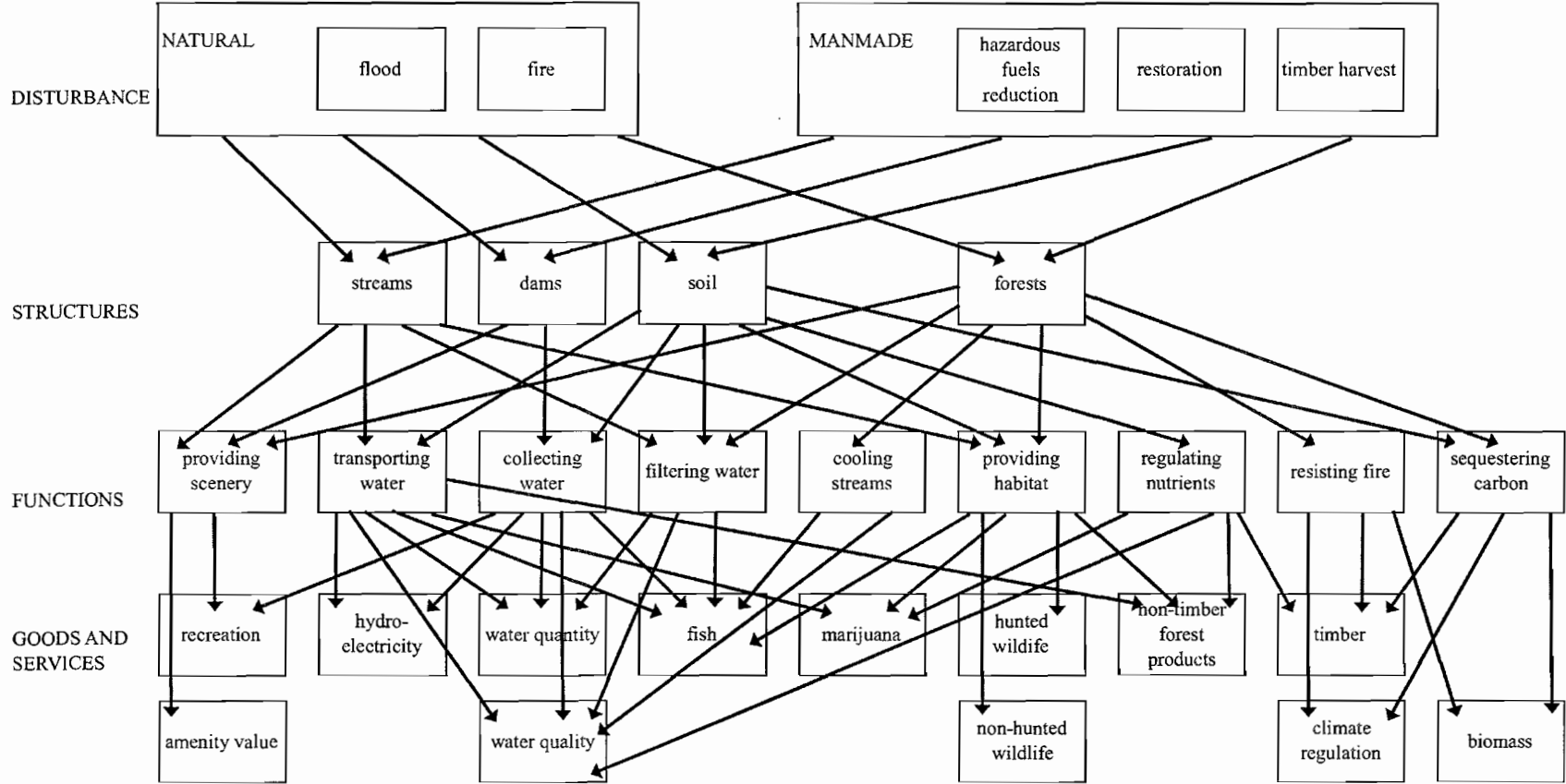
Ideally, data presented in this project should represent the entire county. However, such data were not always available. Often, data were only available for within the Shasta-Trinity National Forest. The scope of the data is designated for each service or function. The indicators for each good or service were available from a different source, which correlated with a variety of spatial scales. Coordinating spatial scales is an important barrier to ecosystem services valuation.

Ansink et al. point out that “both [services and function assessment] approaches fail if they are applied to value functions or services at the global scale- as the precondition of marginality no longer applies, and meaningful prices for functions or services cannot be established at this scale” (2008: 494). This argument supports

performing ecosystem services valuations at a smaller scale, such as the county level. While the methodology used to assess ecosystem services at a county level could be applied to other counties, the actual values used for this assessment should not be applied to other areas.

Attempting to examine all of these services and functions at the county level can seem arbitrary and also necessitates certain inaccuracies. There are numerous formal and informal jurisdictions all at work in the region, including cities, watersheds, National Forests, and ecosystem types. Valuing ecosystem services at the scale of some of these other jurisdictions might be easier due to available data. For example, only looking at ecosystem services within the National Forests might result in increased accuracy. However, this level of valuation would be less relevant to the residents of Trinity County because the National Forests as a whole do not necessarily directly connect to their homes and livelihoods.

Figure 3: Framework for Valuation of Ecosystem Goods and Services in Trinity County



Another criticism of examining ecosystem services at the county scale is that it is not ecologically relevant. Ecosystems functions and services do not stop at county boundaries. However, examining ecosystem services and functions at the scale of the county is a compromise between practicality, accuracy, and utility. Many other types of valuations and indicators are assessed at the local level (particularly the county level), such as those that examine social services, economics, and health. In addition, the county does not simply set spatial boundaries. It also has institutional components that can create change.

This project examines the ecosystem services and functions at a county level. While ecosystem functions are attached to a particular place, the goods, services, and money created by those functions sometimes extend beyond the county level (or any boundary). Economic flows and some services are transportable. Examining the reach of these flows is important to understand the ecological and economic dynamics of Trinity County.

Temporal Scope

Any measurement of environmental quality, including the value of ecosystem services, varies over time. Environmental quality varies daily, seasonally, and over other time scales and in addition is affected by disturbance of various types. Often, averages are used (Freeman 2003: 36). However, as Freeman points out “inevitably, summarizing involves a loss of information” (Freeman 2003: 36). The problematic aspects of all measurements of environmental quality are something that valuation of ecosystem services must confront.

Assessing ecosystem services value over time is more useful than assessing ecosystem services value at one point in time. It is the changes in the value of ecosystem services that are most important in assessing their marginal value: “both actual and potential future supplies of services should be included in their [ecosystem services’] valuation” (Ansink et al. 2008: 492). Heal suggests valuing market prices over time. When measured using a snapshot approach, these indicators underestimate the economic value lost by ecosystem destruction because “the price of a good or service rises as it becomes scarcer. This is particularly true of goods and services that are essential to human welfare, such as food, water, and clean air” (Heal 2000: 28). According to Fisher et al., most assessments focus on current services delivery or total economic value (2008: 2062). Not only do assessments over time allow for assessment of marginality, they also may allow assessment across various land uses as these uses change. Assessments performed over time may also include predictive judgments like the assumed future value of biodiversity conservation or rebuilding a wildlife population. While this approach is more useful, it is difficult to get the needed data to carry out, and it this approach difficult apply to policy.

Other research emphasizes the importance of future discounting: “We could likewise value a forest as the present discounted value of its carbon sequestration and biodiversity support services and its recreational services.” (Heal 2000: 26). This assessment does not examine discounting in any quantitative sense. However, it is important to consider how discounting is changed by the long temporal scales often relevant to ecosystems. In addition, an assessment over time rather than a snapshot

assessment allows understanding of the seasonality and the annual cycle of value that some services have. A framework for valuation that allows the value of a service to change is important. This type of framework could reflect changes in management decisions and societal preferences, and even allow for futures planning based on different management scenarios.

Despite the advantages of modeling data over time, this valuation primarily takes the snapshot approach. I tried to understand whether these data were atypical, following a trend, or had been consistent over several years. When possible, I tried to examine data over a period of several years. Major events in natural resource history in Trinity County tended to affect the data significantly, such as the implementation of the Northwest Forest Plan. These events shift the values of ecosystem goods and services over time. One major difficulty in ecosystem services valuation is uncertainty about the usefulness of historical data in predicting future values. However, the framework of the model should allow future data to be substituted into it. This would allow the approximate calculation of values of ecosystem services and functions in the future, though would not be reliably predictive.

Ideally, ecosystem services valuation examines a range of data rather than a snapshot of the current time period because of the variability inherent in natural systems. Some years are atypical, not only because of the economic climate but because of the ecological conditions. In addition, some policies that control the distribution of ecosystem services and ecosystem function are not effective on an annual basis. For example, the current distribution of water from the Trinity River is a “long term average”

of 50% to the river and 50% to the Central Valley. This distribution may not be accurate on an annual basis. Taking this longer term or average perspective may overlook economic losses or gains that arise through short-term shortages in the services that ecosystems provide.

Data Limitations

Like most valuations of ecosystem services, this analysis was considerably limited by data availability. In addition, these data that are available are not centralized. Both the data, and the understanding of the meaning and usefulness of the data, rested with different agencies and organizations. Often, these agencies do not know how their data could relate to data other agencies held. The units and timeframes differed significantly. Data often exist only in paper form. Agencies do not share databases, when databases exist at all.

Selecting and Defining Services

In this project, the services being valued have values in the market. Use-values are employed in this evaluation. However, many other services could be valued if more non-use values were used. For example, this valuation does not include bequest value, the value people place on the existence of a resource (Ansink et al. 2008: 492). More comprehensive values for these services could be determined if indirect use and passive use methods were used.

Services chosen for valuation in Trinity County were chosen for a variety of reasons. Landowners, regulators, and other organizations working in the community also identified these functions and services as important. Also, these functions and services

were ones examined in the Millennium Ecosystem Assessment that also had relevant, available, and measurable data in Trinity County (Layke 2009: 6).

Some goods and services that may exist in Trinity County were not included in this study. These include biodiversity (outside of the discussion of non-hunted wildlife), grazing, and natural hazard mitigation. Other services, such as those that wetlands provide, were also not included in the study because the structure, wetlands, does not exist in significant amounts in Trinity County.

Structures Included in this Study

As indicated in Figure 3, this project examines the following structures: streams, dams, soil, and forests. These structures were selected because they create the ecosystem functions that produce ecosystem goods and services in Trinity County.

Streams, soil, and forests intuitively seem important for inclusion in a valuation of the Trinity County ecosystem. Including dams is not intuitive. Although human created, dams are an important feature of the landscape in Trinity County and produce significant ecosystem services. Their alteration of the landscape is so significant that to leave them out would result in a mischaracterization of many goods and services. However, many would disagree with their inclusion because they are not a feature of the unaltered ecosystem.

This division is an important consideration for ecosystem services valuation. The line between human and natural structures is not firm, and human structures frequently affect natural or ecosystem goods and services. While this valuation examines the relevance of structures, functions, and services to Trinity County on a case-by-case basis,

these questions about what to include are an important argument for a comprehensive approach to modeling the ecosystem.

A more complex valuation could be carried out that values each layer of the four layer diagram (Figure 2) using different methods. Ecosystem structures can be valued by determining their replacement costs. This model values the cost of these structures in a more limited way, by examining the cost of maintaining the structures. These costs show up in this diagram as disturbances to the system. However, examining replacement cost would be a way to measure the stocks of the ecosystem in addition to its flows. While the replacement cost of the dams would be fairly straightforward to calculate, calculating the replacement cost of a forest or stream would be difficult. Often, values of structures rely on some measure of the services provided by that structure. This is where the problem of double counting arises. Other valuations of structures sometimes rely on measures of existence or bequest value. This valuation does not address these issues, but calculating these structures' values could increase society's understanding of the value of the Trinity County ecosystem. However, few mechanisms exist to pay people for the existence value of ecosystems. More mechanisms rely on paying people for the flows from the system, such as ecosystem services.

Functions Included in this Study

The study traces the following ecosystem functions: providing scenery, transporting water, collecting water, filtering water, cooling stream, providing habitat, sequestering carbon, resisting fire, filtering air, and regulating nutrients. Although the structures discussed in this study have other functions, because these functions do not

relate directly to the ecosystem goods and services in this study, they were not included or examined.

Disturbances Included in this Study

Disturbances in this study are inputs into the ecosystem. Ways to measure these inputs could include money spent on developing regulatory mechanisms, enforcement, implementation activities, science, and other research. However, this information is difficult to get at. This study examines both manmade and natural disturbance. It examines flood, fire, hazardous fuels reduction, restoration, and timber harvest.

Overview of Valuation Methods for Chosen Goods and Services

The study values the following goods and services that result from the forest's structure and functions: water quantity, hydroelectricity, fish, timber, recreation, and non-timber forest products, marijuana (typically illegal, but significant), and hunted wildlife. It examines the following goods and services that do not have easily accessible values: biomass energy, amenity value, water quality, non-hunted wildlife, climate regulation, and air quality. This valuation focuses on provisioning services, rather than regulating or cultural services. Both generally and in Trinity County, these services tend to have the greatest local economic impact in addition to their social benefits. They are also easier to measure. As a result, more data are available for these services, reflecting the perspective that "you manage what you measure and you measure what you care about" (Layke 2009: 18). This focus is also logical because as Layke described, "indicators for most regulating and cultural services are weak, lagging behind those for most provisioning services" (Layke 2009: 18).

While this project uses a variety of indicators to understand the value of various ecosystem services, these other values are translated into monetary value. Some valuations use indicators other than monetary value, such as employment, energy, or other measures specific to the goal of the valuation. For example, to understand the dietary dependence of a community on its natural resources, a valuation might use the indicator of fish products as a percent of total animal protein in peoples' diets (Layke 2009: 14). By using monetary value as an absolute indicator of ecosystem value, this valuation examines the financial dependence of the economy on the ecosystem function and services on Trinity County. By using monetary value as a required absolute indicator, some services get left out.

shows some goods and services that are valued in this analysis. They are arranged from those that can be measured using direct use indicators to those that require indirect use indicators. These services can be seen as existing along a continuum, with indicators closer to the indirect use side requiring progressively more abstract techniques, less based on local economic impact, to understand their value. As the placement of a good or service progresses towards the indirect use side, that good or service becomes less well indicated by current market values.

Figure 4: Direct and Indirect Use Indicators

DIRECT USE
timber
fish
water
energy
recreation
climate regulation
amenity value
biodiversity
INDIRECT USE

Table 1, modeled after the table in Brander et al., shows some ecosystem functions and services discussed in this valuation project (2006: 226). The value type of the measures used to indicate the value of the service is indicated, as are possible valuation methods. Details related to how each ecosystem good or service was valued in this study are in the results section of this thesis.

Table 1: Examples of Functions, Goods, Services, and Valuation Methods

Ecological function	Economic goods and services	Value type	Possible Valuation Methods
collecting water	water quantity hydroelectricity recreation	direct use direct use direct use	market prices market prices travel cost method
filtering water	fish	direct use	permit prices
resisting fire	timber climate regulation	direct use direct use indirect use	market prices market prices replacement cost
providing habitat	fish biodiversity	direct use non-use	permit prices contingent valuation
sequestering carbon	timber climate regulation	direct use direct use indirect use	market prices market prices replacement cost
providing scenery	recreation amenity value	direct use direct use indirect use	travel cost method contingent valuation hedonic pricing
transporting water	hydroelectricity water quantity fish marijuana	direct use direct use direct use direct use	market prices market prices permit prices market prices

Modeled after Brander et al. 2006: 226

Methods of Valuation of Disturbances

Because the people who are paying for the protection of the source of the outputs are not typically the same people as who benefit, assessing ecosystem services on a countywide scale also provides a big picture view of those functions and services as they flow from inside to outside the system. Understanding who pays and who benefits is useful “to help modify systems of national accounting to better reflect the value of ecosystem services and natural capital” and “for project appraisal, where ecosystem

services lost must be weighed against the benefits of a specific project” (Costanza et al. 1997: 259). Often, discussions surrounding payments for ecosystem services look to the future, setting up new mechanisms for paying to protect ecosystem function. However, it is important not to lose sight of the fact that many agencies, organizations, and individuals are already paying to maintain, improve, and restore ecosystem function. Often, these payments are overlooked and thus underestimated. This study tries to identify the payments currently being made.

Sources and Calculations for the Valued Services

Overview

An important aspect of examining each of the goods and services in this study is putting them within the broader context of Trinity County. This context is ecological, historical, and social. To understand this context, I talked with people from Trinity County, including the Watershed Resource and Training Center and the various government agencies in Trinity County. I also examined the literature to understand the connections between disturbance, ecological structures, ecological functions, and ecological goods and services. The literature also provided information about the community and history of Trinity County.

For the goods and services without a direct market examined in this study, this type of contextual analysis describes my methodology for obtaining my results. For the goods and services with a direct market, described below, obtaining prices associated with these values required a more extensive methodology.

Water Quantity

To calculate the value of water quantity, I examined the supply of water to the Westlands Water District from the Central Valley Project (CVP). For 2009, this totaled 195,716 acre-feet (Westlands Water District 2010). In 2009, Trinity County provided about 11% of the water to the CVP, so about 21,529 acre-feet (Dietz 2010). I examined four values for this water: the amount paid to the Bureau of Reclamation, the amount generated for the Trinity County Public Utility District (Trinity PUD), the amount of money charged by the Westlands Water District, and the amount of money generated for the restoration fund, as required by the Central Valley Project Improvement Act. To summarize the benefits from Trinity County water, I used the amount of money charged by the Westlands Water District to avoid double counting and to understand the total value produced by the water. The amount of money charged by the Westlands Water District includes the payments by the Westlands Water District to the Trinity PUD, the Bureau of Reclamation, and the restoration fund.

The water volume from Trinity County was multiplied by the cost of service that is paid to the Bureau of Reclamation, \$28.69 per acre-foot (Westlands Water District 2010). In addition, for every acre-foot of water sold to the Westlands Water District from the CVP \$0.11 is assessed for the Trinity County Public Utility District (Westlands Water District 2010). The Westlands Water District sells this water for \$108.94 per acre foot to agricultural users (Westlands Water District 2010). Because most users are agricultural, this rate was used. Domestic and municipal rates are even higher, so the amount

generated is a low estimate. The amount of money generated for the restoration fund, \$9.11 per acre foot, was also calculated (Westlands Water District 2010).

Hydroelectricity

The Bureau of Reclamation manages the dams that create hydroelectricity in Trinity County. This electricity is managed by the Western Area Power Administration (WAPA), which then distributes the electricity to public utility districts all over the west, including the Trinity PUD.

WAPA has not valued electricity using a price per kilowatt hour since 2005. As a result, to calculate the value of the electricity generated by Trinity County, I examined the ratio of Trinity electricity generation to total generation from the entire Central Valley Project for 2009. Then I multiplied that ratio by the Western Area Power Administration's revenue to get the approximate revenue generated by Trinity County. These calculations are shown Table 2. WAPA's revenue goes into the U.S. Treasury. In addition, some money from electricity generation goes directly from WAPA to the Bureau of Reclamation for restoration activities under the Central Valley Project Improvement Act.

Table 2: Revenues from Hydroelectricity for 2009

	Annual
Trinity Powerplant Generation (MWH)	247,234
Central Valley Project Generation (MWH)	3,398,064
Trinity Generation as a percentage of CVP Generation	7%
WAPA Power Revenue	\$76,016,728
Revenues Associated with Trinity Generation Based on ratio of Trinity generation to total CVP generation	\$4,927,810

Source: Dietz 2010

Fish

To calculate the value of fish in Trinity County, two methods were used. The first was the revenues from fishing licenses. This information came from the California Department of Fish and Game (California Department of Fish and Game 2009). This money is paid to the state, not to Trinity County. The number of each type of permit issued for Trinity County was multiplied by the price of the permit issued for Trinity County. This data was available for 2005.

The second method used for estimating the value of fish in Trinity County was the travel cost method, which was used by the Trinity River Mainstem Fishery Restoration Environmental Impact Statement (U.S. Fish and Wildlife Service et al. 2000). This study estimated that estimated the net economic benefit of recreational fishing to be \$65 per day for fishing salmon and steelhead. Based on estimates from salmon and steelhead punch cards, the average number of trips to Trinity County for salmon and steelhead fishing between 2003 and 2005 were 5,437 (Jackson 2007: 44). This suggests that the

annual of recreational fishing is at least \$353,405 in 2000 dollars. In 2009 dollars, this is \$442,363.

Table 3: Trinity County Fishing Licenses 2005

	Number	Revenue
Annual resident	3630	\$115,252.50
Annual non-resident	14	\$1,193.50
One day	678	\$6,949.50
Two day	1017	\$16,272
Ten day	205	\$6,508.75
Abalone stamp	18	\$274.50
Bay Delta enhancement program	62	\$310.00
Second rod stamp	206	\$2,008.50
Salmon punch card	2463	\$3,694.50
Steelhead report card	2324	\$11,620
Total		\$164,083.75

Source: California Department of Fish and Game 2009

Timber

To calculate the value of timber, I used 2009 data from the California Board of Equalization, which collects information about volume, price, and origin of timber harvested in counties in California. I used 2009 data to maintain consistency with data on other services, even though both the volume and price of timber from Trinity County was much lower in 2009 than in previous years.

Marijuana

Data related to marijuana production are less available than data related to other ecosystem goods and services. According to the Forest Service Region 5 spokesman John Heil, 40,000 acres of public land in the US contain marijuana (Driscoll 2010). I assumed that the proportion of public land in Trinity County that contains marijuana is the same as

the proportion of public land in the United States that is estimated to contain marijuana gardens, 0.02 percent. This estimate is very conservative. Using this number, Trinity County probably has about 323 acres of marijuana growing on its public land. Assuming production of 1742 pounds per acre, Trinity County's public land produces approximately 563,312 pounds of marijuana (Caulkins 2010: 15). I assumed a price of \$3,000 per pound, the wholesale price in Sacramento in 2008 (U.S. Department of Justice 2008: 22).

Recreation

To understand the value of recreation, I used both measures of economic impact and non-use methods. To recreate on National Forest lands, users must pay a recreation fee. I used this data to understand a lower bound on willingness to pay. In 2005, the Shasta-Trinity National Forest collected \$1,180,219 in revenue from 2,443,000 visitors through this recreation fee (U.S. Forest Service 2006).

To understand the value of hiking, I examined surveys that used the travel cost method. Steven Hackett uses the zonal travel cost method to estimate the economic value from wilderness visits in the Trinity Alps (2000). I took his results and converted them to 2009 dollars. Data was not available local to Trinity County to calculate the local economic impacts of off-highway vehicle.

Lake activities create significant economic impacts for Trinity County through a variety of revenue streams. These include a portion of the fees from concessionaires and the economic impact from those traveling to the lake. The Trinity River Mainstem Fishery Restoration Environmental Impact Statement estimated that the number of

recreational visitor days to the Trinity Reservoir was 265,800 in 1991. This statement estimated the economic impact of a visitor day to the area reservoirs to be \$11 per day. This suggests that there is an estimated \$2,900,000 impact (U.S. Fish and Wildlife Service et al. 2000: D-25). These data were converted to 2009 dollars.

The Trinity River Mainstem Fishery Restoration Environmental Impact Statement estimated the number of recreational visitor days to the Trinity River at 214,000 in 1995. A user survey conducted in 1993 and 1994 by the Biological Resources Division of the US Geological Survey identified the economic benefit of recreation for different activities. It was estimated to be \$36 per day for boating, \$26 per day for swimming, and \$65 per day for fishing for salmon and steelhead, and \$33 per day for off-river activities such as hiking. This statement used these average per-day values to estimate the total benefits of recreation along the Trinity River to be \$9,900,000 (U.S. Fish and Wildlife Service et al. 2000: D-2). Because this value includes fishing, accounted for elsewhere in the model, the estimate of fishing was subtracted from this number.

Hunted Wildlife

The Shasta-Trinity National Forest is a California B2 hunting zone, which means 55,000 licenses are issued each year (California Department of Fish and Game 1999; California Department of Fish and Game 2009). However, not all deer tags are issued. In Trinity County, 994 deer were killed in 2008 (Mohr and Heminway 2009). Because county data are not available for how many deer tags were issued, I assume that the ratio of deer killed to deer tags issued is approximately the same for both Trinity County and

California as a whole (Equation 2). This suggests that approximately 11,141 deer tags were issued in Trinity County, as indicated in Table 4.

Equation 2: Deer Tags in Trinity County

$$\frac{\text{Killed in California}}{\text{Issued in California}} = \frac{16941}{189983}$$

$$\frac{\text{Killed in Trinity County}}{\text{Issued in Trinity County}} = \frac{994}{x}$$

$$x = (994 * 189883) / 16941$$

$$x = 11141$$

Source: California Department of Fish and Game 2009; Mohr and Heminway 2009

Table 4: Estimated Deer Tag Revenue 2009

	All California Number Issued	Percentage by Type	Estimated Number in Trinity County	Cost of license	Revenue from Trinity County
Resident 1 deer	142833	75%	8376	\$22.25	\$186,367
Non resident 1 deer	869	0%	51	\$227.25	\$11,581
Resident 2 deer	43108	23%	2528	\$28.75	\$72,678
Non resident 2 deer	67	0%	4	\$227.25	\$893
Lifetime	2036	1%	119	\$17.25	\$2,060
Duplicate tag	1070	1%	63	\$8.75	\$549
Total	189983	100%	11141		\$274,127

Source: California Department of Fish and Game 2009

Non-Timber Forest Products

To estimate the value of non-timber forest products in Trinity County, I use information from the Forest Service's Timber Information Manager. This database has information about permits granted by the Shasta-Trinity National Forest to people collecting from districts within Trinity County in 2009. These permits were issued for a

variety of products, including fuelwood, mushrooms, conifer boughs, and other products. Their values are described in Table 5. This estimate does not include non-timber forest products that were not collected from Shasta-Trinity National Forest, particularly those on private lands.

Table 5: Forest Service Permit Revenue from Non-Timber Forest Products 2009

Commercial Christmas trees	\$246
Commercial fuelwood	\$533
Commercial matsutake mushrooms	\$330
Commercial non-matsutake mushrooms	\$2,875
Conifer boughs	\$40
Driftwood	\$20
Fuelwood	\$22,475
Personal matsutake mushrooms	\$500
Personal non-matsutake mushrooms	\$1,020
Personal Christmas trees	\$8,330
Personal plants	\$80
Poles	\$290
Scientific and educational plant collections	\$170
TOTAL	\$36,909

CHAPTER IV

RESULTS

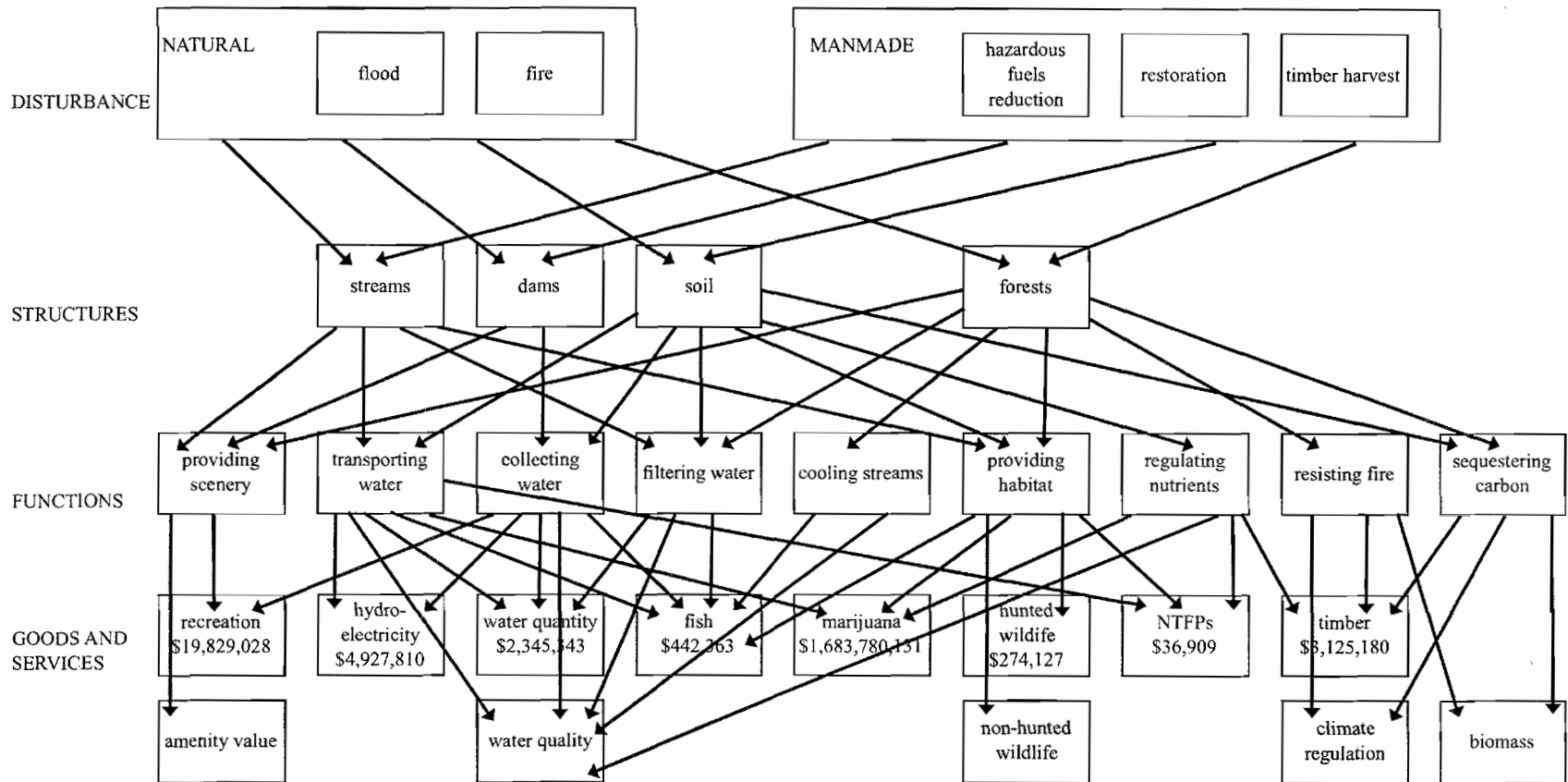
Framework

Figure 5 describes the economic and ecological framework for Trinity County. It describes the ecosystem structures, goods, and services in Trinity County as well as and the relationships between them formed by both ecosystem functions and ecological, social, and legal constraints. It also describes the prices found for the goods and services in 2009 dollars.

Disturbance Results

While valuation of ecosystem services is a rapidly expanding area of study, few of these valuations include significant discussion of how those services are created or maintained. Some studies examine related topics, such as replacement cost, which identifies what it would cost to replace the particular structure or service being valued. This approach values ecosystem structure rather than inputs to the system, and often overlooks the idea that ecological function can be a matter of degree. Replacement cost suggests that ecosystems either exist or do not exist, rather than acknowledging that they are maintained. In general, because these inputs to the system that maintain the ecosystem are not calculated, the value of these disturbances is underestimated.

Figure 5: Valuation of Ecosystem Goods and Services in Trinity County



The structures and functions that create ecosystem goods and services can be maintained and improved through ecological restoration and other management activities. These costs are both capital costs (building structures and often replacing or completely restoring an ecological structure that previously existed) and operational costs (maintaining structures and functions that exist). Overlooking the actions, positive and negative, that society can have on ecosystem structures, goods, and functions, isolates ecosystems from society. This isolation can lead to thinking that ecosystem goods and services are infinitely valuable, or not valuable at all, rather than promoting the understanding of their economics-based value to society. Ecosystem services valuation is often used to suggest why maintenance of ecosystem services is important, but often does not recognize the value of the maintenance currently occurring. Understanding this maintenance both explains the economic impact created through restoration and other natural resource management jobs, and also provides information about who pays to maintain ecosystem function. Often in ecosystem services valuation and payments for ecosystem services, the focus is often on future willingness to pay, which is important, but can overlook the costs currently being paid by someone to maintain those functions.

This study recognizes both natural and man-made inputs to the system. These inputs are called disturbance because they change the structure, functions, and goods and services of the ecosystem in various ways. They often work on all of these levels at once.

Though it is important, valuing disturbance is particularly difficult. Disturbances are often costs people pay, so could be subtracted from the total benefits created by the system. However, these disturbances also have economic impact independent of their

effects on ecosystem goods and services. Disturbances create jobs and economic activity. These characteristics seem to indicate that work done to maintain ecosystem function contributes to the economic impact of the Trinity County ecosystem.

Additionally, some disturbances affect ecosystem structures and functions negatively. They reduce ecological function. These types of disturbances can be valued economically in two ways: reduction in value of ecosystem goods and services and costs to suppress the disturbance. While the latter is significant and often has detrimental impacts on other efforts to maintain or improve ecosystem function, suppression activities can have significant economic impacts on jobs and other indicators.

Restoration

Many agencies and organizations work to maintain and restore ecosystem functions in Trinity County. The maintenance of these functions appears in the diagram of Trinity County as a manmade disturbance. Restoration seeks to improve ecosystem function. One way to value this work is to examine the budgets of these organizations. In keeping with the scope of this study, this section examines those budgets at an abstract level. A thorough analysis of the restoration economy of Trinity County is not undertaken in this study.

Unpublished research on the restoration economy of Trinity County found that between \$3.4 million and \$3.9 million was spent annually on restoration work in Trinity County between 2000 and 2002 (Baker 2004: 2). The 2002 data, with the same data in 2009 dollars, is presented in Table 6. This report points out that the Trinity River is the primary driver of the restoration economy in Trinity County.

Like ecosystem goods and services, restoration and other disturbances have both economic impact and social benefit. Restoration requires labor and other types of inputs that may or may not come from Trinity County. The location where the economic impact of restoration is directed cannot be determined by simply examining the size of the restoration budgets of these organizations.

Understanding restoration budgets is also complicated by the fact that the money for this work often comes from multiple sources. While the restoration budgets of these organizations are summarized in Table 6, the origins of this money could be grant funding, mandated charges or funds from ecosystem services, or other mechanisms. Tracing this money is very complicated. Understanding how the money is distributed between projects is also difficult.

Hazardous Fuels Reduction

Hazardous fuels reduction changes the structure of forests with the goal of improving ecological function, particularly resistance to fire. Significant amounts of money are spent on reducing hazardous fuels to prevent fire, even though these expenditures come with tremendous opportunity costs to other parts of government agency budgets. Although preventing fire maintains the ecosystem functions that produce environmental goods and services that benefit many, hazardous fuels reduction is primarily paid for by the federal government.

Table 6: Restoration Budgets

	2002	In 2009 Dollars
BLM	\$94,218	\$111,613
US Forest Service	\$235,800	\$279,334
US Fish and Wildlife	\$0	\$0
US Bureau of Reclamation	\$350,000	\$414,618
CA Department of Forestry	\$16,091	\$19,062
Department of Fish and Game	\$848,320	\$1,004,940
National Fish and Wildlife Foundation	\$94,200	\$111,592
State Water Resources Control Board	\$520,000	\$616,004
Trinity County Department of Natural Resources	\$72,850	\$86,300
Sacramento Regional Foundation	\$175,000	\$207,309
NRCS	\$56,391	\$66,802
Resource Advisory Committee	\$903,944	\$1,070,833
Miscellaneous	\$215,039	\$254,740
CA Department of Transportation	\$331,900	\$393,177
TOTAL	\$3,913,753	\$4,636,325

Source: Baker 2004: 30

Understanding the amount of money spent on hazardous fuels reduction is complicated, because it is often completed under the auspices of timber harvesting or the use of biomass for energy. Researchers should be careful to avoid double counting when examining hazardous fuels reduction as a disturbance to the system.

Timber Harvest

Though timber is an ecosystem good, timber harvest is also a disturbance. It affects ecosystem structures and functions through changes in runoff, sedimentation, and other factors. Mitigating these effects to reduce their impact on ecosystem structures and functions has significant costs. For example, in 1993 the BLM (funded by the Trinity River Task Force) purchased 60% of the Grass Valley Creek watershed, which had been heavily logged by its previous owners, for \$9.1 million in order to reduce sedimentation

to improve fish habitat (Baldwin 2002). In the 1998 fiscal year, more than half of Trinity restoration expenditures (about \$50 million of \$90.8 million) were spent on building and maintaining sedimentation reduction facilities (such as dams and pools), purchase of the Grass Valley Creek watershed, and rehabilitation of the watershed (Friends of Trinity River 2010). Maintenance of the watershed involves both removal of fine sediment upstream (such as near the Grass Valley Creek watershed) and the introduction of coarse sediment to improve fish habitat downstream.

Flood

Flooding can change ecosystem structures and functions significantly. Though not common in Trinity County, it is an important periodic disturbance to the system to acknowledge. It affects both the ecosystem structures and their operations. This can have substantial effects on ecosystem goods and services. Streams, dams, soil, and forests' abilities to transport, collect, and filter water is altered substantially. This can have significant effects on revenues from water quantity and hydroelectricity. Because prices depend not just on the amount of water, but also its timing, there are significant timeframe implications that make it difficult to quantify the effects of flooding. Along with direct detrimental impacts to structures, such as damage to dams or loss of forests and soils, the economic value of floods can be understood by examining potential revenues lost to flooding, such as poorly timed hydroelectricity production or reductions in recreational revenues due to water table fluctuations. Like with other disturbances, understanding whether these values should be included as positive or negative values is difficult.

Fire

Fire is unique in this model because it affects all four layers of the ecosystem, as described by the model used in this study (Figure 2). Within the disturbances level of the model, fire both appears as a natural disturbance, due to its effects on ecosystem structure, and through its manmade prevention, hazardous fuels reduction. As a natural disturbance, it has both local economic impact and more broad social impacts. Fire's impacts also reveal the problematic nature of valuing disturbances in the system. While the economic impact is in part positive- suppressing fires can create local jobs- it also comes at considerable detriment to the local community broader society, as indicated by air quality and other factors. Accounting for these positive and negative effects in a valuation of ecosystem services is difficult. In addition, it has significant impact on other ecosystem functions including providing habitat, cooling streams, filtering water, providing scenery, sequestering carbon, and regulating nutrients. These effects are difficult to quantify. The scarcity created by significant fires does not always show up in changes in the price of water or hydroelectricity, even though the long term viability of those flows is affected by the negative impacts of fires on ecosystem function.

The economic inputs to the ecosystem caused by fire include both the cost of suppressing the fires and the cost of the damage to ecological, physical, and human capital. Suppression costs have varied. Suppression of the Big Bar fire of 1999, which burned 125,000 acres, cost \$110 million, although this figure includes suppression costs for Humboldt County (Trinity County Resource Conservation District and Watershed Research and Training Center 2005: 1). In 2008, suppressing the fires in Shasta-Trinity

National Forest that burned 208,460 acres cost \$160 million (Morris 2009).

Figuring out how these suppression costs should enter into a valuation is challenging.

Estimating the effects of fire in ecosystem services valuations is difficult, because the occurrence of fires is not predictable and society generally seeks to prevent fires, despite recognizing them as an important characteristic of the ecosystem. Still, these disturbance events are important characteristics of the ecosystem and economic system and have significant impacts on ecosystem function, goods, and services. As a result, ecosystem services valuation should find ways to incorporate fire into the discussion of the value of the ecosystem.

Goods and Services Valued in the Direct Market

Although the ecosystem of Trinity County creates a number of goods and services, not all of these goods and services currently have direct markets, where buyers pay for that particular goods or services. The value of the goods that have a direct market, such as water quantity, timber, and recreation, are described below. Both those who are willing to pay for these goods and services and those who make the rules of the market, such as regulators and entrepreneurs, determine which goods and services have direct markets.

Water Quantity

Water plays a major role in many ecosystem functions that create ecosystem goods and services within Trinity County. Water's role is particularly important to examine because ecosystem goods related to water- water quantity and water quality- are

also sold outside of the county and have economic impacts beyond county boundaries that are particularly significant.

Like many decisions about water all over the world, the decision of how to allocate water quantity has been contentious in Trinity County. While out-of-county, downstream users pay to use the water delivered by Trinity County, there are other uses for this water that the community, National Forest, the Hoopa, and others deem significant. For example, maintaining water quantity in the Trinity River creates fish habitat for salmon both within Trinity County and downstream.

Two events important to the water allocation decision-making process, which have always been intertwined with regulations related to salmon catch, were the development of the State Water Plan in 1931 and the Central Valley Project (CVP) in 1933 (Durham 2005: 12). The Central Valley Project diverted water from the Trinity River for both irrigation and hydropower. Construction of infrastructure to carry out this project did not begin until 1938, with the construction of the Shasta Dam, meaning that “the waters of the Trinity continued to flow to the sea, while the state’s control of the CVP flowed to the federal government” (Durham 2005: 13).

Many of the conditions of agreement that protected the needs of Trinity County endorsed by the Trinity County Board of Supervisors in 1952 were not included in the bill (Durham 2005: 18). Many also questioned the methodology of collection of flow data, particularly as it related to requirements for fish (Durham 2005: 24). In addition, in the negotiations about the use of the Trinity River water, no one discussed the government’s obligations to protect tribal fishing and water rights (Durham 2005: 33).

In April 1963, water was first diverted out of the Trinity River (Durham 2005: 44). The Trinity Dam, completed in fall of 1963, controls the releases from Trinity Lake, which are used by a 105,000-kilowatt power plant and is regulated in Lewiston Reservoir, seven miles downstream. Lewiston Dam, which has a 350-kilowatt power plant, regulates the flows to the fish hatchery and the downstream fishery. From Lewiston Lake, water flows through Clear Creek Tunnel (10.8 miles) to a 141,000 kilowatt powerhouse, then into Whiskeytown Lake behind Whiskeytown Dam on Clear Creek. From Whiskeytown Lake water flows through Spring Creek Tunnel (2.4 miles) to a 150,000 kilowatt powerplant and then into Keswick Reservoir on the Sacramento River (Durham 2005: 44).

Between 1963 and 1977, the US Bureau of Reclamation diverted an average of 1.249 million acre-feet per year, about 92% of the average annual flow (inflow into Clair Engle reservoir) during this period, and 100% of the average annual average flow at Lewiston since 1912. This amount was nearly double the annual diversion approved by Congress (Durham 2005: 52).

The Trinity River Stream Rectification Act (P.L. 960335) of 1980 provided money for the construction of a sediment collection dam and sediment collecting ponds to capture sediment from the logged, fragile Grass Valley Creek watershed. Later the entire 17,000 acre Grass Valley Creek watershed was purchased from Champion National. Construction and restoration cost about \$50 million, more than half of the total Trinity expenditures through 1998's fiscal year (\$90.8 million)(Friends of Trinity River 2010)

In October 1992, the Central Valley Project Improvement Act was passed, which directed the Secretary to operate the CVP to meet requirements to restore fish and wildlife under state and federal law (Durham 2005: 52). It required instream releases in the Trinity of at least 340,000 acre-feet per year for 1992-1996 and required the flow study to be completed by September 30, 1996 and submitted to Congress by December 31, 1996 (Durham 2005: 63). The 12-year Flow Study, intended to inform the effect of various water flows on Trinity's fisheries and wildlife, began in 1984. It was released to the public on May 20, 1999, well after the required release date (Friends of Trinity River 2010). In 1996, the Westlands Water District, the largest water district in the nation, tried to repeal the Central Valley Project Improvement Act (Durham 2005: 64). Between July and November 1998, Trinity County testified before the State Water Resources Control Board in the Bay-Delta Water Rights Hearing, demonstrating that water diverted from the Trinity River was used in soils high in salinity, selenium and other harmful trace elements in the Westlands Water District in the San Joaquin Valley. Because Trinity County offered proof that the diversions had resulted in environmental catastrophes in both river basins, Trinity argued that delivery of water to the contaminated soils in the Westlands Water District, constituted a wasteful and unreasonable use of water in violation of state and federal law (Durham 2005: 65).

A combination EIS and EIR was released in 1994 describing impacts from changes in water allocation that supports Secretarial decisions on water flows into Trinity River, dam operating criteria and evaluation of habitat restoration projects. Unlike the

Flow Study, the EIS/EIR evaluated other impacts and alternatives (for example, raising the height of the dam or getting rid of it).

On December 19, 2000 (four years after the Congressionally mandated deadline), Interior Secretary Bruce Babbitt issued a Record of Decision (ROD), returning some of the water to the Trinity River. This ROD had the concurrence of the Hoopa Valley Tribe. It had a permanent flow volume schedule and new operating criteria for the two dams. This decision was challenged by the Westlands Water District (Friends of Trinity River 2010).

The Record of Decision sets the release volumes for in-stream release depending on the climate that year. In all years, these releases are timed to improve ecological function (move sediment, transport seeds, improve fish habitat, etc.)(US Fish and Wildlife Service and Hoopa Valley Tribe 1999: xxx)

Table 7: Instream Release Volumes

Extremely Wet	815,200 acre feet
Wet	701,000 acre feet
Normal	646,900 acre-feet
Dry	453,600 acre feet
Critically Dry	368,600 acre-feet
Average (weighted by water-year probability)	594,500 acre feet

Source: US Fish and Wildlife Service and Hoopa Valley Tribe 1999: xxxi

The balance between the amount of water that is sent to the Central Valley and the amount of water that continues downstream in the Trinity River changes year by year. The current agreement is that over a long term average 50% of the water goes to the river, 50% goes to the Central Valley. There is some debate about whether long term average is

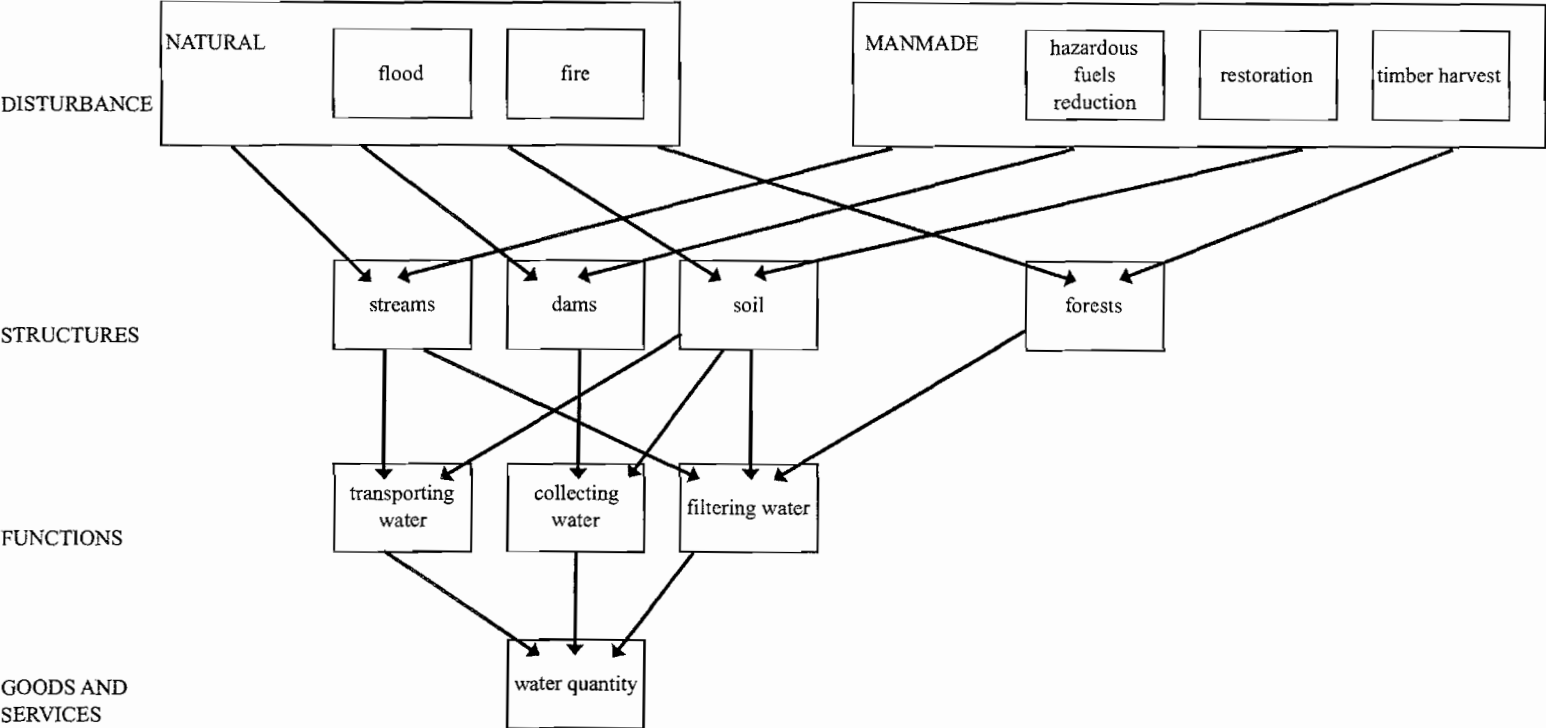
measured daily, monthly, or annual intervals. Recently, this division has been met on an annual basis.

The allocation of water from the Trinity River provokes a lot of discussion and disagreement concerning what freshwater ecosystems need in terms of quantity, quality, and timing of water flow. These discussions involve both values and changing scientific understanding about watershed health. But determining this information is a crucial step (Baron et al. 2002: 1248-9). "The American public, when given information about the management alternatives, supports ecologically based management approaches, particularly toward freshwaters (CEQ 1996)" (Baron et al. 2002: 1249). In addition, forest water catchment yields depend on non-physical factors. The economic value of water is not only determined by its ecological function (Vira and Adams 2009: 159). "If any change in these factors (e.g., pollution, dam construction, channelization) affects the value of water to downstream users, the conservation case for forest preservation is undetermined, without any change in the characteristics of the forest itself. The provision of water services from an upstream forested catchment might support the case for conservation of the natural capital in the biodiversity of the forest, but only if these services are actually delivered to the downstream end user" (Vira and Adams 2009: 159).

Diagram

Figure 6 describes the disturbances, structures, and functions that affect water quantity.

Figure 6: Provision of Water Quantity



Structures and Functions

Streams, dams, soil, and forests all create the functions that affect water quantity. In Trinity County, the Trinity River and its artificially channeled diversions (Clear Creek Tunnel and Spring Creek Tunnel) serve as these streams that transport and filter water. While the aim of stream restoration work required by the Trinity County Stream Rectification Act (1980) and the Central Valley Project Improvement Act was primarily to protect other ecosystem goods and services (particularly fish), this restoration also protects water quantity.

Rarely is the protection of forests and streams discussed in terms of their effects on water quantity, even though ensuring that water quantity and the distribution of that water is highly contentious.

Usually, dams and other catchment structures like lakes and reservoirs are understood to be the primary structures that ensure water quantity. In the Trinity County system, there are several dams and reservoirs that are used to hold to maintain, manage, and distribute water quantity over time. Most of these dams are associated with hydroelectric powerplants, another ecosystem service. Trinity Dam stores 2,448 thousand acre-feet (TAF) in Trinity Lake. Below Trinity Lake, Lewiston Lake stores 14.66 TAF. From Lewiston Dam, some water flows into the Trinity River for the fish hatchery and the downstream fishery more generally. The 2000 Record of Decision designates the amount of water that flows into the Trinity River (U.S. Department of the Interior 2000). The rest of the water flows through Clear Creek Tunnel to Whiskeytown Lake, which stores 241 TAF. From Whiskeytown Lake, water flows through Spring Creek Tunnel into

Keswick Reservoir and then into the Sacramento River and to the Central Valley. These structures ensure water quantity.

In addition to dams, however, there are other ecosystem structures that control water quantity. Soil also holds and slowly releases water, ensuring water quantity. Due to disturbances such as forest fires, this soil structure can be degraded and regulation of water quantity changes.

Goods and Services

The amount of water going to the Westlands Water District via the Central Valley Project (CVP) includes water from Trinity County. For 2010, the amount of water going to Trinity County is estimated to be 335,212 acre-feet, though between 1988 and 2010 this allocation has varied from 195,716 acre feet in 2009 to 1,150,00 acre feet (the legal limit). In 2009, about 11% of CVP water came from Trinity County. At a rate of \$28.69 per acre-foot, the Bureau of Restoration was paid \$617,660 for the portion of the water coming from Trinity County. The Trinity Public Utility District also is paid \$0.11 per acre foot for this water, bringing an estimated \$2,368 to the county in 2009. In addition, the Westlands Water District's rate includes money for restoration, \$9.11 per acre-foot. This money is used for environmental mitigation of the Central Valley Project, as required by the Central Valley Project Improvement Act. About \$196,127 was generated for these restoration efforts. Agricultural users were charged \$108.94 per acre foot for this water, creating \$2,345,343 for the Westlands Water District. This price difference includes fees and operations and management costs for both the San Luis Delta Mendota Water Authority and the Westlands Water District. This final figure was used in the

summary of the value of ecosystem services in Trinity County to avoid double counting, but understanding revenues generated to these other participants is important too.

Examining the magnitude of the difference between how much money is paid to the Trinity PUD, how much money is paid to the Trinity Bureau of Reclamation, and how much money is paid to the Westlands Water District is revealing. While each of these purveyors of water have different infrastructure and operational costs, they were paid significantly different amounts for the same water. The amount of money that went to the Westlands Water District was almost one thousand times as much as went to the Trinity PUD.

Limitations

There are limitations to this method for calculating the value of water quantity. This calculation ignores the other users of Trinity County water who are within Trinity County. This data could be gathered by examining information about water districts that are registered with the California Department of Water Resources and examining rates charged to those districts. Because some users are not registered with the California Department of Water Resources, additional analysis would be needed. Using the information about water districts from the California Department of Water Resources, a per capita estimate of water use could be applied to the number of Trinity County households that are not part of water districts to estimate the total volume of water used in Trinity County. Some unit value could be applied to this volume, though users who are

not part of water districts are not paying for this water. This analysis was not carried out for this project.

Hydroelectricity

The electricity produced by hydroelectric dams from the Trinity River supplies the Trinity Public Utility District and the Redding Public Electric District. This energy is integrated into the Central Valley Project, which supplies the Sierra Nevada Region of the Western Area Power Administration. When this electricity is produced, how much water is required to produce that electricity, and the change in amount and price of this electricity at different water levels are all important components of understanding the economic impact of hydroelectricity from the dams on the economy of Trinity County. However, data are not collected on all of these components.

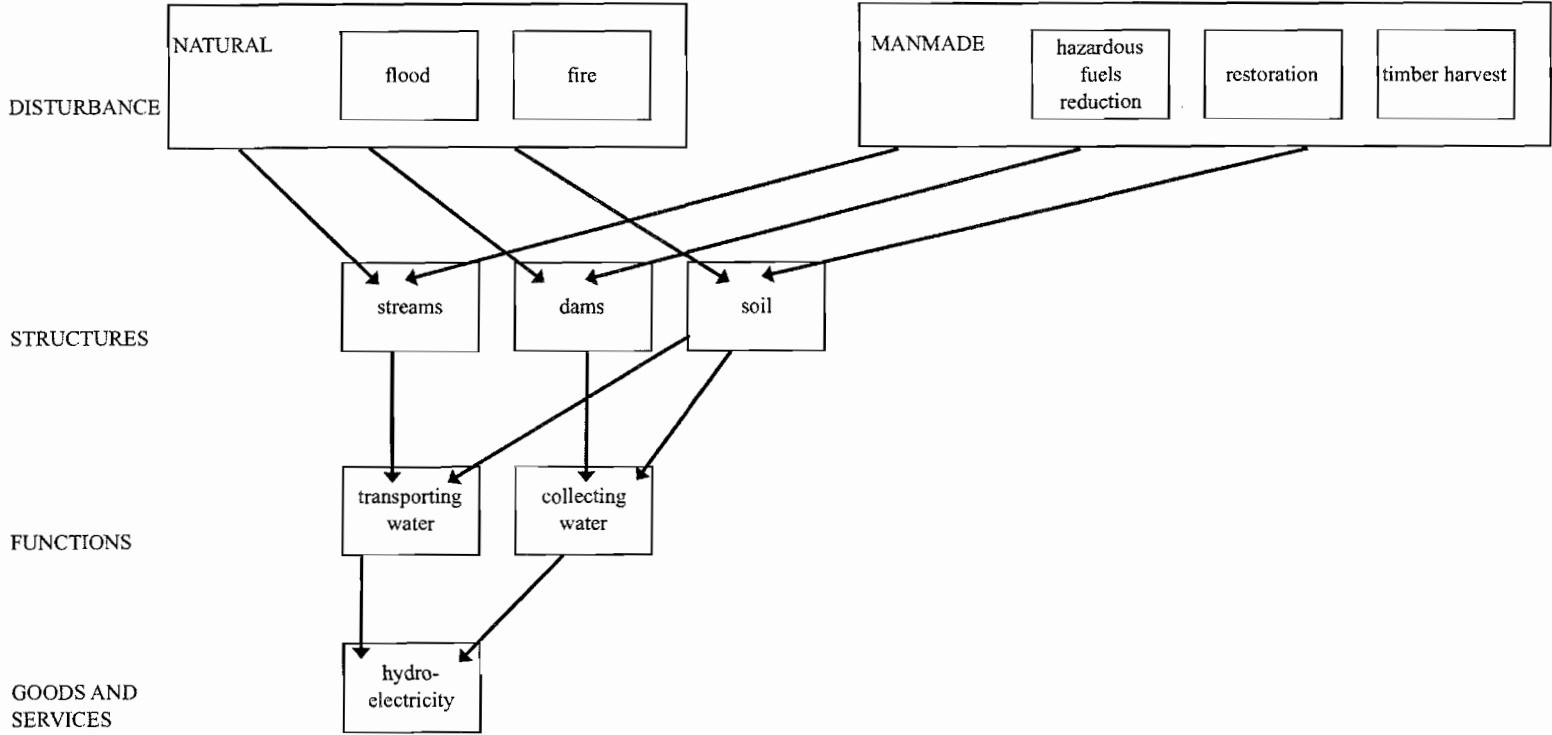
Diagram

Figure 7 describes the disturbances, structures, and functions that affect hydroelectricity.

Structures and Functions

Hydroelectricity is dependent primarily on dams. The dams in the Trinity River system create significant amounts of electricity. The Trinity Dam contains a 105,000 kilowatt powerplant and the Lewiston Dam contains a much smaller 350 kilowatt powerplant. Streams and soil are also important structures for hydropower.

Figure 7: Provision of Hydroelectricity



Goods and Services

The Western Area Power Administration (WAPA) collects detailed data on power generation in Trinity County. This detail of these data in particular would allow connections between who pays and who benefits to be developed, because data about the benefits are collected in a disaggregated form and accessible to the public. (WAPA is a public agency.) In 2005 WAPA stopped paying and charging on a kilowatt-hour basis. Instead, WAPA pays charges based on percentage use or contribution to total electricity generation.

In 2009, the total revenues associated with Trinity County generation totaled \$4,927,810 for 247,234 megawatt hours, about seven percent of the Central Valley Project's generation in 2009. The price of water varied significantly by season, prices in April through September being about a third of prices from October through March in 2009. Management of both the reservoirs and the ecosystems as a whole ensures that Trinity County has water in the summer months to fetch those high prices.

Limitations

There are limitations to the way hydroelectricity values were calculated. This total is for the year, but the revenues, the amount of water, and the proportion of water fluctuate a lot throughout the seasons, and the way the forests are managed changes how and when the water flows through the system. This calculation adds the revenues for the quarters together, but there are other approaches to calculating this value. Trinity Dam is also a peaking power plant- it only operates when there is high demand for power and prices are high, even though there are no separate Trinity prices to differentiate this.

Theoretically, the value of the Trinity power could be much higher if they were not paid as a percentage of total generation but instead were paid based on the value when they generated the power.

Fish

Along with recreational fishing, commercial and tribal fishing activity also occurs in Trinity County. The values of these fisheries were not estimated in this report because I did not find data about these fisheries.

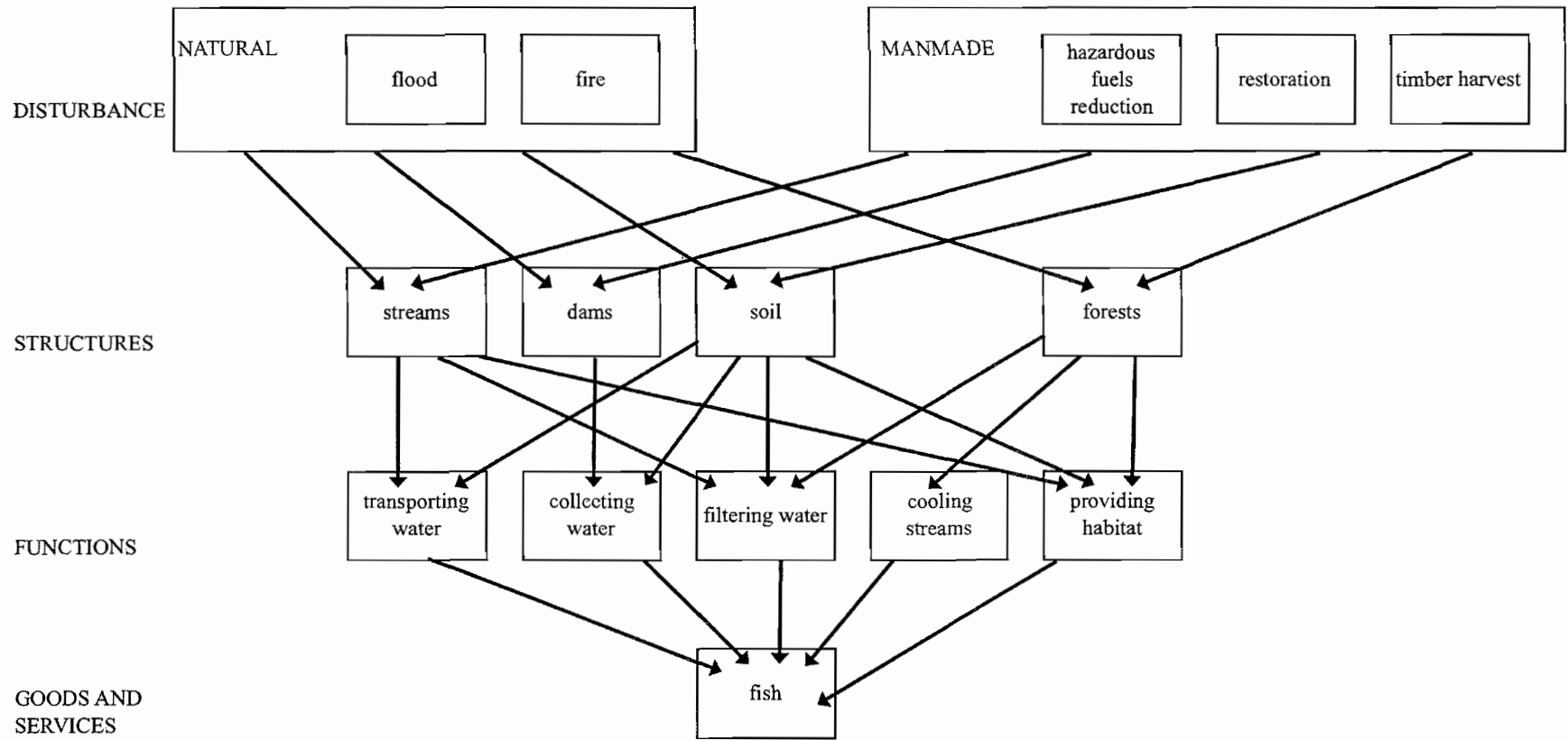
Diagram

Figure 8 describes the disturbances, structures, and functions that affect fish.

Structures and Functions

To create an ecosystem in which fish can survive, streams, dams, soil, and forests are all important components. Streams and the reservoirs collected water to provide the environment in which the fish live. The soil serves to transport and filter the water needed for the fish. Forests and other vegetation cool the streams that allow fish, especially salmon and steelhead, to survive. Significant maintenance and restoration work is devoted to improving fish habitat, and much of the debate concerning water allocation is about maintaining functional fisheries.

Figure 8: Provision of Fish



Government agencies spend significant amounts of money addressing the results of degraded soil structure which influence fish habitat; sedimentation is a major problem for many of the dams in Trinity County and the Bureau of Reclamation has spent both operational costs (dredging) and capital costs (new sedimentation dams) on addressing issues related to soil structure. The Trinity River Stream Rectification Act (P.L. 96-335) of 1980 provided money to construct sediment collection dams and pools and to maintain and dredge these pools (Friends of Trinity River 2010) .

Goods and Services

This study examines two methods of estimating the value of recreational fishing in Trinity County, payment for fishing licenses and travel cost method estimates of the economic impact of fishing visits.

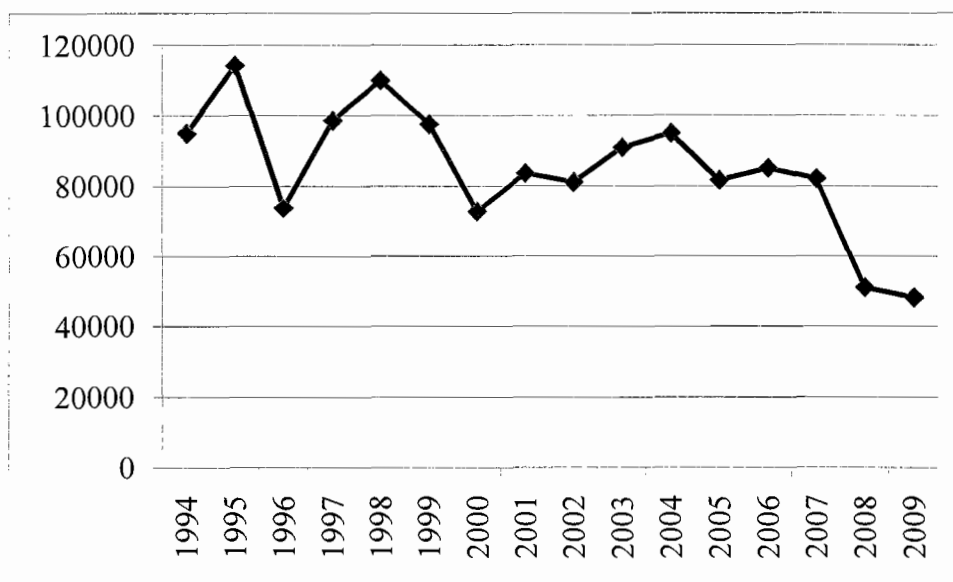
Revenues from fishing licenses do not directly impact communities because much of the money goes to the state rather than Trinity County itself. In 2005, \$164,083.75 was collected from licenses in Trinity County. In 2009 dollars, this equals \$180,500.

Using travel cost calculations, the Trinity River Mainstem Fishery Restoration Environmental Impact Statement estimated the net economic benefit of recreational fishing to be \$65 per day for fishing salmon and steelhead (U.S. Fish and Wildlife Service et al. 2000: D-2). Based on estimates from salmon and steelhead punch cards, the average number of trips to Trinity County for salmon and steelhead fishing between 2003 and 2005 were 5,437 (Jackson 2007: 44). This suggests that the value of recreational fishing is at least \$353,405. In 2009 dollars, this equals \$442,363.

Timber

Like other goods, the amount of value that can be gained from timber is constrained by laws and regulations that limit timber harvest. With the implementation of the Northwest Forest Plan and other social and legal factors, the amount of timber harvest in Trinity County has decreased substantially since 1994, as described in Graph 1.

Graph 1: Net Board Feet Harvested from all Trinity County Lands



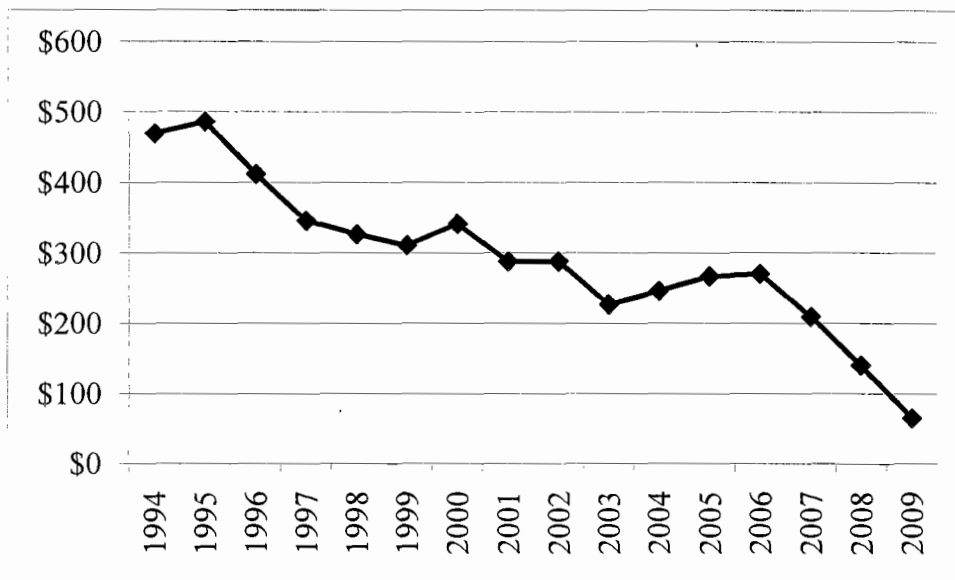
Source: California Board of Equalization 2009

The price per unit of timber has also decreased, as described in Graph 2. The proportion of timber harvested from public lands (versus private lands) in Trinity County has fluctuated between 1994 and 2008, but has always remained below 50%, as described in Graph 3. Additionally, in California overall, the price of timber harvested on public land has consistently been much lower than timber harvested on private land (California Board of Equalization 2009). This difference has gotten more extreme in recent years. In California, between 1978 and 1993 the unit price of timber from public land was between

23% and 64% of the price of timber from private land. Between 1994 and 2009, the unit price of timber from public land ranges between 4% and 18% of the price of timber from private land, with the trend being consistently downward.

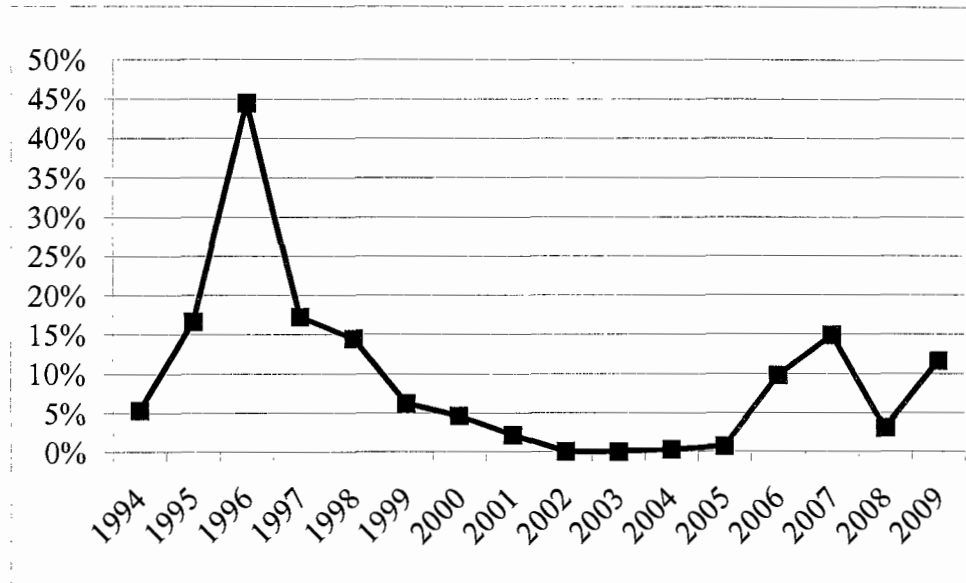
Between 1994 and 2009 the value of the timber harvest in Trinity County decreased from \$44.5 million dollars to \$3.1 million dollars. The amount of timber harvested in Trinity County and the value of that timber has varied tremendously in recent years.

Graph 2: Dollars per Thousand Board Feet in Trinity County



Source: California Board of Equalization 2009

Graph 3: Percent of Timber Harvest on Public Land



Source: California Board of Equalization 2009

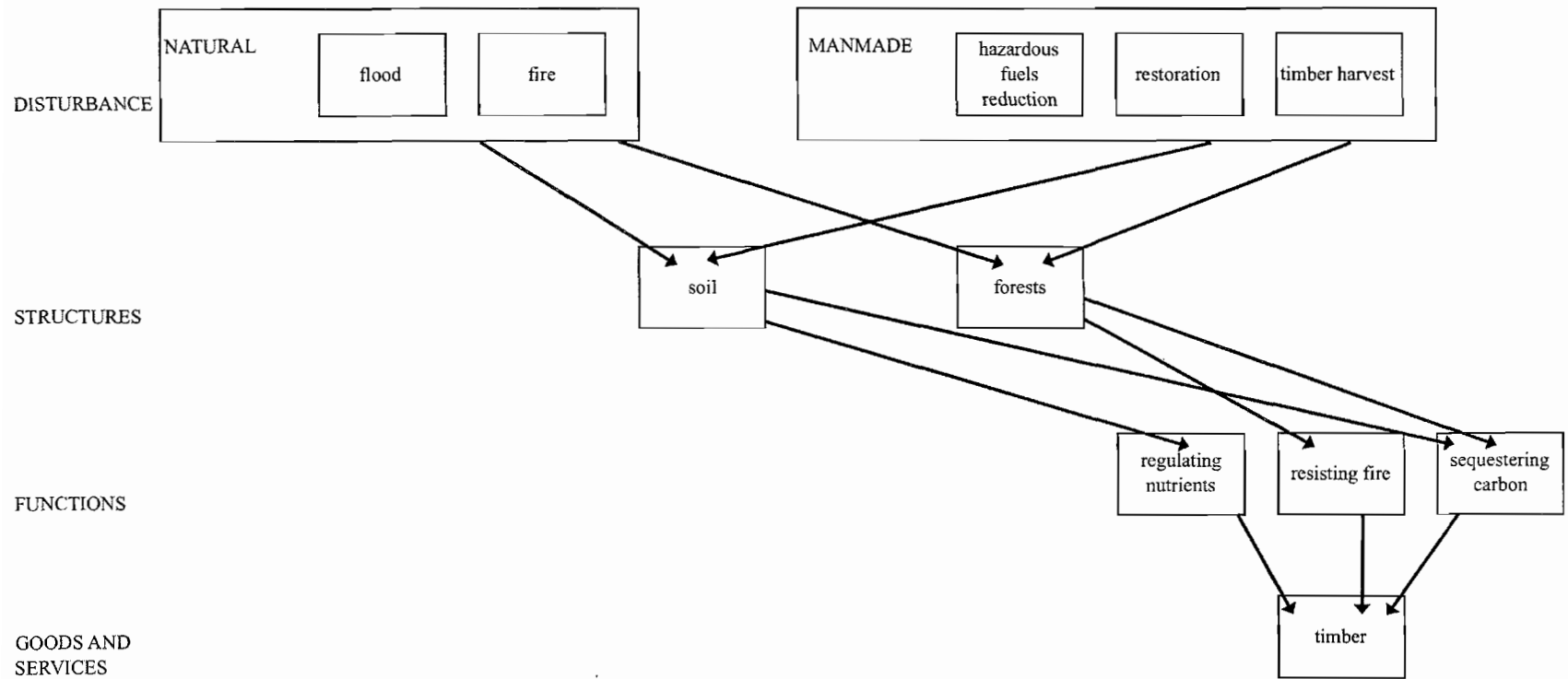
Diagram

Figure 9 describes the disturbances, structures, and functions that affect timber.

Structures and Functions

The ecosystem good timber comes from the ecosystem structure of forests. Timber production also relies on soil to sequester carbon and regulate nutrients. Forests both sequester carbon and resist fire to create timber.

Figure 9: Provision of Timber



Goods and Services

As discussed elsewhere in this study, taking a snapshot approach to valuing ecosystem services is problematic because of ecological and other types of variation. This seems particularly true of timber, which has decreased in value in Trinity County. This low value was particularly true in 2009, the year included in the summary analysis. Not only was less timber harvested than even the year before, the price of that timber was less than half of what it was in 2008. To match the other services valued in this study, 2009 data were used for timber. However, using data from another year would suggest that the value of timber harvest, as an ecosystem service, was much higher. In 2009, fully 48,154 MBF were harvested in Trinity County. This harvest was worth \$3,125,180. Approximately twelve percent of this harvest was from public lands.

Ideally, researchers could establish a rate of sustained yield of harvest from Trinity County. This rate, and the prices implied by this rate, would be a useful indicator of the ecosystem good of sustainably harvested timber. However, timber could only be harvested at this rate if political, economic, and social institutions allowed this rate of harvest.

Marijuana

Marijuana demonstrates that societal norms can contradict an ecosystem good's value in the market. Although timber is frequently referred to as the largest legal cash crop, the assumption is that the cash crop with the highest value in Trinity County is actually marijuana (The Sierra Institute 2002: 3). Significant amounts of marijuana are grown on public lands, particularly in California.

The disturbances to the system caused by marijuana production are also significant and complex. The manmade inputs to the system are for the destruction of this ecosystem good, rather than its maintenance or production. Some estimate that it would cost more than \$300 million to remove the estimated 28,000 acres of marijuana on national forest land in California, at the rate of \$11,000 per acre to remove marijuana plants, clear irrigation systems, and replant native vegetation (Darling 2007).

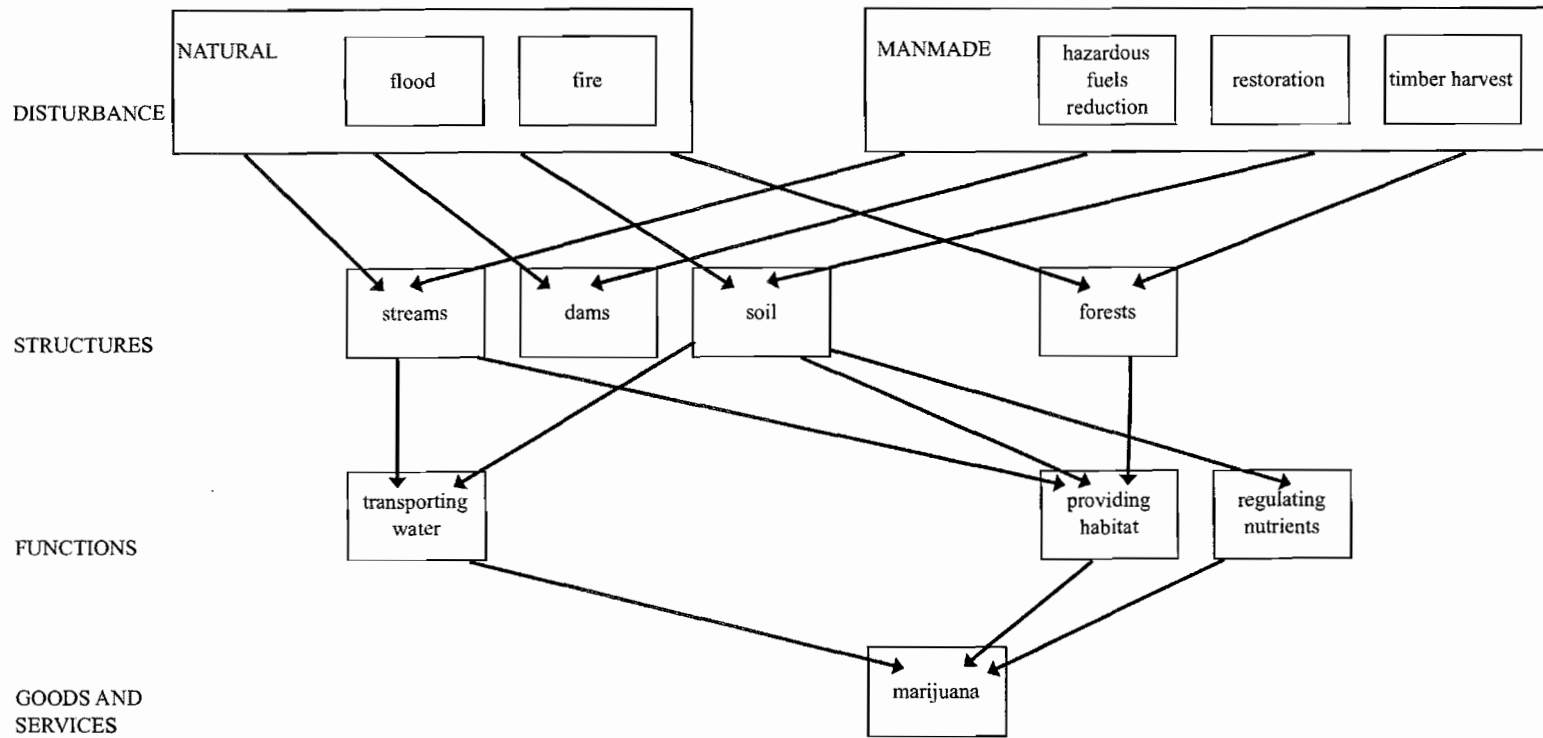
Diagram

Figure 10 describes the disturbances, structures, and functions that affect marijuana.

Structures and Functions

The forest structure provides an environment within which marijuana can be grown. This environment provides both the ecological structure and the societal structure (or lack thereof) that allow successful production of marijuana. The forest, soils, and streams provide the ecosystem within which marijuana is grown. Growing marijuana on public lands, which have limited resources for oversight, allows marijuana production to occur as well. Aside from its illegality, marijuana's relationships to ecosystem structures and functions are similar to other non-timber forest products. Marijuana production depends on ecosystem structures to transport water, provide habitat, and regulate nutrients.

Figure 10: Provision of Marijuana



Goods and Services

Data related to marijuana production are less available than data related to other ecosystem goods and services. Conservatively estimating that the proportion of public land in Trinity County that contains marijuana gardens is the same as the proportion of public land in the US that is estimated to contain marijuana gardens, Trinity County probably has about 323 acres of marijuana. Assuming production of 1742 pounds per acre, Trinity County's public land produces approximately 563,312 pounds of marijuana (Caulkins 2010: 15). Assuming a price of \$3,000 per pound (U.S. Department of Justice 2008: 22), this creates \$1,689,936,548 of economic output, some of which is in Trinity County. In 2009 dollars, this equals \$1,683,780,131.

Recreation

Maintenance of the social benefits (including economic impact) created by recreation requires recognizing the framework that creates these benefits, which is important for multiple reasons. First, the maintenance of the structure and functions that generate recreational benefits creates economic impact. Also, without recognizing the genesis of environmental benefit managers and policymakers will not always make decisions that maximize and sustain these benefits and could inadvertently destroy these benefits.

Like many other services, recreation is often undervalued because it is in part a public good. Postel and Carpenter note, "in countries such as the United States, where enjoyment of the outdoors is on the rise, a large group of people benefit from these recreational services, but the total value of their enjoyment is difficult to measure" (Postel

and Carpenter 1997: 202). Like other services, understanding the value of recreation requires examining more than just collected fees.

To measure the economic impact of recreation, researchers can examine the value of goods and services purchased on a local area due to recreation. This may include fees of any type. These sorts of purchases can be linked to economic benefits in a local community.

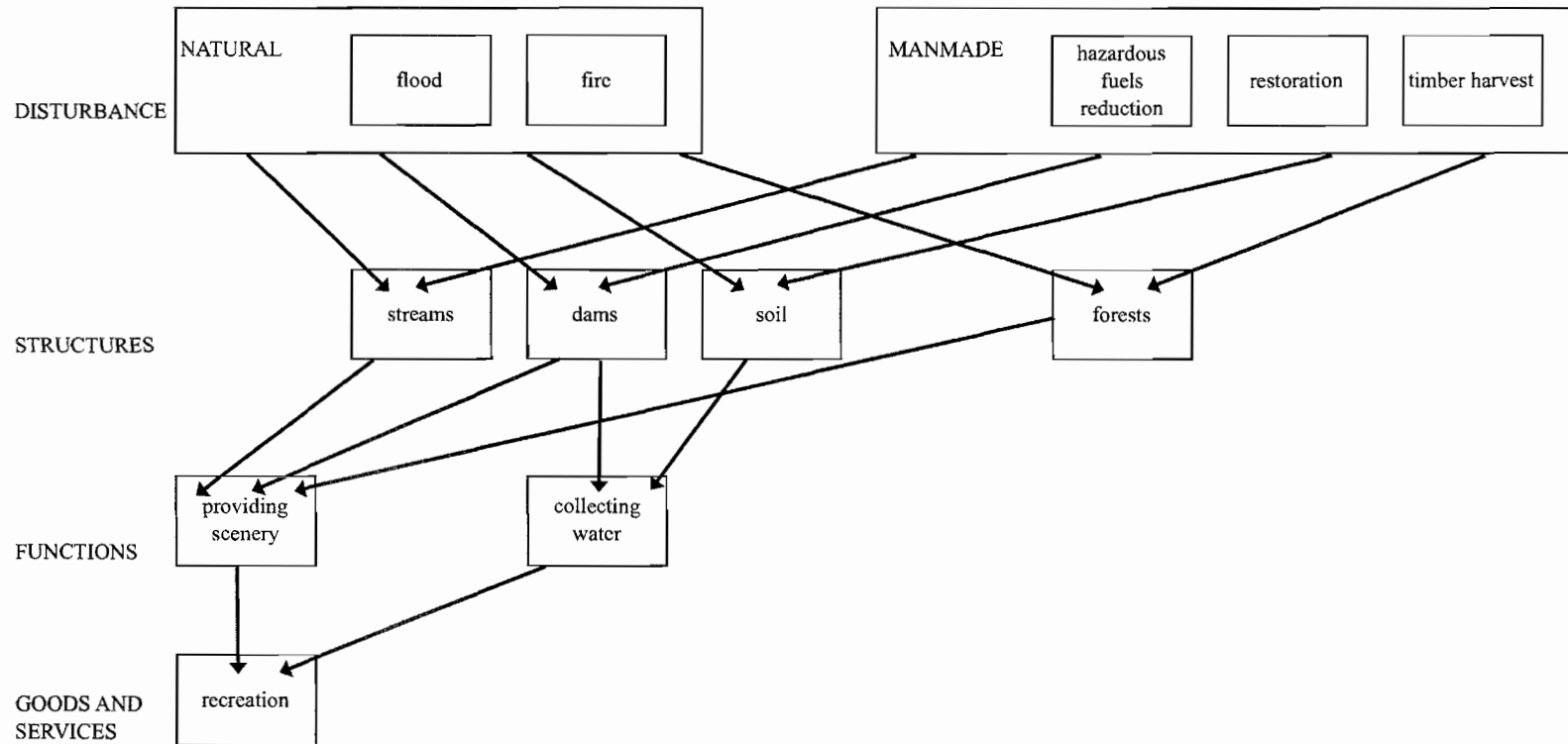
However, this approach underestimates the full economic value of recreation. Hotelling proposed that understanding the cost of visiting a national park should include knowing the cost of getting to the park (Hotelling 1949). This proposal spurred the development of the travel cost method of estimating the value of an environmental resource. While this method does not include existence values, it does use real rather than hypothetical expenditures. Travel cost methods estimate demand (through willingness to pay) using the travel costs required to visit a site (Brander et al. 2006: 228).

The contingent valuation method uses hypothetical questions to obtain actors' willingness to pay (Brander et al. 2006: 228). This method can be used to indicate the value of biodiversity and water quality improvements. Contingent valuation is not actually based on transactions, unlike other methods. Instead, contingent valuation is a survey methodology (Heal 2000: 28).

Diagram

Figure 11 describes the disturbances, structures, and functions that affect recreation.

Figure 11: Provision of Recreation



Structures and Functions

Recreation is dependent on both the provision of scenery and the collection of water. Scenery is provided by forests, dams, and streams. Water is collected by dams and soil.

Goods and Services

To recreate on National Forest lands, users must pay a recreation fee, which implies a lower bound on willingness to pay. In 2005, the Shasta-Trinity National Forest collected \$1,180,219 in revenue from 2,443,000 visitors. Its expenditures were \$951,579 (U.S. Forest Service 2006). Through their participation in the Recreational Fee Demonstration Program, the Shasta-Trinity National Forest is allowed to keep 80 percent of the fees collected to use locally (U.S. Department of the Interior and U.S. Department of Agriculture 2000). In addition, the Shasta-Trinity National Forest is one of two forests testing special-use fee retention. As a result, the local economic impact of all of the Shasta-Trinity National Forest fees is much higher than the impact in other forests. However, the economic impacts and social benefits of recreation in Trinity County extend beyond these fees.

As discussed earlier, one method to estimate the social benefits of an environmental resource is the contingent valuation method. This approach uses surveys to determine how much the respondent would be willing to pay for an environmental benefit, such as recreational use. It measures both active use values from recreation and passive existence values. Contingent valuation methods can be less accurate when users simply assume more is better without completely understanding what is implied by more

of the environmental resource and what budget constraints are faced when it comes to maintenance of that environmental resource (Diamond and Hausman 1994).

Another method of identifying the social benefits of an environmental resource, particularly its recreational value, is by using the travel cost method. This technique has been used to estimate the value of the Trinity Alps Wilderness, an area of Trinity County primarily used for hiking recreation.

Steven Hackett uses the zonal travel cost method to estimate that the economic value from wilderness visits in the Trinity Alps was \$219,028 in net benefits in 1999 (Hackett 2000). This equals \$283,777 in 2009 dollars. While this study did not examine recreational visitation values throughout the entire Trinity Alps Wilderness, its boundaries suggest the estimate of the value of this wilderness for the hiking portion of recreation is a low estimate, rather than a high one. Its boundaries are the North Fork of the Trinity River, the Salmon River drainage, and the wilderness boundary on the south and east, and the Pacific Crest Trail to the north. This eastern section of the Trinity Alps Wilderness has more visitors and covers most of the visits to the area (about 75 percent). In addition, Hackett had access to the data only for this area. His data were based on wilderness permits, which about 80 percent of users complete. As a result, his data probably represent about 60 percent of visitors to the area.

The local economic impacts of off-highway vehicle (OHV) use are difficult to determine. OHV users in Trinity County must have permits, issued by the State of California. A study in 1994 found that expenditures by OHV users for equipment, activities, and events in California generated about \$1.2 billion in economic activity in

1992. The average household participating in OHV use spent \$3,431.41, not including the cost of vehicle purchase in 1994 (Off Highway Motor Vehicle Recreation Division 1994). This report specified that collectively, visitors to Trinity County traveled 30,367 miles off of highways in their most recent trips (Off Highway Motor Vehicle Recreation Division 1994). A study in 2005 found 17.4 percent of Californians participated in OHV activities, more than in the 1994 study (Cordell et al. 2005). This suggests that economic impacts of OHV use may have increased since the 1994 study.

Local economic impacts on Trinity County from OHV recreation seem to be substantial, but are difficult to measure because OHV permitting is done at the state level (and is not attributable to county) and passes to engage in OHV use on National Forest land are covered by more general wilderness passes, which also allow for other types of recreation. In addition, there are local economic impacts on nearby communities through repair shops, guide services, and businesses based on OHV use. These values were not estimated in this study.

Lake activities create significant economic impacts for Trinity County through a variety of revenue streams. A portion of the fees (based on gross receipts) from concessionaires in the lake recreation areas goes to the Forest Service. While this percentage is not public, through the Recreational Fee Demonstration Program a majority of this money stays in Trinity County. Data concerning number of visitor days to the lakes are limited because the Forest Service collects visitor day information at a larger scale.

In Trinity County, reservoir levels are not primarily managed for recreational use. Water levels are primarily determined by the need for hydroelectric power and water use downstream. The levels are determined by the Bureau of Reclamation. Many have discussed the important effect that water level has on recreation (Cameron et al. 1996). Bowker et al. (1994) identify these effects for the Shasta-Trinity National Forest recreation sites in particular. They calculated total annual visitation as a function of water level, draw down, and year. In general the higher the water level, the higher the visitation, suggesting that within the study years, water levels did not exceed optimal levels (Platt 2001: 4). Smaller seasonal drawdowns resulted in greater total visitation.

The Trinity River Mainstem Fishery Restoration Environmental Impact Statement estimated the number of recreational visitor days to the Trinity Reservoir was 265,800 in 1991. This statement estimated the economic impact of a visitor day to the area reservoirs to be \$11 per day. This suggests that there is an estimated \$2,900,000 impact (U.S. Fish and Wildlife Service et al. 2000: D-25). In 2009 dollars, this is \$4,621,413.

The Trinity River Mainstem Fishery Restoration Environmental Impact Statement estimated the number of recreational visitor days to the Trinity River at 214,000 in 1995. A user survey conducted in 1993 and 1994 by the Biological Resources Division of the US Geological Survey identified the economic benefit of recreation for different activities. It was estimated to be \$36 per day for boating, \$26 per day for swimming, and \$65 per day for fishing for salmon and steelhead, and \$33 per day for off-river activities such as hiking. This statement used these average per-day values to estimate the total

benefits of recreation along the Trinity River to be \$9,900,000 (U.S. Fish and Wildlife Service et al. 2000: D-2). Because this value includes fishing, accounted for elsewhere in the model, the estimate of recreation without fishing is used in this section. This value is \$9,546,595. In 2009 dollars, this is \$13,625,538.

Summary

Table 8: Recreation Summary

Recreation Component	Amount	Year	Method	Value in 2009 Dollars
Recreation fee	\$1,180,219	2005	Economic Impact	\$1,298,300
Hiking	\$219,058	1999	Travel Cost Method	\$283,777
Lake activities	\$2,900,000	1991	User survey	\$4,621,413
River activities	\$9,546,595	1995	User survey	\$13,625,538
TOTAL	\$13,845,872			\$19,829,028

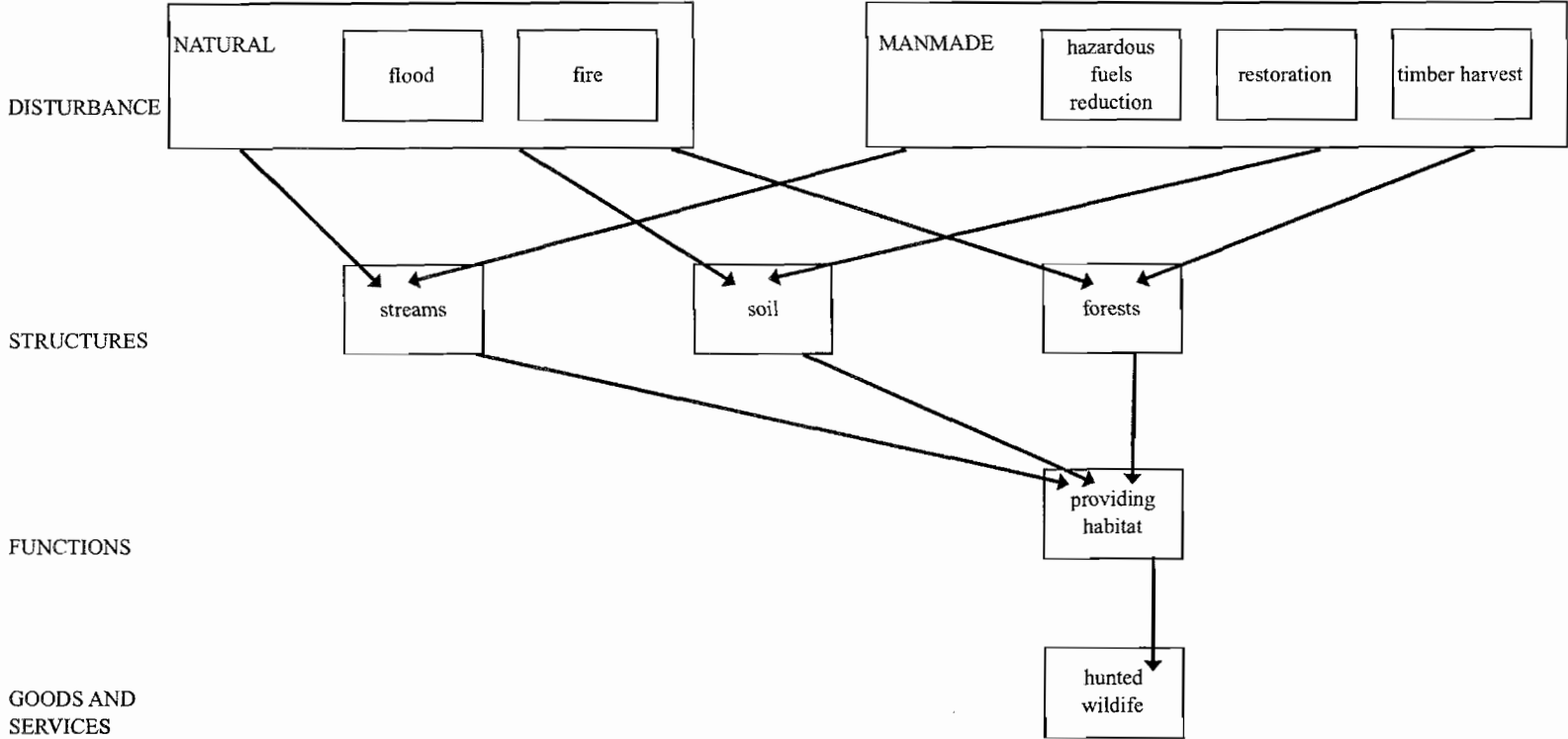
A low estimate of the economic benefits of recreation is \$19,829,028, in 2009 dollars. As with other ecosystem services, some of this money goes to Trinity County, while other portions go to the federal government and other beneficiaries. It is particularly difficult to separate out economic impact and social benefit from recreation data because the value of recreation is estimated using so many indirect methods.

Hunted Wildlife

Diagram

Figure 12 describes the disturbances, structures, and functions that affect hunted wildlife.

Figure 12: Provision of Hunted Wildlife



Structures and Functions

Hunted wildlife is mostly dependent on the ability of the ecosystem to supply habitat for the animals being hunted. However, the ecosystem structures of streams, soil, and forests all provide habitat for hunted wildlife.

Goods and Services

Approximately 11,141 deer tags were issued in Trinity County. The approximate revenue from these deer tags was \$274,127. While not all of the revenue from these tags benefits Trinity County, some of this revenue is spent on local habitat maintenance and restoration.

There are a variety of ways to value hunting beyond simply calculating the possible economic impact of deer licenses. Bennett and Whitten used the travel cost method to estimate duck hunters' willingness to pay to hunt and better estimate the economic impacts of this hunting (2003). Buschena (2001), Boxall (1995), and Bilgic (2009) discuss lotteries as a way of better matching the supply of licenses with the demand for those licenses. This method could also increase revenues, increasing local economic impact.

Non-Timber Forest Products

Non-timber forest products (NTFPs) are “items gathered from the forest that have spiritual, subsistence, or market value” (Everett 2001: 337). In Trinity County, the NTFPs of particular value are products from plants, fungi, and lichens (Everett 2001: 337). Demand for NTFPs is growing, particularly for medicinal herbs. Communities previously dependent on timber revenues are looking to NTFPs as an alternative economic basis,

though it is unclear whether local communities benefit from large scale NFTP harvesting (Everett 2001: 338). Harvesters are often from outside of Trinity County and the profits go to exporters (Everett 2001: 338). In particular, when NTFPs are harvested from public land, “their revenues do not cover the cost of their management,” especially as new NTFPs are discovered to be marketable and desirable (Everett 2001: 339).

Collection of non-timber forest products is a permitted activity on national forest land. Managing non-timber forest products has been an increasingly important role for the Forest Service, particularly as legal constraints on the harvesting of timber forest products have increased (Everett 1997: 1).

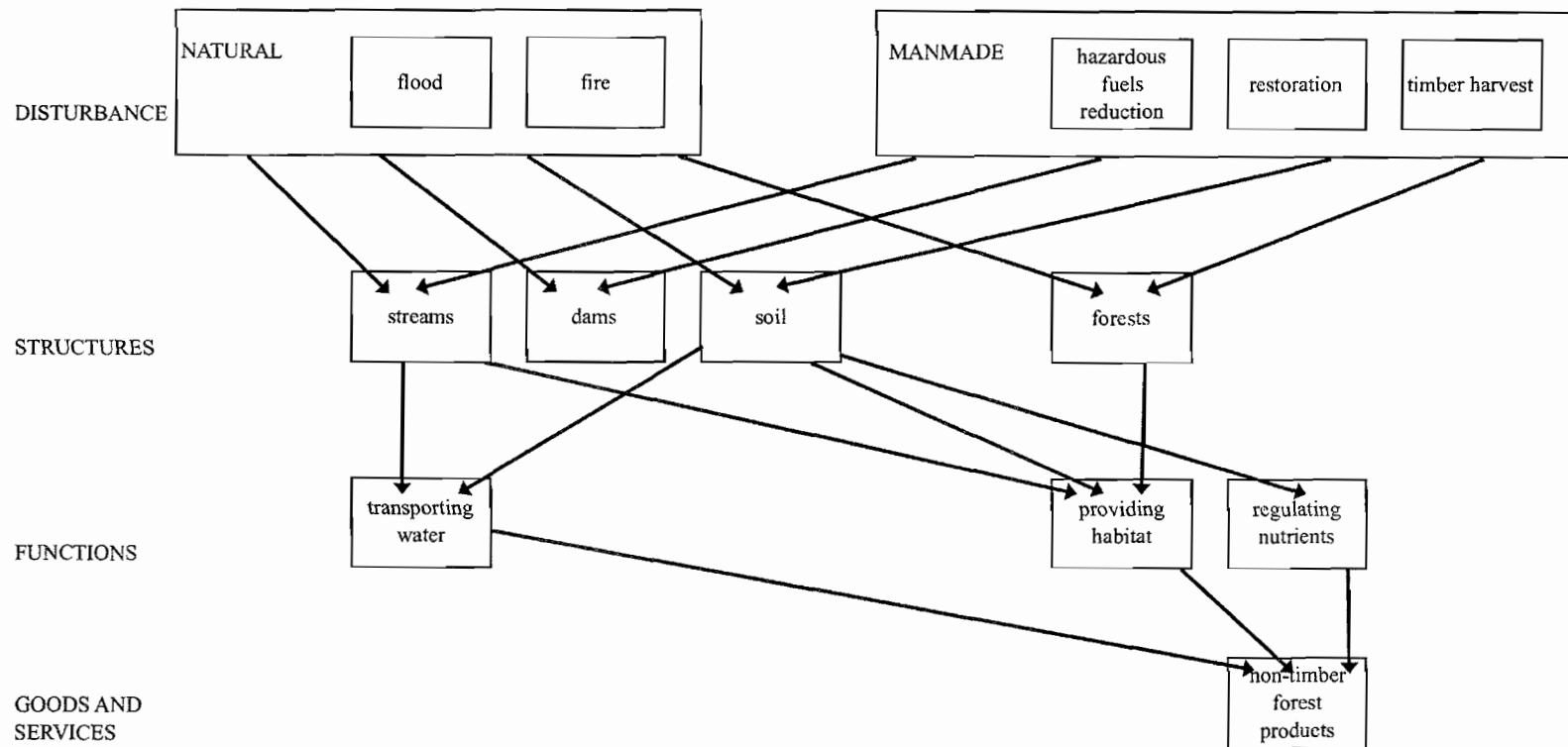
Diagram

Figure 13 describes the disturbances, structures, and functions that affect non-timber forest products.

Structures and Functions

While the primary structure for non-timber forest products is the forest itself, the soils and streams of the ecosystem also support ecosystem functions important to non-timber forest products in Trinity County. Non-timber forest products depend on ecosystem structures to transport water, provide habitat, and regulate nutrients.

Figure 13: Provision of Non-Timber Forest Products



Goods and Services

To estimate the value of non-timber forest products in Trinity County, I use information from the Forest Services permits granted by the Shasta-Trinity National Forest to people collecting from districts within Trinity County in 2009. These permits were issued for. This estimate does not include non-timber forest products that were not collected from Shasta-Trinity National Forest, particularly those on private lands. The total value for these non-timber forest products is \$36,909.

Goods and Services not Valued in the Direct Market

Energy from Biomass

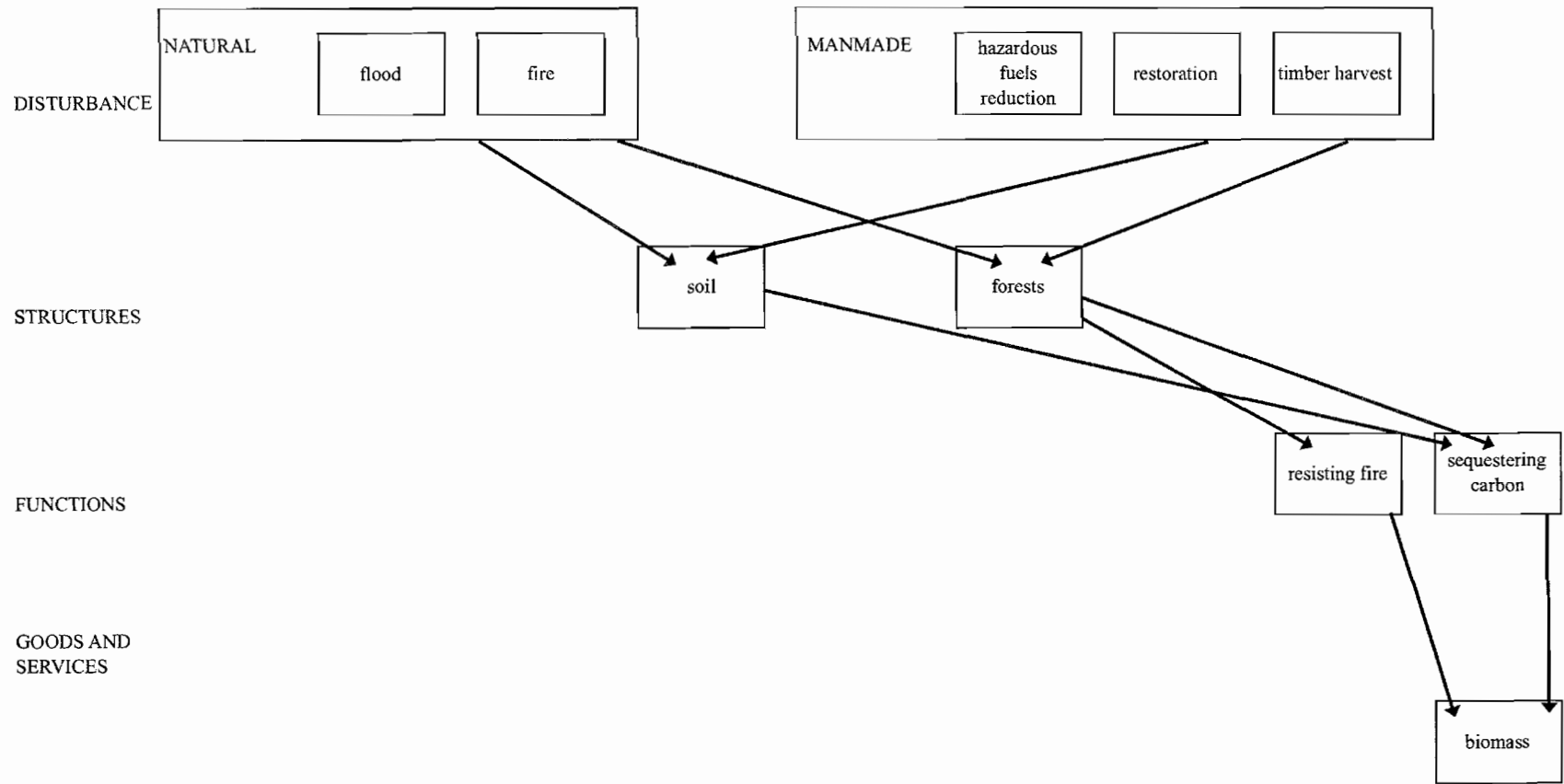
Diagram

Figure 14 describes the disturbances, structures, and functions that affect biomass.

Structures and Functions

The production of biomass for energy relies on structures and functions similar to timber production, but the quality of these structures (particularly the forest) can differ. Materials for biomass generation can come from forest thinning. Forests sequester carbon to produce biomass fuels to use for biomass generation. Through thinning, forests are rendered more resistant to fire.

Figure 14: Provision of Biomass



Goods and Services

Although there currently is not the needed infrastructure to generate energy from biomass in Trinity County, there is extensive local and statewide interest in developing this infrastructure (Martin et al. 2006). If this infrastructure were developed, Trinity County's forest ecosystem could create energy from biomass, an ecosystem good. The Pacific Southwest Research Station prepared a report for the California Energy Commission examining forest management for wildfire reduction and energy production using biomass generation (USDA Forest Service 2009: 3).

This report's model used forest thinnings to generate electricity. This model suggested \$1.58 billion could be generated from thinning on 2.7 million acres of contiguous forest (USDA Forest Service 2009: 3). Trinity County's public land totals approximately 1.6 million acres. In addition to generating money from electricity, this report found that 22% fewer acres would be burned by wildfires in a model forest that was thinned for energy production using biomass. This reduction in wildfire would result in \$246 million in avoided wildfire damages and \$18 million in avoided fire suppression costs (USDA Forest Service 2009: 3).

Water Quality

Like other goods and services, there are numerous measures of water quality, some of which affect human uses of water and others which do not (Layke 2009). As Freeman points out "even providing a descriptive characterization" of water quality is "a formidable task. Water quality cannot be represented by a single number on some scale, but rather is an n-dimensional vector of the relevant parameters. Which subsets of these

parameters are most important in influencing the uses of a body of water (commercial fishing, boating, or swimming, for example) is still a major question for research” (Freeman 2003: 35). In particular, Freeman points out that predictive models for these parameters are difficult to develop. For example, although many water quality models examine dissolved oxygen, dissolved oxygen levels are not directly related to the water quality required for fish habitat or recreational use (Freeman 2003: 35).

Diagram

Figure 15 describes the disturbances, structures, and functions that affect water quality.

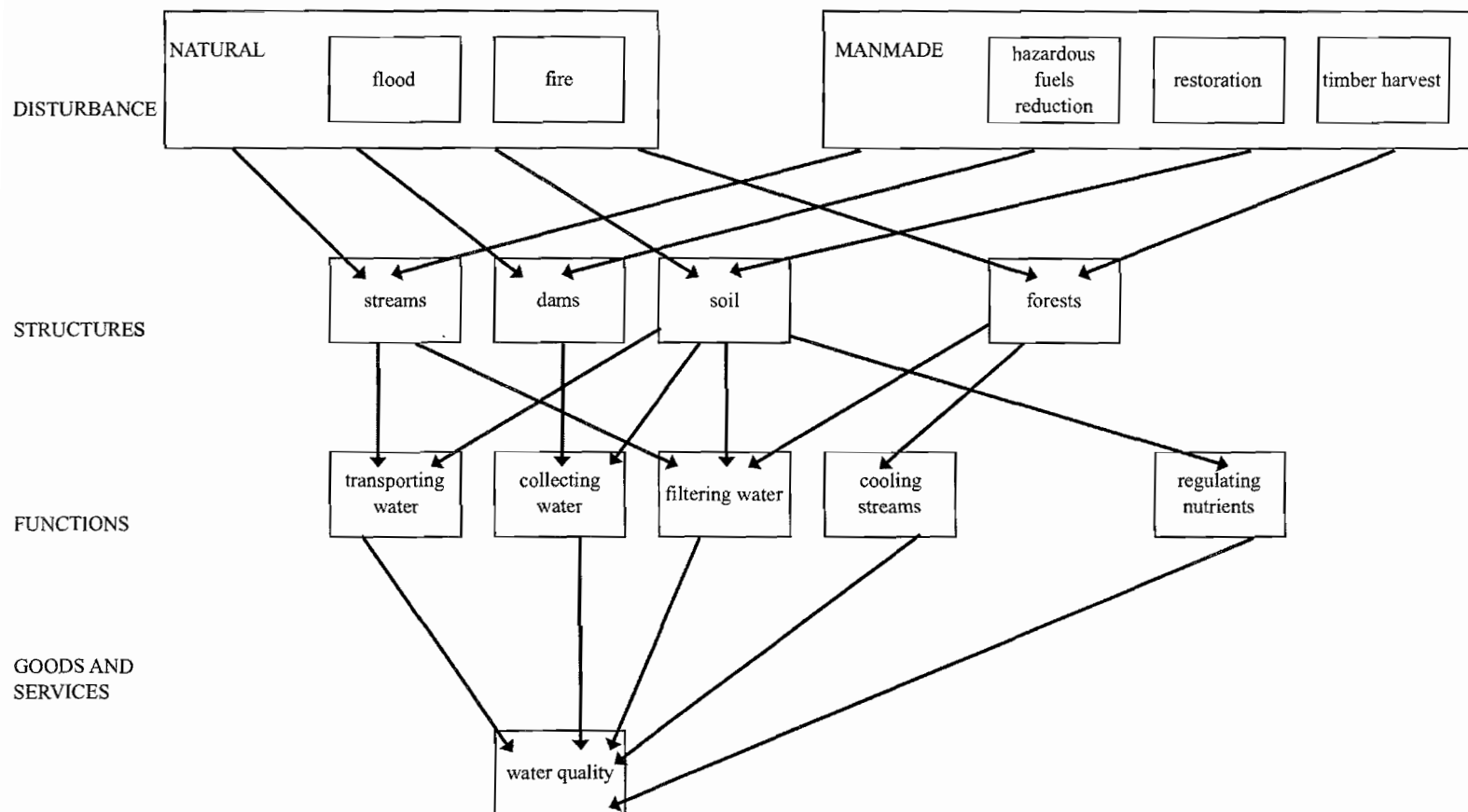
Structures and Functions

Water quality depends on all of the structures and many functions described in the Trinity County system. Streams and dams collect and then transport water; this collection and dilution of pollutants affects water quality. Streams and soil also filter water, removing pollutants. Soil regulates nutrients flowing into the streams. Forests play an important role in cooling streams, which is important to some aspects of water quality.

Goods and Services

Currently in Trinity County, payments by water users for water quality do not exist. However, water that flows from Trinity County must meet certain water quality requirements. Water quality from Trinity County is carefully monitored, both that which flows into the Trinity River and that which is diverted for the Central Valley Project. Maintaining good water quality is something water users may be willing to pay for. Maintenance of that water quality depends on maintenance of the Trinity County ecosystem.

Figure 15: Provision of Water Quality



Water quality markets may be some of the first markets for ecosystem services to develop. These markets may relate to nutrient levels, water temperature, or other types of water pollution. Trinity County has a resilient structure to maintain good water quality.

Non-Hunted Wildlife

Markets do not currently exist for non-hunted wildlife. In addition, there is significant debate in the literature about whether biodiversity, another classification of non-hunted wildlife, can be valued and thus whether it is an ecosystem good or service. That said, significant amounts of money are being paid using public budgets for the protection of biodiversity. Society is paying for biodiversity, whether or not it can be quantified or increased.

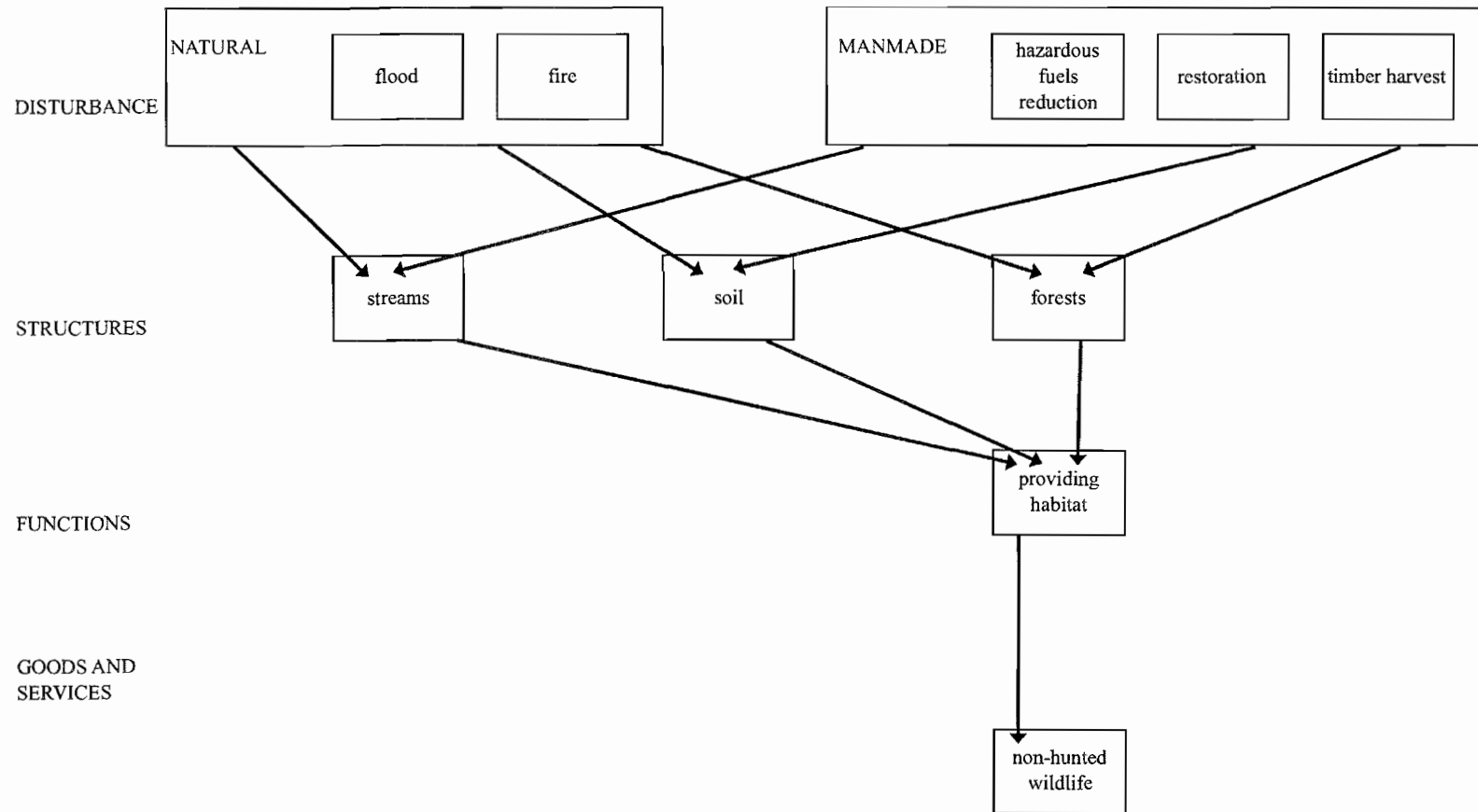
Diagram

Figure 16 describes the disturbances, structures, and functions that affect non-hunted wildlife.

Structures and Function

Streams, forests, and soil structures all create the habitat in which all wildlife, including non-hunted wildlife, live. Significant resources are invested in maintaining these ecosystem structures so that they adequately provide habitat for non-hunted wildlife, particularly those that are listed as threatened or endangered.

Figure 16: Provision of Non-Hunted Wildlife



Goods and Services

Although non-hunted wildlife and biodiversity do not have a direct market, significant resources are spent on ensuring adequate numbers of non-hunted wildlife. Non-hunted wildlife, particularly that which is threatened or endangered, is an interesting example of goods whose production is carefully monitored and maintained despite not having a market. This monitoring is of course due to legislative requirements. There has been significant discussion about creating markets for biodiversity, but others question whether biodiversity is an ecosystem service at all because it does not have substitutes. Once a species is extinct, it cannot be substituted. While people could pay to improve habitat for threatened species, or maintain all ecosystem functions to ensure a broader functional ecosystem that is more likely to allow a diversity of species to thrive, markets that allow buyers to pay for the existence value of a particular species are difficult. Thus far, markets have not addressed existence value very well.

Climate Regulation

Sierra Pacific, which owns some of the private land in Trinity County, has decided to sell carbon credits from its holdings (Bailey 2009). While the current market for carbon credits is weak, climate regulation could be a significant service that the ecosystem of Trinity County offers.

There is significant discussion around whether or not public lands should participate in carbon markets, as they become available. While they could enter the market slowly and be used to muffle disruptions in the emerging market, there are also concerns that they could flood the market.

Diagram

Figure 17 describes the disturbances, structures, and functions that affect climate regulation.

Structures and Functions

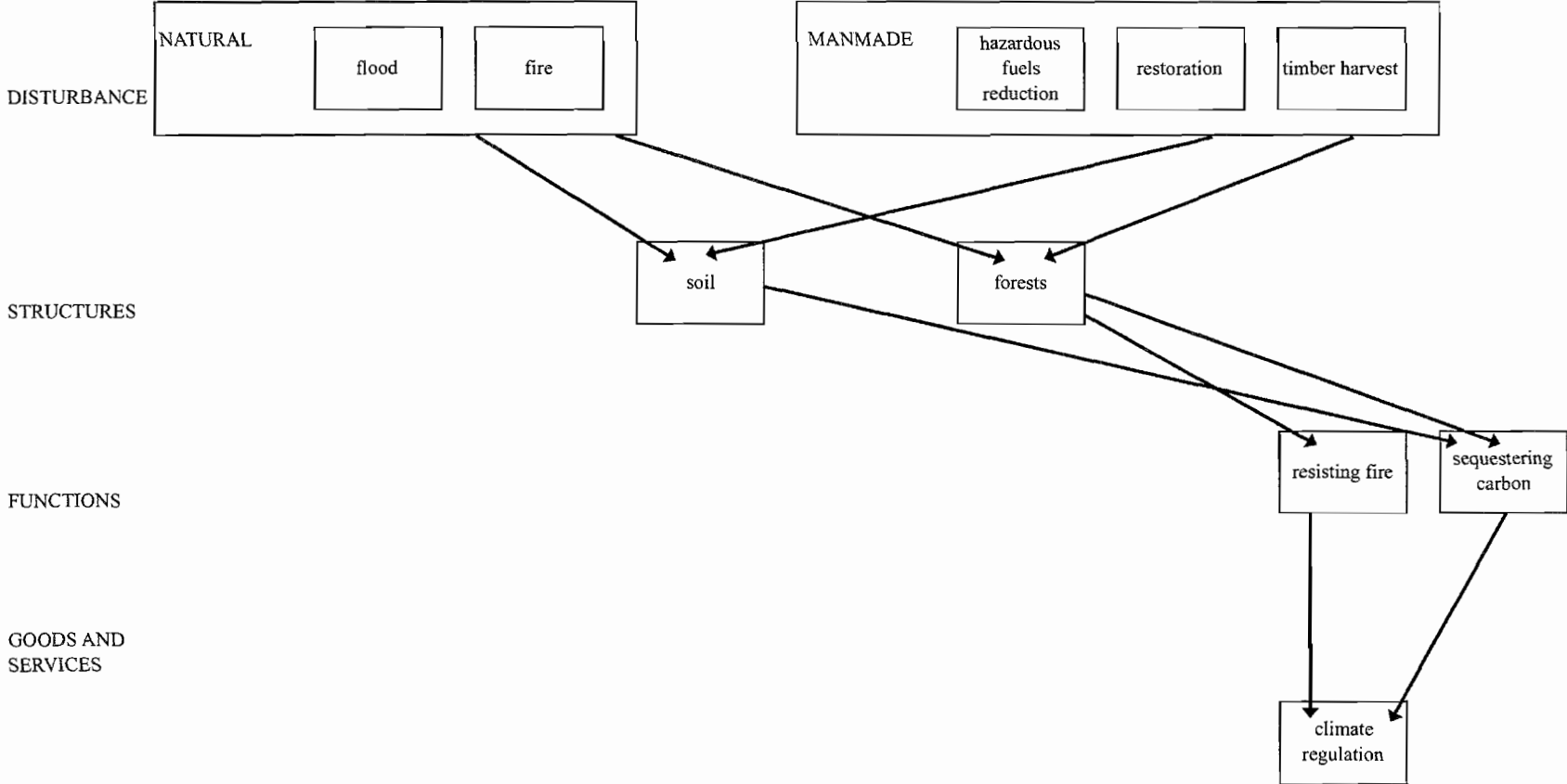
Climate regulation depends on having a forested landscape. This forested landscape sequesters carbon and resists fire, producing climate regulation. Like biomass, the structures and functions that create the service of climate regulation are similar to timber, but the way a forest is managed for carbon may differ.

Goods and Services

The primary good that climate regulation creates is currently carbon credits. While a direct market exists for carbon credits, and Sierra Pacific plans on participating in that market using carbon sequestered in Trinity County, the value of carbon credits in Trinity County was not estimated in this study. This value could be estimated with information from Sierra Pacific about the forests in Trinity County that they plan to involve in a carbon market.

Carbon accounting is a complex field. Different carbon markets follow different methodologies for measuring carbon sequestration, and carrying out this valuation requires significant labor and collection of baseline information. More generally, managing for carbon sequestration is particularly contentious and difficult. The role of forest fires, controlled and otherwise, in management for carbon sequestration is debated in the literature. Maximizing climate regulation also creates tradeoffs in the production of other ecosystem goods and services such as timber harvesting and possibly biodiversity.

Figure 17: Provision of Climate Regulation



Amenity Value

Amenity value plays a subtle role in Trinity County. It can be observed in the price a resident is willing to pay for a house with certain characteristics in Trinity County, such as a view. Amenity value also affects decisions about where to harvest timber and how to design public and private land. Studies to understand amenity value have been carried out many locations. Their methods and possibly their values could be applied to Trinity County to understand the importance of amenity value to the economy.

Diagram

Figure 18 describes the disturbances, structures, and functions that affect amenity value.

Structures and Functions

Streams, dams, and forests all provide scenery. It is this scenery that creates amenity value, the value gained from an asset, such as land, being in the location where it is. Usually this value comes from beauty, accessibility to desirable locations, or other characteristics.

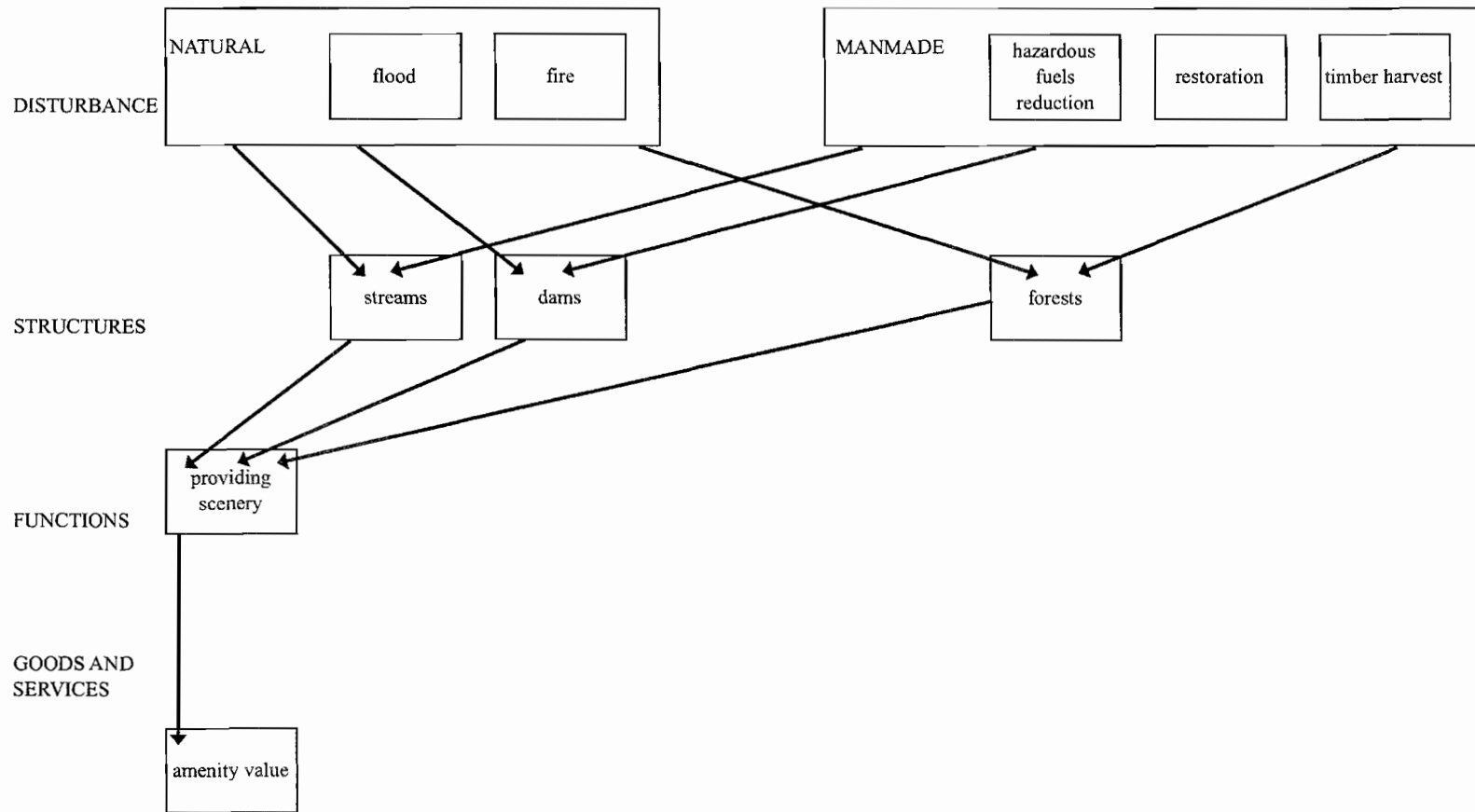
Goods and Services

Amenity value is usually measured using hedonic pricing models. One way to carry out this type of valuation in Trinity County would be to examine the difference in prices between housing in Trinity County and other locations with similar housing but less beauty or access to desired amenities.

Another way to examine amenity value is to look at the amount that Sierra Pacific spends to create visual buffers from the land that is logged, or the Forest Service spends

on landscape architecture and other aesthetic features. These techniques would measure inputs to the system, however, and not the amenity value of Trinity County.

Figure 22: Provision of Amenity Value



CHAPTER V

DISCUSSION

Table 9 summarizes the values of ecosystem goods and services discussed in Chapter IV, Results.

Table 9: Value of Ecosystem Goods and Services Summary

	Value	Year	Value in 2009 Dollars
Water quantity	\$2,345,343	2009	\$2,368
Hydroelectricity	\$4,927,810	2009	\$4,927,810
Fish	\$353,405	2005	\$442,363
Timber	\$3,125,180	2009	\$3,125,180
Marijuana	\$1,689,936,548	2008	\$1,683,780,131
Recreation	\$19,829,028	mixed	\$19,829,028
Hunted wildlife	\$274,127	2009	\$274,127
Non-Timber Forest Products	\$36,909	2009	\$36,909

The value of ecosystem goods and services in Trinity County is at least \$1,712,417,916. Leaving out marijuana, because its production on public lands is illegal, the value of ecosystem goods and services in Trinity County is at least \$28,637,785. In 2002, \$3,913,753 was spent on restoring ecosystem function. Significant other inputs went into fire suppression, hazardous fuels reduction, and sedimentation reduction.

This analysis confirms that while economic activity in Trinity County has shifted away from timber, it is still based on natural resources. Maintaining this basis is important to those who benefit from Trinity County's ecosystem, which includes Trinity County residents but is not limited to them. Understanding who benefits from those

ecosystem goods and services is also important. While some goods and services have economic impact within the county, the benefits of some others, like hydroelectricity and water quantity, accrue outside the county.

In addition to shifting who pays and who benefits, there are opportunities to value new services, or value services at a higher rate. This study's estimate of the total value of ecosystem services of Trinity County of \$29 million can be calculated to equal about \$18 per acre of public land. (This estimate assumes that public land provides most of these services.) Although this study does not examine benefits transfer in great detail, comparing the number I calculated for the value of goods and services in Trinity County with the number other studies of ecosystem services would suggest using benefits transfer is an interesting exercise that contrasts economic impact and social benefit.

I found studies valued temperate forest ecosystem services at different rates: between \$122 per acre from Costanza's 1997 report to a 2008 study specific to federal lands that valued forest land at \$845 per acre (Costanza et al. 1997; Ingraham and Foster 2008). These studies each include different services and have different methodologies. However, the implications of the difference between \$29 million in economic impact, found in this study, and \$191 million or \$1.3 trillion in societal benefit implied by these other studies, are significant. The scale of the difference between what exists now and what could exist suggests significant opportunities for shifting the societal benefits of ecosystem services and creating mechanisms that turn this societal impact into local economic benefit.

Using the estimate of \$29 million as the value of ecosystem services in Trinity County, about \$2,200 per capita created in Trinity County. Of course, little or none of this money is going back to the 13,000 people who live in Trinity County. Nor is this money going directly to the maintenance of this public land. Instead, this money is in general accruing to others, or to the federal government. The money that goes to the federal government pays for the maintenance of the ecosystem structures in Trinity County, but very indirectly. Even within the federal government, there are not connections between money earned from services, like water quantity, and money paid to maintain those services.

These results are inaccurate. Data was unavailable and was collected for other purposes, not specific to ecosystem services valuation. Because there is no set methodology for ecosystem services valuation, the methodology used to estimate the value of ecosystem services in Trinity County could be criticized for its inconsistent methods, timeframe, and accuracy. At best, this estimate represents a lower bound for the value of ecosystem services in Trinity County. Costanza et al. discuss the need for accuracy in ecosystem services valuation (2006: 80). Valuations with low accuracy are useful for increasing public awareness, those with medium accuracy are useful for establishing priorities and making policy decisions, and those with high accuracy are useful for decisions that involve irreversibility, such as species extinction (2006: 80). This valuation is intended to promote an understanding of the flows into and out of Trinity County. While future participation in ecosystem services markets would require more accurate valuation of particular goods and services (since, at this point, coordinated

ecosystem services payments and markets are rare), this valuation gives a big picture view of the role of ecosystem services in the economy and ecology of Trinity County.

This project faced challenges related to lack of data, uncertainty about how to deal with illegal activities, and goods and services that compete and affect each other's values. Although I converted data to 2009 dollars, measuring all ecosystem services on an annual basis may not reflect that service's value accurately, because the value could be much higher or lower at different points in the year. While this variability is characteristic of some other non-environmental goods and services, because ecosystem services are dependent on the same ecosystem structures and functions, it is useful to coordinate the timeframes of these measurements.

Because it is illegal to grow marijuana, knowing how to discuss its value is difficult. In addition to its estimated value, information about the cost of marijuana eradication is available. This work creates jobs, but it reduces the economic impact of marijuana. Its value could be completely discarded because it competes with other ecosystem services preferred by society, such as recreation. But marijuana production also creates economic impacts, positive and negative. Like the various economic impacts related to fire in Trinity County, it is difficult to know whether economic values related to marijuana production should be added to or subtracted from the value of ecosystem services in Trinity County. This computation is only made more difficult by trying to include social preferences and laws in economic valuations of ecosystems.

Finally, maximizing the production of one good or service can reduce the production of another good or service. Using diagrams to understand the relationships between different goods, services, functions, and structures illustrates these connections. However, the ecological complexity of these relationships and the effects that the production of various goods and services have on each other are difficult to understand.

CHAPTER VI

CONCLUSIONS

Methodology

There is no single methodology for ecosystem services valuation. There is not a consistent methodology for framing these ecosystem goods and services (determining which ones are relevant and how they relate). There is also not a consistent methodology for evaluating particular goods and services. Methodologies are being developed to make these valuations more comparable and more accurate. However, these methodologies should also be evaluated based on what data are currently available. In addition, valuing and monitoring ecosystem services could provide opportunities for job creation. The methodology used in this project relied on data currently being collected in Trinity County.

Getting information about all of the services was hard, but recreation data were particularly hard to get. This is unfortunate because recreation seems to play such a large part in the economy, and tourism is traditionally promoted as a primary means of economic development for natural resource-based communities. The difficulties faced in collecting recreational data from a variety of government agencies and organizations at a variety of timeframes are symptomatic of a larger problem. Even when significant resources exist that are currently collecting data, such as the government agency presence in Trinity County, these data are not being collected in a comprehensive way. Managing

ecosystems for ecosystem services will be very difficult if data are not centralized and not comparable.

Prices

Like all goods, prices for ecosystem services vary. This makes management based on the value of the ecosystem services risky, particularly because land managers do not have much experience managing ecosystems based on prices rather than functions. If the market value of the ecosystem goods and services declines, maintenance of those goods and services can be decreased. Sometimes this decrease in function is not recoverable when the demand rebounds. Some ecosystem structures and functions have minimum levels that must be maintained to avoid the collapse of these systems. One way to partially address this problem is through localization of payments for ecosystem services.

Because ecosystem services are so time dependent, understanding their value based only on these prices can also be problematic for these reasons. These prices fluctuate, and so using a snapshot approach is ineffective. That said, a more continuous value of the economic impact of an ecosystem service is less accurate. Addressing these timeframe issues is difficult. This study tries to create a middle ground through the development of an admittedly complicated framework. The framework tries to allow for a whole-system, long-term perspective but that also creates a methodology for a short-term or snapshot understanding of ecosystem value as it is needed for policy decision-making. However, more work must be carried out to address the fact that we manage for both the short and long term.

From Practices to Results

Ecosystem services valuation shifts the method of achieving ecological goals from best practices to measurable results. There are many practices that create jobs and have social benefits that become less valued if focus shifts to results rather than practices. Additional reasons to continue these practices would be needed and validated if these practices were to be maintained within a framework of management for ecosystem services.

In addition, basing evaluation of ecological goals on results can be problematic. Sometimes good practices that are improving or maintaining ecosystem functions result in no change in the value of ecosystem goods and services. This makes their effectiveness hard to measure and hard to endorse or continue, unless for when these practices are not carried out and ecosystem functions degrade, in turn degrading ecosystem goods and services. Because ecosystem goods and services are often not valued, even this indicator sometimes does not identify useful practices. Diagrams showing the interrelationships of functions, goods, and services are important to try to recognize the relationships between functions and services, even when these relationships do not result in change in economic value. At a broader scale, practices include both disturbances (physical action) and policies (institutional actions). Some practices maintain function, others degrade function, and others change functions entirely. Social values dictate which functions society considers necessary to maintain.

Disturbances

Understanding the amount currently being spent on maintaining ecosystem function is important. Currently these inputs to the system are underestimated and misunderstood. Going forward, improving payments for ecosystem services does not simply involve increasing payments for ecosystem services. It also involves examining who pays and who benefits, and possibly creating mechanisms to connect these two groups.

Approach

Legislative structures have redirected activities on the forest so that they create different goods, such as endangered species habitat and recreational land, which benefit broader society. But these goods do not create local economic impact and jobs in the way that timber did. If we recognize that people are an intrinsic part of the maintenance of natural resources, we must recognize a dual purpose for public lands. Along with valuing these public lands for the outputs that they create, for their social benefit, we must create mechanisms that allow people to do this work, and pay them for the work they are already doing. The legislative actions that shifted value to particular social benefits did not create corresponding economic mechanisms that create jobs to maintain those benefits.

In a discussion of the ecosystem services (ESV) literature, Costanza et al. (2006) said “truly transdisciplinary approaches are required for ESV in which practitioners accept that disciplinary boundaries are academic constructs largely irrelevant outside of the university, and allow the problem being studied to determine the appropriate set of

tools, rather than vice versa” (Costanza et al. 2006: 63). These conclusions try to focus on the problem being studied and forming the groundwork to develop the appropriate tools. Ecosystem services valuation must examine what data is actually available. It also must examine the relationship that valuation has with payments for ecosystem services, job creation, and the economies of the communities being valued.

REFERENCES

- Ansink, E., L. Hein and K. P. Hasund (2008). "To Value Functions or Services? An Analysis of Ecosystem Valuation Approaches." *Environmental Values* 17(4): 489-503.
- Bailey, E. (2009). California timber firm to market its forests as weapon against global warming. *Los Angeles Times*. Los Angeles, California.
- Baker, M. (2004). The Organization of Natural Resources Restoration Work in Trinity County: An Overview. Forest Community Research.
- Baldwin, K. C. (2002). Grass Valley Creek Watershed Fire Management Plan. Trinity Resource Conservation District. Douglas City, CA.
- Barbier, E. B. (2006). *Valuing Ecosystem Services as Productive Inputs*. 43rd Panel Meeting of Economic Policy, 21-22 April 2006, Vienna.
- Barkmann, J., K. Glenk, A. Keil, C. Leemhuis, N. Dietrich, G. Gerold and R. Marggraf (2008). "Confronting unfamiliarity with ecosystem functions: The case for an ecosystem service approach to environmental valuation with stated preference methods." *Ecological Economics* 65: 48-62.
- Bennett, J. and S. Whitten (2003). "Duck hunting and wetland conservation: Compromise or synergy?" *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie* 51(2): 161-173.
- Bilgic, A. and W. J. Florkowski (2009). "The impact of license regulation on the number of recreation trips: is it worth considering?" *Journal of Regulatory Economics* 35(1): 45-69.
- Bowes, M. D. and J. V. Krutilla (1989). *Multiple-Use Management: The Economics of Public Forestlands*. Washington, D.C., Resources for the Future.
- Boxall, P. C. (1995). "The economic value of lottery-rationed recreational hunting." *Canadian Journal of Agricultural Economics-Revue Canadienne D Economie Rurale* 43(1): 119-131.

- Boyd, J. and S. Banzhaf (2007). "What are ecosystem services? The need for standardized environmental accounting units." *Ecological Economics* **63**: 616-626.
- Brander, L. M., R. Florax and J. E. Vermaat (2006). "The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature." *Environmental & Resource Economics* **33**(2): 223-250.
- Brown, T. C., J. C. Bergstrom and J. B. Loomis (2007). "Defining, valuing, and providing ecosystem goods and services." *Natural Resources Journal* **47**: 331-376.
- Buschena, D. E., T. L. Anderson and J. L. Leonard (2001). "Valuing non-marketed goods: The case of elk permit lotteries." *Journal of Environmental Economics and Management* **41**(1): 33-43.
- California Board of Equalization (2009). California Timber Harvest by County. California Board of Equalization.
- California Board of Equalization (2009). California Timber Harvest Statistics. California Board of Equalization.
- California Department of Fish and Game (1999). Deer Hunt Zone B2.
- California Department of Fish and Game (2009). Approved 2009 Deer Hunt Seasons by Zone.
- California Department of Fish and Game. (2009). "Department of Fish and Game Statistics." from <http://www.dfg.ca.gov/licensing/statistics/statistics.html#Hunting%20Licenses>.
- Cameron, T. A., W. D. Shaw, S. E. Ragland, J. MacCallaway and S. Keefe (1996). "Using actual and contingent behavior data with differing levels of time aggregation to model recreation demand." *Journal of Agricultural and Resource Economics* **21**(1): 130-149.
- Capistrano, D. (2005). *Ecosystems and human well-being: multiscale assessments : findings of the Sub-global Assessments Working Group of the Millennium Ecosystem Assessment*, Island Press.
- Capistrano, D., C. K. Samper, M. J. Lee and C. Raudsepp-Hearne (2005). Summary: Integrated Assessments and Multiple Scales. *Ecosystems and Human Well Being: Multiscale Assessments*. D. Capistrano, C. K. Samper, M. J. Lee and C. Raudsepp-Hearne. Washington, D.C. , Island Press. **4**.

- Caulkins, J. P. (2010). Working Paper: Estimated Cost of Production for Legalized Cannabis, Rand Drug Policy Research Center.
- Chan, K. M. A., M. R. Shaw, D. R. Cameron, E. C. Underwood and G. C. Daily (2006). "Conservation planning for ecosystem services." *Plos Biology* 4(11): 2138-2152.
- Collins, S. and E. Larry (2007). Caring for Our Natural Assets: An Ecosystem Services Perspective. Pacific Northwest Research Station, United States Department of Agriculture: Forest Service. Portland, OR.
- Cordell, H. K., C. J. Betz, G. Green and M. Owens (2005). Off-Highway Vehicle Recreation in the United States, Regions and States: A National Report from the National Survey on Recreation and the Environment. Southern Research Station, United States Department of Agriculture: Forest Service.
- Costanza, R., R. d'Arge, R. deGroot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. Oneill, J. Paruelo, R. G. Raskin, P. Sutton and M. VandenBelt (1997). "The value of the world's ecosystem services and natural capital." *Nature* 387(6630): 253-260.
- Costanza, R., M. Wilson, A. Troy, A. Voinov, S. Liu and J. D'Agostino (2006). The Value of New Jersey's Ecosystem Services and Natural Capital. Burlington, VT, Gund Institute for Ecological Economics, Rubenstein School of Environment and Natural Resources.
- Daily, G. C. (1997). Introduction: What are Ecosystem Services? *Nature's Services*. G. C. Daily. Washington, D.C., Island Press.
- Daily, G. C. (1997). *Nature's Services*. Washington, D.C., Island Press.
- Darling, D. (2007). Drug czar gives warning: Federal official calls marijuana growers dangerous terrorists. *The Record Searchlight*. Reading, California: July 13, 2007.
- Davis, R. K. (1963). "Recreation planning as an economic problem." *Natural Resources Journal* 3(239-249).
- de Groot, R. S., M. A. Wilson and R. M. J. Boumans (2002). "A typology for the classification, description and valuation of ecosystem functions, goods, and services." *Ecological Economics* 41: 393-408.
- Diamond, P. A. and J. A. Hausman (1994). "Contingent Valuation: Is Some Number Better than No Number?" *Journal of Economic Perspectives* 8(4): 45-64.

- Dietz, D. (2010). Western Area Power Administration: Trinity Powerplant Data Request. K. MacFarland.
- Driscoll, J. (2010). Gardens in the forest: Trinity County bust shows pot alive and well on federal lands. *Times-Standard*. Eureka, CA.
- Durham, D. J. (2005). How the Trinity Lost Its Water, Friends of Trinity River.
- Ehrlich, P. and A. Ehrlich (1981). *Extinction: the causes and consequences of the disappearances of species*. New York, Random House.
- Everett, Y. (1997). A Guide to Selected Non-Timber Forest Products of the Hayfork Adaptive Management Area, Shasta-Trinity and Six Rivers National Forests, California. Pacific Southwest Research Station, Forest Service, United States Department of Agriculture. Albany, CA: 64.
- Everett, Y. (2001). "Participatory Research for Adaptive Ecosystem Management." *Journal of Sustainable Forestry* **13**(1): 335-357.
- Fisher, B., K. Turner, M. Zylstra, R. Brouwer, R. de Groot, S. Farber, P. Ferraro, R. Green, D. Hadley, J. Harlow, P. Jefferiss, C. Kirkby, P. Morling, S. Mowatt, R. Naidoo, J. Paavola, B. Strassburg, D. Yu and A. Balmford (2008). "Ecosystem services and economic theory: Integration for policy-relevant research." *Ecological Applications* **18**(8): 2050-2067.
- Freeman, A. M. (2003). Measuring values, benefits, and costs. *The Measurement of Environmental and Resource Values*. A. M. Freeman. Washington D.C. , Resources for the Future.
- Friends of Trinity River. (2010). "Trinity Division History." from <http://www.fotr.org/tdhistory.html>.
- Gutman, P. (2007). "Ecosystem services: Foundations for a new rural-urban compact." *Ecological Economics* **62**: 383-387.
- Hackett, S. C. (2000). The Recreational Economic Value of the Eastern Trinity Alps Wilderness. Arcata, CA, School of Business and Economics, Humboldt State University.
- Hardin, G. (1968). "The Tragedy of the Commons." *Science* **162**(3859): 1243-1248.
- Heal, G. (2000). "Valuing ecosystem services." *Ecosystems* **3**(1): 24-30.

- Hotelling, H. (1949). An Economic Study of the Monetary Valuation of Recreation in the National Parks. National Park Service and Recreational Planning Division, U.S. Department of the Interior. Washington, D.C.
- Ingraham, M. W. and S. G. Foster (2008). "The value of ecosystem services provided by the U.S. National Wildlife Refuge System in the contiguous U.S." *Ecological Economics* **67**(4): 608-618.
- Jackson, T. A. (2007). California Steelhead Fishing Report-Restoration Card: A Report to the Legislature. California Department of Fish and Game. Sacramento, California.
- Kaufman, L. and P. Dayton (1997). Impacts of marine resource extraction on ecosystem services and sustainability. *Nature's Services*. G. C. Daily. Washington, D.C., Island Press: 275-293.
- Kline, J. D. (2007). Defining an economics research program to describe and evaluate ecosystem services. Gen. Tech. Rep. PNW-GTR-700. F. S. US Department of Agriculture, Pacific Northwest Research Station. Portland, OR: 46.
- Krutilla, J. V. (1967). "Conservation reconsidered." *American Economic Review* **57**: 777-789.
- Layke, C. (2009). Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators. Washington, D.C., World Resources Institute.
- Liu, S., R. Costanza, A. Troy, J. D'Agostino and W. Mates (2010). "Valuing New Jersey's Ecosystem Services and Natural Capital: A Spatially Explicit Benefit Transfer Approach." *Environmental Management* **45**: 1271-1285.
- Ludwig, D. (2000). "Limitations of economic valuation of ecosystems." *Ecosystems* **3**(1): 31-35.
- Martin, L. J. and B. Blossey (2008). "A framework for ecosystem services valuation." *Conservation Biology* **23**(2): 494-496.
- Martin, N., S. Brown, S. Petrova, T. R. H. Pearson, A. Dushku and J. Kadyszewski (2006). Pilot Project Opportunities for Carbon Sequestration in Shasta County, California. California Energy Commission, PIER Energy Related Environmental Research. **CEC 500 2006 072**.
- McComb, G., V. Lantz, K. Nash and R. Rittmaster (2006). "International valuation databases: Overview, methods, and operational issues." *Ecological Economics* **60**(2): 461-472.

- Mohr, R. C. and S. Heminway (2009). 2008 California Deer Kill Report. California Department of Fish and Game. Sacramento, CA.
- Morris, S. (2009). Seeking better fire prevention. *The Trinity Journal*. Weaverville, CA.
- Nelson, E., G. Mendoza, J. Regetz, S. Polasky, H. Tallis, D. R. Cameron, K. M. A. Chan, G. C. Daily, J. Goldstein, P. M. Kareiva, E. Lonsdorf, R. Naidoo, T. H. Ricketts and M. R. Shaw (2009). "Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales." *Frontiers in Ecology and the Environment* 7(1): 4-11.
- Off Highway Motor Vehicle Recreation Division, C. D. o. S. P. a. R. (1994). Off highway vehicle (OHV) recreation's \$3 billion economic impact in California and a profile of OHV users: a family affair. California Department of State Parks and Recreation. Sacramento, CA.
- Pagiola, S., A. Arcenas and G. Piatais (2005). "Can Payments for Environmental Services Help Reduce Poverty? An Exploration of the Issues and the Evidence to Date from Latin America." *World Development* 33(2): 237-253.
- Palmer, M. A. and S. Filoso (2009). "Restoration of ecosystem services for environmental markets." *Science* 325: 575-577.
- Postel, S. and S. Carpenter (1997). Freshwater Ecosystem Services. *Nature's Services*. G. C. Daily. Washington, D.C., Island Press.
- Pritchard, L., C. Folke and L. Gunderson (2000). "Valuation of ecosystem services in institutional context." *Ecosystems* 3(1): 36-40.
- Ridker, R. G. and J. A. Henning (1967). "The Determinants of Residential Property Values with Special Reference to Air Pollution." *The Review of Economics and Statistics* 49(246-257).
- Smail, R. A. and D. J. Lewis (2009). Forest Land Conversion, Ecosystem Services, and Economic Issues for Policy: A Review. Pacific Northwest Research Station, United States Department of Agriculture: Forest Service. Portland, Oregon.
- Swallow, B. M., M. F. Kallesoe, U. A. Ifikhar, M. van Noordwijk, C. Bracer, S. J. Scherr, K. V. Raju, S. V. Poats, A. K. Duraipappah, B. O. Ochieng, H. Mallee and R. Rumley (2009). "Compensation and Rewards for Environmental Services in the Developing World: Framing Pan-Tropical Analysis and Comparison." *Ecology and Society* 14(2): 26.

- Tallis, H., P. Kareiva, M. Marvier and A. Chang (2008). "An ecosystem services framework to support both practical conservation and economic development." *Proceedings of the National Academy of Sciences of the United States of America* **105**(28): 9457-9464.
- The Sierra Institute (2002). Northwest Economic Adjustment Initiative Assessment: Hayfork, CA Case Study.
- Trinity County Resource Conservation District and Watershed Research and Training Center (2005). Trinity County Community Wildfire Protection Plan with Recommendations on Trinity County Values at Risk from Fire and Pre-Fire Fuels Treatment Opportunities.
- U.S. Department of Justice (2008). National Illicit Drug Prices. U.S. Department of Justice. Johnstown, PA.
- U.S. Department of the Interior (2000). Record of Decision Trinity River Mainstem Fishery Restoration: Final Environmental Impact Statement/Environmental Impact Report. U.S. Department of the Interior.
- U.S. Department of the Interior, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and Forest Service U.S. Department of Agriculture (2000). Recreational fee demonstration program. National Park Service. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Land Management and Forest Service U.S. Department of Agriculture.
- U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Hoopa Valley Tribe and Trinity County (2000). Trinity River Mainstem Fishery Restoration: Environmental Impact Statement/Report. U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Hoopa Valley Tribe and Trinity County.
- U.S. Forest Service. (2006). "FY 2005 Forest Service Revenue, Expenses, and Cost of Collections." from <http://www.fs.fed.us/passespermits/docs/accomps/wo-rpt-congress/fy05-financial-data.pdf>.
- U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, and Hoopa Valley Tribe (1999). Trinity River Flow Evaluation Final Report. Secretary of the Interior. Washington D.C.
- USDA Forest Service (2009). Biomass to Energy: Forest Management for Wildfire Reduction, Energy Production, and Other Benefits. Public Interest Energy Research Group. California Energy Commission. **CEC-500-2009-080**.

- Vira, B. and W. M. Adams (2009). "Ecosystem services and conservation strategy: beware the silver bullet." *Conservation Letters* **2**: 158-162.
- Westlands Water District (2010). Westlands Water District Water Supply: 1988 through 2010.
- Westlands Water District. (2010). "Westlands Water District: Water Rates and Charges." from https://cs.westlandswater.org/district_web_info/wwd/rates/waterrates.pdf.
- Wilcox, A. and J. Harte (1997). Ecosystem services in a modern economy: Gunnison County, Colorado. *Nature's Services*. G. C. Daily. Washington, D.C., Island Press: 311-328.