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# Economic Valuation of Watershed Services for Sustainable Forest Management: Insights from Mexico

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## 1. Introduction

Ecosystem services are the benefits that people obtain from ecosystems (Brauman et al., 2007). Recognizing the importance of the services provided by ecosystems for human well-being is not a new idea, going as far as Plato (Feen, 1996) and the economic conceptualization of ecosystem values (Coase, 1960; Feen, 1996). However, the scientific and practical interests in assessing and trading ecosystem services have not gained momentum until the 1990s when pioneering works by Daily (1997) and Costanza et al. (1997) galvanized the field. Among the ecosystem services that received increasing attention in the recent years are the hydrological services due to the role of water as a vital, and sometimes decisive, element in human life (Pare et al., 2008). Hydrologic services encompass a range of benefits that terrestrial ecosystem produces in terms of freshwater. These services can be grouped as: improvement of extractive water supply, improvement of in-stream water supply, water damage mitigation, provision of water related cultural services, and water-associated supporting services (Brauman et al., 2007).

The majority of hydrological services take place in the highlands of forest watersheds (Messerli et al., 2004). In these areas, upland forest watersheds work as a source that collects, manufactures, and distributes water and provides hydrological services to lowlands (Neary et al., 2009). Various components of the water cycle (i.e., evaporation, infiltration, surface run-off) critically depend on forest cover. If the forest cover is affected, so it will be the quality and quantity of the water provided to downstream users (Brown et al., 2005). In developing countries, such as Mexico, changes in forest cover are caused among other things by the local economic conditions in which landowners live. While searching for basic needs (food and shelter), they exercise excessive pressure over the forests eventually triggering forest fragmentation and deforestation (Perez-Verdin et al., 2009).

Based on the methods used for their economic valuation, hydrological services can be classified into two broad categories of values: marketed and non-marketed. The economic

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value of the former is reflected through the market price determined mainly by its demand and supply (i.e., drinking water) while the latter, traded under imperfect markets, requires a more complex evaluation that involves evaluating consumer's preferences and behavior (i.e., evaluation of recreation sites). The sum of these services gives the total economic value (TEV) of a forest watershed. Because of the quasi-public good nature of hydrological services and the presence of externalities, failure to recognize the TEV of a watershed can lead to depletion, degradation, and overexploitation of forest resources and eventually loss of social welfare (Plottu & Plottu, 2007).

Recently, research has focused on assigning economic values to environmental services to redirect policies for sustainable forest management. The intention is to help landowners reduce the impact of externalities by giving monetary incentives and implement best management practices to regulate the quality/quantity of water (Pagiola et al., 2003; Muñoz-Piña et al., 2008). Among the new schemes include the formal articulation of incentive-based instruments, such as Payments for Ecosystem Services (PES) and Markets for Ecosystem Services (MES) (Jack et al., 2008; Gómez-Boggerthun et al., 2010). While the design and operation of various international PES and MES programs have been started by local governments, many of them now promote the participation of the private sector, non-government organizations, and the general public (Paré et al., 2008).

The major objective of this chapter is to underline the importance of assigning economic values to hydrological services as a means to achieve sustainable forest management. The paper first introduces critical inputs of the water balance and best management practices for watershed resources. It also describes the types of watershed services and how they can be valued. The paper then analyzes the cases where non-market valuation techniques have been implemented for various types of watershed services in Mexico. And finally, it discusses the operation of a Mexican PES program and its impact on watershed services.

## 2. Water balance and best management practices

The assessment of available water resources is central to economic valuation of hydrological services. The economic valuation of water resources involves knowledge of the supply and demand sides and eventually to the search for effective management policies. The determination of available water within a watershed is given by the water balance and depends on the magnitude of inputs and outputs and the storage capacity. The basic input is precipitation ( $P_T$ ) and is either lost to evaporation ( $E_V$ ) and transpiration ( $T_R$ ) or routed through small pathways of overflow and interflow to give surface runoff ( $Q$ ) and infiltration ( $I$ ) (Hiscock, 2005). Thus, the water balance model, estimated for a given period of time ( $\partial A/\partial t$ ), is the difference between inputs and outputs. The larger the difference between inputs and outputs, the more supply water there is to end users. In this case, Inputs =  $P_T$  and Outputs =  $I + E_V + T_R + Q$ . Therefore, the water balance can be expressed as:

$$\partial A/\partial t = P_T - (I + E_V + T_R + Q) \quad (1)$$

In mountainous forest watersheds, precipitation is partitioned into throughfall, interception loss, and stemflow (Navar, 2011). Throughfall is the rainfall portion that reaches the ground by passing directly through or dripping from tree canopies. Interception loss is the rainfall retained on the canopy that evaporates back to the atmosphere; it is composed mainly on the amount of precipitation stored by canopies and the evaporation of stored canopy water.

Stemflow is the rainfall portion that flows to the ground via trunks or stems (Dunkerley, 2008). Litter retains part of the throughfall and stemflow and infiltrate into the mineral soil increasing soil moisture content. Evapotranspiration is the amount of water vapor that leaves soil and vegetation via evaporation and transpiration. Factors that control evaporation from soils are the current water content, the water content at wilting point, and the soil water content at field capacity. Factors that affect transpiration are the type of vegetation, density, and age.

Conventional forest management practices, that include logging and grazing, affect tree density, canopy cover, and tree composition and structure (Brown et al., 2005). Hydrologic studies in the United States have demonstrated that selective harvesting and clear-cutting promotes increased discharge because of a reduction of stand density and canopy cover that demand less water for transpiration (Swank et al., 1988; McBroom et al., 2008). Non-conventional forest disturbances that cause tree mortality include forests fires, pests and diseases, strong winds, etc. Forest fires of large spatial scales and severity, in addition to tree mortality, also cause soil water repellency (Martin & Moody, 2001). Water repellency reduces infiltration and often promotes surface runoff and soil erosion beyond any other forest disturbance (Pierson et al., 2008). In general, tree mortality beyond natural causes reduce interception loss and transpiration leaving more net precipitation (throughfall) for other processes such as soil moisture content, aquifer recharge, and surface runoff (Brown et al., 2005; Ikawa et al., 2009). In addition, streamflow and aquifers are enriched with sediments and chemicals washed out from the soil that reduces usability. Other human-related disturbances are road construction and maintenance, and harvest-related activities that promote soil compaction and reduce soil infiltration at specific places in the watershed.

The aim of best management practices (BMP) is to reduce the effect of non-point and point sources of degradation that affect water quality and quantity (McBroom et al., 2008). Examples of non-point sources, which are characterized by a widespread and diffused generation, include cropland, harvesting areas, animal feedlots and grazing lands, impervious surfaces (e.g., roads, land rocks, deforested sites, urban areas), and construction sites (Neary et al., 2009). Transport of sediments, organic matter, and nutrients, such as nitrogen and phosphorus are examples of point sources. Harvesting, grazing, and agriculture can lead to increased rates of runoff and erosion. Rates of material export from impacted watersheds to water resources, while highly variable within and between land uses, exceed those for natural or undisturbed land uses (Andreassian, 2004). Because of this characteristic, the application of BMP is mainly oriented to reduce the effect of non-point sources.

Effective BMPs to reduce the effect of non-point source loads should target changes in current land-use practices, construction and operation of equipment, machinery, and the use of structures to retain or otherwise control the movement of water and material (McBroom et al., 2008; Neary et al., 2009). Also, effective BMPs need to consider the local conditions (e.g., geology and soils, topography, climate, and hydrology), landowner expectations, and the nature of the source of the polluting material (e.g., harvesting, grazing, or agricultural land uses) in which impacts are occurring. Overall, watershed BMPs are oriented to (1) minimize soil compaction and bare ground coverage, (2) separate exposed bare ground from surface waters, (3) exclude fertilizer and herbicide applications from surface waters, (4) inhibit hydraulic connections between bare ground and surface waters, (5) avoid disturbance in steep convergent areas, (6) provide a forested buffer around streams, and (7) build stable road surfaces and stream crossings (Jackson & Miwa, 2007; Neary et al., 2009).

In Mexico, the national water, environmental protection, and forest laws are the basis for regulating watershed management practices. Coupled with the federal laws, almost every state in the country has specific regulations that complement those issues where the federal laws do not apply. Based on this set of laws and regulations, common examples of BMPs that involve forest vegetation and water include: the provision of forested buffer around streams, stabilization and closure of third-order roads immediately after harvesting, construction of culverts on primary and secondary roads crossing streams, pre-harvest planning for cutting, skidding and loading zones to avoid increasing hydrologic and sediment source connectivity to stream channels, and the perpendicular arrangement of forest residues to reduce soil erosion, among others.

In the past, the implementation of these BMPs was adopted by landowners who would evaluate the cost and benefits in either doing another activity or doing nothing. Since these practices, which we have identified as externalities, would reduce their economic profits, many landowners did not comply with the regulations leading to increased rates of erosion and sedimentation (Muñoz-Piña et al., 2008). Nowadays, the cost of BMPs is mostly shared with the government; however, the private sector, non-government organizations, and the general public are participating as well. This type of cost-share programs, which embrace the known concept of internalizing externalities, is discussed in section 4 of this chapter.

### **3. Economic valuation of watershed services**

The need of economic valuation of watershed services stems from their quasi-public and non-rivalry nature, the presence of externalities, and scales of production (Pattanayak, 2004; Brauman et al., 2007; Plottu & Plottu, 2007). In a market economy, watershed services without economic values will not be provided at optimal levels. The quasi-public, non-rivalry nature implies that it is difficult, if not impossible, to exclude an individual from using watershed services (e.g. soil retention), and several individuals can use them simultaneously without diminishing each other's use values. The presence of externalities means that the economic benefits of users of these services will not be deviated to compensate providers. And regarding the scale of production, these services are characterized by economies of scale in production; the larger the watershed, the lower the marginal costs (Pattanayak, 2004).

Valuation of watershed services also implies understanding the different types of benefits a watershed offers to ecosystems and society. A forest watershed not only functions like a basin which receives and stores water from precipitation, surface runoff, or infiltration, but also cleans water, retains sediments, provides habitats for wildlife, sinks CO<sub>2</sub>, and offers many environmental amenities for humans (Brauman et al., 2007; Locatelli & Vignola, 2009). Some of these benefits can be valued through conventional methods that use market-based approaches. For example, the useful life of a dam can be valued through estimations of the rate of sedimentation and the years left to sustain fish. Other benefits require detailed information and more complex approaches that estimate for example the value of environmental services for present, future generations, or consider the presence of externalities (Field, 2008). For example, if fewer recreation opportunities are provided in the watershed, due to water loss resulting from harvesting or grazing, recreationists may act and eventually offer a fee to preserve the watershed and recover the loss of recreation opportunities. In this section, we provide a brief summary of the different watershed values and the means to estimate them.



### 3.1 Watershed values

For the purpose of this work, we will focus on two main types of watershed values: use and non-use values (Freeman, 2003; Field, 2008). Use values, which consist of consumptive and non-consumptive uses, refer to the situations where people directly or indirectly interact with resource use (Field, 2008). Consumptive use values are derived from extractive resource uses such as timber, commercial fishing and hunting, and the use of water for irrigation and drinking. Examples of non-consumptive uses values are benefits from resources with a minimal or imperceptible extraction and include those from boating, swimming, ecotourism, and camping.

Non-use or passive-use values refer to the situations in which people place monetary values on resources independent of their present or future use (Field, 2008). For example, people may be willing to support a long-term program intended to maximize water quality even though their offspring, not they, will receive the benefits. Despite the controversy that these types of values should not be considered in mainstream economics, because they reflect altruism and difficulty to assess, Freeman (2003) argues that non-use values can be defined within a utility theoretical framework and should be considered as public goods. Freeman further contends that ignoring non-use values could lead to wrong policies and resource misallocation.

The rationale for assigning values to watershed services also lies on the many biochemical cycles that take place in the watershed, the water and soil conservation functions, and the provision of wildlife habitats and amenities (Pearce, 2001; Pattanayak, 2004; Brauman et al., 2007). Water is the principal medium in which many chemical reactions occur and watersheds provide a variety of conditions in which those chemical reactions take place (Ward & Trimble, 2004). Water, Carbon, Nitrogen, Oxygen are among the key elements whose maintenance depends on the management of forest watersheds. Altering these cycles could interrupt the flow of environmental services, particularly water, to downstream communities (Figure 1). Therefore, the main question is how these hydrological processes, defined by a local drainage unit, can be manipulated to be fairly useful to society.

Figure 1 shows the relationship between hydrological processes and economic values to humans. A change in physical or chemical properties of water causes a change in the quality and quantity of the liquid provided. Discharges from non-point pollution sources affect the quality of water and force resource managers to use expensive processes, equipment to clean the water. Conversely, to address the feedback loop, excessive fishing may cause a change in the fish population. Estimating an improvement of watershed benefits involves the use of economic models to determine the monetary units people place on both use and non-use values (Freeman, 2003).

The TEV is a concept that illustrates the whole worth of ecosystem services. Due to the nature of some services, hypothetical markets are created to elicit values through a variety of economic techniques, including: (a) direct market valuation approaches, (b) revealed preference approaches, and (c) stated preferences approaches (Freeman, 2003; Champ et al., 2003;). Direct market valuation methods use data from actual markets and thus reflect actual preferences or costs to individuals. Revealed preference techniques are based on the observation of individual choices in existing markets that are related to the ecosystem service subjected to valuation. Stated preference approaches simulate a demand for ecosystem services by means of surveys on hypothetical changes in the provision of ecosystem services (TEEB, 2010). Selection of the best technique depends on the objectives of the researcher, the type of use values, and the type of ecosystem services under evaluation.

Again, due to the nature of some watershed services, uncertainty is an issue that must be considered in every valuation work. As suggested by TEEB (2010), one way to deal with uncertainty is the use of the data enrichment or data fusion approach which combines the use of revealed and stated preference methods. The main advantage of these hybridized approaches is that they overcome technical uncertainty due to application of valuations tools and uncertainty with regard to preferences about ecosystem services. However, their application generally depends on available financial, human, or time resources.

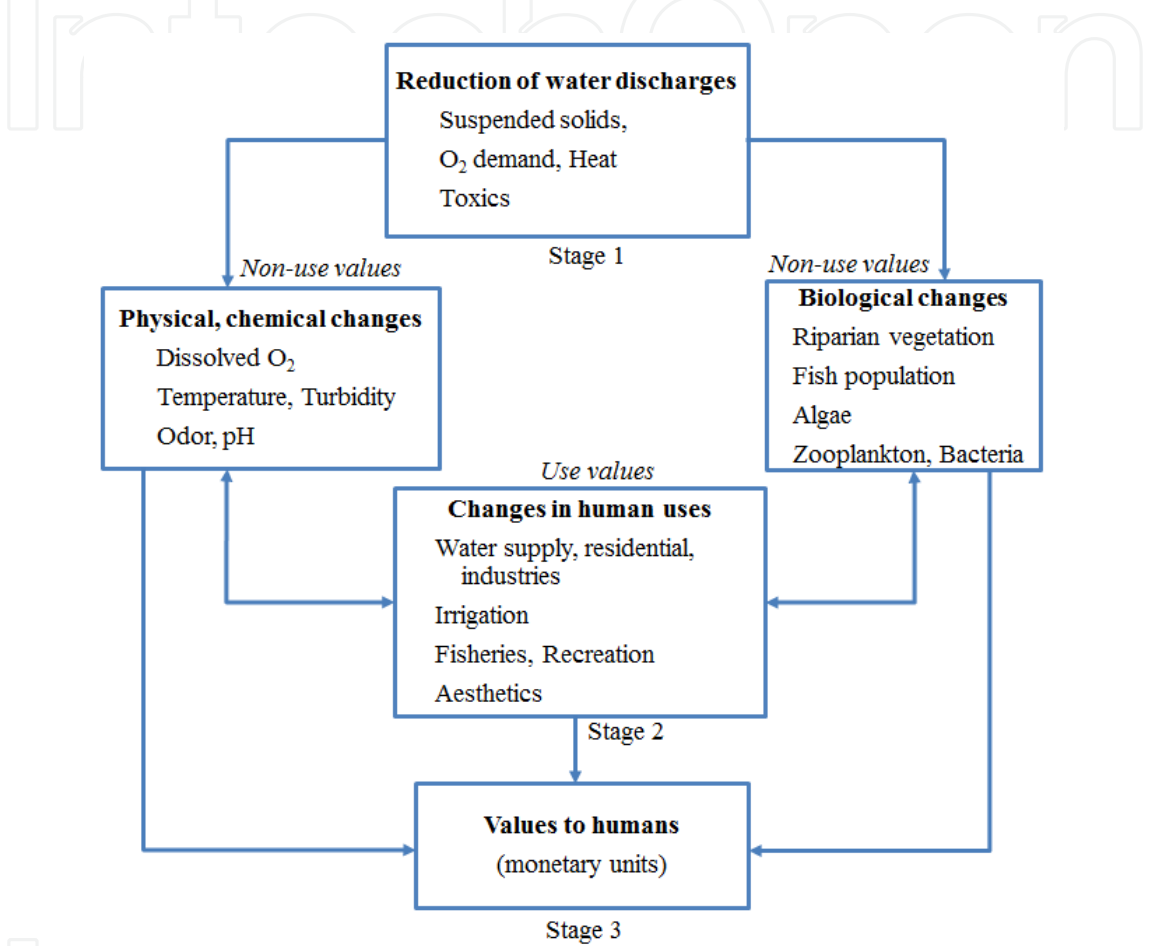


Fig. 1. Types of hydrological values and flow of services to society. The sum of use and non-use values gives the total economic value (From Freeman, 2003, page 31).

3.2 Theoretical framework of economic valuation

Because of the diversity of watershed benefits, which include use and non-use values, placing monetary units depends on the type of services provided, the actual and desired conditions of the watershed, and people’s social status (Freeman, 2003; Brauman et al., 2007). Although valuation of all watershed benefits is possible, many studies focus on few or single services. The most common benefits include drinking, irrigation, wildlife habitats, prevention of soil erosion, flood protection, fisheries, and hydropower (see Pearce, 2001; Locatelli & Vignola, 2007, for a literature review of watershed services). To account for reliable estimations of the watershed value, information on the extent of the change in quality and/or quantity of the service is required. The marginal value, the extra monetary units a person would be willing to pay for an additional unit of the service, depends on the

magnitude of the change a person expects with her/his contribution as well as on the beginning and ending points of that change (Brauman et al., 2007).

Concerning to watershed services, willingness-to-pay (WTP) is the maximum amount of income an individual will pay for an improvement in current conditions of the watershed, or the maximum amount of money to avoid a decline in those current conditions (Freeman, 2003). The WTP measure for valuing watershed services is a function of a vector of individual's social characteristics (such as income, education, family size, among others), the price ( $p$ ), and quantity of the service ( $q$ ) (Freeman, 2003). Theoretically, WTP can be expressed as either in terms of an utility function  $V(p, q, y)$ :

$$V(p, q^*, y - WTP) = V(p, q, y) \quad (2)$$

or in terms of the minimum expenditure function  $m(p, q, u)$ ,

$$WTP = m(p, q, u) - m(p, q^*, u), \text{ when } u = V(p, q, y) \quad (3)$$

where  $y$  is income and  $q^*$  represents a new condition or improvement in the watershed service ( $q^* > q$ ). The WTP is thus the amount of money to pay that would make such individual indifferent between the current condition ( $y$  and  $q$ ) and the new, improved state  $[(y - WTP), q^*]$ .

To estimate the economic value of watershed services, particularly non-consumptive or non-use values, typically researchers use a stated preference technique called Contingent Valuation (CV). This technique employs survey-based information to directly elicit households' preferences and build a contingent market through which respondents may state their willingness to pay for a specified provision change in a particular service (Mitchell and Carson 1989). The CV approach first involves describing the current situation of a non-market good, how it can be improved, and then asking respondents whether or not they would pay for the improvement of the good (Boyle 2003). It is called contingent valuation, because people are asked to state their willingness to pay contingent on a specific hypothetical scenario and description of the environmental service (Carson & Groves 2007). The willingness-to-pay results can then be used by decision makers to weigh policy options. Details on CV description can be found in Mitchell & Carson (1989), Boyle (2003), Schlapfer (2008), TEEB (2019), among others.

#### 4. Valuation of watershed services in Mexico

In recent years, various studies have been conducted to estimate the value of watershed services using non-market valuation techniques in Mexico. To document these cases, several sources of information where a consistent valuation approach was used were reviewed in this chapter. The first information source included a literature search from all available databases (e.g. Web of Science) and the web for nonmarket valuation studies. A brief review of the abstracts and introductions served to select articles directly related to watershed services and the valuation approach. Second, all articles relating to the topic were thoroughly reviewed to identify the main watershed services and other information needed to be considered. The search also included the citations of published articles to find any unpublished data or papers. Besides the WTP amount and the watershed service being evaluated, additional information collected in the review was altitude, latitude, longitude, and precipitation. The search eventually gave 13 cases including Mexico City and other



cities located across the country. The watershed services ranged from wildlife habitat preservation, soil retention, and recreation, to drinking, irrigation, fishing, and hunting. The cases identified were compiled and georeferenced in a geographical information system (GIS) database.

Table 1 shows the cases included in the literature review. Most of the studies were located in high elevation areas (e.g., more than 1,000 meters above sea level) which gave indication of the relevance of the watershed highlands to provide environmental services, and the need to protect them. The WTP, obtained through the contingent valuation approach, ranged from US\$ 0.45 to 15.8 per month and household, being the Mexico City the case with the highest WTP. These figures represent between 0.33 and 11.8% of the 2011 per-capita minimum wage (the minimum wage is US \$134/person/month; DOF, 2010). The main types of services provided by the watersheds were wildlife habitat, drinking, and soil retention. The most common management practices proposed in the studies were reforestation, soil conservation works, and reducing harvesting, grazing and risk of fire, among others.

It is important to note that in many studies it was difficult to clearly identify the main watershed service. During the search, several works were discarded due to the inconsistency of valuation approaches, the service being evaluated, and the type of WTP units (for example, WTP was expressed in \$/month/person, \$/year/household, \$/visit, etc). Out of the 25 studies reviewed, only those listed in Table 1 were selected since they allowed cross-site comparisons. Based on the predominant service, each case was classified into two major groups: those with consumptive use values (e.g., drinking, fishing, irrigation and hunting) and those with non-consumptive use values (ecotourism, wildlife habitat, recreation, soil retention); the latter also included non-use values. The classification yielded seven cases in the first group and six in the second. To test for WTP differences in the type of use values, one-way analysis of variance indicated that there was no significant relationship in the WTP<sup>†</sup> ( $n=13$ ,  $F=2.541$ ,  $p=0.14$ ). Neither there was for elevation ( $n=13$ ,  $F=0.001$ ,  $p=0.99$ ) and moisture index ( $n=13$ ,  $F=0.978$ ,  $p=0.34$ ), the two additional physical variables of the cities. The lack of significance in the WTP differences means that individuals appreciate both consumptive and non-consumptive uses similarly. However, in practical terms, the individual benefits estimated for consumptive use values were 47% higher than those for non-consumptive use cases.

#### 4.1 Government-supported watershed markets

Various Latin-American countries have started programs to intensify the production of watershed services in forest ecosystems. In 2003, Mexico launched an innovative PES program to help landowners to protect forest watersheds in critical areas of the country. The program, called in Spanish as *Pago de Servicios Ambientales Hidrológicos* (PSAH), had three main goals: to reduce deforestation in areas with severe water problems, apply best management practices for sustainable forestry, and reduce illegal logging (Muñoz-Piña et al., 2008). The PSAH consisted of direct payments to landowners, whose lands were mostly covered by temperate or tropical forests, during a 5-year period in which landowners executed a series of BMPs to protect the watersheds. Part of the PSAH's innovative approach is that it was funded through an earmarked portion of federal fiscal revenues from water

<sup>†</sup> Due to the small sample size, differences between the use values were also evaluated with the non-parametric Mann-Whitney test. Results corroborated the results of no significant differences for WTP, elevation, and moisture.

fees, so the program involved users and producers of environmental services. The payment, offered as an economic compensation or subsidy, was based on the opportunity cost of using the land for agriculture or livestock (Muñoz-Piña et al., 2008), not on the non-market valuations we have discussed above. Initially, it oscillated between US\$ 23 and 30 per hectare depending of the type of forest (CONAFOR 2004)†.

As expected, the PSAH received various criticisms. The government used the opportunity costs of the two primary economic activities (agriculture and livestock) to estimate the compensation. Though there are no official reports, this was probably due to the type of information available initially. Government officials have said that these payments are currently under evaluation and will be reassessed with new information based on market and non-market methods. Also, the PSAH has been regulated by the government itself who

Study site	Watershed service <sup>a</sup>	Type of use value <sup>b</sup>	Elevation (meters)	Moisture index <sup>c</sup>	Adjusted WTP (US\$/month) <sup>d</sup>	Source
Ciudad Obregon, SON	WH, F, SBR	NC	35	0.146	6.12	Ojeda, et al. (2008)
San Luis Rio Colorado, SON	F,H, SBR	C	40	0.055	6.39	Sanjurjo (2006)
Parral, CHIH	D	C	1,620	0.089	8.91	Vasquez et al. (2009)
El Salto, DGO	D,SR	C	2,540	0.250	2.08	Silva-Flores et al. (2010)
Tapalpa, JAL	I,D	C	1,950	0.135	9.10	Lopez-Paniagua, et al. (2007)
Mexico City, DF	D	C	2,240	0.064	15.81	Soto and Bateman (2006)
San Cristobal de las Casas, CHIS	D,WH	C	2,120	0.306	1.82	Gutierrez-Villalpando (2006)
Tepetlaoxtoc, EDOMEX	WH	NC	2,300	0.088	4.98	Jimenez-Moreno (2004)
Oaxaca, OAX	WH	NC	1,555	0.105	3.11	Garcia-Angeles (2006)
Tlaxco, TLAX	WH, SR	NC	2,588	0.074	1.83	Orozco-Paredes (2006)
Metztitlan, HGO	WH, SR	NC	2,080	0.091	0.45	Monroy-Hernandez (2008)
Alamos, SON	WH, SR, D	NC	400	0.046	8.23	Chan-Yam (2007)
La Paz, BCS	D	C	10	0.048	10.15	Aviles-Polanco, et al. (2010)

<sup>a</sup> WH, Wildlife habitat; D: Drinking; I, Irrigation; F, Fishing; H, Hunting; SBR, Scenic Beauty and Recreation; SR, Soil Retention

<sup>b</sup> C= Consumptive, NC = Non-consumptive

<sup>c</sup> Based on precipitation and evaporation data (Willmott & Feddema, 1992). The moisture index goes from 0 to 1, where dryer areas tend to zero.

<sup>d</sup> Based on February-2011 price levels (US\$1 = MEX\$13) and 10-year average of the National Consumer Price Index =4.03%)

Table 1. Willingness-to-pay for watershed services in Mexico

† We tried to compare the PSAH payments to those WTP values extracted from literature (See Table 1). The comparison turned difficult due to the differences in methods, sampling issues, and monetary units.

acted as a monopsonistic buyer on behalf of water users (Muñoz-Piña et al., 2008). The government basically established a price and waited for landowners to offer their forests for conservation. In retrospective, some landowners may have rejected the program because the compensation was not enough to fully cover transaction and opportunity costs. In addition, the initiators of the program never considered a baseline to monitor the impacts of the economic compensations on the quality/quantity of water. Today, evaluating the performance of the first periods of the program is difficult due to the lack of a monitoring plan (Consejo Civil Mexicano, 2008).

Despite of these and other criticisms, the PSAH has endured and contributed to sustainable forest management by offering landowners more incentives to provide environmental services, while clarifying and defining property rights, thus reducing the impact of externalities (Muñoz-Piña et al., 2008). In the first years of operation, the program had paid almost US \$200 million and protected about 1.5 million has of strategic watersheds (Chagoya & Iglesias, 2009). The PSAH also has received full support from the Mexican Congress which recently authorized the participation of state and local governments, non-government organizations, private entrepreneurs, and society to increase the funds. Examples of this type of mixed funds are found in Centro Montaña de Guerrero; Tehuacan, Puebla; Coatepec and Texizapa in Veracruz; Cupatitzio, Michoacan; and Chinantla Alta, Oaxaca; among others (Paré et al., 2008). Most of the collected fees have been used to implement selected best management practices in the watersheds' highlands.

The examples of multi-stake voluntary participation in the payment for environmental hydrological services have received ample attention due to the commitment of the multiple parties to promote sustainable forest management. Although programs like PSAH are not in themselves sufficient conditions for sustainable forest management, they are necessary conditions for efficient policy making. Assigning property rights to providers and consumers help delineate the responsibilities of each group. The former receives an economic compensation to reduce the effect of externalities in the management of forest resources. The latter express their demand for environmental services through their WTP for receiving a better quality watershed service. The interaction between providers and consumers helps partially correct market failures and eventually reduce forest degradation. Programs like PSAH not only generate the necessary funds for forest conservation, but also will increase the quantity/quality of watershed services (Pagiola, et al., 2003). The future of PSAH and similar programs lies in the clear definition of the real value of watershed services, correct assignment of property rights, and the continuity of funds.

## 5. Conclusions

This chapter discussed the relevance of valuing watershed services to achieve a sustainable management of forest resources in Mexico. It presented a simple method to estimate water balance and identified BMPs, discussed the main types of values a watershed can offer, how they can be valued, and examples of cases based on non-market valuation and government-supported programs. Due to their non-exclusive, non-rival characteristic, watershed services need to be economically valued using diverse approaches to be produced at optimal levels. Their valuation through opportunity costs may not reflect the total economic value, particularly of non-use values.

The Mexican PSAH, one of the largest in its type, is a clear example of the international concern for redesigning effective management policies for watershed resources (Muñoz-Piña et al., 2008). However, there are still a number of challenges for mainstreaming this type of programs. Turner & Daily (2008) summarized three key constraints that need to be overcome before ecosystem services become operational: 1) information failure, where decision-makers lack scale-relevant detailed information on important ecosystem services and their tradeoffs; 2) institutional failure, where property rights and institutions are lacking to ensure legitimacy and equity; 3) market failure, where investments in long-term ecosystem health can be discouraged due to shared benefits and missing prices for public goods.

We have reviewed several cases of non-market valuation that estimated the benefits of watershed services in Mexico (Table 1). Results indicate that there is no significant relationship between WTP, moisture index, and elevation with the two types of values (i.e., consumptive and non-consumptive uses). Considering the low number of cases found in the literature, more research is clearly needed to evaluate the relationship between WTP and the benefits of environmental services, and motivate the interest for creating markets, particularly of non-use values. Here, researchers must incorporate a diversity of geographical areas and services to scale up these markets and incentive programs. They also must employ appropriate valuation tools to tackle the problems associated with reliability of results such as survey design, definition of contingent valuation scenarios, and testing for survey variations of results (Wittington, 2002). More work is necessary to understand the benefits of use and non-use values of watershed services, disseminate the results of pilot projects (success stories), and incorporate all interested sectors of society. This kind of work would increase public's level of awareness and their perception over changes in the provision of environmental services. The participation of government and other institutions (such as landowners represented by *ejidos*<sup>§</sup>) can help to identify critical watersheds for cities, private companies, or non-government organizations. In incipient markets, such as in Mexico, government participation is essential in promoting the type of service most needed for users.

Devising PES programs, such as PSAH, as a rent based on the watershed services preserved (or on the decline in the rate of its loss), necessitates translating ecological functions as measurable and traceable unit of services provided due to the payment (Wunder, 2007). Providing economic incentives to enhance ecosystem service delivery would be ineffective if policies are implemented without tools to differentiate those who alter their management practices in response to the incentive from those free-riders whose behaviors are essentially unaltered (Gilenwater, 2011). To overcome the constraints from the institutional failure, the government must clarify how the service in question and its value will be measured and monitored. We believe that combining market and non-market valuation techniques clarifies the scale of economic distortions due to uncertainty and should help understand the importance of both use and non-use values. The impacts of non-point sources to streamflow can be monitored by establishing a paired-watershed design, which utilizes a calibration period and a control watershed to detect changes in hydrology of a treatment watershed.

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<sup>§</sup> Ejidos is one the agrarian reform outcomes generated by the Mexican revolution in the 1920's. As defined by Alcorn and Toledo (1998) an ejido is as an expanse of land, title to which resides in a community of beneficiaries of the Agrarian Reform. Most of the ejidos are collectively owned or cooperatively farmed and the products are also marketed collectively.



Finally, although programs like PSAH are not the panacea to water quality and deforestation problems (Muñoz-Piña et al., 2008), they should be considered in the design of policies for sustainable forest management. PES programs need to reflect the real value of services so providers allocate their maximum effort to internalize the externalities. The real value will come with the use of appropriate economic methods that consider both use and non-use values of watershed services. The involvement of other actors, such as the private sector and non-government organizations, is necessary to improve decision-making and ensure that these kinds of programs achieve their goals.

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## 7. References

- Alcorn, J., Toledo, V. M. (1998). Resilient resource management in Mexico's forest ecosystems: the contribution of property rights. In F. Berkes and C. Folke, (Eds) *Linking social and ecological systems*. Pages 216-249. Cambridge University Press, Cambridge, UK.
- Andreassian, V. (2004). Waters and forests: from historical controversy to scientific debate. *Journal of Hydrology*, 291: 1-27.
- Aviles-Polanco, G., Huato-Soberanis, L., Troyo-Diequez, E., Murillo-Amador, B., Garcia-Hernandez, J.L., Beltran-Morales, L.F. (2010). Valoración Económica del servicio hidrológico del acuífero de La Paz, B.C.S.: Una valoración contingente del uso de agua municipal. *Frontera Norte* 22 (43), 103-128
- Boyle, K.J. (2003). Contingent valuation in practice. In Champ, P.A., Boyle, K.J., Brown, T.C. (Eds.) *A primer on nonmarket valuation* (pp. 111-169). Kluger Academic Publishers. Norwell, MA.
- Brauman, K.A., Gretchen, C., Duarte, T. K., Mooney, H.M. (2007). The nature and value of ecosystem services: An overview highlighting hydrologic services. *Annual Review of Environmental and Resources*, 32:67-98.
- Brown, A. E., L. Zhang, T. A. McMahon, A. W. Western, R. A. Vertessy. (2005). A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *Journal of Hydrology*, 310:28-61.
- Carson, R.T., Groves, T. (2007). Incentive and informational properties of preference questions. *Environmental Resource Economics*, 37, 181-210.
- Chagoya, J.L., Iglesias, L. (2009). Esquema de pago por servicios ambientales de la Comisión Nacional Forestal, México. In Sepulveda, C., Ibrahim, M. (Editores). *Políticas y sistemas de incentivos para el fomento y adopción de buenas prácticas agrícolas*. Capitulo 10 (pp. 189-204). Centro Agronómico de Investigación y Enseñanza, CATIE. Turrialba, Costa Rica.
- Champ, P.A., Boyle, K.J., Brown, T.C. (2003). *A primer on nonmarket valuation*. Kluger Academic Publishers. Norwell, MA.



- Chan-Yam, L.B. (2007). *Valoración económica del agua para conocer la disponibilidad de pago en comunidades presentes en ÁPFF Sierra Álamos - Rio Cuchujaqui, Álamos, Sonora*. Tesis. Universidad Autónoma Chapingo. Chapingo, México. 138 p.
- Coase, R.H. (1960). The problem of social cost. *The Journal of Law and Economics*, 3(1): 1–44.
- CONAFOR (Comisión Nacional Forestal). (2004). Reglas de operación del programa de servicios ambientales hidrológicos. *Diario Oficial de la Federación* (18 de Junio 2004). [Available at [http://www.semarnat.gob.mx/leyesy normas/Acuerdos/ACUE\\_SERV\\_AMB\\_HI DRO\\_18\\_06\\_04.pdf](http://www.semarnat.gob.mx/leyesy normas/Acuerdos/ACUE_SERV_AMB_HI DRO_18_06_04.pdf), last time accessed June 1, 2011].
- Consejo Civil Mexicano. (2008). El Programa de pago por servicios ambientales hidrológicos de la Conafor: revisión crítica y propuestas de modificación. In Pare, L., Robinson, D, Gonzalez, M.A. (Editores). *Gestión de cuencas y servicios ambientales. Perspectivas comunitarias y ciudadanas* (pp. 259-276). INE-SEMARNAT. Mexico, D.F.
- Costanza R., d'Arge R., deGroot R.D., Farberk S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill RV., Paruelo J., Raskin R.G, Suttonkk P., Belt V.D. (1997). The value of the world's ecosystem services and natural capital. *Nature* 387(6630): 253–260.
- Daily, G.C. (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press: Washington, DC.
- DOF (Diario Oficial de la Federación). (2010). Comisión Nacional de los Salarios Mínimos. Vigencia a partir del 1 de Diciembre del 2011. *Diario Oficial de la Federación*. [Available at [http://dof.gob.mx/nota\\_detalle.php?codigo=5172213&fecha=23/12/2010](http://dof.gob.mx/nota_detalle.php?codigo=5172213&fecha=23/12/2010), Last time accessed: Jun 14, 2011].
- Dunkerley, D.L. (2008). Intra-storm evaporation as a component of canopy interception loss in dryland shrub: observations from Fowlers Gap, Australia. *Hydrological Processes*, 22: 1985-1995.
- Feen, R.H. (1996). Keeping the balance: ancient Greek philosophical concerns with population and environment. *Population and Environment*, 17(6): 447–458.
- Field, B.C. (2008). *Natural resource economics*. Waveland Press, Inc. Long Grove, Illinois.
- Freeman III, A.M. (2003). *The measurement of environmental and resource values. Theory and methods*. Resources for the Future Press. Washington, D.C.
- Garcia-Angeles, A. (2006). *Valoración económica de los servicios ambientales de Santa Catarina Ixtepeji, Distrito de Ixtlán, Oaxaca*. Tesis. Universidad Autónoma Chapingo. Chapingo, México. 163 p.
- Gillenwater. M. 2011. *What is additionality? Part 1: a long standing problem*. Discussion Paper No. 001. GHG Management Institute: Washington, DC. [Available at [http://ghginstitute.org/wp-content/uploads/2011/03/AdditionalityPaper\\_Part-1\\_ver2\\_FINAL.pdf](http://ghginstitute.org/wp-content/uploads/2011/03/AdditionalityPaper_Part-1_ver2_FINAL.pdf), last time accessed Jul 25, 2011].
- Gómez-Baggethun E, de Groot R, Lomas PL, Montes C. (2010). The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. *Ecological Economics*, 69(6): 1209–1218.
- Gutierrez-Villalpando, V. (2006). *Valoración económica del agua potable en la zona urbana de San Cristóbal de las casas, Chiapas*. Tesis de Maestría. El Colegio de la Frontera Sur. San Cristóbal de las Casas, Chis.

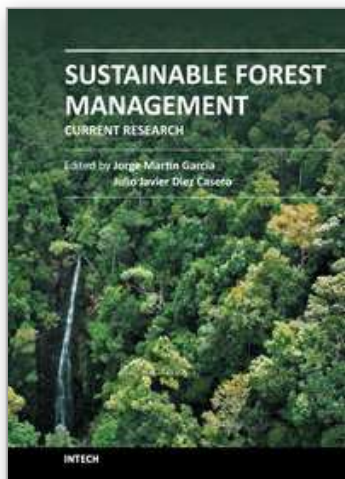
- Hiscock, K. (2005). *Hydrogeology: principles and practice*. Blackwell Publishing. Malden, MA.
- Ikawa, R.; Shimada, J.; Shimizu, T. (2009). Hydrology in mountain regions: observations, processes and dynamics. In Marks, D. *Proceedings of the International Commission on Snow and Ice Hydrology: Hydrology in Mountain Regions: Observations, Processes and Dynamics* (pp. 25-33). July 2007. Perugia, Italy.
- Jackson, C.R., Miwa, M. (2007). Importance of forestry BMPs for water quality. In *Proceedings of the Louisiana Natural Resources Symposium: Human and Other Impacts on Natural Resources—Causes, Quantification, and Implications, August 13–14, 2007*. Louisiana State University, Baton Rouge, pp. 10–31.
- Jimenez-Moreno, M.J. (2004). *Valoración de algunos recursos naturales, para conocer la disponibilidad de pago por servicios ambientales en el municipio de Tepetlaoxtoc*. Tesis. Universidad Autónoma Chapingo. Chapingo, México. 75 p.
- Locatelli, B., Vignola, R. (2009). Managing watershed services of tropical forests and plantations: Can meta-analyses help? *Forest Ecology and Management*, 258 (9): 1864–1870.
- Lopez-Paniagua, C., González-Guillén, M.J, Valdez-Lazalde, J.R, de los Santos H.M. (2007). Demanda, disponibilidad de pago y costo de oportunidad hídrica en la Cuenca Tapalpa, Jalisco. *Madera y Bosques* 13(1): 3-23.
- Martin, D.A., Moody, J.A. (2001). Comparison of soil infiltration rates in burned and unburned mountainous watersheds. *Hydrological Processes*, 15: 2893–2903.
- McBroom, M. W., R. S. Beasley, M. T. Chang, G. G. Ice. (2008). Storm runoff and sediment losses from forest clearcutting and stand re-establishment with best management practices in east Texas, USA. *Hydrological Processes*, 22:1509-1522.
- Monroy-Hernandez, R. (2008). *Valoración económica del servicio ambiental hidrológico en la reserva de la biosfera barranca de Metztitlán, Hidalgo*. Tesis. Universidad Autónoma Chapingo. Chapingo, México. 87 p.
- Mitchell, R.C., Carson, R.T. (1989). *Using surveys to value public goods: the contingent valuation method*. Resources for the Future Press. Washington, D.C.
- Messerli, B., Viviroli, D., Weingartner, R. (2004). Mountains of the world: vulnerable water towers for the 21st century. *Ambio*, 33(13): 29-34
- Muñoz-Piña, C., A. Guevara, J.M. Torres y J. Braña. (2008). Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results. *Ecological Economics*, 65(4):725-736.
- Navar, J. (2011). Stemflow variation in Mexico's northeastern forest communities: Its contribution to soil moisture content and aquifer recharge. *Journal of Hydrology*. In press. doi: 10.1016/j.jhydrol.2011.07.006
- Neary, D.G., Ice, G.G., Jackson, C.R. (2009). Linkages between forest soils and water quality and quantity. *Forest Ecology and Management*, 258: 2269–2281
- Ojeda, M.I., Mayer, A.S., Solomon, B.D. (2008). Economic valuation of environmental services sustained by the Yaqui River Delta. *Ecological Economics*, 65: 155-166.
- Orozco-Paredes, L.M. (2006). *Balance hidrológico y valoración económica de la producción de agua en la microcuenca del Río Zahuapan, Tlaxco, Tlax.* Tesis. Universidad Autónoma Chapingo. Chapingo, México. 174 p.

- Pagiola, E., Bishop, J., Landel-Mills, N. (2003). *La venta de servicios ambientales forestales. Mecanismos basados en el mercado para la conservación y el desarrollo*. INE-SEMARNAT. Mexico, D.F.
- Paré, L, Robinson, D., Gonzalez, M.A. (2008). *Gestión de cuencas y servicios ambientales perspectivas comunitarias y ciudadanas*. INE-SEMARNAT. Mexico, D.F.
- Pattanayak, S.K. (2004). Valuing watershed services: concepts and empirics from southeast Asia. *Agriculture, Ecosystems and Environment*, 104: 171–184
- Pearce, D.W. (2001). The economic value of forest ecosystems. *Ecosystem Health*, 7(4): 284–296.
- Perez-Verdin, G., Kim, Y-S., Hospodarsky, D., Tecle, A. (2009). Factors driving deforestation in common-pool resources in northern Mexico. *Journal of Environmental Management*, 90:331-340
- Pierson, F.B., Robichaud, P.R., Moffet, C.A., Spaeth, K.E., Williams, C.J., Hardegree, S.P., Clark, P.E. (2008). Soil water repellency and infiltration in coarse-textured soils of burned and unburned sagebrush ecosystems. *Catena*, 74: 98–108.
- Plottu, E, Plottu, B. (2007). The concept of total economic value of environment: a reconsideration within a hierarchical rationality. *Ecological Economics*, 61: 52–61.
- Sanjurjo, E. (2006). *Aplicación de la metodología de valoración contingente para determinar el valor que asignan los habitantes de San Luís Río Colorado a la existencia de flujos de agua en la zona del Delta del Río Colorado*. Dirección de Economía Ambiental. INE-SEMARNAT. Mexico, D.F.
- Schlapfer, F. (2008). Contingent valuation: a new perspective. *Ecological Economics*, 64: 729–740
- Silva-Flores, R., Perez-Verdin, G., Navar-Chaidez, J.J. (2010). Valoración económica de los servicios ambientales hidrológicos en El Salto, P.N., Durango. *Madera y Bosques*, 16(1): 31–49.
- Soto, M.G, Bateman, I.J. (2006). Scope sensitivity in households' willingness to pay for maintained and improved water supplies in a developing world urban area: Investigating the influence of baseline supply quality and income distribution upon stated preferences in Mexico City. *Water Resources Research*, 42: 1–15.
- Swank, W.T., Swift, L.W., and Douglass, J.E. (1988). Streamflow changes associated with forest cutting species conversions, and natural disturbances. In *Forest Hydrology and Ecology at Coweeta*. W.T. Swank and D.A. Crossley (Editors). pp 297–312. Springer Verlag, New York.
- TEEB (The Economics of Ecosystem and Biodiversity). (2010). The economics of valuing ecosystem services and biodiversity. In *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*, Kumar P (ed). (Chapter 5, 133 p). UNEP, Bonn, Germany.
- Turner, R.K, Daily, G.C. (2008). The ecosystem services framework and natural capital conservation. *Environmental and Resource Economics*, 39(1): 25–35.
- Vasquez, W.F., Mozumder, P., Hernandez-Arce, J, Berrens, R.P. (2009). Willingness to pay for safe drinking water: evidence from Parral, Mexico. *Journal of Environmental Management*, 90: 3391–3400.
- Ward, A.D., Trimble, S.W. (2004). *Environmental hydrology*. CRC Press. Boca Raton, Florida.

- Whittington, D. (2002). Improving the performance of contingent valuation studies in developing countries. *Environmental and Resource Economics*, 22: 323–367, 2002.
- Willmott, C.J, Feddema, J.J. (1992). A more rational climatic moisture index. *The Professional Geographer*, 44(1): 84 – 88.
- Wunder, S. (2007). The efficiency of payments for environmental services in tropical conservation. *Conservation Biology*, 21(1): 48–58.

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Sustainable forest management (SFM) is not a new concept. However, its popularity has increased in the last few decades because of public concern about the dramatic decrease in forest resources. The implementation of SFM is generally achieved using criteria and indicators (C&I) and several countries have established their own sets of C&I. This book summarises some of the recent research carried out to test the current indicators, to search for new indicators and to develop new decision-making tools. The book collects original research studies on carbon and forest resources, forest health, biodiversity and productive, protective and socioeconomic functions. These studies should shed light on the current research carried out to provide forest managers with useful tools for choosing between different management strategies or improving indicators of SFM.

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