6 An Integrated Approach to Forest Ecosystem Services

Coordinating convening lead author: José Joaquín Campos

Convening lead authors: Francisco Alpízar, Bastiaan Louman and John Parrotta

Contributing author: Ina T. Porras

Abstract: Forest ecosystem services (FES) are fundamental for the Earth's life support systems. This chapter discusses the different services provided by forest ecosystems and the effects that land use and forest management practices have on their provision. It also discusses the role of markets in providing an enabling environment for a sustainable and equitable provision of FES, and describes a standardized approach for designing effective PES (Payment for Environmental Services) that takes into consideration the biophysical, demand (beneficiaries) and supply (providers) components, as well as institutional requirements of a PES scheme. The chapter assesses some potential limitations and challenges in the use of market mechanisms in general, and PES schemes in particular, for sustaining the provision of forest ecosystem services, such as difficulties to demonstrate that services are actually being provided, lack of an effective demand for the services or restrictions from the supply side, as well as other limitations related to institutional capacity and scale. The main challenge is probably in establishing long term, sustainable financing mechanisms that effectively internalize environmental services in the appropriate institutional frameworks. To overcome these challenges, research and management need to take into consideration larger temporal and spatial scales, as well as integrate the different components in the landscape and in the policy and decision-making processes.

Keywords: Forest ecosystem services; sustainable forest management; forest functions; environmental services; market-based instruments; payment for environmental services (PES); standardized methodology for PES design; limitations of PES approach.

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6.1 Introduction

Forest ecosystems, both natural and those established by afforestation and reforestation, are among the most important providers of environmental services that are fundamental for the Earth's life support systems. Services include the maintenance of good air quality and a favorable climate, the protection of hydrological functions and provision of good quality water for consumption, generation and maintenance of soils and their fertility, the protection of biological diversity, pollination of economically important crops, biological control of agricultural pests, provision of timber, a wide range of non-timber forest products, genetic resources used in crop breeding programs, and the numerous other social, cultural, spiritual, aesthetic, recreational, and educational benefits that forests provide. (Daily et al. 1997; de Groot et al. 2002; Nasi et al. 2002).

Historically, the nature and value of these services have largely been ignored until their disruption or loss has highlighted their importance (Daily et al. 1997). Based on available scientific evidence, it is clear that humanity is highly dependent on the flow of forest ecosystem services, yet this flow is dependent on the way in which ecosystems are affected by human activities. Forest ecosystem services are above all affected by forest removal and degradation. While economic forces have been given as one of the major drivers behind such loss (Geist and Lambin 2002), forest management for timber production as an income and employment generating activity has not been able to slow the rate of this loss (Niesten and Rice 2004), except for cases where several enabling conditions are met (Louman and Stoian 2002). In this chapter therefore we propose that the sustainable management of forest ecosystems should incorporate the payment for ecosystem services approach, since one advantage of this approach is that it focuses on managing natural assets for the value they provide to humans, rather than on the problems that result from inappropriate natural resource management. At the same time, it broadens economic options and pays for goods and services that provide benefits without necessarily altering the ecosystem's potential to generate them. The focus on the value of services, rather than on control, is in itself a new paradigm that has great potential for shaping sustainable forestry in many parts of the world.

Ecosystem services are the products of ecosystem attributes and functions that benefit humanity; in this respect, functions only become services to the extent that humans acknowledge them within their social systems of value generation. Ecosystems are dynamic complexes of plant, animal, and micro-organism communities and their non-living environment, interacting as a functional unit; humans are an integral part of ecosystems (Nasi et al. 2002). Human activities having significant impacts on the structure and function of natural systems have become so extensive, particularly during the last century, that all ecosystems on the planet have been altered to some extent. These alterations range from local changes in species population caused by harvesting and habitat destruction, to global changes in atmospheric chemistry and climate resulting from industrial emissions (Costanza and Farber 2002). According to Daily et al. (1997), the most serious human impact on ecosystems is the irreversible loss of native biodiversity, which exceeds the rate of evolution of new species by a factor of 10 000. The annual loss of forest at the global level has been estimated at 0.2%; this includes over 9 million hectares of tropical forests lost each year (FAO 2001). These alterations can significantly affect human welfare now and in the future (Daily et al. 1997; Costanza and Farber 2002; Nasi et al. 2002).

A major goal of human interaction with natural ecosystems is the support of human welfare, including the sustainability of such welfare across generations and its distributional fairness (Costanza and Farber 2002). This is the overarching goal of SFM. One challenge that has to be addressed in SFM is that, unlike forest products, most forest ecosystem services are not paid for. This means that too often, those who own, control or manage forest resources where those services are generated do not capture the economic benefits that result from those services, thus reducing incentives to conserve these ecosystems, particularly the natural ones (Nasi et al. 2002; Niesten and Rice 2004). Some of the challenges in implementing schemes for payment for ecosystem services include identification and quantification of the different services that the forest ecosystems provide; establishment of sustainable financing mechanisms; design and implementation of payment systems that provide adequate incentives to land managers; development and adaptation of institutional frameworks that suit local circumstances; and, finally, ensuring equitable distribution of the costs and benefits among stakeholders (Pagiola et al. 2002).

Market mechanisms are said to balance distribution of costs and benefits according to the needs of producers and consumers. However the market, without intervention, is unable to capture and value ecosystem services; hence there are no financial incentives for forest managers and decision-makers to take them into account to achieve sustainable forest management and sustainable development. Therefore, there is a need for innovation in existing market systems in order to be able to conserve ecosystem services.

The use of market instruments as a means of incorporating the economic value of forest ecosystem services into the financial decision-making process of producers and consumers is a recent tool to resolve longstanding market failures that have had undesirable economic outcomes (Rojas and Aylward 2003). There are several countries where payments for ecosystem services are being implemented. In Costa Rica, for example, a nationwide system has been implemented since 1996, based on recognition by the Forest Law of four services provided by different forest ecosystems in private lands (Campos et al. 2001). In North America, New York City is restoring the natural water purification services of the Catskills watershed (Daily 1999). In many countries different approaches are being developed and tested, for example in Brazil see Box 6.1.

If markets are ultimately to produce welfare improvements, they need to be designed to provide the correct incentives. This in turn requires clear understanding of the relationship between land-use alterations and the ecosystem services provided (Landell-Mills and Porras 2002), as well as sound knowledge of human and ecosystem interactions (Rojas and Aylward 2003). In this chapter we stress the need for further research on the characterization (biophysical and economic) of ecosystem services, and development of the most suitable institutions and policies for implementing payment systems.

Both research and management of ecosystem services will demand integrated approaches that take into consideration larger temporal and spatial scales, as well as the different components in the landscape (actors, land uses, sectors and disciplines) and policy and decision-making processes (Sayer and Campbell 2003).

In this chapter, we will discuss the most relevant issues in an integrated approach to the new paradigm of forest ecosystem services. The chapter is divided into six sections (including this Introduction). In Section 6.2, we briefly discuss the different services provided by forest ecosystems. Section 6.3 discusses the role of markets in providing an adequate environment for a more sustainable and equitable provision of forest ecosystem services. In

BOX 6.1 Selling Carbon Sequestration in Brazil

Ina T. Porras

The Ilha do Bananal/Ecológica Initiative

The Brazilian NGO Instituto Ecológica implements, without mediation, two projects of predominantly developmental character. The main objective is to generate experience with carbon projects that may link the needs of the local communities to eventual carbon credits and social responsibility image of transnational companies. The Carbon Sequestration Project of Bananal Island is located in the Brazilian Amazon. It comprises Bananal Island itself (approximately 2 100 000 ha) and its surroundings to the north and east of the island and part of the APAC – Environmental Protection Area of Cantão.

The project was initially prepared as an international tender organized by Natural Resources International on behalf of the AES Barry Foundation. The tender specified that AES Barry, a gas energy facility, was seeking a project to offset 6 million t C, the estimated amount of emissions throughout the company's expected lifetime, and the focus of the project was to be the social component. However, AES Barry foundation was not able to honor the initial agreement of about USD 1 189 500 (£ 650 000), of which only about USD 183 000 (£ 100 000) were disbursed. Additional funding had to be obtained from the Natura Foundation, the municipality of Bozzano in Italy, the World Bank Millennium LBA program, and an environmental compensation for the construction of the airport at Palmas, the state capital.

The Bananal Project aims to develop and implement an innovative, equitable and sustainable system to offset greenhouse gas emission, through the preservation of existing forests, reforestation, regeneration and implantation of agroforestry systems, development of methodologies for carbon monitoring, and an important social component through environmental education and generation of alternative sources of income. The project worked with two indigenous villages with the objective of introducing beekeeping and indigenous ecotourism. Social effects are difficult to measure at this early stage; however, one important aspect is their effort to involve local communities in discussion and participation in project activities. The main impacts are summarized in the following table:

References

May, P., Boyd, E., Veiga, F. and Chang, M. 2004. Local sustainable development effects of forest carbon projects in Brazil and Bolivia. A view from the field. Environmental Economics Program. International Institute for Environment and Development (IIED), London. 115 p.

Table A. Impacts of the Bananal Project in Brazil (May et al. 2004)

Sustainability and Impact levels	Impact description	
	Positive Effects	**Limitations**
ENVIRONMENTAL		
Global		¤ Not effective in carbon sequestration, only 0.8% of the proposed amount
National/regional	¤ Use of market instruments to support federal and state protected areas; ¤ Avoided deforestation in region of high deforestation rate.	¤ Lack of more robust institutionalization of partnership with government environmental agencies
Regional/local	¤ Development of research in ecotonal region for environment conservation.	
Local	¤ Contribution to environmental awareness.	
SOCIAL		
National	¤ Leveling of research through networking; ¤ Contribution to generation of scientific information on local ecosystem; ¤ Introduction of "sustainable livelihood" approach in social assessment.	
Regional	¤ Provision of support by the Canguçu research center to other researchers.	
Local	¤ Financial support to community income generation micro projects; ¤ Establishment of 4 nurseries with 5 staff; ¤ Distribution of seedlings to community; ¤ Support of establishment of agroforestry; ¤ Capacity building and environmental education for school teachers and community in general; ¤ Assistance to indigenous groups in beekeeping and ecotourism;	¤ No registry of distribution and follow up; ¤ Yet to start in the 2002/2003 rainy season; ¤ Activity suspended due to interruption of funding.
ECONOMIC		
Macroeconomic National/Regional	¤ Carbon projects as alternatives to degrading agricultural systems in the region;	
Macroeconomic Regional/local	¤ Project contributes to attracting other carbon investments in the region; ¤ Job creation during building of the research center.	¤ Not significant employment generation ; in the research center (4 staff) ¤ Temporary employment during building period;
Microeconomic Enterprise	¤ Social responsibility image to AES Barry and Natura.	¤ Insolvency of investor AES Barry interrupted funding

Section 6.4, we propose an approach for designing payment schemes for ecosystem services that considers beneficiaries and providers as well as institutional requirements. Section 6.5 assesses some potential limitations for the use of market mechanisms in sustaining the provision of ecosystem services, such as difficulty in demonstrating that services are actually being provided, lack of an effective demand for the services or restrictions from the supply side, and other limitations regarding institutional capacity and scale. Case studies in Boxes 6.1 to 6.3 describe examples of payment schemes from different regions of the world and the main lessons learned.

6.2 Forest Ecosystems' Goods and Services

Definition of Forest Goods and Services

Forests are valuable for much more than the goods they produce, such as timber, latex, fruits, medicinal plants and other non-timber products, and game animals that are important for food security in many parts of the world. The existence of forests, their components, and their interactions and functions, also influence water quality, climate, soils, effects of natural phenomena like strong winds and heavy rainfall, nutrient cycling, waste decomposition, esthetic beauty, and cultural and religious values. These services have been defined as "the range of conditions and processes of the (forest) ecosystems and their components that help sustain and fulfill human life" (adapted from Daily et al. 1997), while Nasi et al. (2002) provide a more utilitarian definition: "the outcome of ecosystem functions that benefit human beings".

Although at least some of these services have been discussed for several decades, only recently has a more systematic approach to their valuation and characterization been attempted, linking ecosystem functions to ecosystem goods and services (de Groot et al. 2002; Nasi et al. 2002). The functions have been defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (de Groot 1992, cited in de Groot et al. 2002). Thus, de Groot et al. (2002) recognize four groups of functions: regulating functions that maintain essential ecological processes and life support systems; habitat functions that provide a suitable living space for wild plant and animal species; production functions that provide goods, such as timber and non-timber products; and information functions that provide opportunities for cognitive development. The regulating and habitat functions are essential for the maintenance of ecosystems, and without them the other two functions would not exist. For example pollination, a regulating function, does not directly benefit people, but it provides the service of pollination of fruit trees (for example by insects and bats), without which fruit production would not take place.

These four groups, outlined in Annex 1, bring together at least 15 functions, each of which may provide one or more goods and services. At the same time, some goods and services may require more than one function for their maintenance or provision. A continuous supply of timber, for example, will depend directly on production functions, which in itself will depend on habitat functions (a space for the timber species to live) and regulating functions (e.g. climate regulation, pollination, seed dispersal). While providing timber as a good, maintenance of these ecosystem functions will also contribute to the provision of services, such as maintenance of both a favorable climate and suitable living space for other plants and animals (thereby maintaining biological diversity).

The same grouping can also be used for the services provided by ecosystems. Thus, regulating functions lead to regulating services, and habitat functions to the maintenance of biological diversity for current and future provision of other services and goods. Production functions lead to tangible goods, while the information functions lead to reflection, inspiration, knowledge, recreation, and the maintenance of social, cultural, and spiritual traditions and values associated with forests. The most discussed and more generally appreciated services are the regulation of the carbon, nutrient and water cycles (regulating), maintenance of existing and restoration of degraded ecosystems (habitat), scenic beauty (information) and the provision of goods (production).

It should be kept in mind that while ecosystems functions may exist everywhere, they do not necessarily result in the provision of goods and services of the same quality or quantity at every location. Thus, regulation of the water cycle is a function of all forest ecosystems, but only becomes a service if its results are directly felt by people. In many mountainous areas forests may contribute to the provision of drinking water and reduce the risks of flooding. While in many remote areas of the Amazon basin this function is important, it does not provide direct services if there are no people to benefit from them. Similarly, regulation of the carbon cycle is a function of all forests, but the service of maintaining a favorable climate through carbon sequestration and storage may be better provided by forests that show rapid biomass accumulation and permit long term storage, such as araucaria (*Araucaria* sp.) and eucalypt (*Eucalyptus* spp.) forests in Australia, and teak (*Tectona grandis*) plantations in Indonesia or Costa Rica, which may produce timber volumes of up to 20 m^3/ha/year for periods of 20–40 years. Following harvest, this timber can be used in buildings for a long period of time.

Maintenance of biological diversity, recognized as an ecosystem service by the government of Costa Rica, and one of the benefits for which international organizations are prepared to pay (Rodriquez 2002), in itself is not a service except under conditions where forest biological diversity provides timber and non-timber goods and services, such as pollination and pest control, in adjacent agricultural areas. Rather, it is often a *condition* of forests that may provide new products, new knowledge, and future opportunities to adapt to diseases, pests and changing environmental conditions. As such, it is closely related to the habitat services. In that respect, the maintenance of biological diversity could also be considered as a "supporting service". While greater biodiversity may reduce future economic and ecological risks, it is not a prerequisite for increasing the value of the forest. Indeed, less diverse forests have proven to have a greater current economic value than more diverse forests: the natural pine forests of Central America and Mexico, for example, have greater harvestable timber volumes than the highly diverse neotropical rainforest. They are, however, more susceptible to pests, diseases and invasive species, as the recent outbreaks of a bark beetle (*Dendroctonus frontalis*, Coleoptera: Scolytidae) in Belize, Honduras and Nicaragua have shown.

Services from Other Relevant Ecosystems

In the above paragraphs, functions and services of forest ecosystems were discussed. A number of these functions and services, however, can also be found in other ecosystems, although to a different degree. Wetlands, for example, are known to play an important role in preventing flooding, since they serve as temporary storage areas for large masses of water. They also can be major sources of food and biological diversity, while algae and woody vegetation contribute to the fixation and storage of carbon. In many countries, wetlands have been modified to become major food producing areas, showing the potential contribution of wetlands to improving and maintaining soil productivity. Wetlands also often function as migratory habitats for bird and fish species, so that their loss may have strong negative effects on other populations and ecosystems. At the same time, they often are located in the lower parts of watersheds, and any removal of forest vegetation resulting in soil loss and contamination or changes in peak and base flows will affect the wetlands.

Coral reefs are known for their potential to reduce the force with which waves arrive on the shore, thus reducing the impact that storms may have over the land in terms of erosion and flooding. They are also a rich food source, and provide very specific habitats for a large number of fish and other sea animals. In addition, coral reefs are an attractive tourist destination.

Agricultural systems may increasingly contribute to the provision of ecosystem services. Incorporation of trees as live fences or as shade contributes to the fixation and storage of carbon, as well as providing habitats and corridors for many insect, bird and small mammal species. Combining trees with perennial crops, soil conservation measures and a very restricted use of chemicals, agricultural systems may also contribute to maintaining water quality for consumption use and reduce the risks of flooding. Trees, shrubs and non-commercial herbaceous plants in agricultural systems may also contribute to pollination and the reduction of crop damage due to pests and diseases. On the other hand, they may also be the cause of some damage, and it is important to know which plants and animals can be tolerated and which not.

Much of what has been discussed in the previous paragraphs can also be relevant for other types of ecosystems, and the approaches for their management and valuation described in this chapter can at least partially be applied to these other ecosystems.

6.3 Market Efficiency and Market Failure

From an economic perspective, most forest ecosystem services are regarded as positive externalities. In general, externalities are defined as unintended side-effects of the consumption or production decisions of an economic agent. These "side-effects" will in turn affect the consumption or production decisions of other agents. For example, a farmer facing a decision to convert a forest land in order to use it for agriculture will base his or her decision on the potential profitability of the different alternatives. But in his or her decision, the farmer might not take into account that, by converting the forest, he or she is also putting an end to or reducing the flow of services derived from the forest ecosystem. Indeed, it is easy to imagine that, as a side-effect of the owner's decision, other agents will be affected and hence forced to consume or produce differently. If the farm is located in a small watershed used as a source of potable water, the increased run-off and erosion rates from the agricultural activities might force the water company to incur additional costs to restore drinking water quality, for example. Additionally, if the forest was regarded as having high biodiversity conservation value, the farmer's decision to clear the forest might negatively affect important ecological functions and services at the local or global levels and hence hamper efforts to protect this resource elsewhere. Alternatively, if the farmer decides to keep the natural forest cover, he or she will be generating a flow of positive externalities in addition to the private benefits that accrue to him or her as owner of the land.

In essence, the presence of external effects – either positive or negative – introduces a gap between the benefits expected by the private decision-maker and the benefits expected by society as a whole. Considering the example described above, although the landowner's decision to convert the forest might be correct from a private perspective, it might be inefficient from a social perspective, once the total costs and benefits from all the affected agents are factored into the equation.

Somewhat more complicated is the analysis of the farmer's decision to keep the natural forest cover. Since forest owners consider only the private flow of benefits enjoyed by maintaining the natural forest cover in their land, disregarding the other social benefits that follow (water and biodiversity protection, for example), then these forest environmental services would still be undersupplied compared to the optimal benchmark case in which decisions follow a social welfare maximization criteria (Costanza and Farber 2002). An obvious solution to the problem outlined above is to sell those forest environmental services, just as any forest owner might sell goods like timber, or non-timber forest products like fruits.

The problem with this solution lies in the nature of the good or service to be sold. In the case of timber, the private nature of the good (i.e. all benefits from the good are enjoyed solely by the owner) allows for markets to be established and to work properly in reaching an equilibrium price that balances the needs of consumers and producers alike (there are exceptions to this, for example in cases where illegal logging takes place).

Unfortunately, many forest environmental services are not private goods, but rather can be categorized as public in nature. One of the main characteristics of public goods is non-excludability, i.e. it is impossible or prohibitively expensive to exclude somebody from benefiting from them. In such a circumstance, it is unlikely that somebody will pay for a good or service if it can be enjoyed anyway, with or without payment. This is then a typical situation in which free functioning markets fail to work properly or even exist, due to potential free riding. In summary, although forest ecosystem services are produced in land that is privately owned, they are *de facto* free to everybody, i.e. property rights to these services are not well established.

Any solution to the problem outlined above must then go first to a process of establishing property rights to goods and/or services previously regarded as free. In cases where "few" agents are involved, i.e. where free riding is unlikely and transaction costs are low, one could in principle argue in favor of a solution along the lines above, in which suppliers and beneficiaries of environmental services effectively negotiate a joint solution. If property rights to the services are assigned to the forest owner, he or she could then argue for compensation for providing those services. If property rights initially belong to the beneficiaries of the services, then they could impose restrictions on the use of the land and relax them in exchange for compensation. This way of approaching the problem of externalities is known as a Coasian solution (Coase 1960). Alternatively, if property rights to the environmental services are assigned to a community, or more generally to an organized collectivity encompassing providers and beneficiaries alike, one could in principle consider a common property approach to solving the problem of externalities – provision of environmental services – in which the optimal private decision is aligned with the optimal social solution through a set of rules and a suitable redistribution of duties and rights (Ostrom 2002). This is a very promising option for small rural communities regarding water services.

In many cases, though, the number of affected agents and high transaction costs, among other factors, will make it impossible to reach a solution via the mechanisms proposed above, forcing the government to intervene. Historically this intervention has taken the form of direct regulation. There are two broad forms of direct regulation. The first one involves direct provision of environmental services regarded as important, via the expropriation of land and the establishment of natural protected areas, among other tools. Following our previous discussion, the government is then basically buying the property rights to the environmental services by acquiring the natural ecosystems that provide those services. Notably this is a policy that can and has achieved good results, provided that funds are available to the government to purchase the land and effectively manage those protected areas.

The second type of direct regulation can basically be described as setting restrictions on the decision making process of the forest owner. Prohibitions or legal limits on how to use the land are probably the most typical examples. In Costa Rica, for instance, forest conversion has been prohibited by law since 1996, and land owners are not allowed to harvest trees along water courses or in steep slopes inside their property, in an effort to reduce vulnerability and erosion (Campos et al. 2001). This example serves well to illustrate the pros and cons of this type of regulation. On the one hand, prohibitions and legal limits to the use of land might very well achieve important results in terms of preserving or even increasing the flow of ecosystem services. They are simple to design and comparatively easy to monitor, and hence have tended to be the preferred tool for policy-makers in the environmental arena. However, particularly in developing countries, monitoring efforts have been hampered by lack of financial and technical resources. Moreover, these sorts of restrictions tend to be costly to implement from the perspective of the forest owner. Not only is the owner obliged to follow certain restrictions in the use of his or her land, but he is also required to assume all the costs related to complying with the restrictions, including not only the additional costs (mitigation measures and infrastructure, for example), but also notably the forgone profits. In essence, the landowner is subsidizing the provision of environmental services for the benefit of the whole society.

In light of the shortcomings of direct regulation and declining government budgets, there has been in recent years an increasing interest in and use of what economists call market-based instruments (O'Connor 1999; Serôa da Motta et al. 1999). Instead of imposing restrictions on the decision making process, as in the case of direct regulation, market-based instruments hope to affect decisions by introducing new elements into the equation. Notably, the intention is to tilt the balance in favor of an optimal provision of environmental goods and services by affecting the relative profitability of the different options available to the agents. Producers and consumers are left free to make their own decisions, while taking into consideration the signals sent by the government regarding the value of different environmental resources. The most traditional market based instrument is a tax on emissions (Pigou 1932), by which firms are left free to pollute as much as they want, provided that they pay a tax on each unit of pollutant emission. In particular, one way to adjust to the regulation is to develop new, cleaner methods of production (Porras 2001; Pagiola et al. 2002).

A mechanism of payment for environmental services falls into the category of market-based instruments in the sense that it attempts to tilt the decision of the landowner towards practices that maintain or enhance the flow of environmental services, and away from unsustainable activities. As mentioned above, since all the costs of sustainable practices are borne by the landowner but only part of the benefits are captured privately – social benefits are basically public – land owners are justifiably adopting too few sustainable practices compared to the social optimum. As long as these social environmental services are provided for free, owners will not give them much attention when making land-use decisions (Nasi et al. 2002; Pagiola et al. 2002; Ortiz 2003).

Returning to the initial concept of externalities, the provision of environmental services will no longer be an uncompensated, positive side-effect of the landowner's decision to maintain forest cover on his or her land, but rather will be a conscious effort to increase profits. If the payment is correctly designed and implemented, one can expect an optimal provision of environmental services for society. Additionally, since the beneficiaries of environmental services will be required to pay to finance the provision of these services, they will also stop considering these resources as free, and will therefore hopefully make better use of the available resources.

A final issue remains to be discussed. In a previous paragraph we mentioned that markets without intervention will fail to achieve an optimal provision of environmental services due to the public nature of these services and the free riding problem. A payment for environmental services mechanism requires the creation of a market for environmental services in which providers and beneficiaries of those services interact in pursuit of their interest, but it can by no means be a non-intervened market. A third party, for example an NGO, the government, an international organization, or a water company, to name a few, needs to intervene to bring the beneficiaries to the table and make sure that they do not free ride. The exceptions to this statement are cases in which a Coasian solution (described above) is possible. In those cases, rather than establishing a market for environmental services, the parties get involved in direct negotiations in order to define the suitable payment for the services exchanged.

6.4 Designing Payment Schemes for Environmental Services

As mentioned above, an institutionalized market for environmental services is a powerful tool for achieving a better use of environmental resources and the services they provide. Such markets do not appear spontaneously; rather, they require the careful intervention of a regulatory body. This regulatory body might take different forms depending on the type or

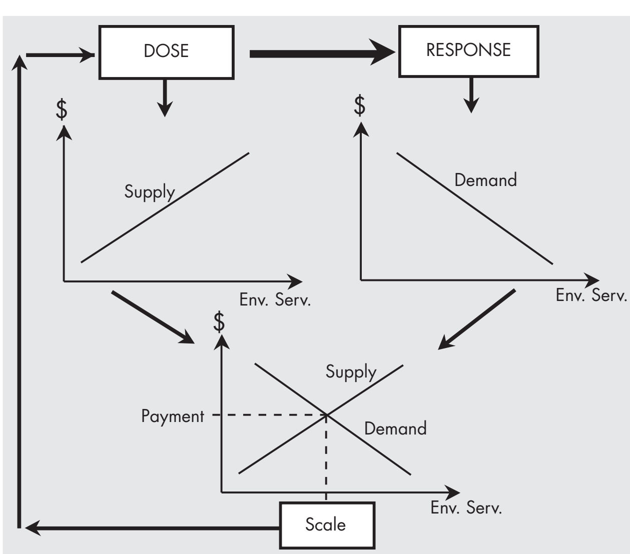

Figure 1. The required "dose" of activities that generate environmental services, i.e. the "response" and their corresponding costs (supply) are balanced against the amount of environmental services demanded to establish market equilibrium.

BOX 6.2 Selling Watershed Services in Pimampiro, Ecuador

Ina T. Porras

Water problems have been common in Pimampiro, a small municipality in the Andean region of Ecuador. Until 2001, domestic water users received the water service two days a week for only two hours per day; and the quality of the distributed water was lacking. In 2001 the Municipality, with support from FAO and the Inter-American Foundation, embarked on a series of projects oriented towards improving infrastructure and capacity of delivery.

The main water source for the town of Pimampiro is the River Palaurco, which is used for irrigation and for drinking water, and has its headwaters in the Páramos de Angocfavcha. Without proper hydrological studies to back it up, common perception in the area was that water flows could be ensured not only by improving infrastructure (a new treatment plant and tunnel were introduced in 2001, ensuring 24h service for the town), but also by protecting the forests and páramo located in the headwaters, as it was believed that forests ensure water flows, particularly during the dry season, and water quality by preventing erosion (personal communication, representatives of CEDERENA). A new system of Payments for Watershed Services was introduced in 2001; in which downstream water users pay upstream landowners to protect existing forests and páramos.

Description of the Scheme

The main water uses in the area are irrigation and household use. Nevertheless, the scheme only includes 1350 families residing in the Pimampiro City. The town consumes 12 l/s, and tariffs are USD 0.80 for 17 cubic meters (Luis Paspuel, September 2002, in Ecodecisión 2002) and USD 1.80 for industrial or commercial uses. While water is heavily subsidized by the Municipality, the majority of people in the city agreed that it is important to protect the watershed.

The "sellers" of the environmental service of watershed protection are organized under the Nueva América Association, that groups 24 individual property owners (although land was initially bought as an unit) comprising a total of 638 hectares, of which 62% is covered by forest, 26% by páramo, and 12% is dedicated to agriculture and livestock. The forest is located in the buffer zone of the Ecological Reserve Cayambe Coca, and approximately half of it is still primary forest. Even though access to the area is difficult, it faces strong deforestation pressure.

Property sizes range greatly, from 12 to 120 hectares with an average of 43. Most families are mestizos, with an average of six children. The main economic activities include agriculture and livestock, complemented with wood extraction, and harvesting crops in lowlands, that pays an average of USD 2–3 per day. Slopes are very steep, and slash and burn practices are a common denominator for agricultural activities.

The initiative springs from an ongoing community forestry management project organized by DFC. It is funded by FAO, the Inter-American Foundation (IAF) with USD 15 000 seed capital, and with the 20% fee increase on the water bills collected by the Municipality of Pimampiro. CEDERENA, an NGO that evolved from DFC and the Environment and Tourism Unit (UMAT) of the Municipality of Pimampiro acts as an intermediary (see Figure A).

Payments are between USD 0.5 and USD 1 per hectare depending on land use (see Table A). The final figures are not based on economic analysis of the value of the environmental service, but are the result of a political negotiation and the Municipality's capacity to pay. The 20% increase in water

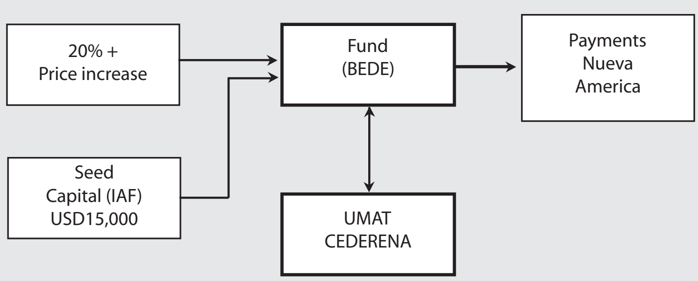

Figure A. Institutional arrangements in Pimampiro (Echavarría 2004)

types of environmental services regarded as relevant (e.g. case studies in Boxes 6.2 and 6.3 from Ecuador and Costa Rica).

Irrespective of the type of regulatory body involved in the creation of markets for environmental services, an integrated approach is required if these markets are to function properly. This section is an attempt to outline a standardized methodology for the creation of markets for environmental services. As such, it draws on many documented experiences in different countries (among others, Landell-Mills and Porras 2002; Pagiola et al. 2002; Rojas and Aylward 2003; FAO 2004) and some work in progress by the authors (CATIE-GEF 2002; CATIE-Focuencas 2004). Although we attempt to present a general approach, the proposed methodology is clearly more suitable for regional or local initiatives, rather than for establishing a national program for environmental services.

The proposed methodology has four basic components, namely: (i) a biophysical analysis of the provision of environmental services; (ii) identification and measurement of an effective demand for environmental services on behalf of the potential beneficiaries; (iii) measurement of the costs of providing environmental services; and (iv) construction of the appropriate institutional setting for the selected scale of intervention. It is important to note that the proposed methodology will utilize a cyclical approach in which the size of the required "dose" of activities that generate environmental services and their corresponding costs are balanced against the fees produces roughly USD 500/month, and this defines the maximum amount of money that can be paid. The total money available is then divided according to land uses within the area under Nueva América Association.

Table A. Payment Categories in Pimampiro (USD/month/ha)

Payment Categories	Payment
Páramo without human intervention	1.00
Intervened *Páramo*	0.50
Primary Forest	1.00
Intervened Primary Forest	0.50
Secondary Old Forest	0.75
Secondary Young Forest	0.50
Agriculture and Livestock	0
Degraded Land	0

Sustainability Impacts of the Pimampiro Project

Payments begun in January 2001 and so far approximately 20 families have benefited. While it is difficult to assess socio-economic impacts of the project, a recent survey by Ecodecisión and Ecociencia show the following:

¤ Median value of payments is USD 21.1 per month, which is slightly less than half the family's income. Most participants indicate that the payment is the main motivation to conserve the forest and paramos.
¤ While it is very difficult to completely verify it, most payments seem to be used to fulfill short-term family budget requirements. For example, payments were used mostly for education at the beginning of the school year.
¤ On the demand side, the majority of those interviewed are willing to pay for water provision and maintenance of forest cover.
¤ Despite the good impacts, the Municipality also faces problems related to its limited capacity to make the payments, which are made after a form of "blackmail" from landowners who are not receiving payments ("if you don't pay me, I will deforest"), despite the fact that deforestation is illegal in Ecuador.
¤ Transaction costs are rather high, and so far have been subsidized by the Municipality and CEDERENA, but the initiative is trying to become self-sufficient and cover costs of technical assistance and monitoring. The strategy is to try to include other water uses, such as irrigation, to expand the pool of demand and the capacity to pay.
¤ The environmental impacts of the initiative are very difficult to ascertain, as the project began with rather nebulous hydrological information and no measures were obtained before or during the current life of the project. At a more subjective level, existing forest and paramo are being conserved, and land practices are improving in the area.

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Echavarría, M., Vogel, J., Albán, M. and Meneses, F. 2004. The Impacts of Payments for Watershed services in Ecuador: Emerging Lessons from Pimampiro and Cuenca. Environmental Economics Program, IIED, London. 61 p.

Ecodecisión 2002. Evaluación de Impacto de los Servicios Ambientales en las Cuencas en Ecuador. IIED, London. 55 p

amount of environmental services demanded (desired response, Figure 1). The regulatory body should provide the necessary institutional arrangements for a "market equilibrium" to be established. This market equilibrium will in turn provide information about the amount of environmental services to be traded and the payment required to provide those services. The logic of the proposed methodology is summed up in Figure 1.

Biophysical Component

The cornerstone of a system of payment for environmental services is a dose-response function relating land use and management with the provision of environmental services. The importance of establishing a clear cause-effect relationship is twofold. On the one hand, the type of response, measured in types and quantity of environmental services is a fundamental piece of information in order to determine the beneficiaries of these services and how much are they willing to pay to enjoy their benefits. On the other hand, the activities involved in the "dose" will determine the minimum required payment (see Figure 1). The parallel with any other productive activity is obvious. The manager of a shoe factory needs to know what he or she will produce, boots or sneakers for example (i.e. the response), and what to do to produce it (the dose of technology, inputs, etc.). In that way, demand and cost functions can be established.

The fact that we are dealing with complex ecosystem functions constitutes the first point of departure from the simple example above. As mentioned in Section 6.2, ecosystems are inherently complicated, multi-product "factories", and our understanding of how each particular ecosystem works is very limited. In the ideal case, we would like to reach a level of understanding where we can accurately predict that if A, B, and C are done to manage an ecosystem, then the provision of a given environmental service will increase by 15%, for example. This is the level of precision required by any shoe factory manager, but we are unfortunately far from that point when it comes to understanding nature. Furthermore, given that ecosystems are highly dynamic, changing systems characterized by discrete changes from one status to another, and a high exposure to unexpected random events, it is very likely that we will never have the amount of information and analytical capacity to establish such a clear dose-response relationship (Limburg et al. 2002).

Consequently, any effort to establish a scheme of payments for environmental services must accept this uncertainty and go beyond available scientific information, and has to make the necessary provisions in those cases where uncertainties are large. At the very least, we need to make sure that the predicted dose-response reaction is in the correct direction, and we need to inform the potential beneficiaries about the risks and time frame involved in their payment. For example, if we intend to increase the availability of water in a reservoir, at the very least we must make sure that our proposed "dose" does not act against our stated purpose, and we must avoid making promises that are not backed by scientific evidence.

The second point of departure with the shoe factory example above has to do with the importance of the provided good. The risks involved in failing to provide crucial environmental services like biodiversity protection, regulation of climate or provision of drinking water, to name just a few, can be very great. Hence, one should aim at erring on the side of caution and encourage the implementation of practices that, given our imperfect knowledge and experience, will most likely contribute to increasing the provision of crucial environmental services even if the dose-response function is not clearly established. This precautionary approach, although perfectly justified on the side of the beneficiaries, should not serve the wrong purpose of reducing efforts spent in obtaining the information needed to improve our understanding of the cause-effect relationships in ecosystem management.

Obviously, diverse environmental services require the establishment of their corresponding dose-response functions, and the complexities involved might be very different from one case to another. In some cases, the same dose can increase the provision of several environmental services. A few examples are provided below.

One of the potentially simpler cases is the global service of carbon sequestration. Natural ecosystems contribute to carbon sequestration either by active absorption in new vegetation or by avoiding emissions from existing vegetation. The "doses" in this case are thus simple: to increase the vegetation cover with species capable of sequestering carbon at high rates, and to avoid deforestation and land use changes that result in increased carbon emissions. Although not a simple task, one could measure the carbon content in plant biomass and associated soils, thereby creating a relation between the dose and the response. Furthermore, since carbon dioxide is a perfectly mixed pollutant, we do not need to be concerned about the location of the carbon offsets (Bishop and Landell-Mills 2002).

The case of biodiversity is more complicated. Not only is there not enough information relating vegetative cover and biodiversity, but also the protection of biodiversity is a highly site-specific service and depends on the location of the plot within the landscape. Two equally-sized plots with the same vegetation might have dramatically different relevance with respect to biodiversity, depending on their location and the composition of the landscape surrounding them. Another layer of complexity is added by the difficulties in actually defining the appropriate unit of measurement for improvements in biodiversity, forcing decision-makers to use approximate, often too simplistic measures (a simple counting of the numbers of butterfly species, for example). Despite the above, there is clear evidence that agricultural landscapes that retain a high and diverse tree cover and that maintain landscape connectivity are more likely to sustain higher levels of biodiversity than those landscapes that have very dispersed and fragmented tree cover (Harvey et al. 2004). Linking this to a suitable prioritization of protection of areas based on, for example, connectivity and proximity to biodiversity-rich or highly threatened areas can justify making a payment to land owners in those areas, assuming an acceptable value of biodiversity can be established.

Finally, our last example is the provision of hydrological services. In the following sections we refer to hydrological services as if it were a single service instead of treating each of the hydrology related services separately. Note that, besides being site specific, these hydrological services might require different treatment depending on the target service. Although this service is certainly of the utmost importance, several unfounded myths prevail, particularly regarding the relation between forest cover and watershed protection (see also Kaimowitz 2001). Most scientific studies attempting to establish this relation have shown that it is highly site specific (soil, vegetation mix, alternative cover, and climate, among several others). Still, most documented cases of PES have followed what is perceived as common knowledge without attempting to gather more solid evidence regarding the true relationship between forest cover and water quality and availability. In an interesting exception to the previous claim, Aylward and Echeverría (2001) and Aylward et al. (1998) show that for an important multipurpose watershed in Costa Rica (Arenal watershed), conversion from pastures to forest might not only be economically unjustified due to losses in livestock income, but would also cause negative effects for the large hydropower plant. The benefits from reduced erosion and sedimentation are very small compared to the costs of reduced water due to increased infiltration and evapotranspiration. Although this might be a particular case, it still serves well to illustrate the importance of gathering appropriate site and purpose specific information for the watershed in which we plan to intervene, in order to define a truly effective approach to the provision of one or several of the hydrological services desired

(Kaimowitz 2001).

A somehow different picture arises from studies relating sustainable agricultural practices and hydrological environmental services (CATIE-GEF 2002; PASOLAC 2004). The correct use of agrochemicals and the adoption of farming technologies with a more permanent soil cover are two simple practices that can have an important effect on chemical runoff and erosion rates from agriculture, particularly for small catchment areas. Note that although the "dose" and the direction of the response are clearer for the case of sustainable agriculture, this does not imply that the exact quantity of environmental services is known. Furthermore, for large watersheds (larger than 1000 km^2) there is scientific agreement regarding the dominance of climate related factors (for example, amount of rain, frequency and variability of large events) over land use factors in determining water availability, erosion rates and water recharge (Tognetti 2000). This may be different over very large land masses (e.g. the Amazon basin), where forests are an important link in the water cycle, and their disappearance may be more important because of their influence on the climate in neighboring regions than because of any direct effects on local water courses.

In summary, although the available information is not enough to establish a clear dose-response function for most, if not all environmental services generated in complex ecosystems, every attempt has to be made to gather as much site specific scientific information as possible through research and monitoring, in order to increase the likelihood of delivering the services promised to those beneficiaries paying for them. Some qualitative information is provided on the effect of different land uses on the forest eco-system services in Annex 1. The more solid the information underpinning the scheme, the more likely the scheme will survive. Moreover, the regulatory agency has to carefully acknowledge the existing limitations underlying the PES scheme in order to avoid disenchantment of the participants (Rojas and Aylward 2003).

Given that we find enough justification to launch a system of PES, a related question has to do with the unit of measurement of those services. As mentioned above, many environmental services are notably difficult to measure in the first place, let alone predicting marginal increases in the provision of these services due to management intervention. This is certainly not a new issue for environmental policy-making. For example, if emissions of a pollutant are not observable, one of the standard solutions is to move backwards along the production process until we find a variable that is related to those emissions yet easy to monitor by the regulator (a particular input, for example).

A similar approach should be used in the case of environmental services. Our proposed solution to this problem is to use a system of indexes that should serve as proxies for the dose-response functions identified for each environmental service, and if several services are involved, one could construct a composite index (CATIE-GEF 2002). This index will use all the available scientific information to relate particular activities in a farm to a standardized scale, so that those activities that are expected to make a large contribution to the conservation of biodiversity will be rated higher on the biodiversity index than activities expected to contribute less. A similar approach will be used for other services. Once a baseline is established, payments could then be related to the index.

Demand Component

The second component of our proposed methodology is the identification and measurement of an effective demand for environmental services on behalf of the potential beneficiaries. After establishing an appropriate dose-response function, the existence of a measurable demand for the services to be provided is the second most important key to the success and to the sustainability of a PES scheme. Only after funds have been secured can we start to think about determining the scale, i.e. spatial (prioritization of areas) and temporal dimension, of our intervention so that the available funds are enough to pay the providers.

Two interlinked tasks need to be completed in order to establish the existence of a demand for one or several of the services provided by a managed ecosystem. Firstly, we need to establish the potential beneficiaries from a program to increase or sustain the provision of environmental services, and secondly we need to be able to measure how much they value those services. For both tasks, the approach used will inevitably be anthropocentric (Farber et al. 2002), since ultimately our intention is to gather funds to finance a given program. For example, the sustainable management of forest and agriculture in a watershed providing drinking water to a populous city will have a much larger economic value than a similar effort in an isolated watershed. For the first case, we could think of establishing an ambitious, large scale, PES scheme (e.g. Catskills watershed for New York City; Daily 1999), whereas for the isolated watershed other tools will have to be devised. Poverty of the potential beneficiaries of environmental services might lead to very low willingness to pay estimates, forcing us to reduce the spatial and temporal scale of the scheme and ultimately to look for other alternatives to a PES scheme. This pragmatic approach to economic valuation is justified by the fact that we are using valuation tools only as inputs into the design of a very particular policy instrument, a PES scheme, and are therefore not interested in obtaining total values or intrinsic values. Notably our estimates will always be below the true value of the resource in question. Although simple to digest for the case of hydrological services, this anthropocentric approach is harder to accept, for example, in the case of biodiversity. We may find ourselves claiming that a PES scheme cannot be based on the protection of biodiversity, no matter how much biodiversity is protected, simply because this service has little or no economic value. We are not thereby affirming that biodiversity has no value in general, we are simply saying that funds for a particular case cannot be raised based on the selling of services related to biodiversity protection.

A closer look at the motivations for demanding environmental services will show that such an anthropocentric approach might not be as restrictive as it seems at first glance. Obviously, the beneficiaries from different environmental services will most likely be different. The first obvious distinction is their location. Some ecosystems provide global environmental services whereas others are more regional or local in nature. Carbon sequestration and hydrological services are prime examples of the former; if we plan to sell carbon sequestration we need to look at the international community as potential beneficiaries, and particularly to Annex 1 countries under the Kyoto Protocol. Hydrological services, on the other hand, are site-specific and user-specific. If we plan to sell hydrological services in a watershed, we need to look on-site for the beneficiaries, and those beneficiaries might be different depending on the service provided. For example, a hydropower plant might be interested in quantity of water and reduced sedimentation, whereas consumers of drinking water might be interested in quality rather than quantity. For other environmental services, we might find that beneficiaries are both local and global, as is the case in biodiversity protection. A recent study showed that rainforest bees pollinating coffee account for a 7% increase in a coffee farm's income (Taylor et al. 2004). In addition, international NGOs acting as representatives of the global community of beneficiaries are able to raise large sums for the protection of biodiversity. These last beneficiaries might be willing to contribute to the protection of biodiversity for its intrinsic value alone.

Information plays an important role in determining who the beneficiaries are and how much they are willing to pay. In some cases, those affected by reductions in environmental services lack the necessary knowledge to realize that a beneficial change is possible provided they are willing to contribute to finance it. In such circumstances the regulator has to make an effort to inform the potential beneficiaries of the possible solutions and their costs, and of the potential risks of inaction. In addition, other potential benefits can be explained, for example a water consumer might be supportive of the idea that investing in forest protection and sustainable agriculture will not only provide hydrological benefits but also other environmental, social and aesthetic benefits. As mentioned above, ecosystems are complex and the provision of environmental services might be severely affected by irreversible changes in their functions after a given critical threshold of degradation or stress is surpassed. The economic value of a program to sustainably manage an ecosystem might change dramatically when we approach these critical thresholds (Farber et al. 2002; Limburg et al. 2002). On the other side, lack of information certainly can play a role, particularly in those cases where risks can be reduced through the implementation of a program to increase the provision of environmental services. In Costa Rica, several hydropower plants are investing heavily in watershed protection using a PES scheme, mostly following a precautionary principle given the lack of solid data. The risk of losing their large investment needs to be reduced by any reasonable means (Alpízar and Otárola 2003; Ortiz 2003).

Once the beneficiaries of the different environmental services are clearly identified, the next step is to measure their actual willingness to contribute to the provision of those environmental services. The use of economic valuation tools can provide the information necessary to determine the funds available for alternative programs or scales of a given program, and the maximum willingness to pay for different amounts of a given environmental service (Tognetti 2000; Alpízar and Otárola 2003; FAO 2004). This measurement in itself constitutes an estimation of the benefits achieved with a given program, and should therefore be considered the upper limit for any potential payment scheme. Still, as mentioned above, in most reasonable cases it constitutes a lower boundary for the true social value of the services provided.

Several methodologies are available to the regulatory agency in pursuit of demand information; the selection of the most suitable method should be guided by the information already obtainable, the type of environmental service at hand and the funds available to do research. The following table contains a list of the most frequently used methods and the context in which their use is recommended.

Irrespective of the method selected to estimate the demand for a given environmental service, particular attention has to be spent on making sure that the object of our effort is the marginal or the discrete change specifically associated with the planned intervention. A common mistake is, for example, to value all hydrological services obtained from a given watershed, instead of the planned improvement from a well-defined baseline.

Supply Component

The third component of the proposed methodology is the measurement of the costs of providing environmental services. Simply put, we need to determine the cost of the "dose" (see Figure 1). This information would then be referenced to demand information in order to determine how ambitious our intervention using a PES scheme should be. Once again, this component needs to start with the identification of

Table 1. The methods used in the valuation of environmental services

Type of methodology	Recommended use
Contingent Valuation Method – CVM (Mitchel and Carson 1989; Whittington 2002)	This is a survey based method in which the respondent faces a hypothetical situation describing a good or service and the particular setting in which that good or service is to be provided. The respondent is asked to state his willingness to pay (WTP). This method is widely used because it can deal with a broad range of situations, including those where no prior experience or information is available
Choice Experiments (Alpizar et al. 2003)	Although similar to the CVM, in this case respondents have to choose their preferred combination of attributes of a given program, including their WTP. This method is particularly useful to design an optimal project or intervention
Replacement or avoided costs method (Freeman 1993)	A decrease in the natural provision of environmental services might require the investment in new technology or additional inputs to compensate for the loss. The sum of all those expenditures is an approximation to the value of reinstalling the natural provision of environmental services. This method needs prior information.
Changes in productivity (Freeman 1993)	A decrease in the provision of environmental services might inevitably have an impact on the production capacity of an economic agent, thereby reducing profits. The reduction in profits is a measure of the damage caused by deteriorated environmental conditions or of the benefits to be attained if environmental conditions are improved. Again, this method requires prior information.

the actual and potential providers of environmental services. Secondly, we need to determine the costs associated with each management practice encouraged to increase the provision of those services. As mentioned in Section 6.3, the whole idea of a PES scheme is to alter the private land use decision of a producer in favor of sustainable practices. Hence, beyond identifying those practices (i.e. the dose-response function) we need to know how much the costs will be and how much to pay in order to achieve the desired switch away from unsustainable practices. Note that in some cases the lack of funds might not be the critical factor hindering adoption; in-kind payments, for example technical assistance, might go a long way in promoting sustainable practices.

Obviously the providers of environmental services will most likely change depending on the type of service we intend to obtain. As discussed above, the provision of hydrological services is site- and user-specific, and therefore requires an extremely careful selection and prioritization of areas in which to intervene. Farmers in priority areas should be characterized according to type and profitability of his or her productive activity, type of property rights (private, communal, insecure), family size, and land availability, among other sorts of information required to understand the decisions and motivations of the land owner, i.e. their livelihood strategies. Other site-specific environmental services like biodiversity and reduction of vulnerability to climatic events also require such information, the critical factor being the lack of substitution possibilities. Since the contribution of each farmer located in the priority areas is fundamental for the provision of the site-specific services, every effort has to be made to understand their decision-making process.

In all cases, though, we need to make sure that the proposed land use and management practices to be implemented in order to increase the provision of environmental services are clearly defined and understood by all participants involved. These practices should be realistic and suitable for the farms involved. Nobody can expect that farmers will adopt a technological package that makes no sense to them, or that is unacceptable given the particular circumstances of their farms. In this sense, a PES scheme might very well be complemented by technical assistance programs.

Once we identify the potential providers of a given environmental service, the next step is to estimate the actual supply curve for it. This requires the ability to measure in monetary terms the costs of marginally increasing "doses" that will in turn generate marginal increases in the supply of environmental services.

In order to quantify the costs associated with the provision of environmental services, the regulatory agency has to identify the impact that the required management practices have on the profitability of the farms. In most cases, a combination of economic valuation methods is needed in order to fully measure all the costs involved. The provision of environmental services might require changes in the technology of production and a combination of inputs that can ultimately result in changes in productivity. These changes, valued using market prices for inputs and final outputs, can give us a measure of the costs involved in supplying environmental services. For the analysis to be complete, we would need to add all additional investments necessary to provide environmental services and/or related to the new required technology. A different approach is needed if the pro-

BOX 6.3 Payment for Environmental Services in Costa Rica

Bastiaan Louman and Ina T. Porras

In Costa Rica, timber production takes place in small private forests and plantations (both forest management and plantation establishment and management have received fiscal incentives since the 70s, mainly in the form of allowing property and rent tax deductions (Rodriquez 2002). In 1990 forest legislation was modified, adding a forest credit certificate (Certificado de Abono Forestal o CAF) to promote reforestation and again in 1992 for the management of natural forests (CAFMA) (Solis Corrales 2001). A credit certificate, the value of which relates to the value of the final timber stand (CAF por adelantado), was added to promote reforestation in small and medium sized properties of rural organizations (Rodriquez 2002), and in 1996 a fourth certificate was established to promote forest conservation (CCB, Costa Rica, Presidencia de la República 1996). All of these certificates are titles with a nominal value that can be sold or can be used to pay taxes or other national tributes.

With the new forest legislation of 1996 the approach towards promotion of plantations, forest management and forest conservation changed. Although certificates are still issued, from 1997 onward a system of payments for environmental services (PES) was introduced, through which owners can also be paid in cash for the maintenance of biodiversity, protection of water resources, storage and sequestration of carbon, and maintenance or enhancement of scenic beauty. The amounts paid for the four services combined are related to the opportunity cost of land in remote rural areas, using the value of cattle production on marginal lands in 1996 as a reference value. The amounts paid during 2001 and 2004 are illustrated in the following table.

While funding for the old incentive system came almost completely from the government's own resources, the new system allowed for innovative financing mechanisms. A first important step was the creation of a capable institutional framework created to deal with markets for environmental services (see Figure A). The framework is under constant evolution and change. Succinctly, the Ministry of Environment, through the National Forestry Fund (FONAFIFO), is charged with channeling government payments to private forest and protected area owners. Payments vary according to the activity undertaken: reforestation, sustainable management of forest and forest preservation (see Table A). Payments are made over a five-year period. In return, landholders cede their environmental service rights to FONAFIFO for this period. When the contracts expire, landowners are free to renegotiate prices, or sell the rights to other parties. They are, however, committed to managing or protecting their forest for the length of the contract. Their obligation is recorded in the public land register and applies to future purchasers of the land.

Having purchased rights to clearly identified environmental services, FONAFIFO can then sell them to buyers at local, national and international levels. Local level buyers to date include hydroelectricity companies (e.g. the Costa Rica National Power and Light Company, La Manguera, Energía Global) who are interested in watershed services, and tourism agencies (e.g. Hotel Melia, rafting companies) interested in landscape beauty. At the international level, FONAFIFO has developed a system to transfer carbon sequestration rights as Certified Tradable Offsets, or Certified Emission Reductions, to buyers via the Costa Rican Office for Joint Implementation (OCIC). The Office for Joint Implementation negotiates with international investors and donors. Certified credits could be purchased attached to a particular project, or as a standardized credit which is drawn from a pool of investments. In addition to income from sales of particular environmental service rights, FONAFIFO receives regular income from a share of fuel tax revenues.

In 2002 the PES in the forest management context was replaced by one for payment for tree planting within agroforestry systems, as a result of the argument that forest management

Table A. PES (in USD) paid per hectare in 2001 and 2004

	2001 (Campos et al. 2001)			2004 (FONAFIFO 2004)		
	Protection	Plantations	Management	Protection	Plantations**	Agroforestry
Total	221	565	344	223	570	0.82/tree
Year 1	44.20	282.50	172	44.60	285	0.533
Year 2	44.20	113	68.80	44.60	114	0.164
Year 3	44.20	84.75	34.40	44.60	85.50	0.123
Year 4	44.20	56.50	34.40	44.60	57	
Year 5	44.20	28.25	34.40	44.60	28.50	
Period of commitment*	5	15	10	5	15	

* Minimum period over which the owner has to commit himself to maintain the forest or plantation in order to receive PES.

** In addition 222 USD/ha is available for plantations that have been established with personal funds, to be paid in five annual installments of 44.40 USD/ha.

vision of environmental services requires changes in the current land use in favor of more environmentally friendly practices – including areas set aside for biodiversity protection, for example. In such cases, we should use the opportunity costs as a measure of the forgone benefits of changing the use of land. Once again, initial investment costs should be added to the final cost of providing environmental services.

A final issue remains to be discussed, namely the relation between the costs of providing environmental services and the proposed index relating a dose – a combination of practices that increases the provision of those services – to a particular response. Since payments will be related to the provision of environmental services inasmuch as that "response" is reflected in the index, one could obviously expect that a farmer will adopt a given technology only if that will result in an increase of the index large enough to raise enough funds to at least cover the costs of adoption. Each point of the index will then

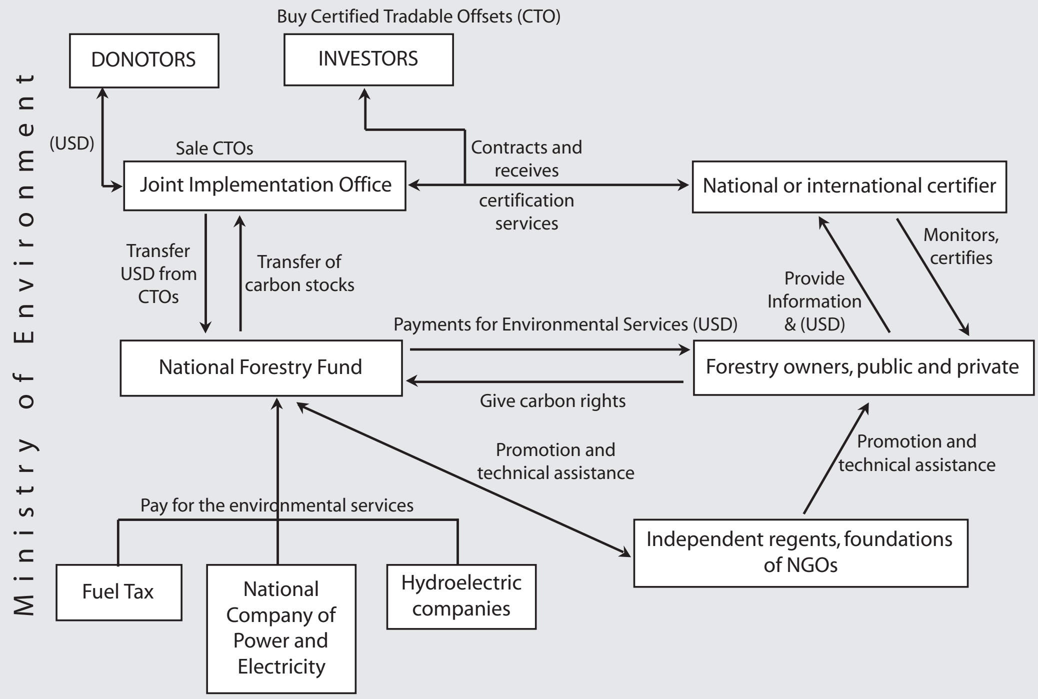

Figure A. Institutional framework of the PES in Costa Rica (Landell-Mills and Porras 2002)

contributes little to the generation of environmental services, and tree harvesting should generate sufficient income to pay for impact mitigating measures oriented at maintaining the forests' environmental services. Until the end of 2003 more than 370 000 ha were submitted to the PES system, 87% of which were protected forest, 7% were under forest management and 6% were plantations (FONAFIFO 2004); this amounts to between 18 and 26% of the total forest area of Costa Rica, or 7.3% of the national territory.

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also be related to the average costs of adopting the necessary practices for increasing the provision of environmental services. These costs will then be the lower bound for establishing the equilibrium payment for a given environmental service.

Institutional Component

The last component of our proposed methodology is the construction of the appropriate institutional setting for the selected scale of intervention. The demand and supply information gathered should now be combined in order to establish an intervened "market equilibrium" (see Figure 1). The regulatory agency interested in using the PES scheme will need to determine both the scale and scheme and the payment required, before establishing this equilibrium. The potentially available funds (demand side) and the costs of providing additional environmental services will ultimately determine how many of those services will be provided. For example, in the case of carbon sequestration the regulatory agency should determine the number of hectares to reforest. In the case of hydrological services, the regulatory agency needs to start from top priority areas and move downwards until the available funds are exhausted. Notably the funds available are obviously related to the quantity of hydrological services demanded and ultimately enjoyed by the beneficiaries, so a stepwise convergent approach is required to reach the equilibrium.

Related to the above is the issue of defining the amount to pay to those adopting sustainable forestry or agricultural practices. In previous paragraphs, we have hinted that this payment is somewhere between the maximum willingness to pay of the beneficiaries for a program of a given scale, and the minimum payment required by the providers of such a program. The decision to set the payment closer to one or the other boundary is basically non-technical. The lower the payment the larger the potential scale of the program, but the smaller the incentives to adopt the desired management practices. In addition, the available funds collected from the beneficiaries will be larger than the funds ultimately paid to the providers, where the difference should cover administrative and operative costs.

The construction of the most suitable payment scheme requires a careful analysis of the local conditions, the legal framework and the potential incentives that such a payment will create. Notably, we need to avoid the creation of perverse incentives. For example, by paying for environmental services in just one part of the farm – say that part that is a top priority for erosion reduction – we might be causing a reshuffling of land uses within the farm, with the farmer converting natural forest cover towards pasture land in some parts of the farm and establishing reforestation plots in those areas where he or she is receiving a payment. Such a situation might force us to include the whole farm into the PES scheme. Most authors agree that payments should include the baseline provision of services – in order to avoid the farmer's cutting the forest in expectation of higher payments – and should be permanent or ongoing as long as the service continues to be provided (Pagiola 2001; Nasi et al. 2002; FAO 2004). Finally, although a PES scheme is not a tool specifically aimed at reducing poverty, we should make an effort to guarantee that such schemes do not exacerbate poverty and/or introduce further social and economic inequities (FAO 2004).

The institutional background required to make such a PES system operational will ultimately be defined by the scale, i.e. the spatial and temporal dimensions of the proposed intervention, and the type of environmental service. Although for carbon sequestration a nationwide initiative might make sense, a more logical approach to hydrological services is to foster local initiatives. Transaction costs are likely to increase with the size of the organization, particularly with respect to operating costs (salaries, monitoring costs, legal costs related to PES contracts, etc.). On the other hand, the costs of establishing an organization (e.g. legal costs) might be fixed irrespective of its size. In any case, these elements might change from one situation to another and a case specific analysis is required in order to determine the most appropriate type of institution. In addition, other things need to be considered such as the level of organization existing in the target area; if farmers are highly organized, for example, a PES scheme might require a smaller institutional capacity (Pagiola et al. 2002).

In its simplest form, the institutional and legal background needed to implement a PES system should consider coordination, the transfer of funding between beneficiaries and providers, the operational aspects of the system and its control and monitoring, which should enable the institution to react to new information and unforeseen changes in the demand or supply of the services. It is important to stress that the institutional framework does not necessarily require the creation of parallel organizations or additional legal normative, as was done in Costa Rica (see Box 6.3). The institutional framework can easily be constructed within a municipality or as a subunit of a water or electricity company. Moreover, establishment and operational costs might be lower if the PES scheme can use an already functional organization. This is particularly true for financial issues. If the organization has well-recognized accounting and auditing practices and is respected by the beneficiaries and providers of environmental services, much can be gained from attaching the PES scheme to it.

6.5 Restrictions to the Proposed PES Approach

Though we have supported the use of market-based instruments such as PES as effective mechanisms for promoting sustainable forest management and hence sustaining the provision of ecosystem services, we acknowledge that in some situations difficulties might arise that would limit the design and/or implementation of such mechanisms. In many of these cases, other solutions might be more efficient, but they are beyond the scope of this chapter.

Restrictions might include the failure to demonstrate that services are actually being provided, the lack of an effective demand for the services, limitations from the demand and/or the supply side, as well as other limitations regarding institutional capacity and scale. The FAO (2004) research that assessed different payment schemes for hydrological services, found several difficulties in the schemes, such as: doubtful cost-effectiveness of the methods, i.e. some programs were not based on studies on demand and supply using economic valuation but were rather politically imposed; schemes were based on "conventional wisdom" and not on sound scientific knowledge on the relationship between land use and hydrological services; unclear definition of the hydrological services and of the service providers and beneficiaries; lacking or ineffective monitoring and control; high dependence on external funding; and finally, concerns regarding possible development of perverse incentives to land users. Some of these restrictions could be overcome by sound design of the schemes as proposed in Section 6.4.

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Forests provide a wide range of goods and services, which can be classified into regulating, habitat, production and information services (see Annex 1).

As was mentioned in Section 6.4, a very critical limitation for developing markets for FES is the difficulty in clearly showing that the FES are being provided and to what degree, particularly in establishing a clear relationship between land use practices and the resulting provision of FES. This is probably more evident for hydrological services. Some helpful generalizations can be drawn (Bruijnzeel and Vertessy 2004). According to Pagiola et al. (2002), the main weakness of most markets for watershed protection (and indeed of most other forms of watershed management) is the lack of good information on the relationship between land use and water services. None of the cases reviewed by these authors devoted much attention to clarifying these relationships, and they concluded that markets for watershed protection generally do not involve directly trading water quantity or quality; rather, they usually involve "selling" land uses that are thought to generate the desired water services. A proposal to overcome this restriction was discussed in the previous section, by using indices as surrogates for such relationships.

For a scheme of PES to succeed, it is also necessary that property rights over service commodities are clearly defined and well established. This is a condition that is not always found in many developing countries. In those situations the designers of the payment schemes will have to develop innovative ways to ensure that payments are received by those actors who generate the services or make the decisions that affect the level and quality of the services provided.

Probably the most critical limitation to market-based mechanisms for forest ecosystem services is the lack of an effective demand for those services. The value of FES depends not only on their nature and magnitude (e.g. biodiversity in the Amazon), but also on the uses to which they are put, as well as the magnitude and preferences of the people using them. Initiatives that pay insufficient attention to demand tend to run into problems (Pagiola et al. 2002). For example, the nationwide payment scheme implemented in Costa Rica since 1997 was based on overly optimistic expectations of the development of carbon markets through the Clean Development Mechanism (Campos et al. 2000).Ecosystem services that benefit society at the global level (i.e. carbon and biodiversity) might require complex negotiations, and implementation may require high transaction costs which could exclude small scale initiatives from taking advantage of these opportunities.

Similarly, limitations may arise if the beneficiaries of FES are unable to actually pay for these services, such as could very often be the case for the use of potable water by poor communities, or if there is not sufficient information available to the actors that benefit from the service, resulting in lack of awareness or biased priorities. In contexts where there is a highly unequal distribution of power or income, for instance, market instruments usually are not capable of solving social conflicts, and may at times exacerbate them. On the other hand, in many social groups water is considered as a right rather than as a market good. In these cases, it is not appropriate to "internalize" the environmental externalities influencing water supply through a market price, since other mechanisms can be more effective and enjoy greater public support, such as community management and territorial planning (FAO 2004).

On the other hand, different difficulties could be experienced if the suppliers' ability to offer the quality and quantity of the services required is limited; for example in the case of high-yield agricultural crops or when other competing land uses, such as urbanization, exist, the opportunity costs could be too high for implementing a feasible PES scheme.

Finally, certain conditions related to the institutional capacity required to effectively implement PES schemes should exist or be created. These institutional conditions are required to resolve property rights problems, to develop appropriate monitoring and enforcement mechanisms, and to support the whole network of regulatory and institutional arrangements that might be necessary for markets to function effectively. Establishing and sustaining this infrastructure is not easy and is rarely cheap; this might require significant time and financial resources, and investments in staff recruitment, sound information from scientific and policy research, proposal development and consultations and participatory processes with key stakeholders, as well as conflict resolution mechanisms.

6.6 Conclusions

In this chapter we have discussed the use of PES schemes as a suitable market-based instrument to achieve sustainable use and management of ecosystems regarded as important, due to their contribution to human welfare in its many expressions. PES schemes are inevitably a long-term alternative in support of the general objective of sustainable development, and paradoxically our main concern lies in the sustainability of the proposed solution itself. Pagiola et al. (2002) stress that the sustainability of this mechanism is even harder to assess than its effectiveness and suggest three dimensions that are critical: a continued demand for the environmental services being sold; a continued ability to supply these services; and the sustainability of the institutional structure created to make the mechanism work. To this we would add the need to constantly improve the "dose-response" function underlying any PES scheme so as to ensure that additional services are provided.

In summary, the paradigm of PES is certainly a promising mechanism for advancing towards the sustainable management of forest and other natural resources. However, its effectiveness requires from designers the careful assessment of the particular social, economic and institutional conditions where these mechanisms will be applied and the willingness to make use of the best scientific information.

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Annex 1. Classification of forest ecosystem goods and services (adapted from de Groot et al. 2002) **and the direction of possible impacts by different land use types in relation to undisturbed forests (from +++, very positive, to – – –, very negative)** (based on Brown and Lugo 1990, Parrotta and Turnbull 1997, Rice et al. 2001, Parrotta et al. 2002 and a revision of RIL studies by Louman 2005).

Goods or services provided	Role of forest ecosystems	Expected impacts of different land uses in relation to undisturbed forests: Forest conversion	New forests	Harvesting of timber and other products *
REGULATING SERVICES				
Maintenance of favorable climate	Reflection of solar radiation and gas regulation	– – –	+ –	+ –
Maintenance of (good) air quality	Gas regulation (absorption, storage, release, for example CO2)	– – –	+ –	+ –
Prevention of diseases	Biological control of vectors	– – –	–	+ –
Flood prevention and mitigation, avalanche prevention, natural irrigation	Regulation of run-off and river discharge; mitigation of coastal impacts of tropical storms and tsunamis (mangrove forests)	– – –	+ –	+ –
Maintenance or improvement of water quality for consumptive use	Filtering and retention of freshwater	– – –	–	+ –
Maintenance or restoration of natural productivity of soils	Retention and formation of soils, nutrient regulation, and improved soil fertility and structure	– – –	–	+ –
Waste control and disposal, buffering and filtering pollutants	Filtering and breakdown of xenic nutrients, compounds and pollutants	– – –	+ –	+ –
Pollination of useful plants	Provide habitat for biota	– – –	– –	–
HABITAT SERVICES				
Provide habitat for (potentially) useful plants and animals	Structure, composition and diversity of forests	– – –	– –	–
PRODUCTION SERVICES				
Production of food, wood and non-wood goods	Conversion of solar energy into edible and other useful plants and animals	+ + +	+ +	+
Genetic material for crop improvement, health care, etc.	Genetic material and evolution in wild plants and animals	– –	–	+ –
Pollination	Provide habitat for pollination agents	– –	–	+ –
INFORMATION SERVICES				
Scenic beauty for ecotourism and recreation	Variety of habitats for a variety of plants and animals	– –	–	–
Inspiration for arts and other cultural and spiritual activities	Existence of specific features	– –	–	+ –
Information for science and education	Existence of habitats	– – –	–	+ –

* Assuming application of RIL techniques and planning of non-timber forest products harvests