Tyndall°Centre
for Climate Change Research

Marketing ecosystem services through protected areas and rural communities in Meso-America: □

Implications for economic efficiency, equity and political legitimacy

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October 2006

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This paper was submitted to *Global Environmental Change –Human and Policy Dimensions-* in April 2006 and it is currently under review for re-submission

Summary

Ecosystem services regulate and support natural and human systems through processes such as the cleansing, recycling, and renewal of biological resources, and they are crucial for the long-term viability of human development in economic, social, cultural and ecological terms. Some of these services encompass, for example, carbon dioxide fixation, watershed regulation, and erosion control. During the last decade, we have seen an increase in the number of projects trading ecosystem services. These projects rest on the premise that they will contribute to environmental sustainability and rural development. In this paper we investigate the economic and social implications of four projects commercialising watershed recharge and carbon sequestration by native forests in Meso-America. Selling ecosystem services in protected areas becomes more economically efficient due to negligible opportunity costs but it also results in less equitable outcomes, as rural communities and forest resource users become excluded from participating in decision-making and accessing development benefits. When ecosystem services are commercialised by rural farmers, payments neither cover opportunity costs nor meet local income expectations. However, farmers benefit from complementary project activities, such as forest management training and agricultural extension support. We argue that limited economic impact and inequitable outcomes can be explained by problems of institutional design and projects' inability to account for context-related factors, particularly property rights.

1. Introduction

Ecosystem services regulate and support natural and human systems through processes such as the cleansing, recycling, and renewal of biological resources, and they are crucial for the sustainability of human development in economic, social, cultural and ecological terms (Daily*, et al.*, 1997). However, as the world's population and the global economy grow in the future, the demand for these services and the likelihood of negative impacts are likely to increase (Millennium Ecosystem Assessment, 2005). For this reason, markets for ecosystem services and Payments for Ecosystem Services (PES) are increasingly advocated by global environmental and research institutions as a means to secure the provision of these services and solve problems ranging from biodiversity and habitat loss to desertification and climate change (Adger*, et al.*, 2005).

Advocacy of markets for ecosystem services and PES is embedded in a logic of market environmentalism which has become prominent since the late 1980s (Smith, 1995). As the benefits provided by ecosystem services are neither priced nor marketed, resource users do not take into account the degradation of these services in their resource management decisions. Market environmentalism thus promotes the assignation of property rights and pricing of nature's services, which can then be traded within a market that will assign high prices to scarce services and encourage the sustainable management of renewable resources (Liverman, 2004). In practice, markets for ecosystem services and PES consist of transferring economic resources from consumers to providers of ecosystem services so that the former benefit economically while the latter receive the *right* to use the resources provided by the service in question. It is also argued that markets for ecosystem services and PES can improve livelihoods and well-being, promote local sustainable forest management and strengthen community-based institutions (Smith and Scherr, 2002), as well as enhance ecosystem health (Matthews*, et al.*, 2002) and secure

new sources of funding for biodiversity conservation (Walsh, 1999). In essence, they aim to fulfil a dual mandate of environmental sustainability and social development.

Such expectations have translated into the establishment of numerous initiatives throughout industrialised and developing countries. These cover a wide range of ecosystem services, predominantly in the fields of biodiversity conservation, watershed conservation and carbon dioxide fixation by forests (Table 1). Latin American countries, particularly in Meso-America[*], have pioneered the implementation of pilot projects to market ecosystem services in the developing world. In the mid 1990s, Costa Rica brokered the first agreement between its National Institute for Biodiversity and a major US pharmaceutical company to facilitate the company's access to genetic resources in exchange of a share of eventual product developments (Rojas and Aylward, 2003: 13-14). At the same time, the Costa Rican government also established a PES national schemes through which forest resource owners were paid for forest conservation, management and reforestation activities. The State gained carbon emission offsets and watershed rights which were in turn distributed to the private companies in charge of financing the scheme (*ibid.*: 37-43). Also in the mid 1990s, other Meso-American countries, such as Belize and Mexico, hosted carbon forestry projects under the Activities Implemented Jointly pilot phase of the United Nations Framework Convention on Climate Change (UNFCCC) and established PES schemes similar to the Costa Rican example (Pagiola*, et al.*, 2005).

But can initiatives marketing ecosystem services promote environmental benefits while contribute to rural development as their proponents ambitiously claim? There is evidence that Costa Rica's PES is skewed towards wealthy farmers who hold larger forested areas and rely on off-farm income-generating activities (Zbinden and Lee, 2005). Similar results have been found in other carbon and watershed projects in Costa Rica and Ecuador, where projects have been ineffective in involving poor landowners either due to an institutional design biased against small land properties in order to reduce transaction costs, or because the poor could not invest nor allocate land for forest protection in limited land endowments (Albán and Argüello, 2004, Grieg-Gran*, et al.*, 2005, Rojas and Aylward, 2003). Other carbon forestry projects in Bolivia and Brazil have found difficulties in channelling economic resources towards strengthening community-based organisations and implementing other productive activities besides sustainable forest management (May*, et al.*, 2004). This evidence suggests that fulfilling both environmental sustainability and social development through marketing ecosystem services is by no means an easy task.

In this paper we investigate this question further by examining four distinct efforts to commercialise watershed recharge and carbon sequestration by native forests in Meso-America, through either existing protected areas or rural farmers and communities. We highlight the extent to which payments contribute to finance protected areas management, how farmers benefit economically from selling ecosystem services, who participates and remains excluded from these initiatives and why this happens. The paper is structured in five sections, including this

[*] The term 'Meso-America' was coined by Paul Kirchoff in 1943 as the geographical region between Mexico's Sinaloa, Lerma and Panuco rivers and Costa Rica's Nicoya Peninsula. This region has a common ethnical configuration, with a number of ancient cultures sharing religious beliefs, art, architecture, migration and colonisation patterns (Kirchoff, 1943).

introduction. The second section presents a research framework which brings together elements from institutional analysis of global environmental change to analyse the environmental, economic and social implications of marketing ecosystem services. The third section describes the study sites and the methods employed for data collection. Section four outlines and discusses the results, deriving some lessons for the future marketing of ecosystem services. Section five summarises and concludes the paper.

Table 1: Examples of traded ecosystem services and derived commodities

Ecosystem service	Commodity	Description
Biodiversity conservation	Bio-prospecting rights	Investors collect and test genetic material from a designated forest area and compensate property holders for their access.
	Debt for nature swaps	Involves the purchase of discounted developing-country debt, which is exchanged for domestic financial resources to invest in conservation.
	Conservation easements	Landowners are paid to manage their land in ways to achieve conservation objectives.
Watershed conservation	Watershed protection contracts (Best management practices)	Watershed landholders and downstream beneficiaries set out resource management practices which must be implemented in return for payments.
	Water quality credits	They are generated when water-polluting companies offset such pollution by investing in watershed protection elsewhere.
Carbon dioxide fixation	Voluntary emission reductions	They are generated when private or public companies/agencies offset their carbon emissions on a voluntary basis by financing forest conservation or plantation in developed and developing countries. VERs are used to green investors' corporate image.
	Certified Emission Reductions (CERs)	They are generated when investors from Annex-I countries under the Kyoto Protocol fund reforestation and afforestation activities in developing countries through the Clean Development Mechanism. CERs are then used to meet investors' emission reduction targets under the Protocol.
	Emission Removal Units (ERUs)	They are generated when investors and governments from Annex-I countries fund the protection and management of forest stocks in their own countries. ERUs are also used to meet emission reduction targets under the Kyoto Protocol.

Source: Landell-Mills and Porras (2002) and own modifications.

2. Conceptual and analytical framework

2.1. The institutional nature of markets for ecosystem services

In the context of environmental change, institutions exist or are created to influence the way in which humans relate to their environment. They have been defined as systems of rules, decision-making procedures, and programmes that articulate or give rise to social practices in relation to the environment, assign roles to participants, and guide interactions among stakeholders (Young*, et al.*, 1999). Institutions can also produce both intended and unintended outcomes, depending on whether the latter were or not foreseen in the process of institutional design. Traditionally, ecosystem services have been issued by institutions which have set aside some parts of nature from the market through protected areas or other conservation policies. In contrast, it is now argued that marketing nature will foster its conservation and the provision of ecosystem services.

In this paper we define markets for ecosystem services and PES schemes as emerging institutions which attempt to reconfigure human-environment interactions and to promote the involvement of the private sector in the conservation of environmental resources. Their constitutive projects represent the institutional arrangements encompassing the sets of rules, rights and obligations through which markets or PES schemes organise, govern and operate themselves. Where effective institutions for environmental management already exist, projects marketing ecosystem services can reinforce existing institutions and sustainable practices. When land-use management practices for the maintenance of ecosystem services are not in place, the provision of direct economic incentives is expected to act as stimuli to change individual and collective behaviour for the conservation of these services.

We also acknowledge that markets for ecosystem services and PES schemes do not operate in isolation. Projects may be strongly influenced by existing institutions, including formal (e.g., agricultural and forestry policies, collective action institutions) and informal (e.g., traditional practices for natural resource management), which may enable or undermine effective resource management (Agrawal, 2002, Dietz*, et al.*, 2003). Therefore, a research challenge is to become sensitive to the institutional context in which projects are implemented as it can ultimately influence the effectiveness of markets for ecosystem services and PES schemes (Swallow*, et al.*, 2005). Also, it is important to notice how the introduction of markets for ecosystem services may become counterproductive for achieving sustainability, since they may undermine the institutional logic of conservation (Martínez-Alier, 2002).

2.2. Analytical framework

Taking into account design and context-related institutional factors, we propose to adapt Adger *et al*.'s (2003) framework for the analysis of environmental decision-making to the study of markets for ecosystem services. These authors propose to bring together four constitutive dimensions of sustainable environmental governance, namely economic efficiency, environmental effectiveness, equity and political legitimacy, into the analysis of environmental decision-making so that a 'thicker' understanding of environmental decisions can be achieved (*ibid*.: 1097). We suggest here that these four dimensions also enable a better framing of the environmental, economic and social implications of markets for ecosystem services

and PES, while at the same time allow a better understanding of both the intrinsic and contextual institutional nature of these initiatives. In this analysis, we discard environmental effectiveness as an analytical category because the selected watershed and carbon forestry projects have only been recently implemented. Therefore it is almost impossible to demonstrate whether they are effective in enhancing water resources or mitigating carbon emissions. Environmental benefits can only be evaluated as these projects evolve and in-depth, continuous, modelling studies are conducted.

The notion of economic efficiency has a wide range of interpretations depending on the discipline of enquiry (Jollands, 2006). Efficient payments for ecosystem services are considered those which, firstly, provide full compensation of the opportunity cost of providers' land use and, secondly, guarantee that users' payments are lower than the economic value of the positive environmental externality (Alix-Garcia, et al., 2005, Pagiola and Platais, 2002). Following this definition of economic efficiency, monetary compensation in payments for ecosystem services should then cover the full costs of providers' alternative land use practices and simultaneously be lower than any technological solution for the provision of the same positive externality, for instance the costs of treating water in the case of watershed conservation. In this paper, we only examine the first assumption of the previous proposition by comparing the monetary benefits participants receive in exchange of selling ecosystem services with foregone benefits of other land-use activities. We also draw on service providers' qualitative perceptions on the payments value and we unravel which benefits other than monetary payments contribute to explain participation in these schemes. In the case of PES in protected areas, we analyse the extent to which payments compensate for the costs of protection and monitoring activities. We acknowledge that some protected areas may allow for the development of productive activities in buffer zones but, as for the cases examined here, we assume that opportunity costs are negligible.

Finally, our analytical approach embeds the notions of equity and political legitimacy in three distinct analytical variables: people's *access* to project information and activities, *participation* in project decision-making, and the *distribution* of development benefits (Brown and Corbera, 2003). *Access* and *distribution* are informed by the notion of *distributive justice* or *equity* (Dobson, 1998) and we suggest that markets for ecosystem services and PES are equitable only if they maximise the number of local people receiving information and benefiting from these schemes, and they do not make any local stakeholder worse off as a result of project implementation. In turn, *participation* concerns *procedural justice* or *political legitimacy* and relates to how participants are recognised and included in the decision-making process (Fraser, 1997, Paavola, 2003). This three-tiered analytical framework allows us to investigate who is excluded, who participates and benefits from project activities, and why (Table 2).

Table 2: Analytical framework and study variables

<table>
<tr><td></td><td colspan="4">Analytical categories</td></tr>
<tr><td></td><td>Economic efficiency</td><td colspan="2">Equity</td><td>Legitimacy</td></tr>
<tr><td rowspan="2">Study variables</td><td>Degree of compensation to farmers</td><td>Access to information</td><td rowspan="2">Distribution of project benefits</td><td rowspan="2">Participation in decision-making</td></tr>
<tr><td>Degree of contribution to protected areas management costs</td><td>Access to project activities</td></tr>
</table>

3. Case studies and research methods

3.1. Study sites

Las Escobas River Basin is located in the *Reserva Protectora de Manantiales Cerro San Gil* (Cerro San Gil water source protection reserve), cutting across the municipalities of *Livisgton*, *Puerto Barrios* and *Morales*, Guatemala (FUNDAECO, 1999). The river basin has an extension of 707 hectares and supplies drinking water to 5,319 households in *Puerto Barrios* (FUNDADECO, 1999, 2004). In 1998, the *Fundación para el Ecodesarrollo y la Conservación* (Foundation for Ecodevelopment and Conservation, FUNDAECO), which administers the Reserve on behalf of the Guatemalan State, negotiated a PES scheme with a local hydroelectricity company (*Empresa Hidroeléctrica del Atlántico*, HEDASA) on the premise that an increase in forest conservation efforts would ensure continuous water flows and a reduction in sediment loads. In 2002, HEDASA, which also acts as the public water provider, started transferring a monthly payment of US$17.86/ha/year to FUNDADECO so as to improve the management of the river basin. The activities promoted include protecting and managing the hydrographical basin; encouraging sustainable agricultural practices; providing opportunities for low impact eco-tourism; and promoting sustainable forest management through agro-forestry. PES funds come from an increase in the water tariff of US$0.20/month.

Paso de Los Caballos River Basin has an extension of 740.6 hectares and it is located in the municipality of *San Pedro del Norte*, Nicaragua. The main economic activity in the area is agriculture, primarily small-scale cattle ranching and basic grain crops, which account up to 70 percent of household income (Ardón Mejía and Barrantes, 2003). Problems regarding water quality and quantity led 125 households from *San Pedro del Norte* to propose and negotiate a PES scheme with the support of local and regional NGOs, which identified priority areas for funding in the upstream basin recharge area. The 125 households created a water committee and reached 5 individual agreements with upstream landowners, covering a total of 39.2 hectares for reforestation and conservation of the prioritised areas. Each household contributes with US$0.31/month to the PES scheme and landowners receive US$26/ha/year. Landowners commit to avoid fires before, during and after sowing; develop organic agriculture; conduct soil conservation practices; develop agro-forestry systems; promote fore regeneration and commit to prevent livestock from invading the PES areas.

The Fondo Bioclimático Carbon (FBC) project in Mexico is one of the first carbon forestry projects in the world. Participant farmers and communities rely on

subsistence and semi-subsistence maize and bean cultivation, livestock and relatively little commercial agriculture. The project's objective is to provide carbon benefits through forestry systems which are economically viable, and socially and environmentally responsible. There are a total of 4,738 hectares under reforestation and conservation activities funded by several investors -Future Forests, Tetra Pak, International Automobile Federation, The World Bank-, which in exchange receive voluntary emission reductions to offset their greenhouse gas emissions or to provide 'carbon neutral' products and services to their clients. Between 1997 and 2000, the project secured funding for the sale of 60,498 tonnes of carbon dioxide equivalent (CO_2eq)[†] over 30 years at a price of US\$3.27/tCO_2eq, from which a 66.6 percent (US\$2.18/tCO_2eq) is allocated directly to farmers, and the rest is used to cover project administration and managers' salaries. Between 2000 and 2005, investors further contracted an approximate annual average of 36,666 tonnes of CO_2eq (Corbera, 2005b).

The Rio Bravo Carbon (RBC) project is located within the Rio Bravo Conservation Management Area (RBCMA), a national protected area hold in trust by a Belizean NGO -Programme for Belize-. The project aims to demonstrate a technical balance between cost-effective carbon sequestration, economically sustainable forest yield, and environmental protection (Programme for Belize, 2000a). The area dedicated for carbon sequestration occupies 55,000 hectares, representing 52 percent of the RBCMA. Within these, 14,000 hectares have been allocated for conservation purposes while another 39,000 hectares have been allocated for sustainable forest management and community development projects. The project has involved one international conservationist organization -The Nature Conservancy- and one consultancy firm -Winrock International- in brokering an agreement with investors, and preparing carbon sequestration scenarios and forest management plans, respectively. Investors include a consortium of US and Canada based energy utilities. Based on project management figures, the project expects to sequester 10 million tonnes of CO_2eq over the period 1995-2035 with a total expenditure of US\$2.6 million in the first ten years and of US\$3 million in the following 30 years. This translates into an approximate undiscounted price of US\$0.25 per tonne of CO_2eq (Programme for Belize, 1996, 2000b).

3.2. Research methods

Research methods encompass both qualitative and quantitative techniques. Interviewees were classified into four main categories: *users*, *providers*, *potential providers* and *intermediaries*. *Users* are groups of organised people or organisations benefiting from the ecosystem service in question and paying for the coordination and implementation of management activities in the forested areas. *Providers* are stakeholders holding a contractual relationship with the *users* and who commit to implement forest conservation and management practices on their landholdings. *Potential providers* also own land in the area where projects develop but do not hold any contractual relationship with *users* or *intermediaries*. *Intermediaries* are organisations in charge of defining the conservation activities to be performed by the *providers*, and they are held responsible for collecting funds derived from the *users* in order to pay to the *providers* (Table 3).

[†] Measurement unit equalling the concentration of carbon dioxide that would cause the same amount of temperature change in the climate system as the given mixture of carbon dioxide and other greenhouse gases (Intergovernmental Panel on Climate Change, 2001).

Table 3: Stakeholder categories in research case studies

Case study	Users	Providers	Potential providers	Intermediaries
Las Escobas	Urban households	Local NGO	None	Hydroelectric and public water company
Paso de los Caballos	Rural households	Small landholders	Small landholders	Water committee
Fondo Bioclimático	International private companies	Small landholders and communities	Small landholders and communities	Project managers (technical organisation)
Rio Bravo	Utility companies	Local NGO	None	Transnational NGOs

In the watershed cases, we conducted a total of 23 semi-structured interviews and 167 household surveys involving users, intermediaries and providers (i.e., village leaders, government authorities and NGOs). While interviews aimed to generally frame the projects' context and their perceived successes and existing conflicts regarding equity and legitimacy aspects, household surveys documented in more detail the contribution of the project to household income, thus being able to examine economic efficiency matters. In the carbon cases, we conducted 13 in-depth interviews involving service providers (i.e., project managers and farmers' representatives), intermediaries (i.e., project brokers) and users (i.e., investment companies). These interviews also focused on documenting the projects' operative framework and existing trade-offs between project environmental, economic and social objectives. The case of the FBC project allowed for a more in-depth investigation of economic efficiency, equity and legitimacy issues in comparison to the Belizean case. This was so because data was also derived from ethnographic research conducted in two participant villages[‡]. In these localities, a total of 108 semi-structured interviews and questionnaires, in addition to 11 discussion groups involving 108 farmers, were conducted to understand local economic benefits, which factors influenced local participation, who remained excluded from project activities, and the project's contribution to community development.

From an economic standpoint, we estimated the degree of monetary compensation in protected areas by means of different proxies. For those initiatives concerning the provision of ecosystem services through protected areas (Guatemala and Belize), compensation was calculated as the percentage of total management and protection costs covered by PES payments (% Compensation = PES annual income / Protected Area Protection and Monitoring Costs), and also as the ratio between PES annual income and NGO total income (% Compensation = PES annual income / NGO annual income). For community-based schemes (Nicaragua and Mexico), monetary compensation was estimated by two proxies of opportunity cost. The first one relied on subtracting actual PES payments to on-farm profits (e.g., maize and beans cultivation and cattle ranching). The other proxy related PES payments to what providers perceive as a fair price for it. These calculations provided key

[‡] One village encompasses 555 households, 53 of which involved in carbon planting. Another village counts with 1,141 households who collectively develop carbon plantations on common forests and grazing lands.

insights on payments' contribution to the long-term financial sustainability of protected areas and their fairness and ability to alleviate rural poverty.

The following section outlines the economic, equity and legitimacy implications of our case studies. A clear-cut distinction is made between the initiatives protecting watershed and carbon forest stocks through protected areas (Guatemala and Belize) and community-based schemes which manage landscapes to guarantee water quality and enhance forest cover (Nicaragua and Mexico).

4. Results and discussion

4.1. Economic efficiency

PES in *Las Escobas* watershed represent an annual transfer of US$12,642.24 (US$17.86/ha/year) to FUNDAECO, an amount partly obtained from charging an additional US$0.20/month to the households receiving water from HEDASA in *Puerto Barrios*. FUNDADECO annual expenditure is approximately US$158,028, which covers the organisation administrative and operative costs, including the protection of the *Cerro San Gil reserve*. The reserve annual protection expenditure is estimated around US$31,608. Therefore, the PES annual payment accounts only for a six percent of the NGO's total income but a 40 percent of the total costs of protecting and monitoring the reserve. The Belizean case shows certain parallelism to *Las Escobas* in the sense that carbon payments contribute positively to the protection of the reserve. Programme for Belize, has to date received US$2.38 million of carbon investment, from which US$1.28 million has been used to purchase land and expand the protected area, and US$1.09 million has been used to create a resource protection endowment, cover management costs, and finance monitoring and verification studies of existing carbon stocks over a period of 10 years (Programme for Belize, 2000a). The average annual carbon income, excluding land purchasing costs and the resource protection endowment, is US$68,447. Programme for Belize estimates its total annual expenditure in US$1.5 million, including US$775,000 to cover general site maintenance, personnel and ecotourism management, and US$725,000 to cover the costs of developing specific projects (Programme for Belize, 2000b). Consequently, the carbon-NGO income ratio is approximately four percent while the annual average percentage of the RBCMA protection costs covered by carbon funding is 9 percent.

In *San Pedro del Norte*, Nicaragua, providers and potential providers' income is about US$2,000/year and US$1,200/year, respectively, including on-farm and off-farm activities. Thus, taking into account on-farm activities for providers and potential providers, and including all the activities performed on each land, figures show a mean value of US$130/ha/year. When providers were asked about which price was fair for the provision of water environmental services, most of them agreed to a mean price of US$150/ha/year. Both proxies lead to similar values for the compensation of forgone opportunity costs when implementing PES, showing some robustness in our results. Therefore, it is evident that a compensation of US$26/ha/year for the provision of water environmental services does not cover estimated opportunity costs. When compared to providers' annual income, PES payments account for less than 10 percent. In the Mexican case, the first community researched has 42 farmers planting trees for carbon fixation on fallow lands, which previously contained shrubs or open pine forests. Individual farmers' carbon income represents a total of approximately US$280/ha distributed in 6 payments over 25

years. Some of these providers deviate part of such income to employ labourers for planting and felling activities. Some others rely on family labour and carbon incentives are used exclusively to provide for household needs. Income has been spent in a number of ways, including items for agricultural production (e.g., tools, fertiliser, oxen rent), clothes, drugs or food for the household. Project managers have estimated the costs of establishing and managing forestry systems, as well as the opportunity costs of different land-use options, across the region where the project operates (de Jong*, et al.*, 2000) (Table 4). Assuming that carbon payments are equally split in the 25-year period, we come to the figure of undiscounted carbon payments of US$11.2/hectare/year, a value which may cover opportunity costs but would hardly meet both establishment and operational costs in open pine forests.

Table 4: Costs of different forestry systems in Fondo Bioclimático

Land use system	Cost of establishing forestry system (US$)	Operational costs (US$/year)	Opportunity costs (US$/year)
Milpa	212.2	36.1-49.1	0-358.5
Cattle ranching	282.5	39.1-65.1	39-152
Thicket	285.7	76.7-102.7	0-215
Tree fallow	223.4	75.4-101.4	0-215
Oak and montane forest	186	64.3	6.5-130
Pine-oak forest	208.5	63-76	6.5-130
Pine forest	192	87.7-100.7	0-65
Open pine forest	217.5	100.7	0-65

Source: de Jong et al., 2000.

The second researched community in the Mexican case has a forest conservation area of 1,800 hectares, and another 30 hectares are being reforested on common forests and grazing lands. The community has received a total of US$18,000 in three payments for the conservation area between 2000 and 2003 and it will receive an approximate total of US$29,592 for the reforested areas over the next thirty years. To date, the community assembly has been in charge of deciding how to spend the carbon revenues received since 2000. In some occasions, the community invested carbon revenues in collective goods (e.g., community roads, land tax) while in some years community members split the total carbon revenue among themselves, leaving each household with very little, approximately between US$5 and US$10. In this case, it does not make sense to estimate compensation costs as the reforested area is protected by the community. There exist local resource management rules which forbid the use of those areas for other than fuelwood collection purposes and subsistence grazing activities during the wet season.

4.2. Equity (access and distribution) and legitimacy (participation)

In *Las Escobas* initiative, only FUNDADECO and HEDASA were involved in the negotiation process and the early implementation of the scheme, leaving outside those communities which lived around the protected area and who engaged in clandestine timber logging. The lack of stakeholder involvement spurred local conflict, as there was no attempt to mediate the competing interests that existed regarding the access and use of land and forest resources in the watershed area. As highlighted by the protected area manager:

> ‘There is a conflict of interests around the watershed. FUNDAECO tries to conserve the natural resources and community members surrounding the reserve try to appropriate these resources by expanding the agricultural frontier’ (Manager of *Cerro San Gil* Protected Area, *pers comm.*).

As a result of these conflicts, FUNDAECO has recently made a conscious effort to increase public awareness about the environmental benefits deriving from the reserve. Yet, these informative campaigns have not had much impact. In September 2004, an 88 percent of *Puerto Barrios* citizens had no information about the PES scheme. Activities involving communities neighbouring the protected area were still not in place and education efforts were perceived by local land-users as informative rather than empowering.

Seemingly, in the Belizean RBCMA, conversations with project managers revealed that carbon funding has been used to increase the technical know-how of existing personnel, specifically on developing carbon sequestration baselines and forest management plans, and to provide some employment to local people as guards and cooks for ecotourism facilities. However, only a small component of carbon funding has been used in trying to sensitise local people to the importance of Programme for Belize activities for national and global interests in terms of climate change mitigation and biodiversity conservation. In fact, as for the Guatemalan case, conflicting interests regarding resource use and conservation underpin the relationship between the service provider and rural communities:

> ‘Rural communities constantly go into the area to go hunting, to do fishing, to do illegal logging. As a private land owner we have to protect the resource, we have a mission to carry out. These actions increase the pressure on our resources and what we have is pressure from all the nearby communities and from a number of reasons…. in the savannahs we have human-induced fires… others practice free-range cattle ranching…’ (Programme for Belize technical coordinator, *pers.comm*.).

Such conflict is rooted in historical struggles for property rights over forest resources. As in *Las Escobas* case, local communities used to live from logging and hunting and they exercised free access to forest resources, although these were legally owned by existing logging concessions. When property rights were purchased by Programme for Belize, initially with external and then with carbon-project donations, communities were denied access to forest resources for conservation purposes. In exchange, pilot projects on environmental education, local crafts production and agroforestry schemes were implemented during the early 1990s in the buffer zones of the reserve (Programme for Belize, 1996, United Nations Development Programme, 1996). Two years later, these programmes faded out due to a lack of financial resources and a lack of tourists interested in visiting the villages.

In community-based initiatives we also found shortcomings concerning people’s access and participation in project activities. In *Paso de Los Caballos*, the definition of priority areas for watershed conservation and the PES fee was undertaken by a regional NGO (PASOLAC) with limited involvement of service providers. Furthermore, our surveys indicated that PASOLAC’s efforts to empower the local community in making decisions over the PES scheme did not seem to be effective: 68 percent of water users were not aware of it and 78 percent responded that they

were never consulted regarding its implementation. Some potential providers who had not been involved claimed to have land eligible for the programme while others argued that they did not participate because payments did not compensate for the costs of establishing the new land-management options or were simply a mechanism to alienate their land rights. Upstream providers, however, acknowledged that PES had provided some clear benefits. In addition to income gains, they had received technical assistance from PASOLAC for forest protection and regeneration activities, and they had participated in other projects focused on improving agricultural production through sustainable management practices (e.g., crop rotations, organic compost). In turn, water users also perceived that the local water service had improved, although not up to the level they wished to and several users still lacked a daily water supply. Since the creation of the local water committee, users became aware of their daily water restrictions and took an active role in defining water quotas in each community sector. The PES empowered the local community so as to take control of the public water service, increasing its transparency and local participation.

In the Mexican case, access to project activities has increased since 1997. By that time, there were only 42 individual carbon providers from 6 distinct communities. As of September 2005, there are over 650 individual providers representing 33 communities, and three of the latter develop carbon plantations on the forest commons. Respect for local knowledge, farmers' ideas and a process of trial and error in the design and development of carbon forestry activities (Phillips*, et al.*, 2002) is a major cause of providers' growing interest. Project managers, however, have been less effective in involving farmers and communities in making decisions at project management level. In its early years, the project was characterised by a shared decision-making system at both implementation and strategic levels, based on a committee which incorporated community representatives, project managers and the intermediary between providers and service users (global carbon investors). Later on, changes in the project organisational arrangements translated into a concentration of decision-making power in the hands of the project broker (Nelson and de Jong, 2003).

This situation of uneven power at project management level started to change in 2003 with an increase in project managers' decision-making power. This was caused by the broker's progressive disengagement with project development and a growing shared control of carbon funding expenditure between managers and the broker. Still, however, direct providers lack a central role in decision-making. Bi-annual meetings among project managers, rural organisations and community representatives have become institutionalised as a central element of decision-making but they play a mere informative role and no strategic decisions are made in this context:

> 'The project would have to be an organisational rather than an administrative body, in which local communities could be more fully involved in making strategic decisions. However, the people who are now working in the project do not have the necessary experience to organise people to make decisions' (FBC project manager, *pers.comm*.).

Project plantations involve native, timber-oriented species, such as *Pinus sp*. or *Cedrela sp*. Nevertheless, increasing the diversity of planted seedlings has been hampered by the project's reliance on state nurseries, which do not produce a wide variety of seedlings and thus cannot cover local productive needs. Women from the

second researched community, for instance, have a manifest interest in planting fast-growing species in the commons which could be used as sources of poles and fuelwood. And, although they play an active role in the management of the forest commons as fuelwood gatherers and herders (Silva, 2002), they have not been involved in project meetings. Project managers only interact with local leaders, who traditionally marginalise women from decisions concerning the forest commons (Corbera, 2005a). Local providers were also generally unaware of where the carbon revenue was coming from and their rationale for participation was often based on assumptions that can be scientifically contested, such as that planting trees would lead to future increases in rainfall (Calder, 1999). At present, project managers acknowledge that the number of visits to local communities is being progressively reduced due to the expansion of the project and the lack of human and financial resources to visit communities more often. The visits put their emphasis on carbon accounting and monitoring, rather than on the educational side of the project.

4.3. Discussion

The table below summarises our findings according to our three analytical categories: economic efficiency, equity and legitimacy.

Table 5: Economic efficiency, equity and legitimacy outcomes in study sites

Case study	Economic efficiency	Equity	Legitimacy
Las Escobas	PES represent a 6% of NGO total income and cover a 40% of total protection costs	Communities marginalised in project design	The project is implemented and managed by the local NGO There is no participation of local resource users in decision-making
Rio Bravo	Carbon payments represent 4% of NGO total income and cover 9% of total protection costs	Communities marginalised in project design but involved in complementary activities (i.e., ecotourism) in early stages Limited provision of employment to local inhabitants as reserve guards and cooks	Payments are managed exclusively by the local NGO Persistent conflict regarding access to forest resources
Paso de los Caballos	20% compensation of land opportunity costs <10% compensation of providers' total income	Limited participation of potential providers: insufficient communication and involvement in project planning Provision of technical assistance to local providers for forest and agriculture management activities	No apparent conflict with service providers The water committee has increased users' sense of control over water quotas allocation
Fondo Bioclimático*	100% coverage of opportunity costs only for some farmers developing plantations in open pine forests	Increasing access to project activities across participant communities Marginalisation of poor households due to limited land endowment and poor collective action Marginalisation of women due to men's leadership in local project management issues	Centralised decision-making in project management strategic decisions

* Only refers to the two participant communities analysed in this study.

The economic results from our case studies indicate that projects marketing ecosystem services can become effective means to increase the economic resources available to protected areas, reducing the burden on governmental expenditures in this sector and allowing other stakeholders to participate in forest conservation efforts. Yet, ecosystem services revenues still fall below the overall expenditure of protected areas. Our results also show that the provision of ecosystem services through protected areas results in a lack of equity and procedural legitimacy, in particular in the provision of public participation, environmental awareness, and the distribution of income. Protected areas initiatives have been less able to incorporate local communities in project implementation and they have reinforced existing contests over access and control of forest resources within and along protected area boundaries. Such conflicts are common in protected area management (Ghimire and Pimbert, 2000) and PES schemes should confront these issues in order to ameliorate conflict and establish more equitable forms of resource management.

The relatively low impact of payments allocated to individual and community-based providers poses a critical concern, since these instruments are expected to contribute to economic development and poverty alleviation. Nevertheless, we have identified at least three reasons explaining why individual farmers and communities participate in PES schemes even with limited compensation. Firstly, farmers overestimate the value of their land as a strategy to bargain for higher PES payments. In the second community of the FBC project, for instance, several local testimonies recognised that the carbon project made possible to extract economic revenue from an area of preserved forests whose resources are hardly used and accessed by local members. Moreover, they stressed that the carbon project is a cost-effective strategy for collective income generation, as it only implies the dedication of two or three days of collective labour a year and the financial returns benefit all members equally. Secondly, and in addition of economic revenues, farmers value the environmental benefits associated with PES marketing. These include value gained from both marketable and non-marketable goods such as timber, non-timber forest products, firewood, shade, scenery or environmental legacy. Participant farmers in Nicaragua and Mexico emphasised that forests constitute a legacy for their children, which will have both economic (timber and improved water quality) and intrinsic (a recovered environment) benefits. Thirdly, farmers participate because payments are not a main source of income but a small incentive which does not modify significantly households' productive regime. Finally, in-kind payments to farmers and communities, such as training and technical advice, may also enhance participation, although none of our service providers indicated these as key motivating factors.

Our analysis of community-based initiatives allows us to devise a strong relationship between access to and participation in project activities and the existence of sufficient land endowment and forms of collective action (Saunders*, et al.*, 2002). For example, participation in the first community of the Mexican case was driven by households' land endowment, with richer households being those who were able to increase the land allocated for tree planting. Households' participation was dependent on the ability to carry out planting activities in woodlands and pastures while maintaining other hectares for oxen to graze. We found that land-use change from maize cultivation to planting trees for carbon fixation did not occur because it would put farmers' subsistence at risk. Wider participation of community members in the project was constrained by mistrust between the families who had early become

involved in tree planting and those who had not. Existing social conflict undermined collective action and the possibility to develop tree plantations in the commons, which could have benefited equally all households. In addition, as in the case of *Paso de los Caballos*, non-participants were also reluctant to participate in the project because they thought that it would alienate their property rights (Corbera and Adger, 2004). In this sense, it is evident that markets for ecosystem services entail a de facto or de jure definition of property rights over positive externalities. Coase (1960) recognised that the initial allocation of property rights would not influence economic efficiency of a system compensating externalities but would influence equity issues. In our research context, this implies to ask questions such as whether upstream providers have the right to pollute and deforest upper watershed areas and whether industrialised countries and private companies have the right to continue releasing vast amounts of CO_2 into the atmosphere or consuming and polluting water resources. It is also important to recognise who becomes entitled to trade the positive externality among service providers.

Finally, our four case studies are also characterised by the lack of financial resources to increase transparency in project design, to maximise people's access to project activities and to enhance participation in decision-making. This is critical to deliver more equitable outcomes and to ensure that projects do not induce social conflict or undermine collective action (Boyd*, et al.*, 2005). For this to happen, however, initiatives marketing ecosystem services should increase the economic resources available to project managers so that local ecological and social conditions can be well understood prior to project implementation. Awareness of environmental histories, property rights struggles and existing forms of collective action by project managers are critical to identify all potential providers and involve them in project design and implementation. When this is not possible –due to local unwillingness to participate or existing conflicts- project managers should find the means to mediate existing or emerging conflicts and ensure that poorest households do not result worse off as a result of project implementation. This is particularly important when marketing ecosystem services involves an alienation of *de facto* or informal property rights over livelihood resources, as in the Guatemalan and Belizean cases.

5. Conclusion

This paper has analysed the economic and social implications of marketing forest carbon and watershed recharge in Meso-American forests. We have found that, when payments are channelled to an NGO towards the protection and management of protected areas, they partially compensate the costs of protecting and managing such area. When payments are allocated to individual farmers and rural communities, these hardly compensate for local opportunity costs or what farmers perceive as a fair price. Nevertheless, we also found that these payments can contribute to household and community well-being through the provision of material household needs and collective benefits. Critically, all case studies show deficiencies in the degree of stakeholder involvement and they are severely centralised when it comes to making decisions about how projects are designed and implemented.

We have argued that a more contextually-informed calculation of the compensation payment and a better awareness of institutional contexts, particularly property rights conflicts and social relations regarding access to forest resources, are critical to ensure the effectiveness of these activities from an equity standpoint. When projects

are not able to account for the existence of informal or customary property rights over forest resources, they can induce social conflict and generate direct confrontation between rural inhabitants and project managers. Seemingly, project activities which are developed by local communities but fail to account for informal forest resource users can contribute to reify existing inequities in decision-making and favour some local actors' interests over others. Seemingly, if projects do not take into account that only farmers with extensive landholdings participate, they run the risk of creating further economic inequities at the local level.

In order to account for these factors and processes, the extent to which investors are willing to pay for implementing projects with inclusive design frameworks and a dynamic account of local social relations is critical. Otherwise, these emerging projects and institutions run the risk of benefiting only well-established conservation organisations and powerful individuals without involving the poorest in conservation efforts or tackling existing inequalities. If emerging markets for ecosystem services and PES schemes do not provide more substantial degrees of compensation and do not guarantee equitable and legitimate outcomes than those outlined in this paper, they may only help to aggravate existent inequities in accessing and benefiting from the local environmental commons.

Acknowledgements

This research has been developed with the financial support of the Tyndall Centre for Climate Change Research and the BBVA Foundation. The authors would like to thank Alfonso Mercado, Joan Martínez-Alier and Roldán Muradian for their comments on an early draft of this paper. The views expressed, and any errors, remain sole responsibility of the authors.

7. References

Adger, W. N., Brown, K., Fairbrass, J., Jordan, A., Paavola, J., Rosendo, S. and Seyfang, G. (2003) Governance for sustainability: towards a 'thick' analysis of environmental decisionmaking. *Environment and Planning A* 35(6), 1095-1110.

Adger, W. N., Brown, K. and Hulme, M. (2005) Redefining global environmental change. *Global environmental change* 15, 1-4.

Agrawal, A. (2002) Common Resources and Institutional Sustainability. In Ostrom, E., Dietz, T., Dolsak, N., Stern, P. C., Stonich, S. and Weber, E. U. (Ed.), *The Drama of the Commons*. National Academy Press, Washington D.C. pp. 41-85.

Albán, M. and Argüello, M. (2004) *Un análisis de los impactos sociales y económicos de los proyectos de fijación de carbono en el Ecuador. El caso de PROFAFOR-FACE*. Markets for Environmental Services No 7. International Institute for Environment and Development, London.

Alix-García, J., de Janvry, A. and Sadoulet, E. (2005) A Tale of Two Communities: Explaining Deforestation in Mexico. *World Development* 33(2), 219-235.

Ardón Mejía, M. and Barrantes, G. (2003) *Experiencia de Acción Piloto de PSA San Pedro del Norte, Chinandega, Nicaragua. Informe de evaluación de acciones de PSA presentado a PASOLAC*.

Boyd, E., Gutiérrez, M. and Chang, M. (2005) *Adapting small-scale sinks projects to low-income communities*. Working Paper 71. Tyndall Centre for Climate Change Research, Norwich.

Brown, K. and Corbera, E. (2003) Exploring equity and sustainable development in the new carbon economy. *Climate Policy* 3(S1), 41-56.

Calder, I. R. (1999) *The Blue Revolution. Land Use and Integrated Water Resources Management*. Earthscan, London.

Coase, D., 1960. The problem of social cost. *Journal of Law and Economics* 3, 1–44.

Corbera, E. (2005a) Bringing Development into Carbon Forestry Markets: Challenges and outcomes of small-scale carbon forestry activities in Mexico. In Murdiyarso, D. and Herawati, H. (Ed.), *Carbon Forestry: Who will benefit?* Center for International Forestry Research, Bogor. pp. 42-56.

Corbera, E. (2005b) Interrogating Development in Carbon Forestry Activities: A Case Study from Mexico. Unpublished PhD Thesis. School of Development Studies, University of East Anglia, Norwich.

Corbera, E. and Adger, W. N. (2004) Equity and legitimacy of markets for ecosystem services: Carbon forestry activities in Chiapas, Mexico. Proceedings of the Conference: The Commons in an Age of Global Transition: Challenges, Risks and Opportunities. International Association for the Study of Common Property, Oaxaca, Mexico.

Daily, G. C., Alexander, S., Ehrlich, P. R., Goulder, L., Lubchenco, J., Matson, P. A., Mooney, H. A., Postel, S., Schneider, S. H., Tilman, D. and Woodwell, G. M. (1997) Ecosystem Services: Benefits Supplied by to Human Societies by Natural Ecosystems. *Issues in Ecology* 2, 1-16.

de Jong, B. H. J., Tipper, R. and Montoya-Gomez, G. (2000) An economic analysis of the potential for carbon sequestration by forests: evidence from southern Mexico. *Ecological Economics* 33, 313-327.

Dietz, T., Ostrom, E. and Stern, P. C. (2003) The Struggle to Govern the Commons. *Science* 302(5652), 1907-1912.

Dobson, A. (1998) *Justice and the Environment. Conceptions of Environmental Sustainability and Dimensions of Social Justice*. Oxford University Press, Oxford.

Fraser, N. (1997) *Justice Interruptus: Critical Reflections on the 'Postsocialist' Condition*. Routledge, London and New York.

FUNDADECO (1999) *Plan Maestro del Área Protegida Reserva Protectora de Manantiales de Cerro San Gil 1999-2003*. FUNDADECO, Guatemala City.

FUNDADECO (2004) *Actualización del Plan Maestro del Área Protegida Reserva Protectora de Manantiales de Cerro San Gil 1999-2003. Documento de trabajo*. FUNDADECO, Guatemala City.

Grieg-Gran, M., Porras, I. and Wunder, S. (2005) How Can Market Mechanisms for Forest Environmental Services Help the Poor? Preliminary Lessons from Latin America. *World Development* 33(9), 1511-1527.

Intergovernmental Panel on Climate Change (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to The Third Assessment Report of the IPCC*. Cambridge University Press, Cambridge.

Jollands, N. (2006) Concepts of efficiency in ecological economics: sisyphus and the decision maker. *Ecological Economics* 56(3), 343'358.

Kirchoff, P. (1943) Mesoamérica. Sus Límites Geográficos, Composición Étnica y Caracteres Culturales. *Acta Americana* 1(1), 92-107.

Liverman, D. (2004) Who Governs, at What Scale and at What Price? Geography, Environmental Governance, and the Commodification of Nature. *Annals of the Association of American Geographers* 94(4), 734-738.

Martínez-Alier, J. (2002) *The Environmentalism of the Poor*. Edward Elgar, Cheltenham.

Matthews, S., O'Connor, R. and Plantinga, A. J. (2002) Quantifying the impacts on biodiversity of policies for carbon sequestration in forests. *Ecological Economics* 40(1), 71-87.

May, P. H., 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*. International Institute for Environment and Development, London.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being. Synthesis*.

Nelson, K. C. and de Jong, B. H. J. (2003) Making global initiatives local realities: carbon mitigation projects in Chiapas, Mexico. *Global Environmental Change* 13(1), 19-30.

Paavola, J. (2003) *Environmental Justice and Governance: Theory and Lessons from the Implementation of the European Union's Habitat Directive*. Working Paper EDM 03-05. Centre for Social and Economic Research on the Global Environment, Norwich.

Pagiola, S., Arcenas, A. and Platais, G. (2005) Can Payments for Environmental Services Help Reduce Poverty? An Exploration of the Issues and Evidence to Date from Latin America. *World Development* 33(2), 237-253.

Pagiola, S. and Platais, G. (2002) Market-based Mechanisms for Conservation and Development. Environment Matters. The World Bank Environmental Annual Review, 2002.

Phillips, G., Hellier, G. and Tipper, R. (2002) *The Plan Vivo System - verification status review*. Société Générale de Surveillance; The Edinburgh Centre for Carbon Management, Edinburgh.

Programme for Belize (1996) *Rio Bravo Conservation and Management Area. Management Plan*. Programme for Belize, Belize City.

Programme for Belize (2000a) Rio Bravo Carbon Sequestration Pilot Project. http://unfccc.int/kyoto_mechanisms/aij/activities_implemented_jointly/items/1804.php. Date of access: 10th October 2005, Website update: June 2000.

Programme for Belize (2000b) *Rio Bravo Conservation and Mangement Area. Management Plan*. Programme for Belize, Belize City.

Rojas, M. and Aylward, B. (2003) *What are we learning from experiences with markets for environmental services in Costa Rica? A review and critique of the literature*. Environmental Economics Programme. International Institute for Environment and Development, London.

Saunders, L. S., Hanbury-Tenison, R. and Swingland, I. R. (2002) Social capital from carbon property: creating equity for indigenous people. In Swingland, I. R.

(Ed.), *Capturing Carbon & Conserving Biodiversity. The Market Approach*. Earthscan, London. pp. 218-230.

Silva, L. C. (2002) Las formas comunitarias de aprovechamiento de los arboles y arbustos de Rincon Chamula, Chiapas, Mexico. Departamento de Ecologia y Sistematica Terrestres, Division de Conservacion de la Biodiversidad, El Colegio de la Frontera Sur, San Cristobal de las Casas, Mexico.

Smith, F. L. (1995) Markets and the environment - a critical reappraisal. *Contemporary Economic Policy* 13(1), 62-73.

Smith, J. and Scherr, S. (2002) *Forest carbon and Local Livelihood: Assessment of Opportunities and Policy Recommendations*. Occasional Paper 37. Center for International Forestry Research, Bogor.

Swallow, B., Meinzen-Dick, R. and van Noordwijk, M. (2005) *Localizing demand and supply of environmental services: interactions with property rights, collective action and the welfare of the poor*. Working Paper 42. CGIAR Systemwide Program on Collective Action and Property Rights, Washington D.C.

United Nations Development Programme (1996) *Arts & Crafts as Complementary Activity in the Community Outreach Programme implemented by Programme for Belize. Final project report, BZE/PCT-1.2.9*.

Walsh, M. J. (1999) Maximizing financial support for biodiversity in the emerging Kyoto protocol markets. *Science of the Total Environment* 240(1-3), 145-156.

Young, O. R., Agrawal, A., King, L. A., Sand, P. H., Underdal, A. and Wasson, M. (1999) *Institutional Dimensions of Global Environmental Change*. Report No. 9. International Human Dimensions Programme on Global Environmental Change, Bonn.

Zbinden, S. and Lee, D. R. (2005) Paying for Environmental Services: An Analysis Of Participation in Costa Rica's PSA Program. *World Development* 33(2), 255-272.

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