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Linking regional land use and payments for forest hydrological services: A case study of Hoa Binh Reservoir in Vietnam

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ABSTRACT

We have calculated the economic value of forest hydrological services for Hoa Binh Hydroelectric Plant in Vietnam, which is a major power supplier for the capital Hanoi. Our valuation is based on measurements over a six-year period from 2001 to 2006 in 240 permanent sample plots in different vegetation types distributed throughout the watershed. We have synthesized the information with GIS, and carried out simulations with derived empirical models for different land use, electricity price and payment proportion scenarios. Our findings indicate that the economic value of forest hydrological services for electricity production ranges from 26.3 million USD to 85.5 million USD per year; and that the longevity of the hydroelectric plant can be prolonged by about 35–80 years, depending on the state of forest cover in the watershed.

Introduction

The importance and advantage of forests in providing hydrological services are well known, and have been extensively documented (Chang, 2006; Börkey et al., 2005; Hewlett, 1982). Forest hydrological services are beneficial for hydroelectric production, where forests contribute to lower soil sedimentation and store water, and thus, maintain the capacity and prolong the longevity[1] of hydroelectric production plants (Rojas and Aylward, 2002; Nguyen and Vo, 1997). However, while it is clear that payments for ecosystem services (PES) are needed to internalize these positive externalities (García-Amado et al., 2011; Costanza et al., 1997; Coase, 1960), the basis for identifying the proper level of payments is under much discussion and substantially different from case to case (Wunder et al., 2008; Kosoy et al., 2007), creating difficulties for policy decision-making and practical application. Progress in the assessment of ecosystem services has been impeded by the lack of a standardized classification of which services to evaluate and how (Fisher et al., 2009; Boyd and Banzhaf, 2007). This is partly because it is often difficult to measure the output of ecosystem services. Furthermore, ecosystem services often have a "public goods" character which implies non-rivality and non-excludability, especially those from regulation services (Zander and Garnett, 2011; Daily et al., 2009). This leads to underestimation of service value, free-riding, undersupply, and finally, exploitation and environmental damage (TEEB, 2010).

Some of the key prevailing questions in PES schemes, thus, include: (1) who must pay? (2) who are paid? and (3) how much are the payments? Answering these questions can apparently make PES schemes more operational and practicable (Wunder, 2007; Balmford and Whitten, 2003). The quantification and valuation

Abbreviations: ES, Ecosystem Service(s); PES, Payment for Ecosystem Service(s); V_w, Payment for water provision service of forests; V_s, Payment for sediment prevention service of forests; V, *Total* payment for hydrological services of forests; p, *Electricity* price (VND/kWh); η, *Proportion* of increased electricity revenue paid to forest owners for water provision service; γ, *Proportion* of increased electricity revenue paid to forest owners for sediment prevention service; £, *Sediment* delivery ratio; R_p, Rainfall erosivity index; α, Slope (α,°); K, *Soil* erodibility index; Z, Vegetation index; DEM, Digital elevation map; PT, Annual rainfall (mm/year); LT, Annual throughfall (mm/year); MT, Annual stemflow (mm/year); LF, Annual water infiltrated and stored in literfall (mm/year); BM, Annual overland flow (mm/year); BH, Annual evapotranspiration during all rain events (mm/year); TT, Annual rainfall interception (mm/year); WI, Annual soil infiltrated water (mm/year); TH, Annual water taken by plants (mm/year); BD, Annual evaporation water from soil (mm/year); NN, Annual water flowing into the ground water (mm/year); WH, Annual water as soil moisture (mm/year); Ws, Annual water stored in soil (mm/year); CS, Normalized forest cover (%); $\hat{Y}$, Normalized forest area of the whole watershed; CT, Cover of forest trees (%); CS, Cover of shrubs (%); CG, Cover of grasses (%); CF, Cover of literfall (%); A, Soil eroded quantity (ton/ha/year); W1, Forest improvement by expanding forest area; W2, Forest improvement by increasing forest quality; VND, Vietnamese currency unit; USD, US dollar.

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[1] The longevity is herein understood as long as it is technically safe and operable (Wieland and Mueller, 2009).

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of ecosystem services are partly constrained by the disciplinary separation between ecological or environmental sciences and economics. The ecological underpinning of economic studies is often limited (Brookshire et al., 2007); and ecological models generally lack appropriate economic considerations (Brouwer and Hofkes, 2008). Obviously, integrating economics and ecological sciences into an operational decision support system is a key step required for global conservation and sustainability (Wei et al., 2009; Millennium Ecosystem Assessment, 2005).

In Vietnam, although forest hydrological services have been considered important (Water Resource Law 1998; Land Law 2003; Forest Protection and Development Law 2004), the legal framework of the payment for ecosystem services in general, and for forest hydrological services in particular, was established only in 2010 (see Wunder et al., 2005 for a review) with the promulgation of the Government's decree No. 99/2010/ND-CP (see Government of Vietnam, 2010). The decree stipulates that forest hydrological services exist that are advantageous for hydroelectric production, and that these must be rewarded. Thus, the quantification and valuation of those services must be carried out in order to establish a basis for the required payment. In this study we were motivated by three questions: (1) what is the economic value of forest hydrological services with respect to hydroelectric production? (2) since forests belong to different forest owners, how can one establish the level of payments for a specific forest stand? and (3) to what degree do potential land use changes influence the economic value in hydrological services that can be derived from a watershed? So far, we have focused our analysis on the most important forest hydrological services, namely for hydroelectric production via water storage and release (water provision), and in the prevention of soil loss with subsequent sedimentation of the reservoir (sediment prevention). Lower sedimentation plays an important feedback role in the economic system, since the longevity of the hydroelectric plant is prolonged. We applied our framework to the Hoa Binh Reservoir in the north of Vietnam, since the Hoa Binh Hydroelectric Plant and forest owners recently reached an agreement that the plant would pay the forest owners a certain proportion of the increased revenue for forest water provision and sediment prevention services. Our study is, thus, of practical significance for the implementation of this agreement. By extending our results to different land use change and electricity price scenarios, we hope that our findings will contribute useful information with respect to sustainable land use and formulation of forest management policy.

Literature review

PES are designed to provide economic compensation for the services ecosystems supply to society (see Elmqvist et al., 2010 for a review). PES systems must be both voluntary and contingent on the actual provision of ecosystem services (Pagiola, 2008). In order for PES to be implemented, ecosystem services must be identified and evaluated, and payment mechanisms must be established to encourage the provision of these services. Payments are normally given to landowners who implement or maintain desired land uses, which are thought to provide the ecosystem services of interest. In practice, most PES systems are "input-based", meaning that they compensate landowners for "inputs" such as trees planted, rather than for true "outputs" of ecosystem services such as, for example, increased biodiversity (Engel et al., 2008). This is because such outputs are difficult and expensive to assess and quantify.

Monetary value assigned to PES can in theory range from the opportunity costs to landowners to the true value of all ecosystem services provided, minus transaction costs. In reality, PES generally falls between these two extremes. For hydrological services, it is often assumed that the service user is the water use enterprise rather than the water end-user (Montagnini and Finney, 2011). In some cases, these enterprises finance their payments with additional fees levied on their end-users. However, in most cases, water use enterprises use their existing operating budget to make the payment (Pagiola and Platais, 2007). It is also quite often the case that, rather than evaluate, quantify, and monetarize actual ecosystem services provided, PES systems simply compensate landowners for provision cost. In this case, payments can be based on environmental targets and the cost to farmers for providing the desired land use (Pagiola et al., 2002). Obviously, this cost-covering compensation approach has several shortcomings. For example, it restricts the scope to those who bear some costs. Those who bear no costs do not need to be compensated. This is more problematic when service providers who suffer costs look not only for recompense, but also for a "provider surplus" – gains from the transaction that exceed their costs and make them better off (Wunder, 2007). An important characteristic of ecosystems and the services they provide is that they are not homogeneous across landscapes or seascapes, nor they are static phenomena (Fisher et al., 2009). Land use change and regional development clearly have implications for evaluation, quantification and monetarization of ecosystem services and vice versa (Rounsevell et al., 2010; Gren and Isacs, 2009). In this regard, the cost-covering compensation approach is even more disadvantageous.

The concept of ecosystem services is attracting increased attention as a way to communicate societal dependence on ecological life support systems (Turner and Daily, 2007; de Groot et al., 2002). Gómez-Baggethun et al. (2010) review the historic development of the conceptualization of ecosystem services and examine critical landmarks in economic theory and practice with regard to the incorporation of ecosystem services into markets and payment schemes. Daily and Matson (2008) highlight the tremendous value of ecosystem services and urge to turn this recognition into incentives and institutions that will guide wise investments in natural capital, featuring three key fronts: the science of ecosystem production functions and service mapping; the design of appropriate finance, policy, and governance systems; and the art of implementing these in diverse biophysical and social contexts. These arguments are supported by Daily et al. (2009) that we have not yet developed the scientific basis, nor the policy and finance mechanisms, for incorporating natural capital into resource- and land-use decisions on a large scale. Nevertheless some regional or local examples do exist. For example, Kosoy et al. (2007) compare three cases of payments for water-related ecosystem services in Central America based on opportunity costs of forest conservation and stakeholders' perceptions of the conditions on water resources and other issues. Branca et al. (2011) discuss how PES can lower the barriers for the adoption of sustainable land management practices in Tanzania. Zander and Garnett (2011) identify the economic value of ecosystem services on indigenous-held lands in Australia. If implemented properly, PES can be a tool for restoration and rural development. A number of studies have been devoted to a more practical question of how to make PES operationable. Muñoz-Piña et al., 2008 describe the process of policy design for PES in Mexico. Such studies are reviewed by Engel et al. (2008) where they state that PES is not a silver bullet that can be used to address any environmental problem, but a tool tailored to address a specific set of problems: those in which ecosystem services are mismanaged because many of their benefits are externalities from the perspective of ecosystem managers (Kinzig et al., 2011). Two important aspects of PES programs, namely the effectiveness and distributional implications, have also been considered, for example by García-Amado et al., 2011. Some authors have spent efforts to examine tradeoffs in ecosystem services and between conservation and development (Carreno et al., 2012; Raudsepp-Hearne et al., 2010; Rodríguez et al., 2006; Faith and Walker, 1996).