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Viewpoint

Enhancing the potential value of environmental services in urban wetlands: An agro-ecosystem approach

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ABSTRACT

This paper proposes a three-tier process for supporting policy planning of urban agroecosystems. It comprises the following steps: (i) definition of the agro-environmental unit; (ii) measurement of the non-market values; (iii) estimation of opportunity cost. An application to an urban wetland agro-ecosystem within Mexico City is used for illustrating our methodology. We estimated that the wetland agro-ecosystem has a lower-bound monetary value between $15.6 million and $31.5 million USD/ha/y. As the land conversion rate is about 3.73 ha/y, the opportunity cost would be between $22,300 and $44,900 USD/ha/y. Such figures are an objective way to appreciate both the potential enhancement value and the opportunity cost of ecosystem services adjacent to urban areas, providing both urban and environmental policy guidance. We argue that this framework allows for multi-scale analysis and may be applied for other urban ecosystems as well.

Introduction

Agro-ecosystems depend on natural environments from which productivity is enhanced in a sustainable way. In contrast to intensive agriculture, they provide not only food but ecosystem services as well (Porter, Costanza, Sandhu, Sigsgaard, & Wratten, 2009; Sandhu, Wratten, Cullen, & Case, 2008; Zhang, Ricketts, Kremen, Carney, & Swinton, 2007). Most agro-ecosystems are either directly or indirectly linked to urban developments. Indeed, urbanization not only refers to increased paved area, but also implies higher demand for natural resources and ecosystem services. Yet, ecosystem services associated with agro-ecosystems or other modified landscapes are poorly understood (Sandhu et al., 2008).

Increasing urban areas not only threaten agro-ecosystems, but other fragile ecosystems such as wetlands (Ehrenfeld, 2000; Lee et al., 2006). For example, Faulkner (2004) describes the main effects on forested wetlands by urbanization, chiefly habitat fragmentation and hydrological and biochemical changes. Such effects might alter agricultural productivity as Hussain and Badola (2008) have demonstrated for mangrove forests in adjacent agricultural land. In fact, wetlands are fragile ecosystems, and their importance is reflected by the fact that they are the only ecosystems protected under an international convention (Turner et al., 2000). Furthermore, according to Costanza et al. (1997), wetlands are the most valued ecosystems in monetary terms, reaching almost 15,000 USD/ha/y. Hence, losing wetlands area implies an opportunity cost to society because wetlands supply a number of ecosystem services in cities, such as: air filtering, micro-climate regulation, noise reduction, rainwater drainage, sewage treatment and recreational and cultural values (Bolund & Hunhammar, 1999; Breaux, Farber, & Day, 1995; Bystrom, 2000; Ehrenfeld, 2000). Additionally, adjacent agricultural land receives benefits as well (Hussain & Badola, 2008). One way to enhance such effects is by means of ecological restoration (Benayas, Newton, Diaz, & Bullock, 2009) and, in the case of agro-ecosystems, by sustainable agricultural practices (Sandhu, Wratten, & Cullen, 2010).

As the rate of land conversion is high, rapid assessment of economic valuation is needed for environmental policy recommendations in urban planning (Faulkner, 2004). This should be a priority due to the increasing importance of agriculture, the increasing loss of ecosystem services, and the potential for agro-ecosystems to enhance global ecosystem services (Porter et al., 2009). In fact, recent work has shown that ecosystem services provided by either wetlands (Tong et al., 2007; Turner et al., 2000) or agro-ecosystems (Porter et al., 2009; Sandhu et al., 2010) are under-valued. Hence, there is still a need of recognizing the value provided by ecosystem services in watersheds where both rural and urban settlements depend on water provision and other services (Postel & Thompson,

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2005). This has important policy implications, as Porter et al. (2009) demonstrated, since non-market ecosystem services contribute between 50% and 70% of agro-ecosystems total economic value in the EU, suggesting that European agricultural systems should move toward enhanced ecosystem services/agro-ecosystems production.

We agree with Ehrenfeld (2000) that urban wetlands have strong differences from those in the wild, and therefore, specific environmental policy planning should be granted to such ecosystems. Therefore, in this paper we present a case study which we consider useful for illustrating a three-tier process for supporting policy planning of such ecosystems, especially when they are directly linked to agro-ecosystems (Hussain & Badola, 2008). Thus, our paper presents three steps for guiding policy planning for urban and agro-ecosystems wetlands. We argue that sustainable agricultural practices and ecological restoration might lead to enhancement of environmental services value. The three steps are:

1. Defining an agro-environmental unit.
2. Estimating ecosystem services values.
3. Estimating the opportunity cost.

We performed our assessment in Xochimilco wetlands, which is an illustrative example of urban wetlands inexorably linked to an important agro-ecosystem, located within one of the major metropolitan areas in the world: Mexico City. Our paper is thus organized as follows: the next section briefly describes Xochimilco wetlands; this is followed by a section focused on methods and another containing our results and discussion. In the latter section, we offer some policy and planning recommendations.

Xochimilco: an urban wetlands agro-ecosystem

Xochimilco is a rural-urban sector in southern Mexico City where traditional agriculture and several ecosystem services are supplied by means of "chinampas". These are plots where traditional agriculture has been carried out for at least six centuries and used to cover a large extension of what is now Mexico City. During the last decades, intensive agriculture (e.g. greenhouse-based) as well as urban development, have shrunk the chinampas area to about 2600 ha. Several efforts have tried to preserve their natural and cultural values. For example, UNESCO designated Xochimilco a World Heritage Site in 1986; moreover, a natural protected area designated as "Ejidos de Xochimilco y San Gregorio Atlapulco" was declared in 1992, and it is listed under the Ramsar Convention on Wetlands since 2004. A more detailed account of both Mexico City's and Xochimilco's context is given in Aguilar (2008) and Wigle (2010), respectively.

The Xochimilco freshwater ecosystem is composed of channels connecting small lakes and a main wetland. This system is a tropical high altitude water body, which produces distinct hydrological and ecological regimes (Zambrano, Contreras, Mazari-Hiriart, & Zarco-Arista, 2009). The hydrological regime at Xochimilco is marked by substantial seasonal change as the rainy season results in substantial ecosystem expansion due to formation of temporary wetlands that attach to permanent water bodies. It is important to biodiversity as it hosts migratory birds and endemic species of amphibians, fish and crustaceans (Valiente, Tovar, Gonzalez, Eslava-Sandoval, & Zambrano, 2010).

Anthropogenic perturbations have been imposed on this dynamic hydrologic regime. Indeed, recent studies have shown that land use is a strong driver of water quality (Zambrano et al., 2009), ecosystem energy paths (Zambrano, Valiente, & van der Zanden, 2010) and biodiversity distribution, such as the Mexican axolotl, an endemic endangered amphibian (Contreras, Martínez-Meyer, Valiente, & Zambrano, 2009). In order to preserve ecosystem services provided by this agro-ecosystem, conservation and restoration policies must be implemented, considering the high heterogeneity in water quality produced by the regional climate, as well as contrasting land uses.

We believe that our three-tier assessment process is worth trying in an agro-ecosystem, which supplies a number of ecosystem services to millions of people. Moreover, our case study can be useful for guiding both urban and environmental policy and planning in urban ecosystems and agro-ecosystems elsewhere.

Methods

Theory

As stated above, Xochimilco wetlands (actually, an agro-ecosystem) provide ecosystem services with both direct (i.e. market values) and indirect use values (i.e. non-market values). On the one hand, direct values refer to assets traded in formal markets, as in the case of agricultural production. On the other hand, non-market values refer to environmental assets without market prices; such as water infiltration and depuration, biodiversity existence, carbon sequestration or cultural and religious importance. According to Sandhu et al. (2008) and Porter et al. (2009), the total economic value of ecosystem services for agro-ecosystems is given by the sum of both market values and non-market values of ecosystem services.

Market values of ecosystem services are estimated simply by the market prices of produce but non-market values of ecosystem services imply indirect estimates of environmental valuation. Contingent valuation methods are an acceptable approach for assessing environmental non-market goods. However, the requirements and assumptions for having robust values imply high costs and, depending on the issue, high sampling effort. Nevertheless, environmental policy decisions frequently need broad estimates that help decision-making in a short span. Hence, alternative valuation methods are warranted. For a review of methods for estimating the value of ecosystem services in wetlands see, for example, Barbier, Acreman, and Knowler (1997) and Brander, Florax, and Vermaat (2006).

We limit our analysis to three main non-market values of ecosystem services in Xochimilco: water quality improvement, carbon sequestration and endemic biodiversity. Water infiltration, although a chief ecosystem service in most wetlands, it is not particularly significant in our area of study due to a highly impervious aquitard in Xochimilco's underground (Serrano, Perevochtichikova, & Carrillo-Rivera, 2008). We are aware that leaving aside important ecosystem services such as microclimate regulation or cultural amenities will result in lower estimates of total economic value. However, we reckon that giving a first baseline (i.e. minimum level) estimate of monetary value is a useful policy instrument. Indeed, as Barbier et al. (1997) points out, valuation should not be considered as an objective but rather as a policy instrument.

Our method comprised three steps: (i) definition of the agro-environmental unit; (ii) measurement of the non-market values; (iii) estimation of opportunity cost. Detailed explanation follows.

Calculation

Please note that details of all calculations are presented in a worksheet file as Supplementary material.

Step 1: defining an agro-environmental unit

As a first step in our analysis, we defined an agro-environmental unit where measures of ecosystem services in both physical and