Ecosystem Services 19 (2016) 51–64

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Assessing the services of high mountain wetlands in tropical Andes: A case study of Caripe wetlands at Bolivian Altiplano

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ARTICLE INFO

Article history:
Received 28 October 2015
Received in revised form
18 April 2016
Accepted 25 April 2016
Available online 7 May 2016

Keywords:
High Andean wetlands
Altiplano
Ecosystem services
Value
Bolivia
Indigenous communities

ABSTRACT

High mountain wetlands in the tropical central Andes are a representative ecosystem critically important for both global biodiversity and local livelihoods of indigenous communities. This study was intended to characterize and highlight the socio-economic importance of high mountain wetlands in relation to the livelihood and indigenous culture of local human settlements. In this study, we focused on wetlands at Caripe in the Altiplano, a community located at the northeast edge of the Sajama National Park in central western Bolivia. We adopted the ecosystem serve framework combined with economic valuation to assess five major wetland services considered either benefiting local households or of global conservation value, including water supply, livestock grazing, recreation, cultural and natural heritage and aesthetics, and biodiversity. We conducted a field survey including household interviews to collect information needed for assessing considered wetland services that characterizes indigenous community residents, their livelihoods in relation to wetlands, local perceptions on wetlands and provided services, and household willingness to pay in labor time for protecting the cultural services of wetlands. The study found that: 1) the community was characterized by relatively young people of poor education, with most raising livestock and living in extreme poverty; 2) most community households valued local wetlands and were concerned about wetland degradation; 3) lack of awareness or knowledge about wetlands ecological complexity in relation to human impact could be the reason for wetland degradation; 4) the services of wetlands were not equally important to the community; 5) local perception and judgment on wetlands status were based much on the availability, stability, and quality of the services they can derive; 6) livestock grazing generated the highest economic benefit estimated at about US$ 323 per year per hectare of wetlands, followed by biodiversity with an economic benefit of US$200 per year per hectare; 7) the economic value of cultural and natural heritage and sense of aesthetics was estimated at US$ 55 per year per hectare; and 8) the services of recreation and water supply had the lowest economic value of about US$17 per year per hectare and US$9 per year per hectare, respectively. This study sheds some light on the importance of high Andean wetlands to indigenous communities in the Altiplano while identifying research needs for the future.

1. Introduction

High mountain wetlands in the Altiplano, the second largest high-mountain plateau in the world (Guillermoprieto, 2008), are a representative ecosystem (Olson and Dinerstein, 1998). Locally referred to as bofedales, these wetlands are confined primarily to the low Alpine and sub-Alpine belts of the tropical central Andes, at elevations between 3200 m and near 5000 m in the north and central part and greater than 2800 m in the southern limit (Squeo et al., 2006). The natural condition of the area is characterized by hyper-aridity, intense solar radiation, high-velocity winds, hypoxia, wide diurnal temperature variation with daily frosts, and a short growing season (Squeo et al., 2006). Established in the unique environment, these high Andean wetlands are, however, rich in plant species, including highly productive endemic vegetation of the South American puna that grows at hydrological and altitudinal limits for plant life in the cold and arid grasslands of Peru, Chile, Bolivia, and Argentina (Squeo et al., 2006; Villarroel et al., 2014).

High Andean wetlands (HAWs) are important not only for global biodiversity but also for local pastoral-based livelihoods and indigenous culture (Coronel et al., 2007; WWF, 2006; Dangles

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http://dx.doi.org/10.1016/j.ecoser.2016.04.006
2212-0416/

et al., 2014). As green islands in an arid mountainous environment, HAWs are habitat for endemic and/or endangered species, such as Andean flamingo (Caziani et al., 2007; Childress et al., 2008.) and harlequin toads (WWF, 2006; Lehr et al., 2008). With high biomass productivity, HAWs provide critical forage grounds for economically and ecologically important ungulates, vicuña *(Vicugna vicugna)*, llama (*Lama glama*) and alpaca (*Lama pacos*), which constitute the foundation of the pastoral-based livelihoods and culture of indigenous Altiplano communities (Browman, 1984; Lichtenstein and Renaudeau, 2004). HAWs are also an important source of water supply for human consumption in the central Andes region (Mittermeier et al., 1998; WWF, 2006; Coronel et al., 2007). The wise use and management of HAWs, given their ecological and socio-economic importance, is critical to the sustainability of the highlands of tropical Andes in South America.

HAWs are increasingly threatened by human activities, notably intensive grazing, with wetland loss and degradation bringing significant societal costs (Alzerreca et al., 2001). This situation may not be surprising, given the global declining trend of wetlands (Zedler and Kercher, 2005; Dixon et al., 2016), particularly where they are managed as a common pool resource (Adger and Luttrell, 2000; Pretty, 2003). While there are cases for well managed common pool resources through collective action and a sense of shared ownership by resource users (Ostrom, 1990; Ostrom et al., 1999), the declining trend of wetlands including HAWs highlights the complexity of wetland ecology interacted with resource management (Adger and Luttrell, 2000). From the behavior and institutional perspective, the loss and degradation of wetlands due to human activities may be attributed to the lack of information on and thus awareness of the relationship between the health of wetlands and their services and benefits. Indeed, there appears a knowledge gap in linking HAWs and the benefits from ecosystem services for the central Andes region. To improve the use and management of HAWs, information is needed on the economic values of wetland services, how local communities perceive those services, and to what extent conservation of wetlands can be implemented through collection action by local users. Developing a clear understanding related to the above information needs is also a critical step to enhance the management of the highland socio-ecological system promoting sustainability.

In this study, we considered wetlands of the Altiplano of Bolivia. Only few cropping activities are carried out in this region owing to poor soils and adverse environmental conditions, with widespread grazing of camelid livestock on pastureland (Tichit and Genin, 1997; Campero, 2004; Markemann et al., 2009; Treydte et al., 2011), where HAWs serve as forage grounds, particularly in dry seasons (Buttolph and Coppock, 2001; Buttolph and Coppock, 2004). Wetland degradation due to overgrazing plus possible effects of shifting climate patterns is of increasing concern (WWF, 2006). Studies have been initiated under the Law of Mother Earth and Integral Development for Living Well,[1] trying to establish an inventory with classification of wetlands inside the Sajama National Park, Bolivia. Research is being undertaken on high wetlands by the International Peat Society (IPS) in Bolivia, which includes monitoring glacial recession and distribution across the Andes, the hydrological process, and vegetation. Villarroel et al., (2014) studied local management of Andean wetlands by indigenous camelid herders and their social institutions in highland Bolivia. Several studies examined pasture-based livelihood and resource management in relation to environmental impact (Buttolph and Coppock, 2001; Preston et al., 2003; Yager et al., 2008). Yet, no study has explicitly examined the services and socio-economic benefits of HAWs to indigenous communities in this area (Balvanera et al., 2012).

The study was intended to develop a socio-economic assessment of HAWs in relation to the livelihood and indigenous culture of local human settlements. It attempted to use the ecosystem service framework to characterize and highlight the socio-economic importance of HAWs. It was motivated to inform wise use and management of HAWs in future development and decision-making by explicitly identifying and quantifying wetland services and benefits. In this study, we conducted a field survey including interviews with key stakeholders such as government officers and local households to examine local perceptions and interaction with HAWs. We adopted the stakeholders' perspective to identify major ecosystem services provided by HAWs to local community, and applied a set of valuation techniques to estimate the economic values of identified services. This study contributes to understanding of the coupled socio-ecological system of mountain pasturelands and indigenous Andean communities, in which wetlands play a critical role.

2. The Caripe community: case study area

This study focused on HAWs at Caripe, a community located at the foot of the Sajama Peak at the northeast edge of the Sajama National Park in central western Bolivia (Fig. 1). Created in 1939, the Sajama National Park covers a territory of approximately 100,000 ha (Yager et al., 2008). It surrounds Mount Sajama (6542 m above sea level) encompassing a series of valleys and plains, and is characterized by a heterogeneous landscape of grassland, shrubland, bofedales, and open plains (Villarroel et al., 2014). HAWs are mostly found in valley bottoms (3950–4300 m above sea level) and occasionally on mountain slopes (4500–4800 m above sea level), where vegetation is dominated by small herbs, sedges, and grasses forming thick cushions crosscut with streams (Alzerreca et al., 2007; Molinillo and Monasterios, 2007, cited in Villarroel et al., 2014). The park is home to five indigenous communities whose livelihood relies on highly productive HAWs for camelid pastoralism (Yager et al., 2008; Buttolph and Coppock, 2001; Villarroel et al., 2014).

Caripe is located in the Desaguadero sub-basin of the Lake Titicaca basin. The hydrology of the wetlands is affected by the Sajama, the Tomarapi River and some small streams (Molina, 1996). Storage and recharge in the Sajama are regulated by the rainfall-runoff process of the glacier in the upper part of the basin and subsurface runoff originating from the volcanic source of the geological formation that characterizes the landscape of the study area (Molina, 1996). The vegetation of the wetlands comprises mainly grasses (*tholares*), sedges (*pajonales*), and peaty meadows. Cyperaceae and Juncaceae dominate, with overall low and compact growth forms (Beck et al., 2010). The fauna of the wetlands is of Andean origin. At Caripe and across the Sajama National Park, wetlands are currently subject to loss of biodiversity and alterations, due to climate change and overgrazing by llamas and alpacas (Cuesta et al., 2012; Rocha, 2003). Table 1 lists animal species present in the wetlands and their conservation category.

The Caripe community is representative of the area, with a small number of households and wetlands of limited size, ranging across a surface area of 485 ha at an average altitude of 4120 m above sea level (Canedo, 2011). Administratively, Caripe belongs to the municipality of Curahuara Carangas in the Sajama Province of the Oruro Department, Bolivia (Canedo, 2011). Average annual rainfall of 320 mm typically occurs between December and March, followed by arid conditions from April to November (Garcia, 2011). Owing to high altitudes, temperature in the study area is low, with

[1] Law No. 300 "Law of Mother Earth an Integral Development for Living Well" passed by the Bolivia's Plurinational Legislative Assembly in December 2010 took effect on October 15, 2012.