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Burning biodiversity: Fuelwood harvesting causes forest degradation in human-dominated tropical landscapes

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ABSTRACT

This study provides an approximation of the potential impact of fuelwood harvesting in one of the most threatened tropical biodiversity conservation hotspots, the northern portion of the Brazilian Atlantic Forest. We test the relationship between fuelwood consumption and per capita income for 270 households distributed over 7 rural settlements. In general 76% of the households use fuelwood regularly and consume on average 686 kg/person/year of tree biomass, poorer people, however, consume 961 kg/person/year. Harvesting is concentrated to a few early successional species. Yet, annual rural population demand from 210 municipalities may reach 303,793 tons, equivalent to 1.2 to 2.1 thousand hectares of tropical forest. Fuelwood harvesting cannot be ignored as a major and chronic source of forest degradation in highly fragmented and densely populated landscapes and conciliating biodiversity conservation with poverty amelioration is an urgent task.

1. Introduction

Currently, up to 2 billion people depend on forest goods such as fruits, game meat, fibers and fuelwood to meet their basic needs (FAO, 2011; May-Tobin, 2011). Fuelwood harvesting in developing countries is so important that it rivals other sources of industrial energy such as electricity, principally among poor people in rural areas (FAO, 2011; Mead, 2005). In Africa, 58% of the energy supply comes from fuelwood and charcoal and this percentage in Latin America and Asia, though lower, is 15% and 11% respectively, and cannot be neglected as a potential source of ecosystem disturbance (Salim and Ullsten, 1999). Environmental damage from fuelwood harvesting can be significant if too many people depend on too few forested areas and the ecosystem services they deliver. Many tropical biodiversity hotspots (Bouget et al., 2012; Myers et al., 2000) represent such a scenario where numerous human populations rely on vanishing, reduced and fragmented forests to meet their demand for fuelwood, land for agriculture and ingestion of animal protein (Peres et al., 2010; Ruger et al., 2008). However, the environmental impacts of fuelwood consumption are somewhat neglected by both authorities and conservationists, probably because this activity constitutes a cryptic and chronic disturbance thought to be of less concern in the face of other major causes of biodiversity loss such as deforestation due to land use shifts (Bensel, 2008; Puyravaud et al., 2010).

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The synergism between fuelwood consumption and biodiversity maintenance is actually poorly understood but negative feedbacks have been reported elsewhere in the literature (Bensel, 2008; Bouget et al., 2012; Brito, 1997; Mahiri and Howorth, 2001; Ravindranath and Sukumar, 1998; Tole, 1998). In Africa, some protected areas have been encroached by illegal charcoal traders, negatively affecting biodiversity and specifically threatening highly endangered species such as mountain gorillas (Ferraro et al., 2011; Sodhi et al., 2011). Most of the 34 biodiversity hotspots are totally, or principally, located in populous developing countries where a significant portion of the human population depends on biomass for cooking and heating their homes (Barrett et al., 2011; Myers et al., 2000). This can cause significant forest degradation not detected by satellite images and large-scale monitoring of forest cover (Peres et al., 2006; Puyravaud et al., 2010). Therefore, even sustainable and productive socioecological systems may experience pervasive and severe levels of small-scale chronic disturbance.

There is a significant amount of evidence on the major large-scale threats to tropical biodiversity such as habitat loss and forest fragmentation (Busa, 2013; Tscharntke et al., 2012), however, there is a lack of knowledge regarding the impact of several sources of small-scale disturbance, such as fuelwood harvesting (du Plessis and Maennig, 2011). Most reports on the potential impacts of fuelwood harvesting on tropical forests are anecdotal or come from studies aiming to assess poverty and/or energy issues that do not assess the biodiversity status of the forests that provide this ecosystem service (May-Tobin, 2011). On the other hand, at smaller spatial scales the dynamics of fuelwood harvesting can be described through the socioeconomic drivers that may help to feed broader scenarios (du Plessis and Maennig, 2011; Ramos and de Albuquerque, 2012; Top et al., 2004). In Brazil, unfortunately, even these community-based studies are extremely rare but the few that do exist suggest that poverty is positively correlated with fuelwood consumption (Ramos and de Albuquerque, 2012; Ramos et al., 2008a,b).

Conservation programs must consider the "human matrix" in which forest remnants are embedded, by quantifying the magnitude of the chronic small-scale disturbances as a key component of landscape quality (Melo et al., 2013). In Brazil, the Atlantic coastal forest – probably the "hottest of the hotspots" (Laurance, 2009) – was drastically reduced by the expansion of sugar-cane monocultures during the 1970s, but its remnants are currently the main source of fuelwood and game meat for millions of people (Brito, 1997; Medeiros et al., 2012). In the northern portion of the Brazilian Atlantic Forest, the average per capita income is amongst the lowest in Brazil (IBGE, 2011) and millions of people live in this region, where only 11% of the original forest expanse still remains, albeit in a highly fragmented landscape where more than 90% of the forest fragments are smaller than 50 ha (Ribeiro et al., 2009). In this scenario is reasonable to expect that the demand for fuelwood has the potential to be an important source of forest degradation.

Official data on fuelwood consumption is often focused on industrial demands and neglects domestic consumption (Ministério de Minas e Energia, 2011). An alternative for assessing domestic demand is to indirectly estimate fuelwood consumption through its relationships with socioeconomic variables that are officially available through periodic population censuses. This allows reliable estimations that, although rough, are useful as an initial approach and have potential for practical applications and for the design of public policies. In Brazil, fuelwood for cooking and heating is often consumed by poor people that cannot access industrial sources of energy such as gas and electricity due to economic and/or infrastructural constraints (Brito, 1997). We therefore, tested whether household income is negatively related to both the likelihood of consuming fuelwood and the amount of this resource consumed in rural villages of Northeastern Brazil.

In this study we first describe the patterns of fuelwood consumption of 270 families in seven localities that represent the main socioeconomic and infrastructural conditions of rural populations across a $>$50,000 km^2 region. We then assess the nature of the relationship between per capita income and both the likelihood of fuelwood consumption and the biomass of fuelwood consumed by rural populations. Finally, based on the relationships found locally, we estimate: (1) the likelihood of rural populations relying on fuelwood as a function of the per capita income; (2) whether there is any synergism between fuelwood harvesting and shifts in tree species composition due to land use changes; and (3) the magnitude of tree biomass extraction from the forest remnants of the region as a whole. We then discuss our results in the face of the impacts of this cryptic source of forest degradation and its potential consequences for the conservation of a highly threatened and biologically diverse tropical forest.

2. Material and methods

2.1. Study area

The study took place in seven localities in the northern Brazilian Atlantic Forest (Fig. 1; Table 1).This is a distinctive region of the Brazilian Atlantic Forest (hereafter BAF) considered to be a center of endemism for several biological groups such as birds, frogs and vascular plants. It comprises approximately a 56,000 km^2 landscape, highly deforested and fragmented and constitutes one of the most threatened portions of the BAF with less than 11% of its original area still remaining in the form of thousands of forest fragments, most of them $<$50 ha and embedded in a biologically-inhospitable matrix of sugar-cane fields (Ribeiro et al., 2009). The region is also culturally and economically distinctive in Brazil as it harbors the most dense population along the Brazilian coast, combined with one of the lowest rural per capita incomes in Brazil (IBGE, 2011). Such a scenario of poor people living around degraded and fragmented tropical forests in a matrix of sugar-cane plantations belonging to big landowners led poor people to rely on natural resources, such as wood, for several purposes including fuelwood for cooking (Medeiros et al., 2012). The seven localities were chosen because they were representative of the main sociopolitical conditions of the region and were located near important forest remnants (Tabarelli et al., 2005). The localities surveyed were either: (a) small rural villages (less than 50 households) embedded within very large private lands