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# Forest ecosystem services derived by smallholder farmers in northwestern Madagascar: Storm hazard mitigation and participation in forest management

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## ABSTRACT

Tropical dry deciduous forests provide numerous ecosystem services yet their contribution to agricultural production remains underexplored. We address this research gap by quantifying the broader suite of ecosystem services that support small holder farmers and identifying farmers' knowledge of storm hazard reduction benefits provided by forest fragments in Madagascar. We survey 240 households and interview eight key informants to identify household and community responses in two communities with contrasting forest cover trajectories. Using multivariate statistics, results show a heavy dependence on forests for food and raw materials and a majority of the respondents holding a positive view of hazard mitigation services provided by forest fragments. Education levels, earning an income from forest based tourism and honey production are the only predictors of participation in forest management. Positive view of the hazard reduction benefits derived from forests could be due to external influences or personal observations, and together with barriers to participation in forest management need to be further investigated to better link forest management to reduced hazards risks. These findings are significant for forest management policy, as local knowledge and rationale for decisions are instrumental in the success of decentralized forest management and maintenance of vital forest benefits to farmers.

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## 1. Introduction

Tropical dry deciduous forests, one of the most threatened biomes on the planet, hold a high density of mammalian biomass and provide essential ecosystem services to people (Lerdau et al., 1991; Maass et al., 2005). These forests provide water regulation and pollination services as well as food, timber, water for irrigation and non-timber forest products (Maass et al., 2005). Ecosystem services, defined as the benefits people derive from nature (MA, 2005), provide an anthropocentric motivation for sustaining nature to support human needs and society (Fisher et al., 2014). Provisioning services such as timber, food and non-timber forest products that can be used directly by people are more easily linked to human needs (Daily et al., 1997; Barbier et al., 2010; Wunder et al., 2014). However, forests, wetlands and coastal habitats also provide several regulating services that aid in disaster risk reduction by decreasing the exposure of communities to hazards such as floods and storm surge (Sudmeier-Rieux et al., 2006; Brauman et al., 2007; Laurance, 2007; Martin and Watson, 2016). While much attention has been paid to the role of forests in supporting rural livelihoods through provisioning services, less work has been done on

assessing the importance of the hazard reduction functions of forests (Howe et al., 2014). In this paper we address this research gap by providing a detailed case study of the hazard mitigation services generated and valued by smallholder farmers in a tropical deciduous forest mosaic in northwest Madagascar.

Land cover change, particularly deforestation, is hypothesized to increase flood risk (Bradshaw et al., 2007) and is seen as a primary driver of soil erosion and consequent siltation of irrigation channels and agricultural fields (Bakoariniaina et al., 2006; Minten and Randrianarisoa, 2012). Inland forests have been argued to reduce the frequency and magnitude of floods, and there is some consensus that compared with other land uses, tropical forests reduce peak flows from small catchments during small to medium rainfall events (Bruijnzeel, 2004; Alila et al., 2009; Tan-Soo et al., 2014). In the bioengineering literature, forests, especially in mountainous areas, are considered to provide protection for exposed communities from rockfalls, debris flows, erosion, floods and shallow landslides (Brang et al., 2001; Dorren et al., 2004; Alila et al., 2009). Flood risk is also mediated by human decisions about land use and land cover change including the type and location of farms, urban and semi-urban areas, plantations, and industrial areas (Wisner et al., 2004; Wheater and Evans, 2009). Thus the exact relationship between forest cover and changes in flood frequency and magnitude and consequent impacts on people varies

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between sites, with both biophysical and social elements influencing this relationship (Bruijnzeel, 2004; Blöschl et al., 2007).

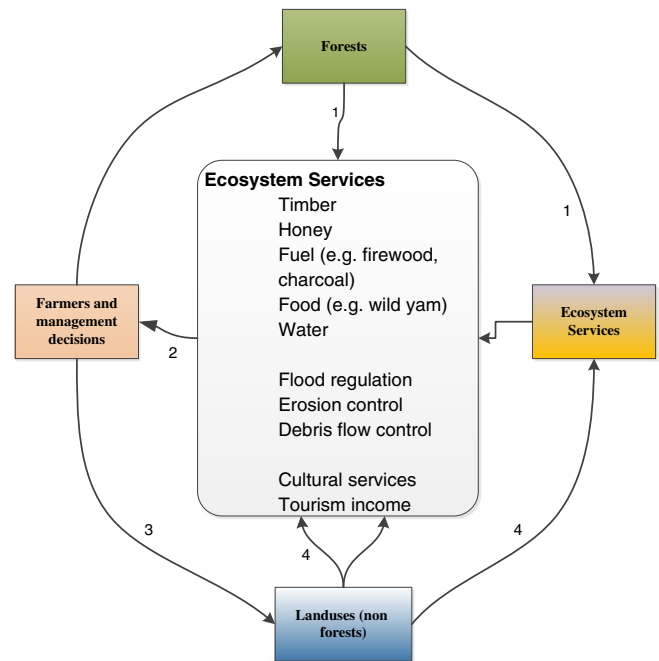
Two of the approaches commonly relied upon in the biophysical assessment of the effects of forest loss on hydrological processes are paired catchment studies and process based modelling (Wilk et al., 2001; Bruijnzeel, 2004; DeFries and Eshleman, 2004; Krishnaswamy et al., 2012; Kuraš et al., 2012). Despite a lack of application in the developing world, studies using these approaches have yielded some consensus on the role of forest cover in reducing flood hazards and different forms of erosion and sediment yield in some situations. For instance, it is understood that total annual water yield (flooding) increases with the percentage of forest biomass lost after conversion and that dry season flow can decrease with time as groundwater replenishment decreases after a number of years (Bruijnzeel, 2004; Kuraš et al., 2012). In general these findings are site specific, and remain difficult to extrapolate to other areas or larger scales as there is too much variation in findings (Bruijnzeel, 2004; DeFries and Eshleman, 2004). Thus, as Van Dijk et al. (2009) and Calder and Aylward (2006) state, there are no simple causal relationships between forest cover change and changes in floods or erosional impacts.

Ecosystem services generated by seasonally dry tropical deciduous forests (TDF) are some of the most understudied set of socio-ecological interactions (Maass et al., 2005) particularly in the developing world. Seasonally dry forests have seen widespread transformation by people and are considered as the most threatened of tropical forests (Miles et al., 2006; Becknell et al., 2012). Madagascar's dry deciduous forests form one of 200 ecoregions identified as ecosystems with high global conservation value that are also facing critical threats (Olson and Dinerstein, 1998). Threats to these forests differ in different regions, with fires and conversion for agriculture the most important direct threats in Africa (Geist and Lambin, 2002; Lambin et al., 2003; Miles et al., 2006). We argue that if the role of forests in reducing excess sedimentation and debris flows and floods in rural areas is to be better understood, a more focused investigation of the environmental knowledge base of local communities in forest frontier regions is needed. Unlike the use of hydrological models or paired catchment studies, we employ a local knowledge and perceptions' approach to assess agricultural risk reduction benefits derived from regulating services provided by forests as it is these perceptions that will shape local land use decisions and the effectiveness of forest management policies. In this paper, using an ecosystem services' lens, we employ household surveys in seven villages in Madagascar as a means to identify local benefits derived from seasonally dry TDFs landscapes, and how hazard mitigation is perceived as an ecosystem benefit valued by farmers in forest frontier areas (Fig. 1). We hypothesize that:

- 1) Farmers in seasonally dry forest mosaics derive livelihood benefits from forest patches, including hazard mitigation services.
- 2) Farmers' understanding of the forest-hydrological cycle linkages is associated positively with less exploitative uses of forests and with perceiving the hazard mitigation benefits of forests, especially with flood regulation.
- 3) Deriving forest use benefits and perceiving hazard mitigation benefits of forests motivates participation in community forest management groups.

We first describe the study area, methods of data collection and analyses performed, then focus on answering three research questions, which address the hypotheses above:

- What are the forest ecosystem services, including hazard mitigation services, and benefits to livelihoods derived by small-holder farmers in seasonally dry deciduous forest zones?
- How do farmers understand the relationship between forest cover and water regulation, and how is this associated with their attitude towards forest ecosystem benefits including hazard mitigation services?



**Fig. 1.** The pathways of ES flows from forests (1) to farmers include the use of raw materials, e.g. timber, honey production, fuelwood, food, tourism income and recognition of regulatory services such as flood and erosion control (2). Such uses and benefits have consequent land use impacts (3) which feed back into ES flows and benefits to farm households and influence forest management decisions (4). Our research questions focus on the uses and perceived regulatory services derived by farmers and linkages to forest management decisions.

- What is the relationship between the acknowledged livelihood benefits of ecosystem services and the willingness of people to actively protect forests (using a proxy variable of engaging in forest management group activities)?

We then present the results on the frequency of use of various forest ecosystem services, whether farmers' acknowledge flood and sedimentation hazard reduction benefits of forest fragments found locally across the study area, and how these uses and attitudes translate into valuation of forests through participation in forest management activities for the site with existing forest management groups. We conclude by discussing the implications of these findings for different aspects of forest management policies, including decentralized governance of forest resources, and implications for linking forest management to agricultural hazard reduction policies and livelihood benefits.

## 2. Study area

We study this problem in the Boeny region of northwestern Madagascar, which experiences a strong seasonal variation in precipitation that influences all aspects of the agropastoral rural lifestyle. The yearly average rainfall is 1700 mm, with a distinct rainy season during November to March (Funk et al., 2015). The region is characterized by small-scale farming and a population dependent upon the surrounding landscape for everyday needs. In addition to farming, land cover includes seasonally dry broadleaf deciduous forest patches, lakes, raphia wetland remnants, and grasslands dominated by the endemic palm, known locally as satrana. Additionally, fruit trees such as the jackfruit tree and papaya are found abundantly in areas of human habitation, with much of the produce being transported to the city of Mahajanga (nearest urban center). Rice farming dominates agricultural production, which can be typically characterized as small-holder subsistence, primarily rain-fed, farming. Maize and cassava form the secondary

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