



Socio-environmental drivers of forest change in rural Uganda



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ARTICLE INFO

Article history:

Received 22 October 2015

Received in revised form 7 December 2016

Accepted 11 December 2016

Available online 22 December 2016

Keywords:

Tree planting
Deforestation
Reforestation
Uganda

ABSTRACT

Tropical deforestation and forest degradation are among the top global threats to biodiversity, carbon storage and rural livelihoods, but the social processes underlying these changes remain difficult to observe across large spatial scales and in data-poor contexts such as tropical Africa. We link longitudinal survey data from agricultural households in rural Uganda to high-resolution satellite data on forest cover change, and use this linked dataset to investigate processes at two scales: tree planting and harvesting at the parcel scale, and deforestation and reforestation at the community scale. This multi-scale analysis reveals that tree planting is more common on parcels with secure tenure, by educated heads and in isolated communities. Deforestation is highest in land-rich, agrarian communities with low population density and high baseline forest cover. These results provide explicit evidence that the social drivers of forest change in Uganda vary across scales, indicating a need for additional multi-scale studies.

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1. Introduction

The social drivers of forest change have been a major focus of study in the human-environment sciences for at least three decades, and will likely remain so given ongoing processes of tropical deforestation and forest degradation (Asner et al., 2005; Hansen et al., 2013). Over that time, a clear consensus has emerged that forest change must be understood as a social process with drivers at multiple spatial scales (Geist and Lambin, 2002), and a growing number of studies have used statistical approaches to examine the multi-scale drivers of tropical deforestation (Pan and Bilsborrow, 2005; Vance and Iovanna, 2006; Gray et al., 2008; Gray and Bilsborrow, 2014). However, despite these advances, most studies remain bound to a particular spatial scale of forest change (usually the pixel), ignoring sub-pixel processes such as tree planting and harvesting that can have important implications for rural livelihoods and carbon storage (Russell and Franzel, 2004; Jindal et al., 2008). Meanwhile, a distinct literature on smallholder tree planting has evolved in isolation from these debates, focusing on technical and legal approaches to promote tree planting (Pattanayak et al., 2003).

These issues are of particular importance in East Africa and in our study country of Uganda. A majority of the highly biodiverse forests of East Africa have already been lost to agricultural and pasture conversion, and the remaining forests are under significant pressure from growing rural populations, rising urban demand for wood products, and weak governance (Obua et al., 2010; Pfeifer et al., 2012). At the same time, wood product sales and agricultural extensification represent key livelihood strategies for a significant fraction of rural households (Angelsen et al., 2014; Babigumira et al., 2014). Adding to the salience of this study area is the near-absence of survey-based studies of forest degradation in tropical Africa. Survey methods allow structured data collection from informed observers over large spatial extents on the nature and drivers of forest change, including many dimensions that cannot be observed by remote sensing or in administrative data sources. Unlike Latin America, where a plethora of large-sample, survey-based studies have provided considerable insight into the social dynamics of forest change (e.g., Rudel et al., 2002; Summers et al., 2004; Pan and Bilsborrow, 2005; Gray et al., 2008), in tropical Africa data limitations have severely constrained this approach (for exceptions see Mertens et al., 2000; Codjoe and Bilsborrow, 2011; Babigumira et al., 2014).

We address these issues via a novel multi-scale analysis of forest change in rural Uganda. We link longitudinal survey data from a large sample of rural households to high-resolution spatial data on forest cover change. This allows us to conduct two distinct analyses:

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First, we investigate tree planting and harvesting at the parcel scale as influenced by characteristics of the parcel, household and community. Second, we model deforestation and reforestation at the community level as influenced by social and biophysical factors. The result is a clear distinction between processes across scales: Deforestation is most likely in agrarian communities with abundant land and forests and can be viewed as frontier process as described below. Tree planting occurs most often on remote parcels with secure tenure in climatically favorable areas, and can be viewed as a livelihoods-driven process. Together these results provide explicit evidence that the drivers of forest change differ across scales.

1.1. Previous studies

1.1.1. Deforestation

A large literature on the socio-environmental drivers of tropical deforestation has developed over the past three decades. Reviews of this work have highlighted findings that deforestation is most likely in areas that are accessible to transportation infrastructure, where legal restrictions on deforestation are absent or poorly enforced, where the incentives for timber extraction and/or conversion to pasture and agriculture are high, and where capital is available to support investments in land use change (Geist and Lambin, 2002). Despite these generalities, the nature of the actors involved varies considerably across contexts, ranging from family farmers, to mid-sized timber and cattle enterprises, to large-scale soy, oil palm and rubber producers (Rudel et al., 2009). In contrast to Southeast Asia and tropical Latin America (where most recent deforestation has occurred and where most recent studies have been conducted), deforestation in tropical Africa is characterized by the continuing importance of subsistence agriculture (Rudel, 2013), reflecting the region's relative poverty and isolation. This pattern of "African exceptionalism" also suggests that small-scale demographic processes may play a particularly important role in explaining deforestation. However, more detailed tests of this hypothesis have been hampered by the absence of data at household and community scales which are most relevant to small-scale deforestation processes.

Also relevant is the growing literature on forest transitions. This literature notes that, in many countries, after long episodes of forest loss the dynamic shifts to reforestation and increasing forest cover (Mather, 1992; Angelsen, 2007). The mechanisms for this shift vary across settings (Perz, 2007), but appear to include increasing scarcity of wood products, declining rural populations alongside rising wages, and increasing agricultural and timber productivity as well as imports (Mather and Needle, 1998; Rudel et al., 2005; Lambin and Meyfroidt, 2010). This perspective suggests that forest scarcity will be associated with lower deforestation, higher reforestation and more tree planting, a hypothesis we test in the analysis below.

1.1.2. The Ugandan context

In Uganda, deforestation occurs in a national context of rapid population growth, rising urban demand for wood products, and weak restrictions on land use in most rural areas. The population is growing quickly at an annual rate of 3.2%. Only 16% of the population lives in urban areas, but that percentage is increasing very rapidly at 2.1% of the population per year (United Nations, 2015). More than 90% of the urban and rural populations use wood products for cooking, and timber harvesting is increasing (MEMD, 2014). These pressures contributed to a loss of 8.5% of tree cover between 2000 and 2012, second only to Kenya among East African countries during that period (Hansen et al., 2013). Remaining forests cover 15% of the land area (Hansen et al., 2013) and include dense montane forests in the Western region, including several protected

areas, and a larger area of fragmented woodlands, primarily in the Central region (Obua et al., 2010; Pfeifer et al., 2012).

The system of land tenure is key part of the context for forest change in Uganda (Place and Otsuka, 2000). It is well-documented that the condition of forest cover is closely related to the status of land and forest tenure regimes (Banana and Gombya-Ssembajwe, 2000; Brasselle et al., 2002; Deininger and Jin, 2006; Fenske, 2011). In Uganda, private lands are held under a complex set of tenure regimes, including freehold (fully private), leasehold (private, leased), customary (governed by local rules), and *mailo* (a colonial system with rights for both title holders and occupants) (Place and Otsuka, 2000). Although there are four different types of land tenure, about 70% of forest (woodland and scattered trees) is on private and customary land, and management of some publicly-owned forests has been devolved to local units of government (Buyinza and Nyakaana, 2010; Obua et al., 2010). While private, customary and public lands are all undergoing intensive deforestation, forests under private tenure still retain greater biodiversity compared to forests under government tenure (Turyahabwe and Tweheyo, 2010). Land tenure rights are also strong determinants for tree harvesting and/or planting (Otsuka et al., 1997), the latter of which has been promoted to mitigate dramatic forest loss. Both private and publicly owned forests serve as key forms of natural capital for rural households, who draw on them for fuelwood, charcoal production, timber production, other forest products, and creation of new agricultural and pasture lands (Khundi et al., 2011; Jagger, 2012).

The policy environment in Uganda is also a key element of the context of forest change. The data used here were collected soon after the restructuring of the forest-sector in Uganda. Included in the 1995 Constitution was a legislative mandate to reform forest management throughout the country (Jagger, 2010). The first step in this reform took place in 1999 with the initiation of the Forest Sector Umbrella Programme (FSUP). The main goal of FSUP was to increase the economic and environmental benefits that Uganda's citizens received from forests through the creation of sustainable and efficient policies that supported decentralized institutions (MWLE, 2004; Jagger, 2010). The creation of the FSUP was followed by the Uganda Forest Policy in 2001, (MWLE, 2001), the National Forest Plan in 2002 (MWLE, 2002), and the National Forestry and Tree Planting Act in 2003 (GOU, 2003), which, among other things, mandated the "sustainable use of forest resources" and the "promotion of tree planting". Throughout this reform process Uganda saw a transition from centralized to decentralized forest management as the Forestry Department was replaced with the District Forestry Service, which currently manages 70% of Uganda's forests, and the National Forestry Authority, which manages 15% of Uganda's forests. The remaining 15% is managed by the Uganda Wildlife Authority (Jagger, 2010). Overall, the goal of the reform process was to improve the lives of Uganda's citizens – particularly the poor and vulnerable – to increase livelihood opportunities in the forest sector, and to preserve the country's forest cover.

In this context, a handful of previous multivariate studies have investigated the drivers of deforestation in Uganda using a combination of survey, remote sensing, and secondary data sources. Place and Otsuka (2000) linked remotely sensed data on tree cover at two time points (1960 and 1995) to community survey and secondary data for 64 village clusters in central Uganda. Analysis of these data revealed that agricultural extensification increased with customary land tenure, population density, and proximity to a paved road, while tree cover loss in non-agricultural areas increased with population density, spatial accessibility, mean rainfall, and baseline tree cover. Subsequently, Pender et al. (2004) used community survey data from across rural Uganda (n = 107) to model the determinants of perceived changes in land use, and found that improved road access led to decreases in forest cover and increases

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