Forest Ecology and Management 304 (2013) 171–181

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

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

Factors controlling patterns of deforestation in moist evergreen Afromontane forests of Southwest Ethiopia

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ARTICLE INFO

Article history:
Received 10 January 2013
Received in revised form 4 March 2013
Accepted 1 May 2013
Available online 30 May 2013

Keywords:
Afromontane
Coffee
Deforestation
Land use change
Logistic regression
Southwest Ethiopia

ABSTRACT

This study aims to contribute to a better understanding of deforestation processes of moist evergreen Afromontane forests by disentangling the role of biophysical and socio-economic factors. Hitherto deforestation patterns between 1957 and 2007 were mapped for 9 villages in the Jimma zone of the Oromia regional state in Southwest Ethiopia on the basis of aerial photographs and high- resolution satellite images. The results show a 19% decline in forest cover since 1957. A spatial analysis of the observed deforestation patterns showed that the way of living and the accessibility to markets has controlled to a large extent the spatial pattern of deforestation during the past 50 years. Forest was lost mainly at remote locations away from the main roads where market integration is difficult. Farmers in these locations are relatively poor and self-subsistent which implies that population increase automatically led to new deforestation. Places very nearby to market places were spared from deforestation because of the presence of off-farm jobs in the towns. Significantly less deforestation was observed in areas that are suitable for the growth of shaded coffee. The areas above 2000 m.a.s.l that are not suited for shaded coffee are typically inhabited by relatively poor households who are living far from roadsides and thus are less integrated to the surrounding major markets. As a result, they depend more on subsistence farming causing more deforestation than other households.

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1. Introduction

Tropical forests worldwide provide the largest biological diversity of plants and animals. It is estimated that they contain at least 50% and almost 75% of the world's animal and plant species respectively (Laurance, 1999; Achard et al., 2002a,b; Frey, 2002). Moreover, they provide many ecosystem services that can be directly related with human well-being at local, regional and global scale levels. Increased deforestation is likely to reduce biodiversity and to result in many other negative impacts on the environment such as soil erosion, nutrient depletion, decrease in the amount of available groundwater, destruction and fragmentation of natural habitats, flooding, increased levels of greenhouse gases, disturbances of the carbon cycle and loss of forest products like pharmaceuticals, timber and fuel (e.g. Angelsen and Kaimowitz, 1999; Laurance, 1999; Achard et al., 2002a,b; Frey, 2002; DeFries et al., 2006; Dessie and Kleman, 2007; Turner et al., 2007).

Despite such crucial benefits, these forests are under continuous pressure from various and adverse human activities and they are being degraded at alarming rate. During the 1980s for example, about 15.4 million ha of tropical forest was lost each year (FAO, 1992) and converted into a mosaic of mature forest fragments, pasture, and degraded habitats (Rudel and Roper, 1997; Laurance, 1999; Verolme et al., 1999). Strategies to slow down and eventually reverse tropical deforestation trends became an important point on the agenda of national and international policy makers.

A global comparison of tropical deforestation rates shows a large spatial variability. Hotspots of tropical deforestation can be found in Southeast Asia, Latin-America and Africa (Achard et al., 2002a,b; Lepers et al., 2005). Recent studies (e.g. Brink and Eva, 2009), however revealed that deforestation rates in many parts of the tropical area are slowing down. In some cases forest transitions, i.e. the transition from a phase of net deforestation to net reforestation have been reported (Mather and Needle, 1998; Mather et al., 1999; Rudel et al., 2005). Table 1 gives an overview of recent studies that describe forest transition in the tropical zone.

Typically forest transitions can be linked with pathways of (1) economic development and migration of the people leading to urban areas, (2) abandonment of arable fields because of land degradation and forest plantation due to forest scarcity and (3) government steered reforestation programmes. Hitherto, however, very few forest transitions have been described in tropical Africa. Possible reasons for this observed delay are an ongoing exponential population growth, a large proportion of people being employed in

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http://dx.doi.org/10.1016/j.foreco.2013.05.001

Table 1
Examples of reported forest transition locations and their respective causes in the tropics.

Reference	Location	Turnover point of forest transition	Main driver
Zhou et al. (2009)	China	2005	Implementation of national scale reforestation programme
Meyfroidt and Lambin (2008)	Vietnam	1990	Economic development and forest plantations
Sánchez-Cuervo et al. (2012)	Colombia	2001	Land abandonment because of internal conflict, economic development
Bae et al. (2012)	South Korea	1955	Implementation of national scale reforestation programme, economic development
Rudel et al. (2002)	Ecuador	1987	Outmigration, expansion of market oriented agricultures
Grau et al. (2003)	Puerto Rico	1940	Economic development and urban growth
Rudel et al. (2005)	India	1990s	Implementation of national scale reforestation programme due to scarcity in forest products

self-subsistence farming and the slow adoption of modern farming technology that could result in higher crop yields (Teka et al., 2013).

Despite the fact that some review papers (Geist and Lambin, 2001) provided a wide overview of factors controlling deforestation processes, such overviews appeared to be insufficient for the development of successful land use policies that could stop deforestation. The main reason for this must be sought in the complex nature of society–environment interactions which are often very site-specific. Since the tropical area is very diverse both from biophysical and socio-economic perspectives, a uniform policy scheme has little chance to be successful. Most studies on tropical deforestation in Africa focus on the tropical lowlands in western and central Africa. However, relatively little is known regarding the society-environment interactions that lead to deforestation of the moist evergreen Afromontane forests in the East-African highlands.

This study aims to contribute to a better understanding of the deforestation processes of the moist evergreen Afromontane forests by disentangling the role of biophysical and socio-economic factors for a study site in the Jimma area of the Oromia regional state in Southwest Ethiopia. The study site is located in a relatively remote location near the waterdivide between the Blue Nile and the Omo-Gibe River basins where ongoing deforestation is causing problems at a national scale level. The local deforestation has been linked with processes of sediment delivery to the main river (Broothaerts et al., 2012), which seriously hamper the functioning of newly installed hydropower plants that are considered to be of vital importance for the economic development of Ethiopia. Moreover, the recent deforestation is perceived as a source of potential conflicts between various land users (Wood, 1993). Shifting cultivators that are driven by poverty get in conflict with forest farmers that collect natural coffee, spices and honey from the natural forests (Wood, 1993).

The main hypothesis of this research paper is that deforestation dynamics and the corresponding patterns in the rural areas of Southwest Ethiopia which are characterized by poor people living from self-subsistence farming are quite different from tropical forest-rich places such as the Amazon or the Congo basins, where deforestation mainly occurs along roads (Mertens and Lambin, 1997; Soares-Filho et al., 2004; Wilkie et al., 2000; Southworth et al., 2011). In order to reveal the spatial logic behind deforestation in the moist evergreen Afromontane forests of Southwest Ethiopia both socio-economic variables describing the various ways of living and biophysical variables were collected and mapped.

In order to better understand the driving factors of deforestation and its related environmental and socio-economic problems, the following specific objectives were considered: (1) to determine and quantify forest cover changes occurred during 1957–2007; (2) to identify and analyze the most significant explanatory variables that lead to forest conversion in Southwest Ethiopia; (3) to establish a predictive deforestation model that takes into account biophysical and socio-economic factors.

2. Materials and methods

2.1. Study area

The selected study area is located near the waterdivide between the Blue Nile River and Omo-Gibe River basins in Southwestern Ethiopia (Fig. 1). It consists of seven villages and two local towns: Yebu and Bilida which are important market places. The total area of the study site, which extends between 7°37′53″N–7°53′00″ N and 36°41′01″E–36°50′44″E, is 184.6 km^2. The study area belongs to the socio-economic sphere of influence of the city of Jimma, with a population of 120,960 inhabitants (CSA, 2007) and located at a distance of 360 km southwest of Addis Ababa, the capital of Ethiopia.

The topography of the study area is dominated by undulating hills dissected by many small tributaries that drain northward to the Blue Nile basin or southward to the Omo-Gibe basin. The overall elevation ranges from 1700 m.a.s.l in the eastern part of the study area to 2400 m.a.s.l in the western part. The climate is characterized by two distinct seasons: a wet season from April till mid September and a dry season from November till January (Legesse et al., 2003). On average, the area receives annual rainfall of ca. 1550 mm with an increasing trend towards the north. The mean monthly air temperature varies between 13° C and 25° C (Personal communication with Mana District Agriculture and Rural Development Office, 2009). Dystric nitisols dominate the area whilst considerable proportion of chromic vertisols, eutric nitisols, eutric fluvisols and dystric fluvisols are also present (BPED, 2000). According to Central Statistics Agency of Ethiopia (CSA, 2007), the study area has a total population of 58,544 resulting in an average density of 317 in h/km^2 which is an increase of 55% since 1984.

Agriculture is the main income source for 86% of the population. Agriculture is characterized by mixed farming systems run by smallholders whereby local households grow cereals and enset (*Ensete ventricosum*) and keep livestock of cattle, goat and sheep. Common cereal crops are maize (*Zea mays*), teff (*Eragrotis tef*), sorghum (*Sorghum bicolor*), and barley (*Hordeum vulgare*). Cereals and livestock products are mainly meant for self consumption. In order to acquire an additional income many households are engaged in beekeeping and the growth of cash crops such as coffee (*Coffea arabica*) and Khat (*Catha edulis*) and various fruits and vegetables. Farmers sell their products on local markets in Yebu, Bilda and the city of Jimma. The long occupational history of the area has resulted in a fragmented landscape with patches of open fields and grazing land alternated with patches of primary and secondary forests.

2.2. Forest cover mapping

The forest cover in 1957 and 1975 was mapped by visual interpretation of aerial photographs at a scale of 1:50,000 provided by the Ethiopian Mapping Agency (EMA). An additional forest cover

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