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Impacts of land-use change on sacred forests at the landscape scale

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ABSTRACT

Sacred forests often exist as isolated patches of natural forest even after conversion of the surrounding matrix to different forms of land-use. This study set out to: (1) evaluate land-cover changes and patch fragmentation in a landscape containing sacred and non-sacred forest patches over 15 years and (2) compare the effects at an individual patch level between sacred and non-sacred forests. Past changes in area and patch fragmentation of land cover classes and individual forest patches in the Gamo Highlands, Ethiopia, were assessed using maximum-likelihood classification of LANDSAT images. Large changes in land-cover occurred during 1995–2010, with 109.4% increase in area of farm and settlement and 36.6% decrease of forest area, with a decrease in number of forest patches by 16.1%, mean size by 26.8%, edge density by 29.1% and shape index by 13.3%. While all four individually studied non-sacred forests decreased in size over this period only four of the six individual sacred forests patches showed reduction in area. Forest patches with sacred status had greater protection by local communities than non-sacred forests in the Gamo Highlands. However, their small size and increasing edge density indicate high vulnerability, especially if an erosion of traditional cultural values reduces their protection.

1. Introduction

Deforestation and degradation of wooded habitats due to anthropogenic activities (especially land-use change) are among the major contributors to current global climate change and biodiversity reduction (Foley et al., 2005; Echeverría et al., 2007; Zanella et al., 2012). Human population growth pressures are expanding the area of land-uses such as agriculture and settlement into natural habitats in all parts of the world to meet the demand for food and housing (Lambin et al., 2003; Kabba and Li, 2011). These land-use changes have led to deforestation, further aggravating fragmentation of remaining forest habitats (FAO, 2003; Ellis-Cockcroft and Cotter, 2014; Riutta et al., 2014). In response to this, large investments have been made in the establishment of nature reserves across the world to preserve large pristine areas. The establishment of these reserves has sometimes not been successful as the initiatives are often politically driven and aspire to achieve environmental benefits without the involvement of immediate users or local communities (Brown, 2003; Bhagwat and Rutte, 2006; Khan et al., 2008; Pullin et al., 2013). On the other hand, many local communities conserve forest patches in their habitation area in the form of sacred forests for cultural purposes (Claudia, 2008; Uyeda et al., 2014). In addition to their cultural significance, these forests are important for the conservation of species useful to local people (Wadley and Colfer, 2004) and of biodiversity conservation importance (Mgumia and Oba, 2003; Anderson et al., 2005; Bhagwat and Rutte, 2006;

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Rim-Rukeh et al., 2013; Tamalene et al., 2014). Consequently, despite increased pressures, they have coexisted with human populations for centuries where they are under the custody of whole communities or sufficiently influential religious leaders. They may therefore serve both local resource needs and international conservation goals (Swamy et al., 2003; Wadley and Colfer, 2004; Kokou et al., 2006; Ormsby and Bhagwat, 2010; Umazi et al., 2013).

Protection of sacred forests that remain in landscapes dominated by agriculture is of critical importance in many countries due to the past rapid loss of natural habitat as a result of land-use change. The value of these forest patches for biodiversity conservation has gained increasing attention through recent studies (Bhagwat et al., 2005; Khumbongmayum et al., 2006; Ambinakudige and Sathish, 2009; Lehouck et al., 2009; Echeverría et al., 2012; Sponsel, 2012; Gao et al., 2013; Tamalene et al., 2014). The continuing protection of these remnant sacred forests by traditional custodians, due to the high local value of the associated culture, has recently been recognized at the international level (Ramanujam and Kadamban, 2001, Ormsby, 2011, Corrigan and Hay-Edie, 2013, Ormsby, 2013). Sacred forests are mentioned in the Convention on Biodiversity (CBD, 1992), the Sacred Site Programme proposal of the United Nations Educational, Scientific and Cultural Organization (UNESCO, 1996) and in the Sacred Natural Site (SNS) management guidelines published by the International Union for Conservation of Nature (Wild and McLeod, 2008). These, however, tend to focus only on the biodiversity and ecological importance of the sacred forests. They do not provide a detailed analysis of the threat posed by land-use activities in the surrounding matrix. Furthermore, there is a lack of spatio-temporal characterization of sacred forests at the patch level or quantification of the rate of change in surrounding land-use/land-cover at the landscape scale, which are crucial indicators of the current status of sacred forests, trends in the recent past and requirements for their future conservation.

Ethiopia has many sacred forests under the stewardship of indigenous communities. They are particularly common in south-west Ethiopia, where they have been protected by strong local beliefs in their status as sacred sites and consequent strict application of religious rules for their protection (Desalegn, 2007; Berhane-Selassie, 2008). The Gamo Highlands are recognized as a particularly important area for these sacred forests: our vegetation survey within sacred forest patches showed high species diversity and abundance in comparison with non-sacred forests in the same region (Desalegn, 2012). They also contain species endemic to Ethiopia, globally threatened species (IUCN, 2010) and species endemic to afromontane forests (Desalegn, 2012). Their size is highly variable (from 0.6 ha to 500 ha) and they are generally surrounded by a matrix of agricultural fields and other land uses associated with human habitation. Although research employing remote sensing and GIS has quantified the land-use and land-cover changes of the area (Desalegn, 2007; Teshome, 2012a,b), no study has been focused at the scale of sacred forest patches. The objectives of this study are therefore to: (1) evaluate the impact of land-use change over the past 15 years on the spatial properties of areas of different land-cover classes across the landscape of the Gamo Highlands and (2) characterize the changes associated with fragmentation occurring to individual patches of sacred and non-sacred forests within this landscape over the same period.

2. Study area

The Gamo Highlands are a section of the south-west Ethiopian highlands, and are located in the GamoGofa Administrative Zone in the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) (Fig. 1). GamoGofa Zone Administration consists of 15 woredas (small administrative unit equivalent to district) of which Gamo Highlands comprise larger portion. According to the population census of 1994, the total population inhabiting the Gamo highlands was estimated to be 700,000 (Freeman, 2002) and this had increased to more than 1 million in 2007 (CSA, 2007). People's livelihoods in the highlands mainly depend on subsistence farming of generally less than 1 hectare (Samberg et al., 2010).

The Gamo Highlands are located on the western escarpment of the Great Rift Valley between 5°53.8′17.52″ to 6°26′22.97″ N and 37°10′35.13″ to 37°42′31.89″ E. The topography of the highlands is characterized by steep slopes, up to undulating plateaus with gentle slopes, as well as detached steep-sided hills and valleys (Desalegn, 2007; Samberg et al., 2013a,b). The elevation of the highlands rises abruptly from 1183 m in the Maze lowlands to the west and from 1200 m at Lake Abaya and Chamo in the east to the central ridges with a maximum elevation of 3500 m at the summit of Mount Guge. The climate of the area is characterized by a bimodal rainfall pattern with high intensity rainfall from June to September and low intensity from February to April. The mean annual rainfall ranges from 500 mm in the lowlands to 1200 mm in the highlands, and the temperature varies from 25 °C in the lowlands to 10 °C in the highlands (Federal Democratic Republic of Ethiopia, 2000).

3. Methods

3.1. Land-cover data and analyses

Cloud-free LANDSAT Thematic Mapper (TM) images of an area of 183 × 183 km covering the majority of the Gamo Highlands were obtained for the years 1995 and 2010. They gave a total sample area in the Gamo Highlands of 66,765 ha. A maximum-likelihood classification of the data of each TM image was carried out to map land cover for mapping units of 0.5 ha. The classification was aggregated into four cover classes of: cultivated land and settlement; forest; open pasture land; wooded grassland. Classification accuracy was verified to 78% for 1995 and 85% for 2010 in ERDAS 9.1 (ERDAS, 2008) using 270 ground control points (GCP) obtained during field survey. The contour map and administrative boundary vector