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Conservation of the Ethiopian church forests: Threats, opportunities and implications for their management

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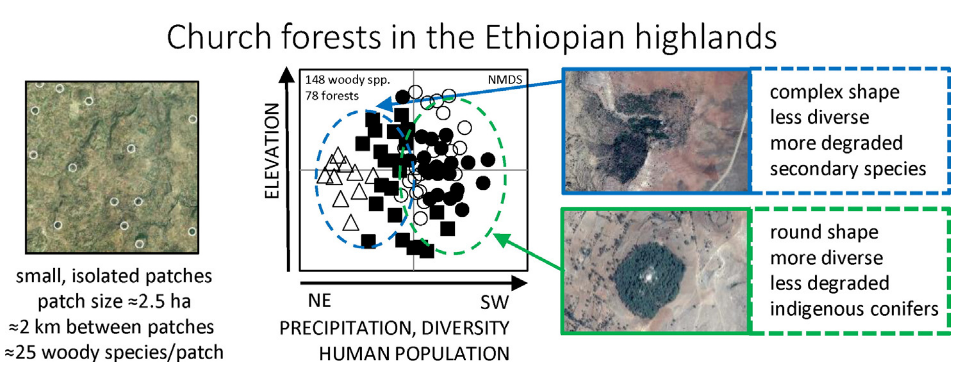
HIGHLIGHTS

- Natural forest in northern and central Ethiopia is mainly confined to 'church forests'.
- We studied 394 forests in satellite images and field surveyed 78 forests.
- Patches are species-poor but communities similar to potential natural vegetation.
- Small patch sizes, isolation, edge effects threaten long-term conservation.
- Improving management, protection and stakeholder benefits are crucial.

GRAPHICAL ABSTRACT



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A B S T R A C T

In the central and northern highlands of Ethiopia, native forest and forest biodiversity is almost confined to sacred groves associated with churches. Local communities rely on these 'church forests' for essential ecosystem services including shade and fresh water but little is known about their region-wide distribution and conservation value. We (1) performed the first large-scale spatially-explicit assessment of church forests, combining remote-sensing and field data, to assess the number of forests, their size, shape, isolation and woody plant species composition, (2) determined their plant communities and related these to environmental variables and potential natural vegetation, (3) identified the main challenges to biodiversity conservation in view of plant population dynamics and anthropogenic disturbances, and (4) present guidelines for management and policy. The 394 forests identified in satellite images were on average ~2 ha in size and generally separated by ~2 km from the nearest neighboring forest. Shape complexity, not size, decreased from the northern to the central highlands. Overall, 148 indigenous tree, shrub and liana species were recorded across the 78 surveyed forests. Patch α-diversity increased with mean annual precipitation, but typically only 25 woody species occurred per patch. The combined results showed that >50% of tree species present in tropical northeast Africa were still present in the 78 studied church forests, even though individual forests were small and relatively species-poor. Tree species composition of church forests varied with elevation and precipitation, and resembled the potential natural vegetation. With a wide distribution over the landscape, these church forests have high conservation value. However, long-term conservation of biodiversity of individual patches and evolutionary potential of species may be threatened by isolation, small sizes of tree species populations and disturbance, especially when considering climate change. Forest management interventions are essential and should be supported by environmental education and other forms of public engagement.

1. Introduction

Sacred groves are community-preserved, often small, forest patches in which certain spiritual, cultural or religious values contribute to the conservation of biodiversity and ecosystem services (Berkes, 2009; Dudley et al., 2009; Ray et al., 2014). Sacred groves may be remnants of earlier more continuous forests or planted or regenerated forest patches in non-forest landscapes (Bhagwat et al., 2014). Because sacred groves are usually protected by local institutions or by-laws that regulate resource use (Kibet, 2011), such sites are often better protected than other small habitat patches, and can therefore play an intrinsic role in biodiversity conservation (Ceperley et al., 2010; Metcalfe et al., 2010; Rutte, 2011; Daye and Healey, 2015). Traditionally, conservation efforts have focused either on large and relatively undisturbed habitats because large areas conserve relatively more species (Laurance, 2005), or on biodiversity hotspots with exceptional concentrations of endemic species under relatively high levels of threat (Myers et al., 2000). However, conserving a number of small habitat patches such as sacred groves can have additional value for conserving biodiversity, for instance by covering a wider variety of habitats than would be achieved by protecting a few large patches of an equivalent total area (Bhagwat and Rutte, 2006; Hokkanen et al., 2009) and thus contributing to higher total biodiversity covered (Benedick et al., 2006). Another important benefit is that a habitat network enabling dispersal amongst sacred groves and other protected areas (Laita et al., 2010; Chiarucci et al., 2012) may make an important contribution to genetic connectivity (Lander et al., 2010) and the survival of species as metapopulations (sensu Hanski, 1998). In particular when it is not feasible to maintain large tracts of pristine habitat, for instance because the landscape is intensively used as cropland after extensive past deforestation (Arroyo-Rodriguez et al., 2009), the conservation and restoration of small habitat patches, such as sacred groves, may turn out to be the final safety net to conserve a high proportion of the landscape's previous biodiversity (Fischer and Lindenmayer, 2002).

Sacred groves exist in many countries (for reviews see Bhagwat and Rutte, 2006; Dudley et al., 2010), and there are well documented examples throughout Asia (e.g. Brandt et al., 2013; Gao et al., 2013; Gunaga et al., 2013; Allendorf et al., 2014) and Africa (e.g. Mgumia and Oba, 2003; Campbell, 2004; Sheridan and Nyamweru, 2007; Kokou et al., 2008; Tankou et al., 2014). In the highlands of northern and central Ethiopia, sacred groves associated with Ethiopian Orthodox Tewahedo churches and monasteries (EOTC) are known as 'church forests'. These church forests are virtually all that is left of the Ethiopian Afromontane forest (Aerts et al., 2006; Wassie et al., 2010; Berhane et al., 2013; Jacob et al., 2014) (Fig. 1 and Figs. S1–S4) and local people rely on these church forests for the provisioning of livestock feed, tree seedlings, fuelwood, honey, clean water and other essential ecosystem services including shade, climate regulation, habitat for pollinators and spiritual values (Cardelús et al., 2012; Amare et al., 2016). In the southwest of the country, shade coffee cultivation has, until now, guaranteed that more or less natural forest remained an important land cover (Tadesse et al., 2014), despite the clear trade-off between coffee productivity and forest ecological quality (Senbeta and Denich, 2006; Schmitt et al., 2010; Aerts et al., 2011; Hundera et al., 2013). In the central and northern Ethiopian highlands, however, high historical land use pressure has resulted in widespread deforestation and land degradation (Darbyshire et al., 2003; Nyssen et al., 2004). Crop land and degraded grazing land are the dominant land covers, with only very few patches of forest remaining and these are almost entirely confined to the vicinity of churches, monasteries and other holy sites such as springs. Churches manage their forests autonomously, and management varies from strict protection (with some churches surrounded by walls and patrolled by paid forest guards) to weak protection with poorly controlled harvesting of trees (Amare et al., 2016). A number of studies has evaluated the conservation value of these church forests at local scales (e.g. Aerts et al., 2006; Wassie et al., 2010; Berhane et al., 2013) but, to date, there is no information on the contribution of church forests to the conservation of biodiversity and ecosystem services at the larger scale, i.e. the entire Ethiopian highlands. This information is, however, urgently needed to enable the integration of these habitat patches into wider (global) conservation strategies (Dudley et al., 2009) and to understand what actions must be undertaken to conserve these forests, which are known for their exceptionally high vertebrate and plant diversity, rich in narrow-range species (Burgess et al., 2006).

The spatial arrangement and patch characteristics of church forests are important because the viability of a population within a habitat fragment or patch depends, amongst other factors, on the number of patches, the size of the individual patches, the isolation of the patches and the edge effects associated with the shapes of the patches (Fahrig, 2003). An understanding of what woody plant communities are conserved in church forests is important because their conservation value at the regional scale depends on the species and communities that persist in the church forests and on how well these communities relate to the potential natural vegetation of the region. Therefore, our main