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Moderate land use shifts plant diversity from overstory to understory and contributes to biotic homogenization in a seasonally dry tropical ecosystem

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ABSTRACT

Most of the world's remaining terrestrial biodiversity exists in tropical ecosystems affected by human activities. Despite the threats to seasonally dry tropical ecosystems, little is known about the impact of human land use change on their conservation value. We used savanna woodlands within the Western Ghats biodiversity hotspot as a case study to understand the effects of human land use on plant diversity. We investigated the effects of three common land-use activities – biomass extraction, livestock grazing and ground fire – on species richness and diversity, as well as species composition in terms of the breadth of geographic ranges of species present. We found that total species richness increased with livestock grazing due to increased understory richness. Overstory diversity and tree sapling diversity and richness decreased with more recent fire. Greater canopy openness was associated with increased understory richness and reduced overstory richness. The combination of fire and livestock grazing are likely to increase canopy openness, leading to a shift in diversity from the overstory to the understory. Although we found no change in species richness or diversity with biomass extraction, areas with biomass extraction had more widely distributed species and fewer narrowly distributed species, indicating land use may lead to biotic homogenization. Our results suggest that a mosaic of protected areas along with areas managed for biomass extraction and livestock grazing would be an effective way to balance the conservation of plant diversity with local communities' needs while maintaining overall levels of plant species diversity in these savanna woodlands.

1. Introduction

Tropical ecosystems are valued for the diversity of species they harbor and the ecosystem services they provide, but ongoing land use change threatens both (Bradshaw et al., 2009). Areas of the tropics with low levels of human influence are few and inadequate for preserving remaining biodiversity (Gardner et al., 2009), so human-managed landscapes must be incorporated into conservation strategies. It is therefore critical to determine the degree to which conservation of biodiversity is possible in human-managed tropical systems (Chazdon et al., 2009).

The Western Ghats region of India provides a highly suitable location to assess the compatibility between human land use and biodiversity. The Western Ghats is the most densely populated of all biodiversity hotspots (Cincotta et al., 2000). The region has a long history (>12,000 years) of human land use (Chandran, 1997), as well as traditional conservation practices such as the recognition of sacred groves (Gadgil and Vartak, 1976). The high densities of both people and biodiversity make understanding the interactions between land use and diversity especially important.

Previous research has shown that human-managed areas can contribute to the conservation of native plant, bird, insect and mammal diversity (e.g., Anand et al., 2010; Gascon et al., 1999; Mayfield and Daily, 2005; Ranganathan et al., 2008; Mo et al., 2011). However, these studies have focused primarily on tropical moist forests. Less is known about the compatibility of human land use and conservation in seasonally dry tropical ecosystems. Although tropical dry forests, savannas and woodlands harbor lower levels of plant diversity than moist forests, these ecosystems are centers of land conversion and fragmentation, provide important provisioning and regulating ecosystem services, and are less protected than moist forests (Balvanera et al., 2010; Chape et al., 2005; Murphy and Lugo, 1986). As a result their conservation in human-managed landscapes is especially critical. In the Western Ghats, seasonally dry tropical ecosystems are important sources of fuelwood, livestock fodder and non-timber forest products (NTFPs) for local communities (Davidar et al., 2010), as well as critical habitat for endangered megafauna (Das et al., 2006).

The diversity of species within an ecosystem is just one of several criteria used to assess conservation value (Gadgil, 1992). The identity of species is also important, with more value often

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accorded to rare species because of the greater possibility of their permanent extinction. While rarity can be defined in multiple ways, including based on geographic range (large vs. small), habitiat specificity (generalist vs. specialist) and local abundance (dense vs. sparse) (Rabinowitz, 1981), here we focus on species that are rare by being narrowly geographically distributed. Human land use can act as ecological filter, leading to the replacement of disturbance-sensitive narrowly distributed species with already-widespread species adapted to human activities (McKinney and Lockwood, 1999). This process of biotic homogenization can occur even when land use does not alter or even increases overall levels of local diversity (Smart et al., 2006). Assessing the conservation value of human-managed landscapes therefore requires accounting for differences in the composition of species within communities in terms of their commonness and rarity, in addition to overall levels of species richness or diversity.

In this study, we assessed the degree to which three very common forms of human land use (specifically, biomass extraction of fuelwood and NTFPs, livestock grazing and ground fire used, in part, to manage grazing areas and NTFP harvest) are compatible with the maintenance of plant diversity in savanna woodland ecosystems in the Western Ghats, India. We focused on the effects of these forms of land use because of their prevalence in tropical forests in Asia and throughout the tropics (FAO, 2010). We addressed three questions:

(1) Does plant species richness and diversity vary with land use (specifically, biomass extraction, livestock grazing and fire), after controlling for variation in abiotic environmental conditions? We investigate the effect of land use on total plant richness, as well as the richness and diversity of the overstory, tree saplings and understory because of the potential for these strata to be affected differently by land use.
(2) Does the breadth of the geographic range of species present within the plant community (as a proxy for degree of rarity) vary with land use, indicating a filtering effect of land use and biotic homogenization?
(3) What are the implications of these findings for the conservation of native plant diversity with human land use in the savanna woodlands of the Western Ghats?

Given the long history of our focal forms of land use in the Western Ghats, we expected they would result in little change in diversity and richness. We expected that more intensive land use would be associated with more common, widely distributed species and fewer narrowly distributed species.

The need to understand the compatibility between human land use and biodiversity conservation is particularly important in India now, given the recent passage and implementation of India's Forest Rights Act. The Forest Rights Act recognizes local communities' rights to manage natural resources and biodiversity and provides for joint management of these resources with the state (Bawa et al., 2011). As such, it creates an opportunity for information about the effects of human land use on biodiversity to be incorporated into management decisions at a local level.

2. Methods

2.1. Study sites and design

Our study was located in savanna woodlands of the southern Western Ghats in the South Indian states of Tamil Nadu and Karnataka. Five study sites (Fig. 1) were chosen to represent a range of land use intensities and included three reserve forests, one protected area and a remnant forest fragment on privately owned land (Table 1). We classified the five study sites into two

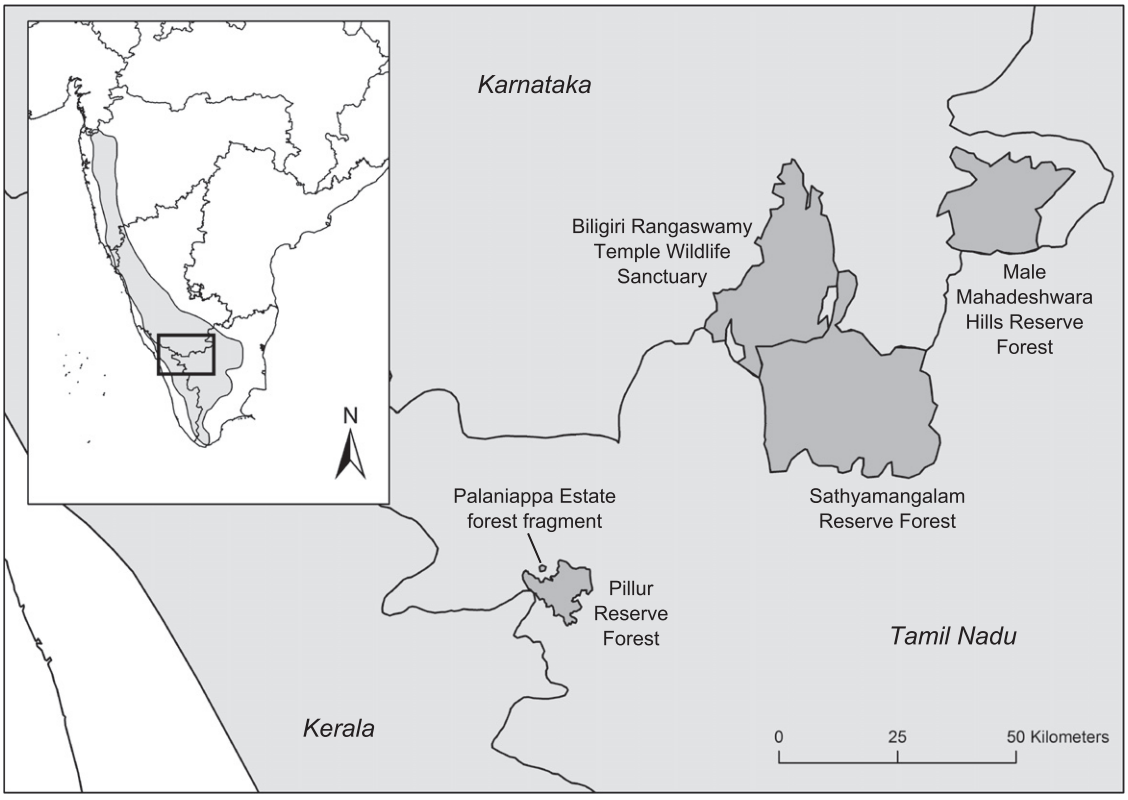

Fig. 1. Map of the study region in South India, with study sites shown in dark gray and the Western Ghats biodiversity hotspot shown in light gray. Boundaries of the forest fragment are not exact.