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Short communication

Spatio-temporal variation in forest cover and biomass across sacred groves in a human-modified landscape of India's Western Ghats

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ABSTRACT

Although the potential for community-conserved areas (CCAs) to extend conservation beyond formal protected areas is widely acknowledged, the scarcity of conservation assessments and monitoring hinders the rigorous evaluation of their effectiveness in many regions. In India, which hosts a high density and diversity of CCAs, the need for more assessments of the ecological and socio-economic properties of these systems to guide conservation planning and policy has been emphasised in recent years. We inventoried the extant sacred grove network against official records of 407 groves across 70 villages in the Kodagu District of India's Western Ghats, and interviewed local communities about their management and conservation. We also evaluated recent trends in aboveground biomass of sacred groves using time-series satellite data from six time-points during the 2000–2010 period, and made comparisons to corresponding trends in nearby State-managed protected forests. Although most of the larger (>2 ha) groves officially listed were forested at present, over two-thirds of the smaller groves listed were either not forested or could not be located. Local communities attributed these declines to encroachment and illicit logging. Time-series satellite data revealed aboveground biomass declines of ~0.5% annually across the sacred grove network over the 2000–2010 period. In contrast, biomass increased during this period at the interiors and edges of State-managed forests in the landscape. Our results highlight that the conservation status of even well-protected CCAs can vary considerably over time, especially given the dynamism in socio-economic, cultural and ecological factors that govern their status. We argue that understanding and addressing this dynamism is crucial to the conservation of CCAs.

1. Introduction

Protected areas (PAs) are today the cornerstone of biodiversity conservation across terrestrial ecosystems worldwide (Gaston et al., 2008). From covering a mere 3.5% of the Earth's land surface in 1982 (Harrison et al., 1982), they now account for over 12% of the Earth's land area (Brooks et al., 2004; Chape et al., 2005). While PAs remain crucial in preventing deforestation and conserving biodiversity in the tropics, a variety of species, communities and ecosystems of conservation importance still occur beyond PA boundaries, on lands under diverse tenure and use (Chazdon et al., 2009). Improving the opportunities for biodiversity conservation on such lands, therefore, remains an important concern. In this context, sacred natural sites and other community-based institutions for protection and management of natural resources are seen as important opportunities to extend conservation beyond PAs, especially in the rapidly developing and densely-populated tropics (Sodhi et al., 2011; Verschuuren et al., 2010). In these community-conserved areas (CCAs), natural resources are managed and protected by locally-developed norms rather than formal legislations, adding conservation value at both local and landscape scales (Bhagwat et al., 2005a; Colding and Folke, 2001; Gadgil and Vartak, 1975; Salick et al., 2007). Yet, there is still uncertainty over the conservation status and conservation potential of CCAs, owing to a relative paucity of documentation and long-term

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assessments (Berkes, 2009; Kothari, 2006; Shahabuddin and Rao, 2010).

While monitoring the effectiveness of conservation strategies over time is generally desirable, it is particularly important in CCAs, where conservation is often one among various other objectives, and sometimes simply a by-product (Alvard, 1993; Rutte, 2011). There is widespread evidence of recent and emerging challenges to CCAs arising from changing cultural beliefs, practices, and socioeconomic forces (Bhagwat and Rutte, 2006; Ormsby, 2011). Moreover, as areas that are under human use, CCAs frequently experience anthropogenic disturbances in the form of resource extraction, hunting, fire and fragmentation (Shahabuddin and Rao, 2010), which, in turn, may affect ecological processes and result in changes over time in habitat structure, species composition, ecosystem function and conservation value. Therefore, monitoring the status of CCAs over time is vital to understand how they add value to mainstream conservation efforts like PAs in a changing world.

Here, we document the current status, evaluate recent trends and explore drivers of change associated with forest cover and biomass of a network of community-managed sacred groves in Kodagu District, located in the Western Ghats Biodiversity Hotspot of peninsular India. This network of sacred forest fragments is interspersed within a production landscape primarily of shade coffee and paddy. These sacred groves harbour a wide variety of native rainforest biodiversity, including rare, threatened plants and endemic bird species (Bhagwat et al., 2005b; Page et al., 2010). Moreover, they complement and enhance conservation by State-owned and managed forests (including PAs) by boosting habitat connectivity in the region (Bhagwat et al., 2005a; Kushalappa and Bhagwat, 2001). Weakening local institutions, diminishing cultural importance and growing demand for forest land, timber and other natural resources feature prominently among a variety of established and emerging threats facing these sacred groves (Chandrakanth et al., 2004; Garcia and Pascal, 2006; Kushalappa and Bhagwat, 2001). However, apart from official lists of sacred groves, which are possibly outdated, and biodiversity assessments from a few relatively well-protected groves (e.g. Bhagwat et al., 2005b), little is known about the current extent, status, trajectories and conservation prospects of this fragmented ecosystem as a whole.

We inventoried the extant sacred grove network and compared their current status to widely-cited official records compiled during the 1980s. We then used time-series satellite data to evaluate recent trends in the forest biomass of sacred groves across gradients of grove size and annual rainfall, and made comparisons to trends in State-managed forests within the same landscape. Finally, we conducted interviews with members of the local community involved in the management and conservation of sacred groves to explore perceptions of cultural values associated with sacred groves, their perceived trends in sacred grove forest cover, and challenges associated with the conservation of sacred groves.

2. Materials and methods

2.1. Study site

The study was conducted in the Virajpet Forest Division in Kodagu District, Karnataka state, in the Western Ghats of peninsular India (12.17°N, 75.8°E; Fig. 1). The study area features mid-elevation tropical wet-evergreen and semi-evergreen forest types (Pascal, 1982, 1986). Administratively, these forests largely fall within one of two categories: forests which are owned and managed by the State (e.g. Brahmagiri Wildlife Sanctuary and adjoining Reserved Forests) and sacred groves, most of which are owned by the State but managed by local communities through decentralised village temple committees (Kushalappa and Bhagwat, 2001; Raghavendra and Kushalappa, 2011). These ancient sacred groves mostly occur as forest fragments embedded in a landscape matrix dominated by shade coffee plantations, which also comprises rice paddies and human settlements (Bhagwat et al., 2005b). According to records compiled by the Karnataka Forest Department in the 1980s, the study area had over 550 sacred groves, totalling over 1000 ha in area (Raghavendra and Kushalappa, 2011). There are at least 18 resident communities involved in management of sacred groves in Kodagu district, with members of the Kodava, Gowda, Amma Kodava and Hegde communities being prominent in the study area (Kushalappa and Bhagwat, 2001).

2.2. Sacred grove inventory and habitat assessment

Between November 2009 and February 2010, we conducted field surveys to inventory the extant sacred grove network in 70 of the 109 villages in Virajpet Forest Division that have sacred groves recorded (Fig. 1a). According to official records of sacred groves published by the Karnataka Forest Department in 1985, these 70 villages contained 407 sacred groves (Raghavendra and Kushalappa, 2011). We visited each village and using information on village name, sacred deity name and listed area, and in consultation with experts and local residents, we attempted to locate these sacred groves. Each site thus located was classified into one of three categories: (1) sites with continuous, closed-canopy tree cover, (2) sites with discontinuous, open canopies, exposed bare ground and invasion by non-native understory species, and (3) sites under non-forest land cover (e.g. plantations, constructions). In the first two cases, the physical forest boundary of the sacred grove was mapped using global positioning system (GPS).

2.3. Trends in aboveground biomass

We evaluated trends in aboveground biomass of sacred groves and other forests in the study area using a six-point time series of satellite images from the 2000–2010 period (years 2000, 2003, 2004, 2006, 2008, 2010). The analysis focused on two main questions: (1) do trends in aboveground biomass of sacred groves vary across space in relation to sacred grove size and location along an E–W gradient of annual rainfall, and (2) how do biomass trends in sacred groves compare to trends in nearby State-managed forests over the 2000–2010 period? Trends in aboveground biomass were assessed using a remotely-sensed index derived from Landsat ETM+ imagery captured by the Landsat 7 satellite. This index comprised the ratio of band 4 (near infrared) to band 5 (short-wave infrared) pixel values – hereafter, ratio45 – which, based on rigorous field testing using biomass estimates from 38 forest inventory plots (3.15 ha in total), was found to be strongly and positively associated with aboveground biomass ($r = 0.66$, $p < 0.00001$; see Appendix A for methodological details). A robust linear method which estimates the median across all pairwise slopes between the six time-points, sometimes called the Sen Slope (Sen, 1968), was used to detect monotonic trends in pixel values of ratio45. The trend estimates were translated to an annual rate of change in percentage terms by dividing by the corresponding baseline value (ratio45 in year 2000) and multiplying by 100.

Relationships between biomass trends, as indexed by ratio45, and sacred grove area (calculated using the mapped sacred grove boundaries) and mean annual rainfall (extracted from interpolated models at 1 km resolution (Hijmans et al., 2005)) were examined using pairwise correlations. The analysis was conducted for 73 sacred groves falling within an annual rainfall range of 2300–3500 mm: the range within which the field estimates of aboveground biomass used to