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Field to a forest: Patterns of forest recovery following shifting cultivation in the Eastern Himalaya

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ABSTRACT

The patterns of vegetation recovery in shifting cultivation landscapes that undergo a cycle of clearing, cultivation and forest regeneration are not well understood in Asian tropical forests. We determined forest recovery patterns by comparing species composition, richness and forest structure in early and late fallows formed following shifting cultivation and in an uncut forest site in a mid-elevation subtropical forest in the Indian Eastern Himalaya. We also examined changes in functional traits of tree species to understand recovery processes with succession. Tree species richness in the 12, 25 and 50-year old sites was 37%, 54% and 82% the value of the richness in uncut forest, respectively, while basal area was 33%, 25% and 41% of the value in uncut forest, respectively. Species composition recovery, however, was low; with even the oldest fallow (50-year fallow) being less than 50% similar to uncut forest in terms of composition. Successional sites that recover over long periods may differ compositionally from uncut forest within a shifting cultivation landscape as these forests are often prone to other anthropogenic disturbances. Functional trait analysis revealed that early fallows were colonized by tree species that are animal-dispersed, insect-pollinated with small fruits and seeds, whereas uncut forest and late successional forests were dominated by species that were tall, self-dispersed, wind-pollinated and of high wood density that are dominant mature forest species in the Himalaya. These results are in contrast with the patterns in functional traits of tree species in successional sites from the Neotropics. This points to the importance of site-specificity in succession following shifting cultivation.

1. Introduction

Shifting cultivation is an agricultural system in which parcels of land are cleared of forests and cultivated for a short period and subsequently left to regenerate for a longer period (Conklin, 1961). Globally, over 300 million people practice shifting cultivation over more than 400 million hectares (Andriesse and Schelhaas, 1987; Kleinman et al., 1996; Mertz et al., 2009). The practice is diverse, ranging from a traditional form that has persisted over several centuries with relatively long fallow periods undertaken in sites adjoining uncut forests to a non-traditional form practiced for economic necessity more recently as a supplementary activity close to urban fringes (Conklin, 1957; Spencer, 1966; Ramakrishnan, 1992). The traditional practice is usually undertaken for subsistence at relatively smaller scales in comparison with other landuses such as monoculture plantations, pastures, large-scale permanent agriculture (Fox et al., 2000; Seidenberg et al., 2003). Unlike other permanent landuses, for the practice to continue over long periods, communities need to retain secondary and primary forests in the landscape (Delang and Li, 2013).

Since the practice involves a continuous cycle of clear-felling and regeneration, shifting cultivation sites provide an opportunity to understand secondary succession patterns. Shifting cultivation fallows have been shown to recover faster in terms of forest structure and species than other abandoned agricultural lands such as pastures, agroforestry, and monoculture plantations (Ferguson et al., 2001). Although fallows may not completely revert to the original forests if the disturbance is terminated, several parameters have been shown to recover to comparable levels, although over relatively long periods (Guariguata and Ostertag, 2001; Peña-Claros, 2003; Finegan and Nasi, 2004; Delang and Li, 2013).

Basal area of trees has been shown to increase over time and reach half the value in the adjoining mature forest within roughly

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three decades in shifting cultivation sites adjoining dry forests (Kennard, 2002; Ruiz et al., 2005) as well as semi-deciduous forests (Kammesheidt, 1999; Toledo and Salick, 2006). Tree density has been shown to initially increase with a decrease or stabilization at later stages of succession (Kammesheidt, 1999; Lebrija-Trejos et al., 2010; Van Do et al., 2010; Aweto, 2013). Plant species richness has been reported to recover to values comparable with those in mature forest in 20–40 years; however, full recovery of species composition, particularly of rare species and species endemic to the region has been reported to take longer than 100 years (Saldarriaga et al., 1988; Vankat and Snyder, 1991; Finegan, 1996; Van Gemerden et al., 2003). Contrasting this, in an Afrotropical site where traditional agriculture was embedded within forests and was undertaken with fallow periods of five to 15 years without the use of fire in creating new fields, species composition in comparison with adjoining forest recovered within 30 years (N'Dja et al., 2008). It is likely that forest recovery is faster in traditional shifting cultivation landscapes than in sites with more recent versions of the practice as shown by some studies (N'Dja et al., 2008). The rate of forest recovery following cultivation is also affected by the number of cultivation cycles in a site (Lawrence et al., 2005).

In addition to documenting forest structure and species diversity in successional sites to understand recovery patterns, an analysis of species functional traits can provide a framework to understand plant ecological strategies and thereby lead to further insights into recovery processes (Verheyen et al., 2003; Poorter, 2007; Raevel et al., 2012). The existing information on functional traits of plants in different successional stages is mostly from the temperate and Neotropical regions (Prach et al., 1997; Tabarelli and Peres, 2002; Verheyen et al., 2003; Flinn and Vellend, 2005; Dölle et al., 2008) and information from Old World sites is largely lacking (but see Asanok et al., 2013; Böhnke et al., 2012, 2014). For instance, while wood density has been shown to be lower in secondary forests in comparison with the values in mature forest in both the regions (Suzuki, 1999; Woodcock, 2000; Asanok et al., 2013), information regarding other functional traits is largely lacking from Old World sites. Among tree species in the Neotropics, the occurrence of wind dispersal decreased, vertebrate dispersal increased, and seed weight and size increased during the successional transition from pioneer to forest stage (Tabarelli and Peres, 2002; Chazdon et al., 2003; Dölle et al., 2008). Prach et al. (1997) found no significant difference between pollination modes of species from early and old successional sites while Chazdon et al. (2003) found that insect pollination was higher and mammal pollination was lower in early successional sites than in old-growth and logged forests.

To compare these trends and to understand forest recovery patterns and processes, we collected information on species richness and abundance, forest structure and functional traits of tree species in different-aged successional sites ranging from 2 to 50 years since cultivation in a traditional shifting cultivation landscape in a subtropical forest in the Eastern Himalaya. We focused on traits that we expected to vary during succession: dispersal mode, pollination mode, seed and fruit size, tree height and wood density. Based on past studies, apriori we had expected tree species in early successional sites to be small-seeded abiotically dispersed species of low wood density in comparison with older successional sites and uncut forest that we expected would be comprised of large-seeded vertebrate-dispersed species of high wood density. We also enumerated species composition of seedlings and saplings to investigate if the species composition patterns and functional traits of the regeneration niche in different successional sites reflected those of the adult tree niche.

2. Methods

2.1. Study area

The study was undertaken in a shifting cultivation landscape around Bomdo village in the Upper Siang district of the state of Arunachal Pradesh in north-east India located at 28.753° N and 94.896° E (Fig. 1). The community forest around the village is contiguous with the Mouling National Park (483 km^2), which is part of the Dihang Dibang Biosphere Reserve (5100 km^2). The average annual rainfall in the district was about 4300 mm (average for years 2010–2013, IMD, 2015). The region has tropical wet- and semi-evergreen forests and sub-tropical broad-leaved forest in the higher areas above 800 m (Singh et al., 1996). The shifting cultivation practice of the *Adi* community in Central Arunachal Pradesh is relatively more systematic in comparison with practices in most of north-east India (Borang, 1997; Teegalapalli and Datta, in press); rather than families cultivating individual plots, 4–8 families in each village cultivate within a single large patch of about 2–4 ha (Teegalapalli and Datta, in press). The fallow cycle; the period within which a cultivated plot is re-cultivated, is 10–12 years which is higher than that practised by several other communities in the region (Deb et al., 2013; Behera et al., 2015). We used a Space-for-Time substitution framework with the assumption that spatial and temporal variation in different-aged successional sites are equivalent (Pickett, 1989). The other assumption was that sites had undergone same number of cultivation cycles since land under cultivation is rotated biennially in the hill slopes around the village (Teegalapalli and Datta, in press).

2.1.1. Vegetation sampling

Different-aged sites or fallows (2, 12, 25, 50 years with two replicates each) following shifting cultivation were selected based on detailed cultivation history maintained by the villagers. The sites were located within 1000 m distance of each other, ranged in elevation from 750 to 1100 m (Fig. 1) and were about 2 ha in area (range: 1.12–3.1 ha, mean [± SE]: 2.23 [± 0.37]), and one of the 50-year old sites was contiguous with uncut forest. Uncut forest in this study represents moderately disturbed uncut forest rather than mature forest that is devoid of any human disturbance.

Vegetation surveys were undertaken between October 2013 and May 2014 in each these sites and in two uncut forest sites adjoining these sites. Trees (diameter at breast height, DBH $\geqslant$ 3 cm) were inventoried and identified to species or genus level in twelve 7 m radius plots located 25 m from each other on alternating sides of a 250-m transect, covering 0.185 ha per site. Overall, we sampled 0.37 ha in each successional stage and each uncut forest site, and a total area of 1.85 ha. The uncut community forest around the village is substantially larger than the successional sites and is contiguous with the forests of the Mouling National Park, therefore in addition to the 24 plots sampled in two uncut forest sites, we sampled 12 more 7-m radius plots, with a total area of 0.55 ha sampled in uncut forest. We enumerated the regeneration comprising of seedlings (height $\leqslant$25 cm) and saplings (height >25 cm to $\leqslant$100 cm) of tree species in each of the four successional stages and the uncut forest sites in 1-m and 3-m radius nested within the 7-m radius plots, respectively. The seedlings and saplings were identified to the species or genus level.

2.1.2. Functional traits

Five functional traits (fruit size, seed size, seed dispersal mode, pollination mode and tree height) of a subset of the data from the entire species pool (70 species of adult trees and 40 species of