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Forest fragment spatial distribution matters for tropical tree conservation

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ABSTRACT

Deforestation and associated forest fragmentation are main drivers of species loss across the tropics. Many studies have focused on how fragment edge effect, size, isolation and shape, affect species persistence within landscapes. Little attention has been paid to the impact of the distribution of the fragments itself on the preservation of local species pools. Here we test the importance of the spatial distribution of remaining forest fragments, relative to other fragmentation effects, on tree species diversity, composition and rarity patterns within a tropical landscape converted to rubber plantations in southern Yunnan, China. We find that the remaining forest fragments are non-randomly distributed in the landscape, with most fragments located at higher elevations, steeper slopes and shade aspects. At the same time we find that most of the observed patterns in tree diversity, composition and rarity are explained by the location of the fragments within the landscape, with very little additional impact of other fragmentation effects, even though fragmentation started more than two decades ago. We conclude that during the initial stages of land use change, the protection of forest areas along the entire environmental gradient should be a prime focus for conservation efforts as it is at this stage that most tree species can be preserved in the landscape. We also stress the importance of small forest fragments for the conservation of tree species, especially because such fragments are usually located in sites with the highest deforestation rates.

1. Introduction

Land use change is considered a main driver of biodiversity loss all over the world (Foley et al., 2005), especially for large-bodied mammals, birds and late successional trees, and can cause rapid ecosystem decay and loss of ecosystem services (Laurance et al., 2002; Terborgh et al., 2001). However, many studies also show that remnant forest fragments can still maintain high phylogenetic diversity (Arroyo-Rodriguez et al., 2012; Mo et al., 2013), harbor a large proportion of original species (Arroyo-Rodriguez et al., 2009; Sodhi et al., 2010), has almost no effect on certain groups of taxa (Andreazzi et al., 2012), while some groups even increase their abundance and diversity (Crooks and Soule, 1999). Such contrasting outcomes of fragmentation are related to how much original forest remains after fragmentation, the size and isolation of individual fragments and the distribution of the fragments over the landscape (Laurance et al., 2002; Pardini et al., 2010; Prugh et al., 2008). For example, lowland forests in Jamaica were cleared at a rate seven times higher than that of montane forests (Chai and Tanner, 2010), leading to disproportionate loss of lowland forest and associated taxa. Similarly, forests fragments with high fruit availability can maintain high avian diversity regardless of the patch isolation and size, but since these fragments are generally located on more fertile soils they are also prime targets for agricultural expansion and thus tend to become rare in fragmented landscapes (Garcia et al., 2010).

In the past 30 years studies in forest fragments focused mostly on impacts of patch size, isolation and edge effects on forest structure, species diversity and composition (Laurance et al., 2002, 2011). However, forests, and especially tropical forests, show strong spatial and environmental structuring of species composition and diversity (Baldeck et al., 2013; Garcia-Lopez et al., 2012; Harms et al., 2001; John et al., 2007; Laurance et al., 2010), meaning that the distribution of the fragments itself will, for a large part, determine the type and diversity of taxa preserved across the landscape (Virgos, 2001). Since forest fragmentation is generally a non-random process, with people targeting areas that are easily accessible or have good soil properties for agricultural production, forest fragments are usually restricted to areas located on steep slopes, poor soils or with inaccessible topography (Summerville and Crist, 2004; Vellend et al., 2008). The spatial distribution of

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forest fragments across the landscape may therefore form a major, but understudied, driver of species loss in fragmented landscapes (Mortelliti et al., 2010; Seabloom et al., 2002).

Tropical Asia is experiencing some of the highest deforestation rates observed across the tropics because of the rapid expansion of mono-culture cash crops such as rubber and oil palm (Koh and Wilcove, 2008; Mann, 2009; Sodhi et al., 2010), resulting in massive forest loss and fragmentation (Gibbs et al., 2010; Mantyka-Pringle et al., 2012). In this study we focus on the role that the spatial distribution of remaining forest fragments play in the preservation of tree species across a tropical landscape in southern China. This area is experiencing a rapid expansion of rubber plantations at the expense of the original tropical forest that used to cover the whole region until a few decades ago (Hu et al., 2008). We hypothesize, based on observations in fragmented landscapes mentioned earlier, that this expansion of rubber plantations is spatially non-random and will result in remaining forest fragments being located on less accessible, steeper, higher and shady slopes. Due to the relatively recent start of forest fragmentation in the study area compared to the long lifespan of trees and the embedding of the fragments within an 'artificial' forest landscape, we hypothesize that tree diversity, rarity and composition patterns in forest fragments will be more related to fragment location than to forest degradation related to fragment size and edge effects.

2. Methods

2.1. Study area

All studied forest fragments were located within a 20 km-diameter circle around the Xishuangbanna Tropical Botanical Garden in Menglun town, Mengla County, Xishuangbanna Dai Autonomous Prefecture, Yunnan Province, China (Fig. 1). Xishuangbanna is located on the northern edge of tropical Southeast Asia and it has the largest area of tropical rainforest in China. In addition, it lies within the Indo-Burma biodiversity hotspot (Myers et al., 2000) and has a native flora of ~3500 plant species (Zhu, 2012). In our study area the average annual temperature varies around 21.5 °C and rainfall around 1563 mm per year, with ca. 80% of the rain falling in the rainy season between May and October (Cao et al., 2006). The topography is characterized by steep slopes with altitudes ranging from 400 to 1460 m. The soils consist mainly of three types: laterite soil, laterite red soil and limestone-derived soil, each with specific forest types (Cao et al., 2006). While the tropical seasonal moist/monsoon forests in the area harbor the highest plant diversity, forests on limestone are characterized by high levels of endemism because of their unique soil and micro-climatic environments (Clements et al., 2006).

Originally, most of the study region was covered by forest; however, rubber plantations have recently become the main driver of habitat loss and fragmentation (Aziz et al., 2010; Hu et al., 2008). Before the 1980s the area was minimally exploited and forests well protected. Today, the landscape around Menglun consists for more than 64% of rubber plantations and about 25% natural forest, most of which is located in isolated patches varying in size, shape and isolation. There are three nature reserves in the area, although parts of the reserves are disturbed because they were used for growing *Amomum* (a ginger) in the forest understory (Hu et al., 2008). Since rubber expansion is the sole cause of forest conversion in this region, all forest fragments are surrounded by a similar vegetation matrix of evenly spaced rubber (*Hevea brasiliensis*) trees.

2.2. Land use classification

For the land use classification we used images from the Global Land Survey (GLS) dataset, which were downloaded from the International Science Data Service Platform (http://datamirror.csdb.cn/gls/glsLook.jsp). We georeferenced the GLS-2010 image using the GLS-2005 image (which was already orthorectified) using ERDAS IMAGINE AutoSync and used a gap-filled Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) to account for relief displacement. Root mean square error for the georeferencing was less than 0.5 pixels (15 m). We then applied a supervised maximum likelihood classification method to the GLS-2010 image. Large homogeneous areas were selected from Google Earth to serve as training areas for the GLS-2010

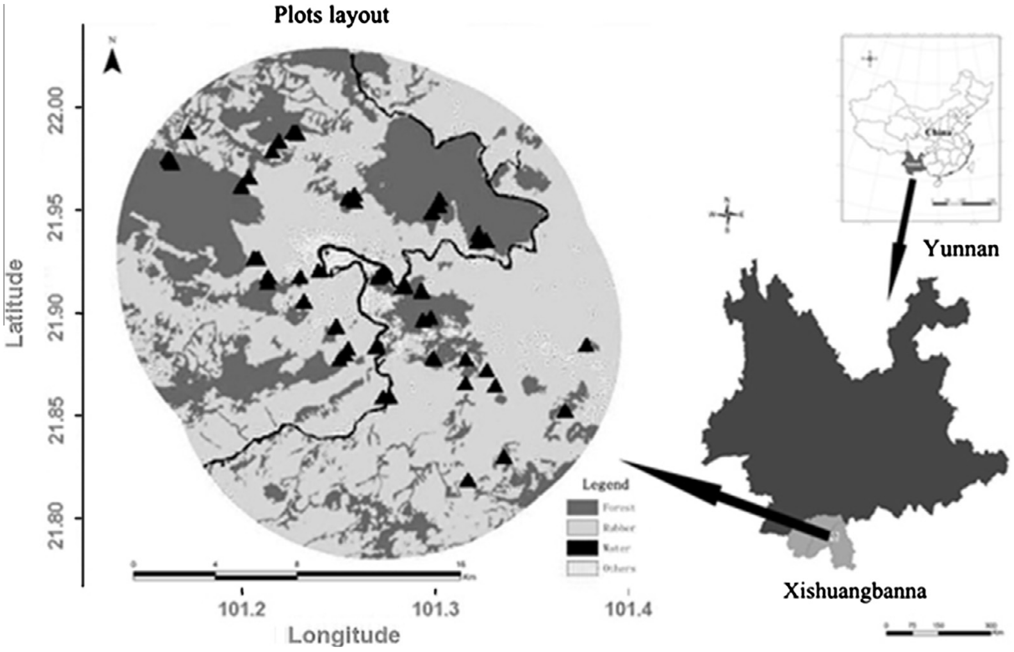

Fig. 1. The geographical location of the 50 plots in China (upper right), Yunnan Province (lower right) and the study area (left). Light gray in the left pannel indicates rubber plantations, dark gray the forest fragments. The fifty plots are indicated by black triangles.