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Shifts in swidden agriculture alter the diversity of young fallows: Is the regeneration of cloud forest at stake in southern Mexico?

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To the memory of Lasksmi Reddiar Krishnamurthy.

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ABSTRACT

For centuries, the *milpa* shifting cultivation, a maize-bean-squash polyculture in itinerant fields has been an essential component of the landscape (MS), in tropical montane cloud forest (TMCF) areas managed by Mesoamerican indigenous communities. At present, *milpas* are being replaced by a maize based semi-permanent system (SP) characterized by tillage, fire suppression, application of synthetic fertilizers, and short fallow periods. The effects of this substitution on post-cultivation fallows are unknown, but may have critical consequences for biodiversity and forest regeneration. In the TMCF area of Sierra Norte, Oaxaca, Mexico, the fallowed areas resulting from both cultivation systems are intermixed across the landscape. We compared the composition, richness, and diversity of vascular plant species in 2–3-year-old MS and SP fallows in this area, and explored the possible role of the adjoining forested areas on fallow plant species richness and density. Tree and herb species composition in the fallows separated into two clusters, one belonging to MS and the other to SP. Pioneer and late-successional TMCF tree species were distinctive of MS fallows, whereas native perennial grass and forb species were distinctive of SP fallows. The composition of other life forms could not be distinguished based on cultivation system. The species richness and diversity of trees, tree seedlings, shrubs, and vines were higher in MS fallows, whereas herb species richness and diversity was similar in both fallow types. In MS and SP fallows, the tree seedling species richness increased with the proportion of adjoining forested areas that were > 20 years old, but not with forests younger than that age. Tree seedling density increased with the proportion of adjoining forested areas > 20 years old in SP fallows but not in MS fallows. The density of trees and shrubs were significantly higher in MS fallows than in SP fallows, whereas herb density was significantly higher in SP fallows than in MS. We concluded that the replacement of MS by SP on the one hand, reduces plant diversity in early fallows and the fallow potential for TMCF regeneration; on the other hand, increases the dependence on adjoining > 20-year-old forests as propagule sources.

1. Introduction

Agricultural fallows are important for biodiversity conservation, forest regeneration, ecosystem services, and traditional agricultural system sustainability (see Chazdon, 2014 for a recent review). Fallows are stages of secondary succession and a passive forest recovery method in traditional agroforestry systems in the tropics (Finegan and Nasi, 2004). Mature tropical forests are declining worldwide, which means that secondary forests are becoming increasingly important as biodiversity reservoirs, including those derived from agricultural practices (Chazdon, 2014). Furthermore, agricultural fallows play a key role in soil and forest regeneration, pest and weed control, and the generation of forest products and services (Kleinman et al., 1995; Ribeiro-Filho et al., 2013; Styger and Fernandes, 2006). Such crucial roles partially explain why traditional shifting cultivation systems have been practiced for centuries and are still commonly practiced in marginal areas across the tropics (Styger and Fernandes, 2006; van Vliet et al., 2012). Furthermore, shifting cultivation systems are also maintained because they "fit well" the constraints faced by many smallholder farmers, i.e., the lack of external inputs and fragile market structures (Kleinman et al., 1995; van Vliet et al., 2012). For instance, *milpa* shifting cultivation (MS) has existed for centuries in tropical montane cloud forest (TMCF) areas in Sierra Norte, Oaxaca State, Mexico (del Castillo and Blanco-Macías, 2007; del Castillo and Pérez-Ríos, 2008). As a result, this ancient system of land management is considered to be a successful way of managing biodiversity conservation and the environment (e.g., Boege, 2008). This agroforestry system consists of the slash-and-burn of a small piece of forested land so that a polyculture of maize, bean, and squashes can be grown for a few years. Then, the land is left fallow and the forest regenerates. Cultivation is shifted to another piece of forested area to

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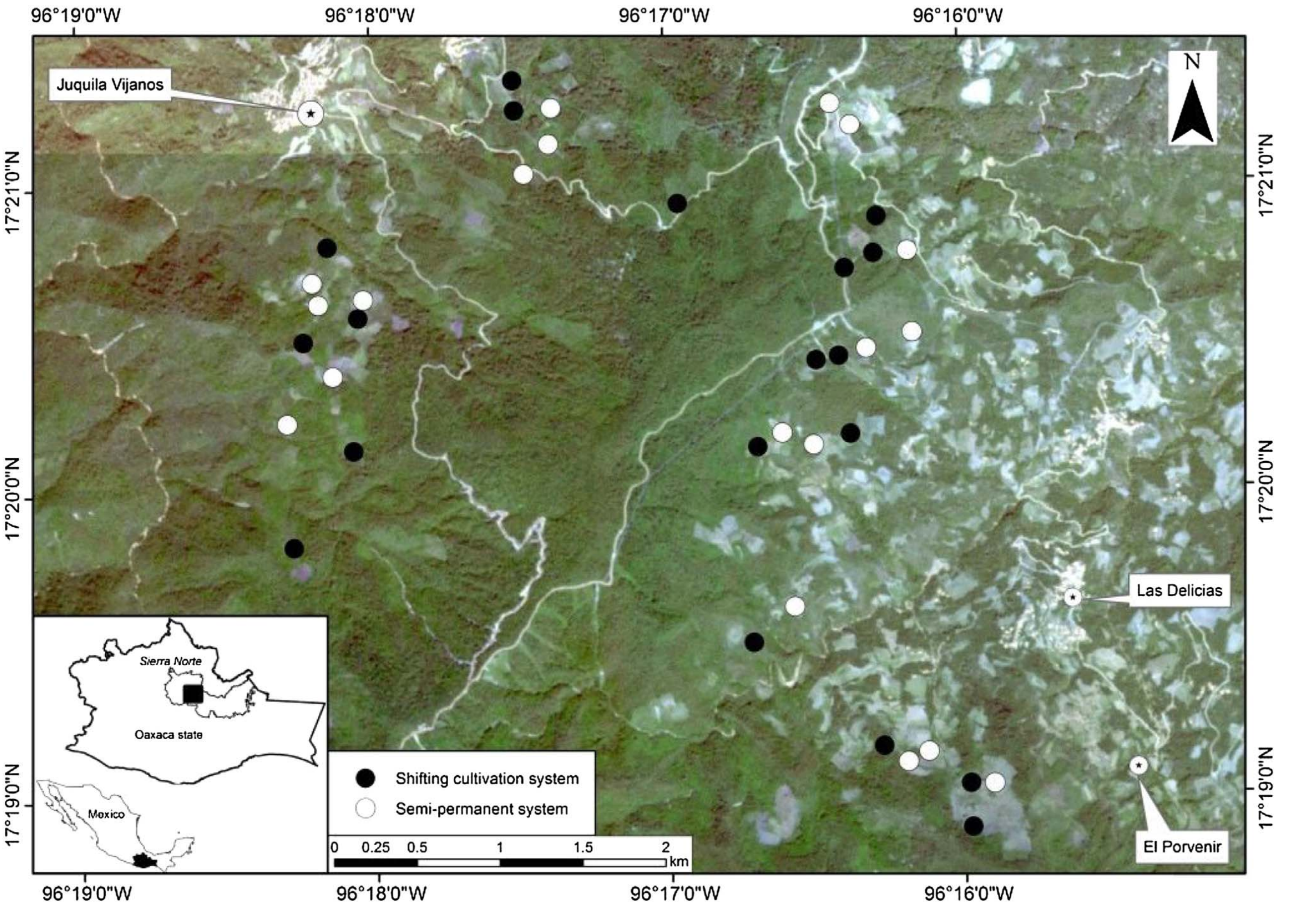

Fig. 1. A 2014 RapidEye image of Juquila Vijanos, Oaxaca, Mexico and the plot location used for the early fallow vegetation assessment in the shifting cultivation agriculture and the semi-permanent systems.

ensure local food crop supply. This spatial and temporal land-use dynamic generates a heterogeneous landscape containing a mosaic of diversified crop fields and fallows of various ages, which include secondary and primary forests (del Castillo, 2015; del Castillo and Blanco-Macías, 2007; Finegan and Nasi, 2004). Thus, MS, as an agroforestry system, should be considered a landscape management method since crop fields interact with other landscape elements. Consequently, cropping system alterations should affect the entire landscape, including the fallows that develop after the land was cultivated.

Shifting cultivation systems allow the agricultural production area to expand and become more intensified. There are also shorter fallow periods and longer cultivation periods (Finegan and Nasi, 2004). These factors can contribute to a reduction in the forested area and the establishment of fallows adapted to frequent clearance and fire. In addition, the intensification of shifting cultivation systems affects the biodiversity of forested areas, soil fertility, and crop yield (Kleinman et al., 1995; Ribeiro-Filho et al., 2013). To enable forested areas to be set aside for conservation, while keeping other areas for intensive cultivation (sensu Green et al., 2005), new local environmental policies, motivated by government economic incentives, have led to the replacement of MS by a semi-permanent system (SP) in southern Mexico (Ibarra et al., 2011; Martin et al., 2011). Such changes in land-use are apparently subtle as both are maize-based cropping systems associated with fallows. However, in contrast to MS, SP is characterized by longer cropping phase, shorter fallow periods, a native maize monoculture, fire suppression, soil tillage, and exhaustive mechanical weed control. As a result, during the cropping period, there have been considerable changes in weed species composition compared to that found in MS fields. The richness and abundance of annual weeds increased and the abundance of perennial weeds decreased (Pérez-García and del Castillo, 2016). However, the impacts of such a substitution on the fallows as biodiversity reservoirs and on their capacity for forest regeneration in TMCF areas have not been investigated yet. Such studies would show how changes in cultivation practices affect the post-cultivation stages.

The potential of fallow periods as biodiversity reservoirs and for forest regeneration in the tropics depends on their capacity to regenerate native species from the soil seed bank, seed rain, and sprouts. These capacities also depend on the degree of environmental disturbance caused by agricultural practices during the cropping phase (Chazdon, 2014; Martínez-Ramos and García-Orth, 2007; Pickett and White, 1985). Thus, different kinds of land-use and their inherent intensity, frequency, and scale of disturbance can affect the regeneration of the native vegetation (Foster et al., 2003; Jakovac et al., 2016). In this regard, the classification of fallow vegetation by life forms can help show how previous cropping management practices act as a habitat filter during the colonization process in the post-cultivation period (Kammesheidt, 1998; Klanderud et al., 2010). The presence of forest fragments from advanced successional stages at the landscape level could be a determinant in the recovery of fallow species diversity (Jakovac et al., 2015). Since seed dispersal in TMCF and secondary forests is very limited (del Castillo and Pérez-Ríos, 2008; Holl et al., 2000; Muñiz-Castro et al., 2006), adjoining forests could become particularly important seed sources for fallow revegetation.

The substitution of MS by SP is still not complete in the TMCF areas of Sierra Norte, Oaxaca. Therefore, fallows derived from both management systems coexist at short distances from each other. As a result, such areas are convenient for studying the effects of replacing the traditional MS with SP systems. In this study, we compared the development of early fallow vegetation in both cultivation systems. We hypothesize that the longer cultivation periods and frequent tillage in SP