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Management intensification in Ethiopian coffee forests is associated with crown habitat contraction and loss of specialized epiphytic orchid species

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Abstract

The moist evergreen Afromontane forest of SW Ethiopia has become extremely fragmented and most remnants are intensively managed for cultivation of coffee (*Coffea arabica*). We investigated the distributions of epiphytic orchids in shade trees and their understory in forests with contrasting management intensity to determine biodiversity losses associated with coffee cultivation and to determine the capacity of coffee shrubs to act as refugia for orchid species. We studied epiphytic orchids in managed forests and natural forests and recorded orchid diversity and abundance in different tree zones of 339 trees and in the understory. Coffee management was associated with a downward shift of orchid species as orchid species were occurring in significantly lower tree zones in managed forest. The number of shrubs in the understory of managed forest was not higher than in natural forests, yet orchid abundance was higher in the understory of managed forests. Local extinctions of epiphytic orchids and species losses in the outer tree zones (a contraction of habitat) in managed forests are most likely driven by losses of large, complex-structured climax trees, and changes in microclimate, respectively. Coffee shrubs and their shade trees in managed forests are shown here to be a suitable habitat for only a limited set of orchid species. As farmers continue to convert natural forest into managed forest for coffee cultivation, further losses of habitat quality and collateral declines in regional epiphytic orchid diversity can be expected. Therefore, the conservation of epiphytic orchid diversity, as well as other components of diversity of the coffee forests, must primarily rely on avoiding coffee management intensification in the remaining natural forest. Convincing farmers to keep forest-climax trees in their coffee forest and to tolerate orchids on their coffee shrubs may also contribute to a more favorable conservation status of orchids in Ethiopian coffee agroecosystems.

Zusammenfassung

Der feuchte, immergrüne afromontane Wald von Südwest-Äthiopien wurde sehr stark fragmentiert und die meisten Überreste werden intensiv für den Kaffeeanbau bewirtschaftet (*Coffea arabica*). Wir untersuchten die Verteilungen von epiphytischen Orchideen in Schattenbäumen und in deren Unterwuchs in Wäldern mit unterschiedlicher Bewirtschaftungsintensität, um die mit dem Kaffeeanbau verbundenen Biodiversitätsverluste zu bestimmen und um die Fähigkeit der Kaffeesträucher, als Refugien

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für Orchideenarten zu fungieren, zu ermitteln. Wir untersuchten epiphytische Orchideen in bewirtschafteten und natürlichen Wäldern und erfassten die Diversität und Abundanz der Orchideen in unterschiedlichen Baumzonen (drei Kronenzonen und Stamm) und im Unterwuchs. Kaffeeanbau war verbunden mit einer Abwärtsverschiebung der Orchideen, indem Orchideenarten in signifikant tieferen Baumzonen im bewirtschafteten Wald auftraten. Die Anzahl der Sträucher im Unterwuchs bewirtschafteter Wälder war nicht höher als in natürlichen Wäldern, aber die Abundanz der Orchideen war im Unterwuchs von bewirtschafteten Wäldern höher. Lokales Aussterben von Orchideenarten und Artenverluste in den äußeren Baumzonen (geschrumpftes Habitat) in bewirtschafteten Wäldern sind höchstwahrscheinlich auf Verluste bei den großen alten Bäumen mit komplexer Struktur bzw. auf Änderungen des Mikroklimas zurückzuführen. Wir zeigen hier, dass die Kaffesträucher und ihre Schattenbäume in bewirtschafteten Wäldern nur für eine begrenzte Gruppe von Orchideen ein geeignetes Habitat darstellen. Indem die Bauern weiterhin natürlichen Wald in Wirtschaftswald umwandeln, können weitere Verluste bei der Habitatqualität und eine damit verbundene Abnahme der regionalen Diversität der epiphytischen Orchideen erwartet werden. Daher muss die Bewahrung der Diversität der epiphytischen Orchideen sowie anderer Komponenten der Diversität in Kaffeewäldern vornehmlich darauf beruhen, dass eine Intensivierung der Kaffeebewirtschaftung in den verbliebenen natürlichen Wäldern vermieden wird. Die Bauern davon zu überzeugen, dass sie die alten Bäume in ihren Kaffeewäldern behalten und Orchideen auf ihren Kaffeesträuchern tolerieren, könnte ebenfalls zu einem günstigeren Schutzstatus der Orchideen in äthiopischen Kaffee-Agroforsten beitragen.

Keywords: Agroforestry; Downward shift; Epiphytes; Forest degradation; Semi-forest coffee; Vertical distribution

Introduction

Epiphytic plants growing on trees are an important yet generally undervalued functional part of forest biodiversity, particularly in rainforests (Diaz, Sieving, Pena-Foxon, Larrain, & Armesto, 2010). They contribute to forest ecosystem services, such as water regulation through cloud and rainwater interception and retention (Munoz-Villers et al., 2012). Furthermore, epiphyte photosynthetic biomass adds to carbon and nutrient cycling of the forest (Diaz et al., 2010) and epiphytic flowering plants support invertebrate communities, including pollinators (Diaz, Sieving, Pena-Foxon, & Armesto, 2012; Murren, 2002).

In undisturbed rainforests, epiphytes are typically vertically stratified (Krömer, Kessler, & Gradstein, 2007). Niche partitioning among epiphytic species usually occurs along microclimatic gradients (Gehrig-Downie, Obregón, Bendix, & Gradstein, 2011; Graham & Andrade, 2004; Karger et al., 2012), with light intensity, wind speed, and air temperature decreasing, and air humidity increasing from tree crown to ground level (Wagner, Bogusch, & Zotz, 2013). In particular, air humidity has been found instrumental in explaining epiphytic diversity in forest canopies (Obregón, Gehrig-Downie, Gradstein, Rollenbeck, & Bendix, 2011).

Forest disturbances caused by human activities such as tree felling, understory removal or silvicultural management have potentially strong impacts on the forest microclimate (Pinto et al., 2010; Wang, Zou, Li, & Li, 2014) and, as a consequence, are expected to significantly alter the diversity and distribution of epiphytes (Boudreault, Coxson, Bergeron, Stevenson, & Bouchard, 2013; Kiraly, Nascimbene, Tinya, & Odor, 2013). Removal of large host trees obviously entails immediate negative impacts on epiphyte diversity as the amount of available habitat in the ecosystem is considerably reduced (Cameron, Goudie, &, Richardson, 2013). The ensuing canopy gaps allow higher levels of irradiation and air circulation, resulting in elevated temperatures, reduced humidity, increased evapotranspiration, and desiccation stress (Laurance, 2004), which in turn may cause declines of epiphytic species richness and strong shifts in epiphyte community composition (Nöske et al., 2008; Larrea & Werner, 2010). Altered microclimatic conditions may also displace or remove the habitat preferences of epiphytic species and thus cause time-lagged species shifts and extinctions, that is, changes in the vertical stratification of epiphytes after the regeneration phase (Wagner et al., 2013) or local extinctions of species unable to regenerate. Understanding changes in epiphytic species diversity and their vertical distribution across the tree crown is of a particular interest in agroforestry systems, where human activities have strong impacts on both upper canopy and understory.

Worldwide, coffee cultivation is one of the most important forms of agroforestry (Waller, Bigger, & Hillocks, 2007) and the effects of coffee agroforest management intensity on different components of biodiversity have been extensively documented, especially in South and Central America (reviewed by De Beenhouwer, Aerts, & Honnay, 2013). So far, most studies on epiphytes in agroforestry systems have focused on changes in community composition and have neglected more subtle changes of within tree distribution patterns. The few studies that statistically researched the effects of forest management on vertical distributions of epiphytes within trees demonstrated that there were fewer epiphytes and fewer species on the outer branches of canopies in managed agroforests compared to natural forests (Haro-Carrión, Lozada, Navarrete, & de Koning, 2009; Moorhead, Philpott, & Bichier, 2010). Other studies demonstrated the importance of the coffee understory for conservation of epiphytes (e.g.,