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Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystem

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Abstract

We studied the relationships of bird and small mammal species richness, composition, and abundance to vegetation structure and economic profitability across a coffee intensification gradient in central Veracruz, Mexico. We conducted 2 years of point count censuses for summer resident birds, 2 years of Sherman live trapping for small mammals, and gathered vegetation structure data at 147 sampling points distributed over 16 sites spanning a cultivation intensification gradient. We calculated net annual revenue per hectare as an index of profitability from economic and management data collected during interviews with plantation owners/managers. Both the species richness and abundance of forest-affiliated birds were significantly greater in floristically and structurally diverse 'bajo monte' coffee and forest compared with commercial polyculture coffee, which was, in turn, significantly richer than statistically indistinguishable specialized shade and sun coffee. Mammal capture rates were extremely low at all but two sites. Forest bird species richness and abundance were explained by multiple linear regression models that included statistically significant effects of shade cover, percent of trees with epiphytes, and canopy height. We found no clear relationship between profitability and biodiversity, with biodiverse bajo monte coffee plantations ranking among the most profitable under all price scenarios. The high profitability of biodiverse bajo monte coffee systems was not dependent on the inclusion of long-term environmental costs or premium pricing systems. Our results demonstrate that high-biodiversity coffee cultivation can be compatible with high profitability, and has significant potential for conserving biodiversity in coffee-growing regions, but only as a substitute for low-biodiversity coffee cultivation, not forest.

Keywords: Agroecology; Birds; Mammals; Coffee; Economics; Mexico

1. Introduction

Increasingly over the past two decades, shade coffee agroecosystems have drawn the attention of the conservation biological community because of the seeming potential to conserve biodiversity while maintaining economic productivity. This potential is underscored by the economic significance of coffee as a commodity, second only to oil in terms of value of international trade for most of the post-World War II period (Ponte, 2002), and its biological significance, as it grows in tropical lower montane forested regions rich in endemic biodiversity. One of the most significant features of coffee agroecosystems from the standpoint of biological conservation is their tremendous variation in vegetation structure and diversity. A generation of field studies (recently reviewed by Donald, 2004) has produced a general consensus that highly intensified sun coffee systems have little biodiversity conservation value, but there is still a great deal of controversy over the

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conservation value of shade coffee systems which may vary widely in vegetation structure and diversity (Philpott and Dietsch, 2003; Rappole et al., 2003a,b; O'Brien and Kinnaird, 2003, 2004; Dietsch et al., 2004).

The sociopolitical and economic dimensions of coffee cultivation and its alternatives lie at the center of this controversy, but have received little study to date (but see Nestel, 1995; Rice, 1999; Gobbi, 2000; Perfecto et al., 2005). Because profit maximization is one of the primary objectives of most coffee farmers, management recommendations based solely upon their biological implications are less likely to have an impact than those whose economic implications can be explicitly understood. Coffee farmers and policy makers need to know not only how much biodiversity you can conserve in coffee and how to do it, but how much it will cost.

That is, assuming it costs anything. The relationship between the biodiversity and profitability of ecosystems is usually assumed to be a trade-off: if you want to save biodiversity, you have to pay for it, and conversely, that the highest profits are achieved in low-biodiversity ecosystems such as biologically simplified ''conventional'' agroecosystems. However, this is not necessarily the case. Examples of synergistic interactions between biodiversity and profitability have been demonstrated in many agroecosystems, and include the control of pest populations by a diverse and robust community of predatory, or ''beneficial'', arthropods, increased pollination services to crop plants by native pollinating insects, and increased soil nitrogen availability created by the N-fixing microbes of leguminous plants (Vandermeer, 1995; Buchmann and Nabhan, 1997; Daily, 1997; Pimentel et al., 1997; Costanza et al., 1997; Perfecto et al., 2004).

The explicit examination of the profit–biodiversity relationship in coffee is still in its infancy, and it is essential that this relationship continue to be explored. Perfecto et al. (1996) drew attention to the increased production costs of intensified, or technified coffee, suggesting that in some cases and depending on the price of coffee, these costs may more than offset the revenue generated by the increased yields of such systems. Gobbi (2000) found that conversion of El Salvadorian coffee plantations to meet ''bird-friendly'' criteria would be financially viable for all plantation types examined, yet this study did not examine biodiversity explicitly, and this conclusion was dependent on farmers receiving a price premium for selling certified bird-friendly coffee. In northern Chiapas, Mexico, Soto-Pinto et al. (2000) found that shade cover was positively correlated with coffee yield when shade cover was between 23 and 38%, with coffee yield only dropping off when shade cover exceeded 50%. In the same system, Soto-Pinto et al. (2002) documented reduced incidence of coffee leaf rust with more shade strata, and reduced spontaneous herb growth with increasing shade density, both of which would contribute to greater net revenue in high shade systems. Additional revenue provided by non-coffee products in these systems has also been shown to improve net revenue (Liza et al., 2003). Further west in Chiapas, Romero-Alvarado et al. (2002) found no significant difference in coffee yields between diverse and *Inga*-dominated shade plantations, though the latter required one fewer annual round of weed removal. In Indonesian coffee, Klein et al. (2003a,b) documented a positive correlation between the species diversity of pollinating bees and coffee pollination and fruit set. Ricketts (2004) and De Marco and Monteiro Coelho (2004) demonstrated similar enhancements of coffee pollination in coffee plantations located in close proximity to forest patches in Costa Rica and Brasil, respectively.

These examples provide some preliminary evidence that the relationship between biodiversity and profitability in coffee agroecosystems is complex, and may include synergies as well as trade-offs. To the extent that there are trade-offs, a rigorous understanding of profit–biodiversity relationships in coffee will help target conservation dollars most efficiently and effectively. To the extent that there are synergies, cultivation techniques and policies can be designed that could potentially generate significant gains for both coffee producers and tropical biodiversity conservation.

Herein, we present the results of a study designed to address the following questions:

(1) How do the species richness, composition, and abundance of native forest birds and small mammals vary across a coffee intensification gradient in central Veracruz, Mexico?
(2) What specific aspects of the vegetation structure of coffee plantations are most closely correlated with patterns of bird and small mammal diversity and abundance across this gradient?
(3) How do management techniques, vegetation structure, cost structure, coffee yield, and prices interact to shape the relationship between biodiversity and profitability in coffee agroecosystems?

2. Methods

2.1. Study system

We conducted this study in the central Veracruz coffee-growing region, between 1000 and 1400 m above sea level on the eastern slope of the central plateau of Mexico. Total annual precipitation in this region varies between 1350 and 2200 mm, while the mean annual temperature is between 12 and 19.5 °C (Manson et al., 2004). There are three well-defined seasons: the relatively dry cool season lasting from October–November to March, a dry warm season during April and May, and the wet warm season from June to September–October (Williams-Linera, 2002). Tropical montane cloud forest (Grubb, 1977; Rzedowski, 1996) is the dominant land cover type in the region, covering 28% of