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Smallholder response to environmental change: Impacts of coffee leaf rust in a forest frontier in Mexico

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A B S T R A C T

Coffee agroforestry systems are a promising approach to the challenge of sustaining both biodiversity and livelihoods in tropical landscapes. However, coffee farmers' response to the unrelenting coffee leaf rust (CLR) outbreak may have repercussions for the potential of coffee agroforestry systems to contribute to biodiversity conservation. Adaptations in management practices could affect the extent to which farmers rely on ecological processes vs. external inputs (e.g., agrochemicals) to support production. This study investigates farmers' response to CLR outbreak through a study in a forest frontier in a Biosphere Reserve in Chiapas, Mexico. We conducted household surveys and fieldwork before the CLR outbreak in 2011-2012 (n = 59), and follow-up surveys after the outbreak in 2016 (n = 48). Before CLR outbreak, farmers were cultivating Arabica coffee varieties in agroforestry systems and generally following agroecological approaches. Most farmers (82%) were certified organic and did not employ synthetic agrochemicals. Farmers (66%) had plans to expand their Arabica coffee agroforests either into forest (35%) or fallow (31%) in response to high farm gate prices. After CLR outbreak, 94% of farmers had CLR-resistant hybrid coffee varieties (HCV) in their possession and were either incorporating them by substituting affected Arabica coffee plants in existing fields, or by establishing new coffee fields with HCV at lower elevations. In attempts to control CLR, farmers (54%) also applied agrochemicals at least once and, to a lesser extent (19%), removed shade trees. Among the farmers (63%) who were planning on expanding coffee production with HCV, more farmers were planning on expanding on fallow (46%) than forest (17%) compared to the period before CLR outbreak (p-value < 0.05). Public and private actors promoted and distributed saplings of HCV and agrochemicals along with technical assistance. The promotion of HCV along with fertilizers may result in a substitution of ecosystem functions with agrochemicals, and the need to acquire seeds and saplings outside of farmers' own resource base and networks. This shift in management strategies generates new instabilities and risks by introducing a new market for HCV about which little is known and by making external agents the holders of productive resources and knowledge.

1. Introduction

Tropical landscapes face the dual challenge of conserving biodiversity and remaining forests, and supporting local livelihoods (Harvey et al., 2008; Bhagwat et al., 2008). Biologically rich landscapes in the tropics are home to many local communities often facing the constraints of economic poverty (Adams et al., 2004; Fisher and Christopher, 2007). For actors concerned with conserving biodiversity and remaining forests, there is an ongoing search for strategies that deliver this goal while also taking into consideration the livelihoods of the local people. A set of strategies that has gained ground in recent decades is payment for ecosystem services based on commodifying ecosystem processes and goods (e.g., water cycling, carbon sequestration) in order to assign them a market value (reviewed in Engel et al., 2008). Whether or not these strategies are successful at ensuring a fair and effective exchange of economic benefits to local communities for

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conserving the biodiversity and forests that provide such ecosystem processes is unclear (Pagiola et al., 2005; Wunder, 2006; Honey-Roses et al., 2009; Calvet-Mir et al., 2015; Prager et al., 2015). For the local communities subject to these and other conservation strategies, supporting livelihoods occurs in a context of conflicting external pressure to simultaneously conserve and produce (e.g., Clough et al., 2011). The challenges faced by local communities are further complicated when we consider that many of the landscapes that they inhabit have been designated as protected areas. Social reproduction in a protected area must occur within additional institutional constraints imposed on how communities may appropriate and manage natural resources (West and Brockington, 2006). This adds another strain to the autonomy that local communities may exercise over their biodiversity and forests in highly contested tropical landscapes.

Shade coffee has received considerable attention for its promising capacity to reconcile goals in conservation biology with supporting local livelihoods in tropical landscapes (Perfecto et al., 1996; Perfecto and Vandermeer, 2008; Bhagwat et al., 2008; De Beenhouwer et al., 2013; Jha et al., 2014). In Mesoamerica, most coffee farms in mountainous areas are small-scale and produce coffee in agroforestry systems (Donald, 2004; Jha et al., 2012, 2014). Coffee agroforestry systems have received considerable attention from the scientific and public communities for their capacity to conserve biodiversity and ecosystem processes (Perfecto et al., 1996; Tscharntke et al., 2011; De Beenhouwer et al., 2013), increase landscape connectivity, and serve as a buffer around forested patches and protected areas (Perfecto and Vandermeer, 2002, 2010; Vandermeer and Perfecto, 2007). Coffee management practices—which range from intensive, shadeless monocultures to rustic shaded agroforests—determine the potential of coffee systems to conserve biodiversity at the farm and landscape levels (Moguel and Toledo, 1999). However, even in the less intensively managed agroforestry systems, the biodiversity conserved may not always be comparable to that found in surrounding forests (Rappole et al., 2003; Ambinakudige and Sathish, 2009; Valencia et al., 2014). The direct and indirect effects of coffee management strategies, such as shade tree management, may lead to significant divergences between the biological and structural compositions of forests and agroforests (Valencia et al., 2015, 2016). For specialists and old-growth forest species, agroforests may not be a suitable habitat (García-Fernández et al., 2003; Tejeda-Cruz and Sutherland, 2004; O'Dea and Whittaker, 2007; Scales and Marsden, 2008). Nonetheless, in the larger global agricultural context, shade coffee continues to be a promising alternative to conventional agriculture (Philpott and Dietsch, 2003).

In addition to its innate value, biodiversity is also valuable for supporting ecosystem processes important for agricultural production, such as soil nutrient cycling, pollination, pest regulation, and microclimate regulation (Swift et al., 2004; Jackson et al., 2007). By cultivating coffee in agroforestry systems, farmers may internalize resources (i.e., avoid the use of agrochemicals) by relying on biodiversity and ecological processes at the farm and landscape levels to support production (Tscharntke et al., 2005; García-Barrios et al., 2017). By managing shade tree biodiversity and vegetative structure based on local and traditional knowledge, farmers harness ecosystem functions to sustain their production (Grossman, 2003; Segura et al., 2004; Cerdán et al., 2012; Valencia et al., 2015). This form of self-provisioning is a livelihood strategy that supports farmers' autonomy by reducing their reliance on external inputs and on policies and resources controlled by external actors (van der Ploeg, 2010; Schneider and Niederle, 2010; Rosset and Martínez-Torres, 2012).

Shade coffee has also been praised for its potential to deliver socioeconomic benefits to farmers cultivating Arabica coffee, a highly valued global commodity whose value is even greater under the growing conditions in mountainous tropical landscapes (e.g., high elevation, shade grown). Shade coffee may achieve additional recognition (and hence a higher market price) when the postulated ecological and social attributes of its production system are showcased via certification labels (e.g., fair trade, organic). Although certification schemes do not contribute to the rise of farmers along the production chain, they intend to benefit farmers by awarding a premium over the conventional price for abiding by voluntary regulations. There are cases that document positive socioeconomic effects of certification schemes (Bacon, 2005; Wollni and Zeller, 2007; Rueda and Lambin, 2013; Chiputwa et al., 2015); however, it is unclear if benefits are widespread and to what extent such benefits actually translate to meaningful improvements in farmers' livelihoods (Utting-Chamorro, 2005; Philpott et al., 2007; Blackman and Rivera, 2010; Beuchelt and Zeller, 2011; Vellema et al., 2015). Often, the farmers that perceive greater socioeconomic benefits are those organized in cooperatives or other local associations that allow them to better negotiate market engagements (Raynolds et al., 2004; Bacon et al., 2008; Lunaa and Wilson, 2015; Mojo et al., 2017). In the end, regardless of certification status, intermediaries and end sellers are the principal profit winners of niche markets for specialty coffee, while farmers remain subordinated at the bottom of the coffee value chain, simply selling a raw commodity (Gresser et al., 2002; Pérez Akaki and Echánove Huacuja, 2006; Soleto and Cruz-Morales, 2017).

Shade coffee in Mesoamerica is characterized by a recurrent history of shocks and crises with important ecological and socioeconomic implications on farmers' livelihoods and the biodiversity conserved in coffee growing landscapes. From the coffee crisis brought by the dismantling of the International Coffee Agreement in the late 1980s to climatic and environmental shocks such as hurricanes and pests, farmers are constantly facing new challenges to navigate (Silva et al., 2006; Eakin et al., 2006, 2012, 2014; Philpott et al., 2008b; Tucker et al., 2010). The most recent shock that has shaken the Mesoamerican coffee growing regions is coffee leaf rust (CLR).

CLR, a fungal disease caused by *Hemileia vastatrix,* has a long history of extreme devastation. In the late 19th century, CLR forced the abandonment of coffee production in large areas of southern Asia (McCook, 2006). In the 1970s, CLR expanded to coffee producing areas in Latin America (Fulton, 1984). However, it wasn't until the 2012/2013 season when CLR began to approach the devastating levels observed in recent years (Cressey, 2013). USAID estimates that between 2012 and 2014, CLR caused one billion dollars in damage and affected the livelihoods of more than two million people in Latin America (USAID, 2014). CLR is still wreaking havoc and coffee smallholders continue to struggle to adapt their livelihoods to a changing environment characterized by persistent pest presence that has significantly diminished coffee yields.

Shade coffee farmers' response to the unrelenting CLR outbreak may have important repercussions on farmers' management strategies and, subsequently, on the potential of coffee agroforestry systems to support biodiversity and ecosystem functioning. Management changes could affect the extent to which farmers rely on ecological processes (e.g., soil nutrient cycling, pollination) produced by the biotic interactions in their fields and landscapes to support production. This may carry important repercussions on farmers' autonomy. This study investigates farmers' responses to regional environmental change through a study on the responses to CLR by coffee smallholders in a forest frontier in a Biosphere Reserve in Chiapas, Mexico. Our aim is to identify farmers' adaptation strategies to CLR and discuss the implications of these strategies on biodiversity and forest cover conservation. We discuss findings using a framework centered on farmers' autonomy. A particular advantage of our study is that we collected data on coffee management practices and tree biodiversity in shade coffee farms and surrounding forests before the CLR outbreak (2011–2012). These data serve as a baseline to which to compare current adaptation strategies and inquire into the causal relationship between CLR outbreak and farmers' responses.

The following section outlines our framework on autonomy. We follow this discussion with a presentation of the sites of the case study, the results of fieldwork and surveys collected before the CLR outbreak, the follow-up surveys conducted after the CLR outbreak, and discuss the implications for our results for future research. We use the case study to