Agriculture, Ecosystems and Environment 206 (2015) 21–32

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Parasitoid wasps benefit from shade tree size and landscape complexity in Mexican coffee agroecosystems

Damie Pak [a,1,*], Aaron L. Iverson [a,1], Katherine K. Ennis [b], David J. Gonthier [c], John H. Vandermeer [a]

[a] Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI, United States
[b] Department of Environmental Studies, University of California-Santa Cruz, Santa Cruz, CA, United States
[c] Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA, United States

ARTICLE INFO

Article history:
Received 26 November 2014
Received in revised form 16 March 2015
Accepted 17 March 2015
Available online 25 March 2015

Keywords:
Agricultural management
Biodiversity
Biological control
Coffee agroecosystem
Landscape complexity
Parasitoid wasps

ABSTRACT

Increased agricultural intensification has led to a decrease in biodiversity and the deterioration of important agricultural ecosystem services, such as biological control. Parasitoid wasps are important biological control agents for many crop pests, and augmenting their abundance and diversity may confer significant economic and environmental benefits. We investigated how management practice, landscape composition, and biotic and abiotic environmental components affect the parasitoid community in coffee farms of Chiapas, Mexico. Local variables pertaining to vegetation structure and diversity, *Azteca sericeasur* (keystone ant species) presence, and abiotic factors such as synthetic chemical usage and altitude were quantified. Additionally, the landscape composition was assessed for different land uses at both 250 m and 500 m radii. Utilizing generalized linear mixed-effect models (GLMM), we found that both local and landscape factors affected the parasitoid community. At the local scale, the proximity of *A. sericeasur* nests benefited parasitoid abundance and diversity, whereas different measures of vegetation structure had both positive and negative effects on parasitoid richness, abundance, and diversity. At the landscape scale, we found neighboring intensively managed farms to have an adverse impact on parasitoids. Surprisingly, parasitoids were also positively influenced by increasing altitude and the use of synthetic pesticides. Our findings indicate that the studied agricultural matrix supports a diverse parasitoid community, and that properly managed vegetation structure and increased landscape complexity may augment natural parasitoid communities. Thus, conservation management should take into account environmental complexity at multiple scales.

1. Introduction

In addition to providing food, fiber, and fuel, agroecosystems provide various supporting, regulating, and cultural ecosystem services, such as nutrient cycling, soil formation, pollination, biological control, and landscape aesthetics (Iverson et al., 2014; Millenium Ecosystem Assessment, 2005). However, agricultural intensification over the past several decades has maximized crop production to the exclusion of various other services, with considerable negative consequences to ecosystem health and biodiversity (Perfecto and Vandermeer, 2008). We are now faced with the challenge of maintaining food production, but reversing the trend of increasing negative impacts of agricultural intensification on humans and the environment (Tscharntke et al., 2012). Designing agroecosystems that decrease the need for pesticides through autonomous biological control is one approach to accomplish this goal (Vandermeer et al., 2010a).

Multiple studies have been devoted to understanding patterns of biocontrol provision in agroecosystems, yet results vary as to if and at which scale environmental heterogeneity is beneficial. On a local scale, organic or diversified farm practices can have a positive impact on natural enemy abundance and diversity (Bengtsson et al., 2005; Döring and Kromp, 2003; Hole et al., 2005), but not always (Clough et al., 2005; Pfiffner and Luka, 2003; Weibull et al., 2000). The structure of the landscape is also often, but not always, highly influential on natural enemies (Batáry et al., 2011; Bianchi et al., 2006; Chaplin-Kramer et al., 2011; Gonthier et al., 2014; Perfecto and Vandermeer, 2008). Structurally complex landscapes

* Corresponding author at: Department of Ecology and Evolutionary Biology, University of Michigan, 2019 Kraus Natural Science Building, 830 N. University St., Ann Arbor, MI 48109-1048, United States.
E-mail addresses: damiepak@umich.edu (D. Pak), iverson@umich.edu (A.L. Iverson), kennis@ucsc.edu (K.K. Ennis), gonthierd@berkeley.edu (D.J. Gonthier), jvander@umich.edu (J.H. Vandermeer).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.agee.2015.03.017
0167-8809/

can support more species through resource provision and diversity, refuges during crop disturbance or seasonality, and migration facilitation (Rusch et al., 2010; Tscharntke et al., 2012).

The effect of environmental heterogeneity on natural enemies is commonly context-dependent, and there are often strong interactions between local and landscape management (Tscharntke et al., 2005). For example, a growing body of research suggests that the benefits of diversified local management are highly contingent on the landscape, where improvements in ecosystem service provision are maximized under intermediate levels of landscape complexity (Tscharntke et al., 2012). At high levels of landscape complexity, species pools of natural enemies may be high enough in the surrounding habitat fragments to maintain relatively high rates of biocontrol even in intensively managed farms (Batáry et al., 2010, 2011; Concepción et al., 2007). On the other hand, in areas where the landscape is very homogeneous (i.e. cleared of natural vegetation), alternative resources may not be sufficient to support a regional species pool of natural enemies, however locally diverse a farm may be (Perfecto et al., 2009).

Parasitoid wasps are important biological control agents of many crop pests. Some studies show parasitoid-mediated mortality rates averaging above 25% and reaching up to 80% on serious agricultural pests, such as the coffee leafminer (Pereira et al., 2007; A.L. Iverson, unpublished data). Augmenting naturally occurring parasitoid populations may therefore have a considerable economic importance (Heraty, 2009). To do so may be challenging in agroecosystems, as parasitoids are particularly sensitive to agricultural intensification due to their small size, low dispersal ability, high-host specificity, and their dependence on diverse habitats to provide both arthropod hosts and floral resources (Landis et al., 2000; LaSalle and Gauld, 1991).

Parasitoid community dynamics do not occur in isolation, and are highly affected by other organisms through direct or indirect interactions (Muller et al., 1999; Völkl, 1992). In farms located in the same region as the present study, the arboreal-nesting ant, *Azteca sericeasur* (Hymenoptera: Formicidae), serves as a keystone species regulating the abundance of other arthropods, including the green coffee scale *Coccus viridis* (Hemiptera: Coccidae), other ant species, and the coffee berry borer, *Hypothenemus hampei* (Coleoptera: Curculionidae) (Gonthier et al., 2013; Jimenez-Soto et al., 2013; Vandermeer et al., 2010a). In terms of parasitoids, *A. sericeasur* is influential through two opposing mechanisms. On one hand, the ant exhibits a negative effect on parasitoids as it attacks potential enemies of the green coffee scale, which benefits the ant through its honeydew production (Liere and Perfecto, 2008). However, large populations of scales often occur in the vicinity of *A. sericeasur* nests due to the mutualism between the two organisms, leading to a larger host population that may attract more parasitoids. Therefore, the effects of *A. sericeasur* on parasitoids may not be unidirectional.

We surveyed the parasitoid wasps in coffee farms of differing agricultural intensities in Chiapas, Mexico to determine how their distribution is impacted by local- and landscape-level environmental characteristics. At the local scale, we evaluated several habitat characteristics including vegetation structure and diversity, as well as *A. sericeasur* presence. We also examined the landscape composition at 250 and 500 m radii. We addressed the following questions: (1) Do parasitoid wasps benefit from local and/or landscape complexity? (2) Is the local or landscape scale

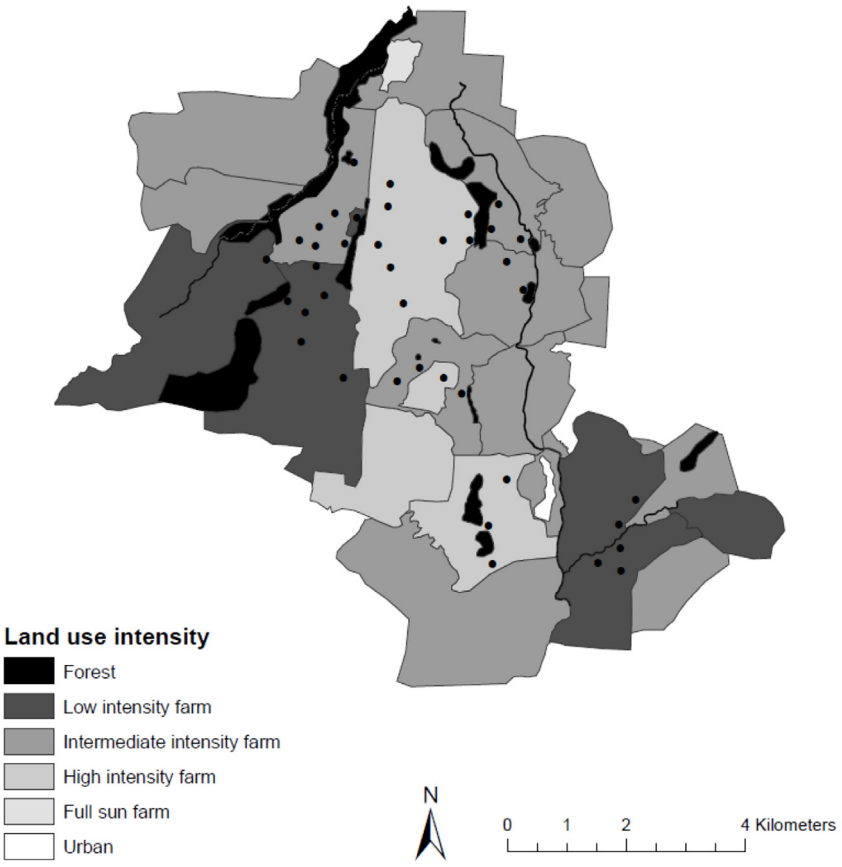

Fig. 1. Map of farms, forests, and town (polygons), as well as plot sites (points), included in the study. All farms were located in the Soconusco region of Chiapas, Mexico.