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Tree cover mediates the effect on rapeseed leaf damage of excluding predatory arthropods, but in an unexpected way

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ABSTRACT

Birds and predatory arthropods are often implicated in pest control, but their relative impact and how this is mediated by variation in tree cover requires elucidation. We excluded birds and ground predatory arthropods from rapeseed plants in 2.5 × 1 m plots in 26 homegardens in Ethiopia, leaving the same sized control plots. From six groups of plants in bird exclosure and control plots, respectively, three groups were excluded from ground predatory arthropods. Data on leaf damage were surveyed four times at weekly intervals. The tree cover and land-use composition within 100 × 100 m surrounding each plots were recorded in the field and from a satellite image within 200 and 500 m buffer zones. The results show that the mean leaf damage was higher on rapeseed plants from which predatory arthropods were excluded than on control plants. However, excluding birds had no or only a weak impact on leaf damage. The mean leaf damage within predatory arthropod exclosures decreased with increasing tree, forest and perennial cover but increased with increasing grazing land cover and annual crop cover, while on control plants it was low across the tree cover variation. This pattern may indicate the presence of a higher density of herbivores on rapeseed plants and also more predatory arthropods (i.e., to control them) in tree-poor homegardens compared to tree-rich homegardens. Hence, tree-poor homegardens in this landscape have sufficient habitat heterogeneity to support natural enemies to deliver significant pest control on rapeseed. Our results show that there was variation in the dynamics of pests and predatory arthropods across the tree cover variation, suggesting changes in landscape composition could affect the pest control services and the outcomes for local farmers.

1. Introduction

Top-down regulation of crop pests by vertebrate and invertebrate natural enemies is an important ecosystem service in agroecosystems (Tscharntke et al., 2005; Zhang et al., 2007; Bianchi et al., 2006; Van Bael et al., 2008; Morrison and Lindell, 2012). Understanding how such effects of natural pest control vary across agricultural landscapes may help farmers to develop management strategies so that they can enhance the benefit from this service (Costamagna and Landis, 2006; Ratnadass et al., 2012; Martin et al., 2013). However, the effectiveness of natural enemies in suppressing crop pests is influenced by processes at both local and landscape scales (Tscharntke et al., 2007; Chaplin-Kramer and Kremen, 2012; Tscharntke et al., 2012). Many studies show that the presence of different land-use types in the landscape, such as high tree density or cover of semi-natural habitats, can enhance the species richness of pest-controlling organisms or the natural pest control services across agricultural landscape (Bianchi et al., 2006; Rusch et al., 2013; Weibull et al., 2003; Gove et al., 2008; Clough et al., 2009), but results are not consistent. Some studies show higher predation from birds (Perfecto et al., 2004; Johnson et al., 2010) and arthropod natural enemies (Langellotto and Denno, 2004; Bianchi et al., 2006) on insect herbivores in complex habitats. Other studies show conditional or no effect of structural complexity on predation from birds or arthropods (Greenberg et al., 2000; Philpott et al., 2009; Martin et al., 2013). In those cases, it is suggested that predation rates could still be related to bird or arthropod abundance (Bereczki et al., 2014; Singer et al., 2012), but how this is connected to the spatial scale at which land-use variables are measured is not fully clear. Moreover, some studies indicate that top-down effects of predatory arthropods may be lower in complex than in simple habitats due to stronger bird predation on predatory flying insects in complex habitats (Martin et al., 2013).

Different predatory groups, such as insectivorous birds and arthropods, may respond differently to complexity even in the

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same landscape, due to species- or group-specific responses (Rand and Tscharntke, 2007; Schmidt et al., 2008; Ruiz-Guerra et al., 2012; Barbaro et al., 2005). However, few studies have so far compared the effects of insectivorous birds and ground arthropods on crop pests (herbivorous arthropods) within a single system (Martin et al., 2013). Even so, initiatives to enhance natural pest control require a critical understanding of the driving factors of the services provided by different groups of organisms in a landscape context (Tscharntke et al., 2007; Gardiner et al., 2009; Veres et al., 2011).

The ecological patterns related to natural pest control could be different between tropical and temperate agricultural landscapes due to the differences in land-use history, diversity patterns, species composition and environmental factors such as temperature, humidity and seasonality (Daily and Ehrlich, 1996; Kakkar and Gupta, 2010). Moreover, our understanding about the natural pest control services provided by predatory arthropods is poor in tropical agricultural landscapes (meta-analysis, Shackelford et al., 2013). In the tropics, due to the small scale farming systems many landscapes are heterogeneous (Perfecto et al., 2004; Harvey et al., 2008). For example, the agricultural landscapes in southwest Ethiopia consist of a mosaic of small land-use types, including annual crop fields, grasslands, forest patches of different sizes and scattered trees. This mosaic of land-use types could influence the natural enemy abundance and the corresponding crop pest suppression services (Abate et al., 2000). For example, heterogeneous farmlands of southwestern Ethiopia harbor a rich bird fauna with about the same species richness of insectivorous birds as in the adjacent forests (Gove et al., 2013), even though the overall species richness increases with tree cover (Gove et al., 2008). In our study area, Engelen (2012) recorded an average of 58 bird species per homegarden and these included many insectivorous species indicating the potential for pest control in this landscape. The dominant groups of ground predatory arthropods in the homegardens are spiders, ants and beetles (Lemessa et al., 2015). Among these groups, the most abundant are ants and spiders; in particular army ants (*Dorylus* spp.) and wolf spiders (family Lycosidae) are rather abundant. Ants seem to be favored by high tree cover, while spider abundances vary across the landscape in relation to several factors including tree cover (positive to some extent), ensete cover (positive) and open non-crop cover such as grazing land (positive) (Lemessa et al., 2015). Other possible ground predators that we have observed in this landscape are frogs, while lizards are infrequent (pers. obs.). In many areas of the tropics, such as in Ethiopia, insecticides are too costly and thus the benefit of natural pest control to farmers could be high. However, how top-down effects of these predator organisms are affected by these land-use variables at both local (homegarden) and landscape scales is not yet understood.

In this study we start to fill this gap by examining the relative top-down effects of birds and ground predatory arthropods on insect damage to leaves. Moreover, we examine how the top-down effects of these predator organisms are mediated by the local and landscape level land-use composition in a heterogeneous tropical agricultural landscape. Hence, we hypothesized that firstly, excluding birds and ground predatory arthropods would cause higher leaf damage to crops; secondly, the top-down effects of these predator organisms would be stronger in areas with a high tree cover than in areas with a low tree cover. This second hypothesis was a consequence of our expectation that habitats with high tree cover provide predators with more refuges and alternative food resources than areas with low tree cover. To examine this, we excluded both birds and ground-dwelling predatory arthropods (e.g., predatory carabids, wolf spiders, etc.) in a factorial experiment and surveyed herbivore damage on rapeseed (*Brassica napus* L.) in twenty-six homegardens. Rapeseed is a globally important oil crop and is commonly grown in southwestern Ethiopia; both its leaves and its seeds are used here (Weyessa and Wakjira, 1999). Moreover, from our preliminary observations and according to local farmers, rapeseed is a fast growing crop and more attacked by insect herbivores such as aphids, cabbage flea beetles and different lepidopteran caterpillars than other vegetables and spice crops.

2. Materials and methods

2.1. Study area

The study was conducted in the agricultural landscape of Gera district of Jimma Zone, southwest Ethiopia (7°34′–7°58′N and 36°04′–36°43′E). The study area is characterized by moderate, undulating land and rugged slopes and lies at 1800–2150 m a.s.l. The major soil types are Nitosols and Vertisols (Nigussie and Kissi, 2012). The wet season is from May to September and the rainfall varies between 1880 and 2080 mm per annum. The monthly mean temperature varies between 14 and 25 °C (District Agricultural Development Office archive, unpublished). The area has remnants of moist evergreen afromontane natural forests (Friis et al., 2010), which are comprised of tree species such as *Pouteria adolfi-friederici* (Engl.) Baehni, *Croton macrostachyus* Hochst. ex Delile, *Schefflera abyssinica* (Hochst. ex A.Rich.), *Syzygium guineense* Wall.,*Allophyllus abyssincus* (Hochst.) Radlk., *Sapium ellipticum* (Hochst.) Pax *Albizia* spp. and *Olea welwitschii* (Knobl.) Gilg. and Schellem. Although evidence suggests that there was reforestation with indigenous trees during the nineteenth century in certain areas (McCann, 1995), during the last 40 years, the forest cover in the landscape has decreased from 54% to 40% (Hylander et al., 2013).

In the study landscape, both annual and perennial food crops are commonly grown in the homegardens and fields (Lemessa et al., 2013). Homegarden is a traditional land-use that involves growing annual and perennial crops as well as livestock rearing within the compounds of individual houses, usually in association with multipurpose trees and shrubs. As in many other tropical regions, rural homegardens in southwest Ethiopia are heterogeneous and a variety of annual and perennial crops such as vegetables, fruit trees and spices, are grown integrated with plants useful for medicines, ornament, fodder and live fences (Soemarwoto, 1987; Kumar and Nair, 2004; Abebe et al., 2010).

Major annual crops in the landscape include teff (*Eragrostis teff*, (Zucc.) Trotter), maize, pulses, oil crops and vegetables (Lemessa et al., 2013). The perennial crops that are commonly grown in homegardens are khat (a stimulant plant) (*Catha edulis* (Vahl) Forssk. ex Endl.), coffee (*Coffea arabica* L.), ensete (false banana) (*Ensete ventricosum* (Welw.) Cheesman) and fruit trees. Apart from these crops, farmers also grow trees in the homegardens and in the surrounding area as plantation woodlots, live fences and to provide shade for homegarden coffee (Abebe et al., 2010; Lemessa et al., 2013; Ango et al., 2014).

2.2. Study design

Using information from satellite images available from Google Earth, we selected 26 rural homegardens (areas around houses in the agricultural landscape). To obtain a large variation in tree cover at different scales among the homegardens, we selected homegardens situated at different distances from edges of large patches of natural forests (0–2260 m, Fig. 1A) and with different local tree cover close to the gardens (within 100 × 100 m with house at the center). Homegardens were selected so that they were well distributed across the landscape and to capture the different level of tree cover and open non-crop land-use type such as grazing lands within the landscape (Fig. 1B1 and B2). The minimum–