Landscape context and plot incidence of coffee rust (*Hemileia vastatrix*), coffee berry borer (*Hypothenemus hampei*) and the root-knot nematodes *Meloidogyne* spp. in Costa Rica

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Summary

This work was addressed to study the relationships between landscape context and the incidence of three noxious organisms with different abilities to spread: coffee rust (*Hemileia vastarix*), coffee berry borer (*Hypothenemus hampei*) and the root-knot nematodes (*Meloidogyne* spp.). We analized these relationships at different spatial scales (radii 50-1500 m) in 50 agricultural landscapes of the Turrialba coffee region in Costa Rica, differing in structural complexity. We found positive correlations between coffee berry borer abundance and the coffee area percentage in the landscape. The correlation was strongest at a scale of 150 m. We also found positive correlations between coffee rust incidence and the pasture area in the landscape. The significance of this relationship peaked at the 300 m radius. We didn't find any significant correlation between coffee root-knot nematodes and landscape. These relationships can be interpreted according to the dispersal ability of the studied organisms. Coffee berry borer is specific to coffee and can fly only at short distances. Coffee rust is an airborne pathogen which is probably favoured by open spaces. Nematodes are almost immobile. We hypothesize that fragmenting coffee regions may help to reduce coffee berry borer dispersal. In contrast, fragmentation of coffee landscape by pasture may increase coffee rust dispersal.

Introduction

Disease and pest attack intensities are mainly determined at the plot level through interactions between the host, noxious organism, environment and agricultural management (Zadoks and Schein, 1979). However, the immigration of noxious and beneficial organisms from outside may also affect pest and disease incidences at the plot scale. Successful immigration is facilitated in landscapes with greater connectivity between resources patches (Zadoks, 1999). Functional connectivity of landscapes depends on the distribution and density of specific land uses, on how these are perceived (hostile or not) by specific organisms, and on organisms' dispersal ability to move across non-habitat areas. In a given landscape context, higher connectivity is therefore expected for generalist noxious organisms with high dispersal abilities. Here, we study the relationship between coffee pest and disease incidence in coffee farms and landscape context. We hypothesize that greater coffee cover within the local context (<1500 radius) will increase pest and disease incidence whereas greater forest cover will decrease it. We use three focal organisms to test these hypotheses: (1) coffee rust

(*Hemileia vastatrix),* (2) coffee berry borer (*Hypothenemus hampei*) and (3) the root-knot nematodes (*Meloidogyne* spp.). These noxious organisms differ by their host specificity and dispersal ability. Coffee rust is coffee specific. Its uredospores are spread by wind over great distances and can even cross oceans (Bowden, 1971). The coffee berry borer is very specific to coffee, however it has been found to reproduce in several plant species (Damon, 2000). The females are able to fly, and probably can be transported by convection winds, over a few hundred meters (Baker, 1984). Root-knot nematodes are able to infect different plant species and, when not dispersed through human activities, can be considered nearly immobile.

Materials and Methods

We conducted a one-year survey starting in November 2008 through November 2009 on 50 coffee plots in the Turrialba region of Costa Rica (Figure 1a). The plots were distributed within a wide range of landscape contexts, from highly fragmented (Figure 1b) to intact coffee plots (Figure 1c). Coffee plots were comprised of eight rows of 15 coffee plants (120 coffee trees per plot). We quantified noxious organism incidence on five systematically distributed coffee trees in each plot, in 2-5 evaluation periods depending on the organism: February-March, May, June-July, September, October-November. We measured coffee rust incidence in all five periods by counting the number of diseased and healthy coffee leaves on three branches per coffee plant (a total of 15 branches per plot). We estimated coffee berry borer abundance four times only (excluding February-March) by counting the number of bored coffee fruits on four branches per coffee tree (20 branches per plot) and the total number of fruiting branches. We assessed root-knot nematodes population densities twice only (May and

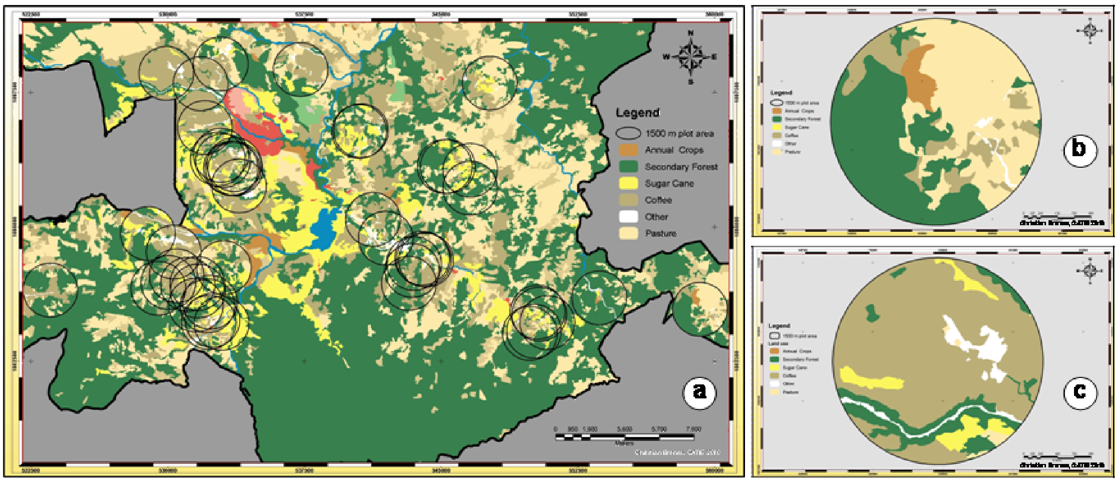

Figure 1. Landscape description within circular sectors of 1.5 km radius centered on the 50 surveyed plots (a), and two selected landscape contexts from highly fragmented (b) to almost intact coffee plots (c), Turrialba, Costa Rica, 2009

September) by sampling coffee roots from the four neighboring coffee plants of each of the five selected trees (20 subsamples per plot).

In our analyses we used the maximum annual percentage of diseased coffee leaves as our descriptor of coffee rust infection. In the case of the coffee berry borer we used the maximum annual number of bored coffee fruits estimated per coffee plant. Finally, for the root-knot nematodes, we used the average population density per 100 g of coffee roots.

To describe the landscape context, we first classified a 2005, 1 m^2 resolution aerial image of the landscape by assigning the land uses within a 1500 m radius around each sample point to one of four land uses: coffee, sugar cane, pasture, and forest. We further verified this classification through ground-truthing. Then, we subdivided the 1500 m radius plot into 12 nested circular plots with the following radii: 50, 100, 150, 250, 300, 350, 400, 450, 500, 1000, 1500 m, and calculated the proportion of each land use at each scale.

Finally, we examined the correlations between plot level pest and disease descriptors and landscape context at each scale mentioned above to determine whether landscape context impacts pest and disease incidence, and at what scale.

Results

We found diverse responses to landscape context for each of the study organisms. There were no correlations between landscape context and population densities of root-knot nematodes as expected. We found multiple significant positive correlations between coffee berry borer infestation and proportion of the landscape in coffee (Figure 2a). The

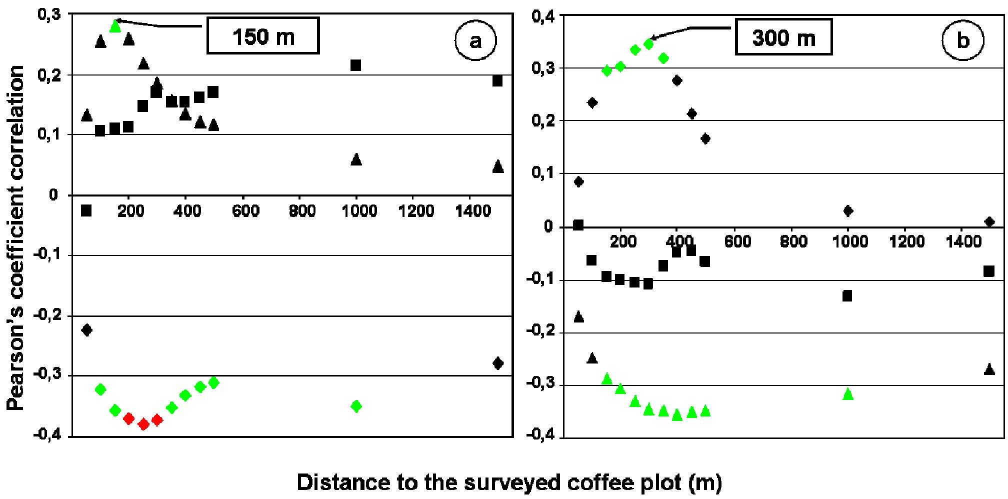

Figure 2. Correlation of coffee berry borer abundance (△), coffee rust incidence(◇), *Meloidogyne* spp. population density (□) versus the percentage of coffee (a) and pasture (b) areas at 12 spatial scales, *P*>0.05 (black) *P*<0.05 (green) *P*<0.01 (red)

significance of this relationship peaked at the 150 m radius (r=0.28, P<0.05; Figures 2a and 3a). Similarly, we found multiple significant positive correlations between coffee rust incidence and proportion of the landscape in pasture (Figure 2b). In contrast to the coffee berry borer, the significance of this relationship peaked at the 300 m radius (r=0.35, P<0.05; Figures 2b and 3b). In addition, multiple negative correlations were obtained for coffee berry borer and the proportion of pasture in the landscape (Figure 2b) and for the coffee rust with the proportion of coffee in the landscape (Figure 2a).

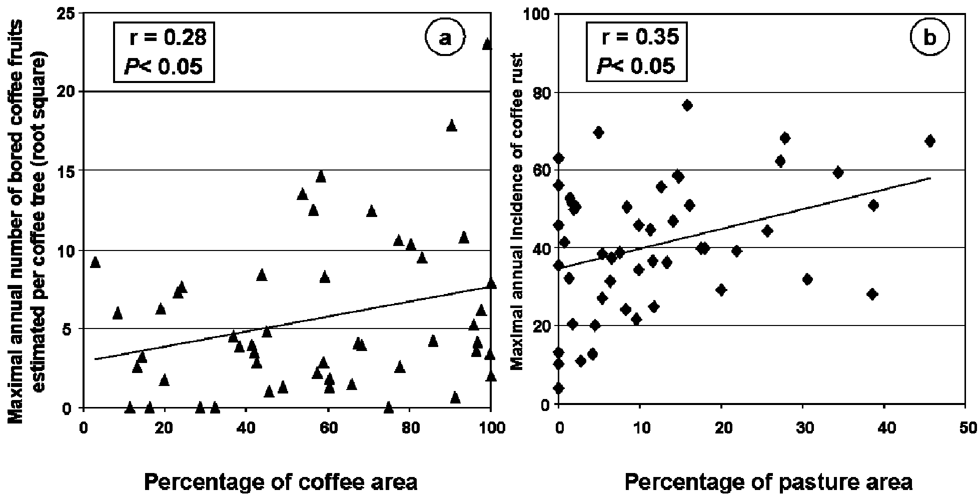

Figure 3. Dependence of coffee berry borer abundance on the percentage of coffee area at the spatial scale of 150 m (a) and of coffee rust incidence on the percentage of pasture area at the spatial scale of 300 m (b)

Discussion and Conclusion

Our results can be interpreted according to the dispersal ability of the studied organisms. Coffee berry borer has low dispersal ability and perceived other land uses as hostile. As a consequence, fragmenting coffee farms at small scales (i.e. interspersing alternate land uses or linear barriers such as riparian corridors) may help to significantly reduce coffee berry borer movement between plots. In contrast, fragmentation of coffee landscape, particularly by pasture, may increase coffee rust dispersal. This is probably because coffee rust is an airborne pathogen whose dispersal is favored by open spaces. Finally, nematodes, which are nearly immobile, were not influenced by landscape context.

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