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REVIEW

Effects of agroforestry on pest, disease and weed control: A meta-analysis

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Abstract

Agroforestry practices may influence pest incidence and abundance both through increased top-down regulation by natural enemies and via bottom-up factors such as moderation of microclimate, soil nutrients and water content. We conducted a meta-analysis of the effects of agroforestry on the abundance of invertebrate pests, weeds, natural enemies and plant damage due to pests and diseases. We also tested whether effects of agroforestry were dependent on crop type (annual or perennial), type of pest association (above or belowground) and weed type (parasitic *Striga* weeds or non-parasitic weeds).

Agroforestry practices resulted in lower abundances of both parasitic and non-parasitic weeds, and in higher abundances of natural enemies. The effects of agroforestry on invertebrate pests and diseases were dependent on crop type. In perennial crops (e.g. coffee, cocoa and plantain), agroforestry was associated with lower pest abundances and less plant damage. However, the effects were not significant in annual crops (e.g. maize, rice and beans). Despite the limited number of crop-pest systems available for the analyses, overall our results suggest that agroforestry is beneficial in terms of pest, disease and weed management.

Zusammenfassung

Negative Auswirkungen von Entwaldung auf Biodiversität und Ökosystemdienstleistungen können durch Aufforstung im Rahmen der Agroforstwirtschaft gemildert werden. Agroforstwirtschaftliche Maßnahmen sind imstande, Vorkommen und Häufigkeit von Schädlingen zu beeinflussen, sowohl durch verstärkte Top-Down-Regulierung mittels natürlicher Feinde, als auch durch Bottom-Up-Faktoren wie Mikroklimaverbesserungen und Veränderungen von Wasser- und Nährstoffgehalt des Bodens.

Mit Hilfe einer Meta-Analyse wurden die Auswirkungen von Agroforstwirtschaft-Maßnahmen auf das Vorkommen von wirbellosen Schädlingen, Ackerunkräutern, natürlichen Feinden sowie schädlings- und krankheitsbedingten Pflanzenschäden untersucht. Getestet wurde ferner, inwieweit sich der Nutzpflanzentyp (ein- oder mehrjährig), die Art des Schädlingskontakts (ober- oder unterirdisch) und der Unkrauttyp (parasitisch (Striga) oder nicht-parasitisch) beim Einsatz von Agroforstwirtschaft auf die Indikatoren der Schädlingsbekämpfung auswirkt.

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Agroforstwirtschaftliche Maßnahmen reduzierten das Vorkommen von parasitischen wie nicht-parasitischen Unkräutern und erhöhten die Zahl natürlicher Schädlingsfeinde. Die Auswirkungen der Maßnahmen auf wirbellose Schädlinge und Krankheiten waren abhängig vom Nutzpflanzentyp. Bei mehrjährigen Nutzpflanzen (vorwiegend Kaffee, Kakao und Kochbananen) führte der Einsatz von Agroforstwirtschaft zu einem Rückgang von Schädlingsbefall und Pflanzenschäden. Der Effekt bei einjährigen Pflanzen (vorwiegend Mais, Reis und Bohnen) war weniger eindeutig. Insgesamt deutet unsere Meta-Analyse darauf hin, dass Agroforstwirtschaft die Bekämpfung von Pflanzenschädlingen, Pflanzenkrankheiten und Unkräutern begünstigt.

Keywords: Natural enemies; Parasitic weeds; Parasitoids; Plant damage; Predators; *Striga* sp.

Introduction

Deforestation and agricultural intensification are the most important drivers of the loss of biodiversity and associated ecosystem services (Foley et al. 2005). The restoration of tree-cover through agroforestry can mitigate the negative effects of deforestation, and complement the protection of pristine forest ecosystems (Tscharntke et al. 2011). Previous studies have reported many beneficial effects of agroforestry including biodiversity conservation and improved soil fertility (Matata, Gama, Mbwaga, Mpanda, & Byamungu 2011; Sileshi et al. 2014). In developing countries agroforestry can improve food security for smallholder farmers by improving soil health and providing firewood, building material, fodder and fruits (Sileshi et al. 2014). Evidence is also mounting that agroforestry influences other ecosystem services delivered by biodiversity, such as pest control (Sileshi, Schroth, Rao, & Girma 2008; Karp et al. 2013). However, quantitative reviews of the effects of agroforestry on pest control are still lacking.

The incorporation of trees into agro-ecosystems through adoption of agroforestry increases habitat complexity, which generally correlates positively with abundance and diversity of natural enemies both at the field (Letourneau et al. 2011; Iverson et al. 2014) and landscape levels (Chaplin-Kramer, O'Rourke, Blitzer, & Kremen 2011; Tscharntke et al. 2011). However, even if increased habitat complexity may result in reduced pest abundances due to top-down regulation, such effects are context-dependent (Chaplin-Kramer et al. 2011). In some instances trees may benefit pests directly by providing resources or improving microclimate, or indirectly by enhancing host plant nutritional conditions or water availability (Sileshi, Schroth, Rao, & Girma 2008). Therefore, it remains unclear to what extent the different agroforestry practices can improve regulation of pests, diseases and weeds in agro-ecosystems.

Earlier reviews and meta-analyses have tested how the diversity or abundance of either pests or natural enemies is affected by factors such as local plant diversity and landscape structure. Letourneau et al. (2011) found a reduction of herbivores and crop damage as well as an increase in natural enemies with increasing crop diversity. According to Iverson et al. (2014), win–win relationships between per-plant yield of the primary crop and biocontrol are likely in polyculture systems that minimize intraspecific competition via substitutive planting. Chaplin-Kramer et al. (2011) found that complex landscapes including natural habitat benefitted natural enemies, but that effects on pests were more variable. Some reviews about pests and diseases in the humid tropics have shown that the impacts of agroforestry are variable and context-dependent (Schroth, Krauss, Gasparotto, Duarte Aguilar, & Vohland 2000; Sileshi, Schroth, Rao, & Girma 2008).

To date, no meta-analysis has been published on the net effects of agroforestry practices on the regulation of pests, diseases and weeds. Therefore, the objective of this meta-analysis was to investigate the effects of agroforestry practices on the abundance of invertebrate pests, weeds, diseases, natural enemies, and crop damage. We also tested whether (1) agroforestry practices affects pests differently in annual vs. perennial crops, (2) whether above and below-ground organisms were differently affected by agroforestry, and (3) if agroforestry practices reduce both parasitic and non-parasitic weeds.

Material and methods

Literature search and data extraction

To retrieve papers that could potentially be suitable for our meta-analyses, we conducted a literature search using ISI Web of Science, focusing on literature published up to October 2013. We searched for studies that reported the effects of agroforestry on invertebrate pests (insects, mites and nematodes), plant diseases (fungi, bacteria and virus) and/or weeds. We considered both sequential and simultaneous agroforestry systems. Sequential systems include improved fallows, relay cropping with trees and rotational woodlot systems where a piece of land is deliberately planted with fast-growing nitrogen-fixing trees. Simultaneous systems include scattered trees in crop land, often known as "parkland agroforestry", alley cropping, cereal-tree intercropping and multi-strata agroforestry (see Appendix A for further descriptions).

The literature search was conducted using 20 terms describing agroforestry interventions and 10 terms describing