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Commentary: Forest Cover Is Critical for Biodiversity Conservation in Tropical Livestock-Dominated Landscapes

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Abstract

Balancing meat production and biodiversity conservation is a major challenge. To address this challenge, we must understand the independent effects of land-use change and production practices on biodiversity across spatial scales. A key question is whether biodiversity will benefit more from habitats embedded in farmland ("land sharing") or preserved elsewhere ("land sparing"). Our multiscale assessment of dung beetle communities in livestock-dominated landscapes from the Yucatan Peninsula, Mexico, supports the latter strategy. New results from phylogenetic analyses and unpublished results from dung removal experiments also highlight the importance of forest cover for preserving dung beetles and their key ecological roles. Both landscape-scale forest cover and macrocyclic lactones (commonly used veterinary drugs) shape dung beetle communities in the Yucatan Peninsula, thus suggesting that a land sparing approach, which maximizes forest protection, may minimize the damage of beef production to biodiversity. However, maximizing yields through macrocyclic lactone use will likely reduce on-farm ecosystem service provision. These surprising results have important implications for the conservation of biodiversity and ecological functions, as they suggest that the best strategies for conserving biodiversity may differ from those focused on delivering ecosystem services. We must therefore consider factors other than just food production and biodiversity conservation when designing land-use strategies.

Keywords

agroforestry systems, cattle production, food production, habitat lost, landscape heterogeneity, species diversity, silvopastoral systems

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The United Nations predicts that the global population will have increased by 34%, reaching nearly 9.7 billion people, by 2050, with much of this growth in tropical regions (Vörösmarty, Green, Salisbury, & Lammers, 2000). Per capita wealth will also increase, driving greater food consumption, particularly of resource intensive foods such as meat (Tilman & Clark, 2014). Increasing meat consumption is particularly expected because of its historical importance as a source of proteins, micronutrients, minerals, and amino acids (Laurance, Sayer, & Cassman, 2014). Therefore, although over consumption of animal products is now associated with some health costs (Machovina, Feeley, & Ripple, 2015; Tilman & Clarck, 2014), livestock production is still the predominant driver of forest loss worldwide, threatening biodiversity and ecological process and driving greenhouse gas emissions (Machovina et al., 2015; Tilman &

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Clarck, 2014). Understanding how to balance food production, particularly meat, with biodiversity conservation is thus of vital importance if we want to preserve biodiversity and to mitigate anthropogenic climate change (Tilman & Clark, 2014).

The impacts of livestock production may differ between different management practices (Thornton, 2010), and therefore, conservationists and environmental scientists must evaluate which approaches minimize these impacts. Much of this debate on how to harmonize livestock production with biodiversity conservation has focused on a range of strategies between two extremes: land sharing and land sparing (Phalan, Onial, Balmford, & Green, 2011; Tscharntke et al., 2012). The former proposes integrating production and conservation in complex multifunctional, but lower yielding landscapes that include wildlife-friendly habitats (i.e., silvopastoral systems), while the latter suggests that productive activities be intensified in farmland, allowing the preservation of distinct conservation areas (Tscharntke et al., 2012). The debate surrounding these approaches has been critiqued due to a lack of consideration of how the spatial scale of analysis affects study's conclusions (Ekroos et al., 2016), for neglecting the importance of landscape context, and for not including the negative externalities of intensive agriculture, such as the increased use of fertilizers and veterinary medicines.

To address these knowledge gaps, we recently assessed the relative importance of landscape structure and livestock intensification practices in shaping dung beetle communities in a Neotropical, livestock-dominated landscape in the Yucatan Peninsula, Mexico (Alvarado, Escobar, et al., 2018). Dung beetles are considered an excellent model for applied biodiversity studies, as they both provide key ecological functions, for example, for the removal of excrement, the recycling of nutrients, biological control, and greenhouse gases regulation, and also act as excellent indicators for wider biodiversity (Gardner et al., 2008). The Yucatan Peninsula's natural vegetation is dominated by tropical dry, semideciduous, and evergreen forests: some of the most threatened ecosystems in the world (Hoekstra & Wiedmann, 2014). The Yucatan Peninsula also offers an excellent opportunity to investigate the effects of different livestock-production practices on biodiversity in a human-modified ecosystem. This system has a long history of natural (i.e., frequent hurricanes and tropical storms) and anthropogenic disturbances, which include waves of intensive land use by Mayan communities, followed by sisal and henequen cultivation in the 19th century, and extensive cattle farming in the 20th century. These major disturbances could have acted as an extinction filter (Balmford, 1996), leaving behind a relatively disturbance resilient biota that can be able to cope with a land-sharing context (Williams et al., 2017).

Interestingly, Alvarado, Escobar et al. (2018) found that landscape-scale forest cover was the most important driver of dung beetle community composition and was positively associated with species diversity and biomass at multiple spatial scales. This suggests that, despite the long history of land use in the region, a land-sparing approach may support dung beetle communities better than a land-sharing approach (Williams et al., 2017). However, Alvarado, Escobar, et al. (2018) also found that the use of macrocyclic lactones—veterinary medicines used to control helminthic, nematodes, mites, and cattle flies—was strongly and negatively associated with beetle diversity, abundance, and biomass at the local (farm) scale. This supports previous studies reporting their negative effects on the ecology and behavior of many different soil invertebrates (i.e., earthworms, flies, wasps, and dung beetles; Jochmann & Blanckenhorn, 2016), with potential negative effect on ecological functions such as the removal rate of the excrement and the processes associated with this function (e.g., nutrient cycle and regulation of potentially harmful species; Verdú et al., 2015).

Our recently published results based on the same data set (Alvarado, Andrade, et al., 2018) show that phylogenetic richness and phylogenetic divergence of dung beetles decrease drastically in landscapes with lower forest cover. As these diversity metrics reflect the accumulated evolutionary history of communities (Swenson, 2014), our findings suggest that the retention of large forest fragments in the Yucatan Peninsula may be critical to prevent the loss of particular evolutionarily linages in the face of increasing livestock production. This novel result also supports a land-sparing strategy, as it highlights the key role that larger forest patches play in biodiversity conservation (Gray et al., 2016). Forests provide particularly favorable microclimatic conditions and food resources for large-bodied, forest-specialist dung beetles (Nichols et al., 2013). Larger forest patches also contribute to minimize negative edge effects in human-modified landscapes (Pfeifer et al., 2017).

We have also found in recent, unpublished analyses that dung removal—a key ecosystem function provided by dung beetles—is strongly limited when livestock production increases in our study landscapes (Figure 1). Interestingly, the loss of forest cover and some forest-specialist species in low-yielding silvopastoral systems (see Alvarado, Escobar, et al., 2018) seems to have a weak effect (if any) on dung removal, as dung removal rate was very high in silvopastoral systems (Figure 1). This can be explained by compensatory dynamics (Supp & Ernest, 2014) in human-modified landscapes. Specifically, the ecological role played for forest-specialist species can be done by those species that usually proliferate in these landscapes, such as small, generalist, or open-area specialist dung beetle species (Alvarado, Escobar, et al., 2018).

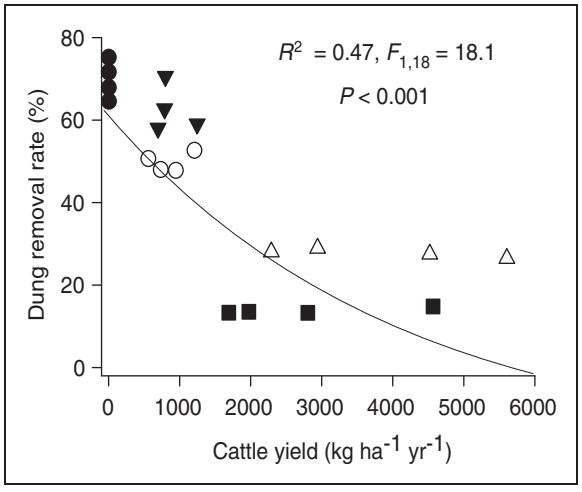

Figure 1. Relationships and fitted curve for percentage of dung removal rate and net cattle production (cattle yield) in the Yucatan Peninsula, Mexico. To quantify dung removal, 24 cylinders (11 cm in diameter and 15 cm in length) containing fresh cow dung (700 g) were placed in each management type (96 cylinders per management type for a total of 480 cylinders). We followed the dung removal experiment protocol proposed by Slade, Mann, and Lewis (2011). Symbols represent each management type ($n = 20$; 1 km^2 each). Black circle: forest patches, white circle: traditional ranches, black upside-down triangle: silvopastoral systems, white triangle: intensified livestock production systems, and black square: maize farms (for details of study area, see Alvarado, Escobar, et al., 2018).

These surprising results have important implications for the conservation of biodiversity and ecological functions, as they suggest that the best strategies for conserving biodiversity may differ from those focused on delivering ecosystem services. We must therefore consider factors other than just food production and biodiversity conservation when designing land-use strategies.

Our research highlights the importance of natural habitat preservation for the conservation of both ecologically and evolutionarily rich dung beetle communities—somewhat surprising given the region's long history of both natural and anthropogenic disturbance (Williams et al., 2017). In addition, low-yielding agriculture (i.e., land sharing) in the Yucatan Peninsula is unlikely to be able to meet predicted future production levels (Williams et al., 2017), meaning that some degree of intensification in production will be necessary. Our findings, alongside similar results showing that aboveground carbon stocks and the population densities of multiple taxa (dung beetles, birds, and trees) decreased extremely rapidly with conversion from forest to agriculture (Williams et al., 2017), confirm that the preservation of large blocks of forest is extremely needed to conserve the region's ecological and evolutionary diversity. However, as the use of macrocyclic lactones also has strong negative impacts on dung beetle communities, finding less harmful methods for increasing yields of livestock systems will therefore be vital to preserve species that can survive in agricultural lands, and the important ecosystem services they provide.

Declaration of Conflicting Interests

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