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Silvopastoral systems and ant diversity conservation in a cattle-dominated landscape of the Colombian Andes

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ABSTRACT

Conventional cattle ranching in Latin America has been based mostly on extensive pasture monocultures planted with minimum tree cover. The current trend towards replacing treeless pastures with silvopastoral systems that include tree and shrub species enhances productivity and provides environmental services within these systems. We studied the ant fauna in cattle farms at La Vieja river basin, Colombia, with the aim of analyzing the relations between tree cover and ant species diversity and composition in different land uses in this cattle-dominated landscape. Monitoring was performed between 2004 and 2007 in 21 plots representing seven contrasting land uses characteristic of this Andean landscape. Ants were sampled with baits (arboreal and ground) and pitfall traps. A total of 68,860 individuals belonging to 227 ant species was recorded. Ant diversity was positively related to the presence of woody vegetation. The largest number of ant species was found in secondary forests followed by improved pastures with trees. Pastures without trees had less than half the number of ant species in pastures with trees. Ant species richness in intensive *Leucaena leucocephala* (Mimosaceae) silvopastoral systems also surpassed that recorded in treeless pastures. This study provides evidence supporting the conservation value of silvopastoral systems at the landscape level in the Colombian Andes. The conservation of forest fragments in this area is vital, as they provide refuge for a unique regional ant fauna

1. Introduction

Human activities continue to transform natural ecosystems at an unprecedented rate, especially in the tropics and subtropics (FAO, 2006). The intensive management of some agroecosystems results in the oversimplification of biological communities and the introduction of chemical inputs (i.e. fertilizers and pesticides) to the environment. In Latin America, extensive cattle ranching is a serious threat to biodiversity (Murgueitio et al., 2011) because it drastically reduces heterogeneity of the ecosystem (Brown and Lugo, 1994).

Direct and indirect links exist between cattle ranching and deforestation. Over the last five decades, the gradual transformation of forests into pastures in Latin America has led to the international designation of cattle ranching as a significant threat to tropical forests (Kaimowitz, 1996; Calle et al., 2013), as it reduces habitat and food resource availability for wildlife, disrupts landscape connectivity and drives the loss of ecosystem services (Forman, 1995; Calle et al., 2001). Studies of North American grasslands suggest that contemporary biodiversity declines are among the dominant drivers of change in productivity and other components of ecosystem functioning (Tilman et al., 2012). In Colombia, a biologically megadiverse country, cattle ranching occupies more than 80% of the deforested land (Calle et al., 2001). Thus, in Latin America, the environmental transformation of conventional cattle ranching into biodiversity-friendly land use systems is unpostponable (Murgueitio et al., 2011).

In the simplest cattle ranching systems, the homogenous matrix (i.e. pasture without shrubs or trees) is generally hostile for wildlife and vulnerable to both fire and the deletereous effects of invading species (Suárez et al., 1998; Rivera et al., 2008). But in spite of the large number of studies that acknowledge these problems, little information exists on the organisms that persist in cattle-dominated landscapes and on how different types of tree cover contribute to the conservation of biodiversity (Hernández et al., 2003; Ramírez and Enríquez, 2003; Schulze et al., 2004; Ramírez et al., 2010; Calle et al., 2013). Unlike pasture monocultures, silvopastoral systems combine improved tropical grasses with trees and sometimes, the high-density cultivation of fodder shrubs (planned biodiversity) for the direct grazing of livestock

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(Swift et al., 1996; Calle et al., 2013). These tree, shrub and pasture components provide physical structures, resources and habitat that support and enhance other plant and animal species (associated biodiversity) (Harvey et al., 2004; Philpott et al., 2008; Giraldo et al., 2010) and maintain several ecological processes vital for the ecological functions of pastoral landscapes (Feld et al., 2010; Murgueitio et al., 2011; Calle et al., 2013). Also, tree products – such as timber and fruit – may be directed to local markets, agribusiness or the protection of biodiversity (Murgueitio et al., 2011).

During the last decade, silvopastoral systems have been actively promoted in Colombia as a means of enhancing biological diversity and environmental services in cattle-dominated landscapes (i.e. water regulation, carbon sequestration and biodiversity conservation) (Murgueitio, 2003), but also in increased productivity and financial returns to the farmers (Calle et al., 2013). Given the current scale of this transformation, it is necessary to measure the effects of this type of management on the associated biodiversity (Rice and Greenberg, 2004; Giraldo et al., 2010).

Different groups of indicator organisms have been used to estimate the effects of human activities on the environment. Indicator taxa are measurable components of the biota that, apart from providing information about the ecosystems, play important roles in conservation and management (Andersen, 1999). Ants are very sensitive to habitat changes, and human disturbance usually results in a significant alteration of ant species composition (Philpott et al., 2009).

Although some studies have examined ant diversity in different fragmented landscapes of the Colombian Andes (Ramírez and Enríquez, 2003; Rivera and Armbrecht, 2005; Ramírez-Ramírez et al., 2009a), little information is available on ants in treeless cattle grazing areas, silvopastoral systems and other land uses in heterogeneous agricultural matrices. In this study, we examined the changes in the diversity of ground and shrub foraging ants in relation to the differences in tree cover and vegetation structure in contrasting land uses in a cattle dominated landscape of the Colombian Andes. These land uses varied from intensively managed to semi-natural and natural.

Differences between land uses in the composition of ant assemblages were explored by comparing the number of species of the genus *Pachycondyla* and the relative abundance of a well-known generalist species, *Ectatomma ruidum*. Ants in the Ponerinae subfamily, and species of *Pachycondyla* in particular, are commonly found in shaded habitats with abundant leaf litter and decomposing wood, where they build their nests and find food resources (Höldobler and Wilson, 1990; Baena, 1993; MacKay et al., 2008). Therefore they can be considered indicators of habitat quality. In contrast, *E. ruidum* is a sun-loving predator ant that thrives in open, simplified habitats (Kugler and Brown, 1982; Rivera, 2003; Domínguez and Fontalvo, 2005; Santamaría et al., 2009); thus its relative abundance should be inversely proportional to tree canopy cover.

We hypothesized that: (1) increased tree cover positively influences ant species composition, diversity and the presence of rare species; (2) different habitat types have different ant species compositions, (3) in a given land use, the number of *Pachycondyla* species reflects habitat quality measured in terms of tree cover, and (4) the relative abundance of the generalist predator *E. ruidum* in different land uses is inversely related to tree shade.

2. Methods

2.1. Study area

We randomly selected 21 sites in seven land-uses, within 11 cattle farms located at the municipalities of Alcalá, Circasia, La Tebaida, Montenegro and Ulloa (Valle del Cauca and Quindío departments), between 990 and 1760 m above sea level, and with annual rainfall of 1000–2000 mm (Table 1, Fig. 1). The topographic relief of this foothill landscape has a predominantly hilly morphology (10–25° slopes), with some mountainous (25–45°) and steep areas (>45°) and only a few relatively flat (0–10°) areas. Secondary forests persist mostly on steep slopes, while the other land uses are more evenly distributed in flat, hilly and mountainous terrain (Méndez and Calle, 2007). Secondary and bamboo forests occupy 11.2% of the landscape. Fragment size varied between 0.5 and 413 ha but 67% of these fragments had areas smaller than 5 ha (Camargo and Cardona, 2005). The designation of land uses followed the criteria described in the Guide for Environmental Service Payment developed by the *Integrated Silvopastoral Approaches to Ecosystem Management* (RISAEM) project (Murgueitio et al., 2004). In the field, the plots were located by means of multispectral satellite images (2.5 m resolution, Quick Bird satellite, Digital globe). All farms were involved in the RISAEM project, which evaluated the role of payment for environmental services on the adoption of sound environmental practices by cattle ranchers, and the effect of these on biodiversity conservation and carbon sequestration (Calle et al., 2001; Murgueitio et al., 2011). Although the landscape conserves some degree of heterogeneity, tree-cover was lost in more than 50% of the territory as a result of the expansion of coffee plantations first and, later, to their replacement with grasslands (Rodríguez et al., 2004). These modifications caused landscape-level degradation and fragmentation of the existing natural habitats, in some cases triggering local or regional extinctions (Kattan et al., 2004).

At the beginning of the study, improved pastures without trees (IPW) were the dominant land-use comprising about 40% of the landscape (unpublished data, 2005–2006 research report). The study area covered three non-overlapping geographic zones within which a site of each of seven land uses was selected; thus a total of 21 sites were sampled. This subdivision was done to minimize site variability confounding the management effects examined.

Table 1
Description and characteristics of land uses assessed in the cattle dominated landscape of La Vieja river basin, Colombia*.

Land use	Code	Grazing	Definition
Improved pasture without trees	IPW	High	Exotic pastures covering 70% or more of the soil surface, high intensity of cattle grazing and no trees
Intensive *Leucaena* silvopastoral system	ISS	High	Pasture with high density of *Leucaena leucocephala* (Mimosaceae) shrubs for direct cattle browsing, with frequent cattle rotation
Live fences	LF	Eventual	Trees, such as *Gliricidia sepium* (Fabaceae) planted as boundaries between plots or farms
Improved pasture with high tree density	IPT	High	Exotic pastures such as *Cynodon plectostachyus* (Poaceae) with 30 or less mature trees per hectare and infrequent rotation
Fruit tree monoculture	FM	No	Homogeneous citrus plantations
Bamboo forest or plantation	BF	No	Giant green bamboo or guadua stands, either relatively homogeneous or combined with native trees, frequently protecting water sources. Guadua (bamboo) is selectively harvested
Secondary forest	SF	No	Native secondary forest fragments of different sizes, generally less than 10 ha, frequently disturbed through timber harvesting and hunting, and surrounded by agriculture or cattle ranching

* More details in Murgueitio et al. (2004).