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Soil fertility gradients shape the agrobiodiversity of Amazonian homegardens

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ABSTRACT

The importance of homegardens for the conservation of agrobiodiversity, the maintenance of farm ecosystem processes, and the economic and food security of rural populations worldwide is increasingly recognized. While biophysical and socio-economic conditions are considered to influence homegarden management, and affect their ecological and societal relevance, little is known about how variation in soil properties affects these agroecosystems. By combining soil data with extensive botanical inventories, we investigated how farmers' use and management of soil variation results in differences in the structure, diversity and the floristic composition of homegardens in Central Amazonia. We sampled 70 homegardens located along the gradient from low-fertility Ferralsols to Amazonian Dark Earths (ADE), i.e., fertile anthropogenic soils created by pre-Columbian populations at least 500 years ago. Our results show that several characteristics of homegardens are significantly influenced by variation in soil texture and fertility. While differences in soil texture are due to natural soil variation, observed heterogeneity in soil fertility was largely the result of pre-Columbian and modern soil transformations. Homegardens on sandier soils tended to be more diverse in plant species and to have more individual plants; homegardens on more fertile soils tended to have fewer trees and palms, more herbs, shrubs and climbers, and a higher total number of species and landraces; variation in soil fertility was significantly related to differences in the composition of species and landraces. Our results show that farmers' use of natural and anthropogenic variation in soil properties influences agrobiodiversity patterns in homegardens. Pre-Columbian and modern soil enrichment increases soil heterogeneity in the landscape, resulting in strong soil fertility gradients that shape the agrobiodiversity of current Amazonian homegardens.

1. Introduction

Homegardens are 'intimate, multistory combinations of various trees and crops, sometimes in association with domestic animals, around the homestead' (Nair and Kumar, 2006; p. 1). They are important agroecosystems in tropical regions worldwide, providing economic benefits and food security for local people, as well as favoring the on farm conservation of water, soil and biodiversity (Kumar and Nair, 2004). Homegardens are considered agroforestry production systems (Nair, 1993; Porro et al., 2012), although "homegarden" is a very generic concept (Kumar and Nair, 2004). In the Amazon Basin, homegardens and other agroforestry systems were the first cultivation systems developed by pre-Columbian populations. They are widespread throughout the basin, and play an important role in local people's subsistence and income (Miller and Nair, 2006; Miller et al., 2006).

Owing to their complex and long-term historical development, Amazonian homegardens are very diverse and heterogeneous (Miller and Nair, 2006), similar to homegardens elsewhere in the world (Kehlenbeck et al., 2007). This diversity also results from an interplay between different socio-cultural and agro-ecological factors that can influence how homegardens and their associated agrobiodiversity are managed (Kumar and Nair, 2004; Kehlenbeck et al., 2007; Perrault-Archambault and Coomes, 2008; Clarke et al.,

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2014). Despite the recognition that soil characteristics can play an important role in the design, management and diversity of homegardens and other agroforestry systems (Szott et al., 1991; Kehlenbeck and Maass, 2004), the effects of soil variation on homegardens have seldom been investigated [but see Fraser et al. (2011a)].

Soils in the Amazon Basin are highly variable, but a large part of the basin (~60%) is occupied by acidic, weathered and nutrient-poor ferralsols and acrisols (Quesada et al., 2011). Homegardens on uplands are often established on these poor soils, but management practices such as burning and mulching, as well as the non-intentional concentration of different sources of organic matter in the surroundings of habitation sites, result in the accumulation of nutrients over time in these environments (WinklerPrins, 2009; Pinho et al., 2011). However, many homegardens are found on patches of fertile anthropogenic soils created in pre-Columbian times called Amazonian Dark Earths (ADE), or *Terra Preta* (Glaser and Birk, 2012). These pre-Columbian anthropogenic soils were likely formed through soil-enrichment processes similar to those that occur in modern homegardens (Schmidt and Heckenberger, 2009; Schmidt et al., 2014), and they add considerable heterogeneity to upland soils where they occur (Fraser et al., 2011c). Farmers have developed specific knowledge and cultivation practices for the use of ADE, and today these soils are part of different land-use systems, including swiddens under shifting cultivation (German, 2003, 2004; Kawa et al., 2011; Fraser et al., 2012; Junqueira et al., 2016), secondary forests (Junqueira et al., 2010, 2011), and homegardens (Hiraoka et al., 2003; Major et al., 2005a; Klüppel, 2006; Fraser et al., 2011a; Kawa et al., 2015; Lins et al., 2015).

Homegardens are one of the most common types of land-use on ADE, since current habitation sites (and their surrounding homegardens) are commonly situated on ADE patches (Hiraoka et al., 2003; Fraser et al., 2011a). When compared with homegardens on nutrient-poor adjacent soils, homegardens on ADE show distinct crop assemblages and a greater importance of exotic species (Major et al., 2005a; Klüppel, 2006; Fraser et al., 2011a). These studies, however, considered ADE and adjacent soils as discrete soil categories, although each of these categories may encompass ample soil heterogeneity especially ADE, as these soils result from

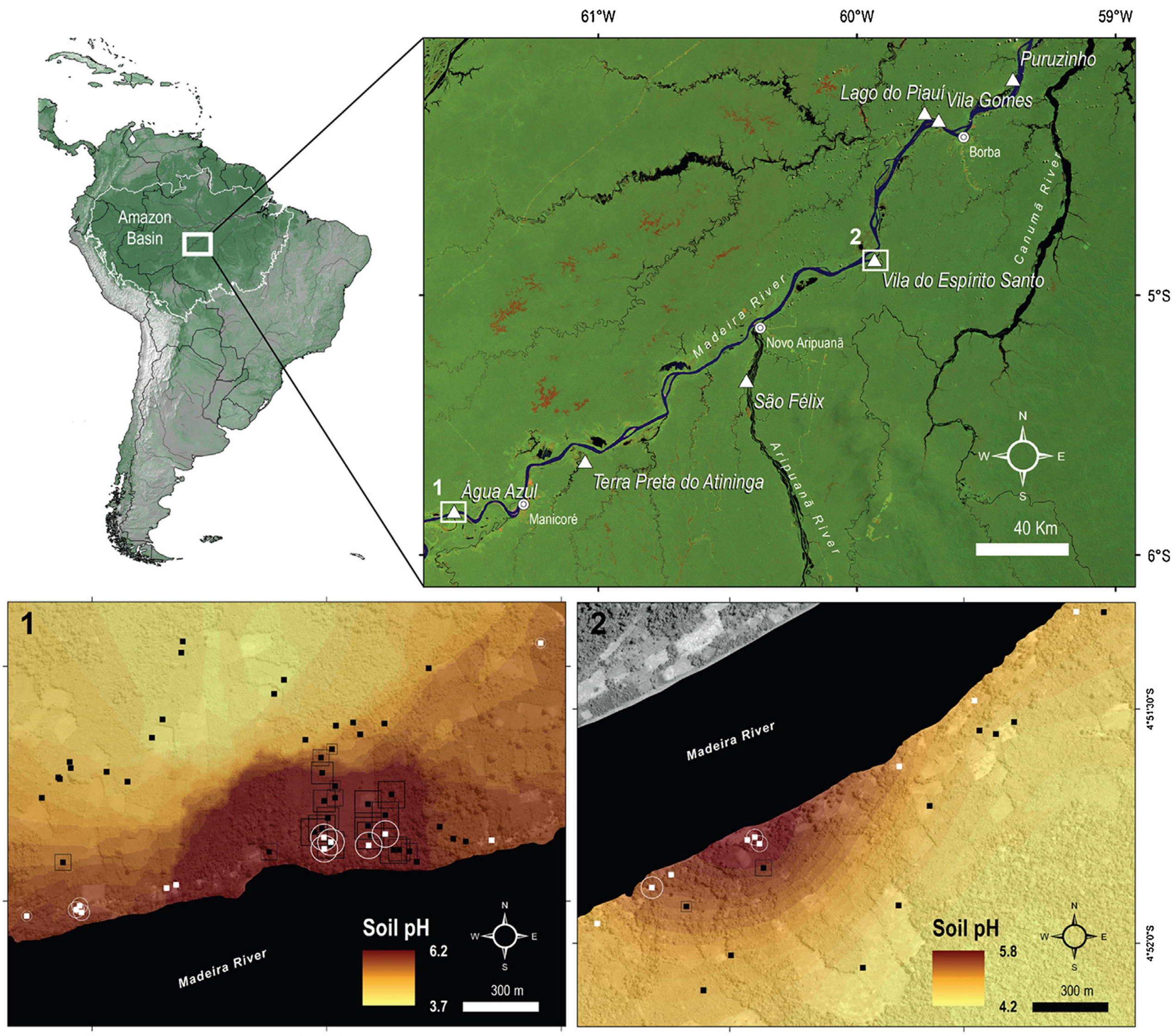

Fig. 1. Location of study sites and representation of variation in soil characteristics in the landscape. White triangles in the upper map represent the seven villages in three municipalities along the middle and lower Madeira River, and white circles indicate urban centers. The lower maps shows the variation of soil pH in two villages (Água Azul, left; Vila do Espírito Santo, right), represented with a kriging interpolation of soil data obtained at all points shown in the figure. White points indicate homegardens and black points indicate the swiddens sampled in these two villages; circles and squares around points represent the density of ceramic fragments observed in the soil surface.