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Contrasting Indigenous Urarina and Mestizo Farms in the Peruvian Amazon: Plant Diversity and Farming Practices

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Abstract. Remote Amazonian communities are often largely self-sufficient, made possible in part by their agricultural skills and deep ecological knowledge of their landscapes. Mastery of their local flora undoubtedly plays a vital role in daily life, yet communities in the Amazon can vary widely in both the diversity of plants that they utilize and in how they manage plants in their agricultural landholdings. The dominant drivers of these differences in ecological knowledge and practices between communities are not clearly understood. We compare the agricultural practices and diversity of utilized plants in an Indigenous Urarina community and a Mestizo community in the Peruvian Amazon. Through field surveys and farmer interviews, we assessed the diversity of utilized plants found in the homegardens (N = 17) and *chacras* (cropped fields; N = 47), as well as multiple agricultural characteristics of the *chacras* and fallow fields (N = 32). Households from the Mestizo community cultivated a larger land area, while both communities utilized relatively short fallow times of < 6 years. Across both communities, farmers make use of a total of 207 plant species belonging to 60 plant families for various resources, including food, spices, medicine, fuel, craft, construction, hunting/fishing, and spiritual/cultural uses. Species diversity of utilized plants was significantly higher in the Urarina community, likely reflecting their longer historical roots in the region, lower reliance on a market economy, greater reliance on farm and forest products, and higher degree of biocultural relationship to the land. Kin size was negatively correlated with homegarden diversity, while increasing household wealth led to more species diversity in Urarina landholdings, but less diversity in Mestizo landholdings. These results suggest that both Mestizo and Indigenous communities, and especially the latter, play an important role in the conservation of traditional ecological knowledge and agrobiodiversity in the Peruvian Amazon; however, increasing market integration may jeopardize the biocultural relationships that undergird this in situ conservation.

Keywords: agrobiodiversity, *chacras*, fallow, homegardens, shifting agriculture

Introduction

The Amazon rainforest has been estimated to include 16,000 tree species (ter Steege et al. 2013) and many of these and other flora provide important foods, spices, fibers, medicines, and resources for crafts, construction, and spiritual/cultural needs for the people who call the Amazon home. Necessitated in part by their historical isolation from the market economy, the traditional ecological knowledge about plants in Amazonian communities is vast (Caballero-Serrano et al. 2019; Coomes and Ban 2004; Denevan et al. 1984; Díaz-Reviriego et al. 2016; Lamont et al. 1999; Major et al. 2005; Padoch and de Jong 1991; Perrault-Archambault and Coomes 2008; Perreault 2005; Toda et al. 2017; Wezel and Ohl 2006). However, this biodiversity and associated knowledge is endangered by assimilation, globalization, deforestation, forest degradation, fragmentation, climate change, and overall decline of species diversity and abundance (Bodmer et al. 2017; Brondizio et al. 2019; Hansen et al. 2013; Parraguez-Vergara et al. 2018; Tudela-Talavera et al. 2016; Vasco et al. 2017). Understanding threats and oppor-

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tunities for conserving this agrobiodiversity and ecological knowledge requires a socioeconomic and ecological perspective of drivers of biodiversity maintenance. Towards that end, in this study, we compare the farming practices and diversity of utilized plants as they relate to household socioeconomic characteristics in an Indigenous Urarina and a Mestizo community in the Peruvian Amazon.

Several studies have investigated the botanical diversity used by Amazonian households; these studies have reported that plant diversity often varies considerably across different communities and regions and for a variety of reasons (Mukul and Herbohn 2016). For instance, in one study, household land wealth, age of garden, and kin group affiliation were the best predictors of the diversity of plants used by Amazonian households (Coomes and Ban 2004). Other studies show that market accessibility or orientation correspond negatively (Hamlin and Salick 2003; Wray et al. 1996), positively (Lamont et al. 1999; Padoch and de Jong 1991; Perreault 2005; Wezel and Ohl 2006), or neutrally (Major et al. 2005) to plant diversity in homegardens and farm fields in Amazonia. The role of cultural background, particularly whether a community is of Indigenous or non-Indigenous origin, in predicting the diversity of plants used by communities is also unclear, with some studies showing it to be an important predictor (Caballero-Serrano et al. 2019; Perrault-Archambault and Coomes 2008; Toda et al. 2017), while others not (Lamont et al. 1999). It is not surprising that the traditional ecological knowledge of Indigenous Amazonians may be considerable given their long history in the Amazon, yet many non-Indigenous Mestizos, including descendants of immigrants of past economic activities, such as the "rubber boom" of ~1870–1920, have been also shown to use high levels of plant diversity, despite their more limited historical presence in the area (Coomes 1995, 1998; Toda 2017).

Of the few studies that have compared the extent of agriculturally managed landholdings among colonist/Mestizo communities and Indigenous communities in the Amazon, the evidence is mixed. Some studies show that Indigenous communities clear less land than corresponding Mestizo communities (Gray et al. 2008; Hvalkof 2006; Lu et al. 2010) and that the land cleared is farmed more sustainably (Rudel et al. 2002, 2004; van Vliet et al. 2013). However, other studies did not find such differences in farming practices (Caviglia-Harris and Sills 2005; Simmons 1997; Vasco et al. 2018); instead, socioeconomic variables, rather than culture, per se, appeared to be more influential. In reality, a gradient of integration into the market economy or market accessibility exists across communities—Indigenous and Mestizo alike—thereby differentially impacting agricultural characteristics independent of ethnic background (van Vliet 2013; Vasco et al. 2018). Due to the variability present in the literature, more studies taking both cultural and socioeconomic variables into account are needed to elucidate factors impacting land-use decisions and levels of plant diversity utilized by Amazonian households.

In this study, we compared two villages in northeastern Peru to determine socioeconomic drivers of species richness and abundance of plants that are used for food, medicine, construction, ritual, and other purposes. Furthermore, we compared the size and duration of cultivation and fallow of agricultural landholdings between communities. One village consisted of Indigenous Amazonian Urarina farmers; the other was a Mestizo village with less historical presence in the region. We submit three hypotheses for testing: (1) because Mestizos have historically been more aligned with markets, they will manage larger landholdings that are more integrated with market economies; (2) because the Indigenous villagers have a longer temporal connection and potentially deeper biocultural relationships with the land and are less market-oriented than the Mestizo villagers, they will have adopted more plant species for various uses within their environment; and (3) plant species richness will correlate with differing household- and community-level socioeconomic indicators. Our comparative design between two neighboring communities of similar size yet different ethnic composition and varying household socioeconomic characteristics facilitates testing these hypotheses.

Methods

Study Sites

The two villages that participated in this study, Nueva Unión (Indigenous, hereafter Unión) and Nuevo Angora (primarily Mestizo, hereafter Angora), are located in the Chambira River watershed of the Amazon basin in northeastern Peru, Department of Loreto, about 230 km WSW of Iquitos (Figure 1). These communities were selected based on their proximity to each other (14 km Euclidean distance), their different ethnic backgrounds, and their willingness to participate in the study. Access to each community, as well as each community's access to markets, is possible only via small watercraft.

Unión (4º 32′ 40.74″ S, 75 º 03′ 54.33″ W, 116 masl; Figures 1 and 2a) is an Urarina community that had 96 people in 18 households at the time of the study (June 2006), and is located on the west side of the Tigrillo River along a tributary, the Quebrada Espejo. Getting to Unión required approximately six hours of travel upstream in a 13 horsepower motorized canoe (~ 12 km Euclidean distance) from the mouth of the Tigrillo at the Chambira River. Unión moved to this site in 1993 from a location a few kilometers downstream on the Quebrada Espejo.

Angora (4º 27′ 56.14″ S, 75º 09′ 46.52″ W, 125 masl; Figures 1 and 2b) is located on the northeast side of the Tigrillo River, a primary tributary of the Chambira River. From the mouth of the Chambira at the Marañon River, it takes about nine hours to travel upstream (~42 km Euclidean distance) to Angora in a motorized canoe. At the time of the study (June 2006), Angora had a total population of 104 people from 19 households, six of which were Urarina and the rest Mestizo. The first residents of Angora arrived in the mid-1960s from other areas of

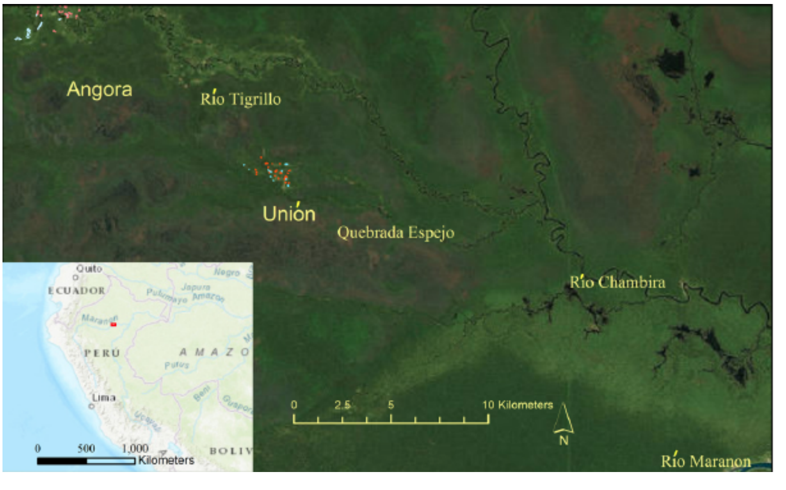

Figure 1. Map highlighting the location of Unión and Angora villages, located along the Espejo and Tigrillo Rivers respectively, which ultimately flow into the Chambira River, and later the Marañon River, a major tributary of the Amazon River, in the Peruvian Amazon. Red (darker gray in black and white) polygons are chacras and blue (lighter gray in black and white) (for detailed view of fields, see Figure 2)

the Amazon and founded the town in 1970. Most households in both Unión and Angora were single, nuclear family units, though in some cases elderly parents lived under the same roof as the nuclear family.

Ecologically, both communities occupy the same watershed and share similar hydrological, geological, and topographical characteristics. They are consequently composed of similar ecosystems, including both seasonally inundated flood plains and upland habitats that rarely, if ever, flood. Both communities are located along blackwater rivers, which are characterized by tannin-rich, acidic water with low nutrient loads resulting from a wetland origin (Coomes 1998). Agriculture, complemented by gathering and hunting, forms the basis of survival for the inhabitants of these two communities.

The region is a flat alluvial zone of the *selva baja* (lowland tropical moist forest) and is dominated by Tropaquult soils (Ministeria de Defensa 1989). The Chambira River basin has an annual precipitation of 3000–3500 mm, with most falling during the rainy season, typically November to April (Kramer 1979). The height of the Chambira River and tributaries may fluctuate over five meters throughout the course of the year, forcing the riverine inhabitants to make significant lifestyle adaptations, including choosing when they plant certain fields and how they construct their houses, e.g., raising the floor on stilts (Kramer 1979).

Study Context

Living in the Chambira and Urituyacu River watersheds north of the Marañon River, the Urarina form a small ethnic group,

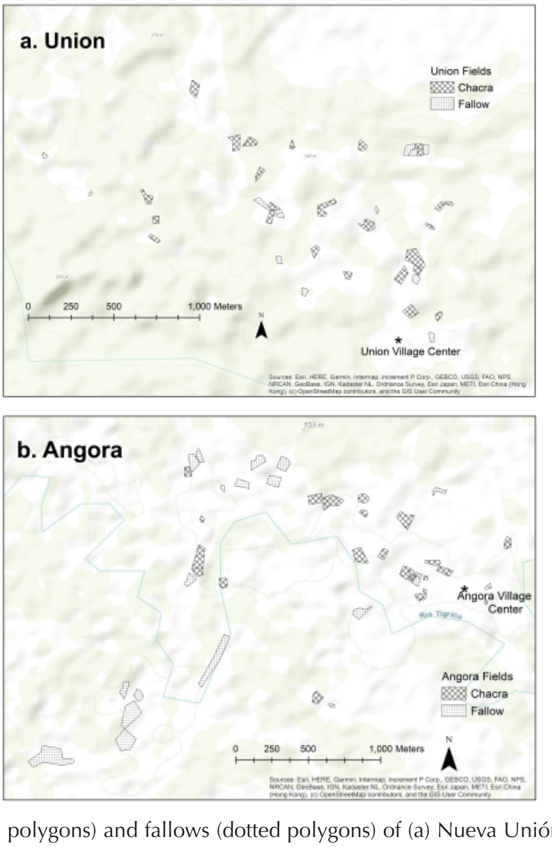

Figure 2. *Chacras* (hatched polygons) and fallows (dotted polygons) of (a) Nueva Unión, and (b) Nuevo Angora. Red pins mark the village center, where most houses and a central soccer field are located.

with a total population estimated at 2500 (Dean 1995a; Díaz Barba 1987) to 5000 (McKinley 2003) individuals. The Urarina generally form villages of 40 to 100 people of bilateral kindreds in single-family houses; they are linguistically isolated from their neighboring ethnic groups (Dean 1995b). They are a semi-nomadic group that practices agriculture, fishing, hunting, and gathering from the forest to provide for their needs (Ferrúa et al. 1980). Their diet consists largely of cassava (*Manihot esculenta*), plantains and bananas (*Musa* spp.), fish, and wild game. Although their involvement with the local market economy varies according to their location and presence of traveling merchants or appropriate transportation (e.g., a motorized boat), most of the Urarina primarily practice subsistence farming and gathering, with occasional sale of crops and forest products when the opportunity arises (Dean 1995a). The money earned from these sales is used to buy the few commodities that are not obtained from the forest, farm, or river, commonly including shotguns and ammunition, machetes, axes, batteries, cloth, mosquito nets, clothing, salt, sugar, pots, fishing hooks, and fishing line.

The Mestizos, the primary culture of the residents of Angora, form the predominant culture of Peru and much of Latin America. Many Mestizos in the rural Peruvian Amazon trace their roots to the rubber boom of 1870 to 1920, when people immigrated to the region to exploit the demand for this resource (Coomes 1995). Contemporary Amazonian Mestizos are a mix of recent and historic immigrants and include many descendants of intermarriages with detribalized Indigenous Amazonians (Hiraoka 1989). These largely Spanish-speaking Mestizos settled in communities primarily located on the shores of the major rivers, such as the Marañon. Because the Mestizos are a heterogeneous group dispersed widely throughout the Amazon, it is difficult to describe their characteristics as a whole. However, the Mestizos that inhabit the same general region as the Urarina (Figure 1) can be described as having adopted a lifestyle that is outwardly similar to that of their Urarina neighbors, albeit they often live in slightly larger villages. This lifestyle is characterized by the same productive activities (e.g., farming, fishing, hunting, gathering), although the landscape in which a community is embedded plays a significant role in determining the relative importance of each of these activities. Mestizo villages may also include a few Urarina families, who are sometimes employed by Mestizos as hired agricultural labor. The primary difference in lifestyle between the two ethnic groups is often the higher involvement of the Mestizos in the local market economy, including the sale of agricultural produce (primarily bananas, plantains, rice [*Oryza sativa*], and cassava), wild-caught fish, wild-collected moriche palm (*Mauritia flexuosa*), and wild-collected palm hearts (*Euterpe precatoria*).

Households in both the Mestizo and Urarina communities manage a set of agricultural areas, including a homegarden, one to several cropped fields (called *chacras*), and fallow fields. Homegardens refer to the space located in the immediate vicinity of the home that is gardened continuously and is not subjected to fallow and subsequent burning. The homegarden or kitchen garden generally hosts a diversity of food, medicine, and spice plants, although usually with low density of each species. The *chacras* are usually located farther from the homes and are for production of the staple crops which provide most of the calories consumed in the household and are farmed using shifting slash-and-burn practices. Usually, the *chacras* yield a single harvest of a staple crop, such as cassava, rice, or maize (*Zea mays*), after which plantains are grown for two or more years until soil fertility is depleted. After plantain production drops, *chacras* are left to fallow for several years before returning the land to *chacra* again.

Household Selection

Nine families in each community met our selection criteria of having both *chacras* and homegardens, being accessible (within 800 m of the town center), and being willing to participate in the study. The remaining nine Unión and ten Angora families in the villages that were not selected to participate were either not involved in farming (e.g., village nurse), were too isolated to contact on a daily basis, or had not yet established their own farming area. In Unión, all selected families were of Urarina ethnicity, while in Angora, one family was Urarina, one was an Urarina-Mestizo intermarriage, and the remaining seven were Mestizo.

Size, Distribution, and Temporal Use of Landholdings

To assess the extent and distribution of the landholdings, we recorded the area and distance from the village center for each household's *chacras* and fallow fields with a GPS. Each farmer was also queried to determine the number of years each of their *chacras* had been in fallow beforehand, and how long they intended to keep it as a *chacra;* they were similarly queried about fallow lands and for the previous land cover of each *chacra* at the time of its most recent conversion, i.e., primary or secondary forest (in agriculture at an earlier date). We contrasted community values of field characteristics using a Welch two-sample t-test.

Botanical Diversity

We conducted botanical surveys in each family's homegarden and *chacras* between March and July 2006 by systematically observing the entirety of the agricultural area, noting all plant species and, in the case of *chacras*, each species' abundance. These surveys were conducted with the farmer, who was queried on the use of each species (i.e., for food, medicine, hunting, construction, fishing, crafts, music, fuel, spiritual/cultural beliefs, or other purposes). Specimens and photographs of plants that were not identified in the field were identified by professional botanists at the Universidad Nacional de la Amazonía Peruana and the Universidad Nacional Agraria La Molina. We calculated species richness and, in the case of *chacras*, abundance values by household and by community.

To record the abundance of each species in the *chacras*, each useful plant species encountered was scored as follows:

a. primary crop species, usually planted in an intercrop association of two to three species (score of 4);
b. secondary species, planted more frequently than 20 trees (defined as > 10 cm diameter breast height [DBH]) per 0.25 ha or greater than 10% of total ground cover area for herbaceous plants, but not planted throughout the field as an intercrop (which would be considered a primary crop); rather, planted only in certain sections of the field and in lesser quantity than the primary crops (score of 3);
c. tertiary species, present in quantities of 10–20 trees (> 10 cm DBH) per 0.25 ha or 5–10% of total ground cover area for herbaceous plants (score of 2);
d. uncommon species present in quantities of fewer than 10 trees (> 10 cm DBH) per 0.25 ha or < 5% of total ground cover area for herbaceous plants (score of 1).

This rating method was selected over a quadrat-based sampling scheme to arrive at a diversity index because the anthropogenic structure of the *chacras*—where species are highly clumped yet interspersed —would require a very high sampling density of quadrats/transects to capture the diversity present. We calculated an abundance-weighted diversity index by summing the scores of all plants present in each *chacra*. Species richness alone was used for the homegarden plant species because they generally included only a few individuals of each species, such that abundance measures would not provide substantial additional information. We contrasted community values of plant diversity using a Welch two-sample t-test.

Socioeconomic Attributes and Relationship to Botanical Diversity

Through semi-structured interviews with both the husband and wife, when possible, we gathered socioeconomic information of the participating households, including the number of family members and their respective ages, number of kin, length of residency in the village, number of years of formal education, household possessions, and number of livestock (poultry, pigs, cows). We quantified household possessions, including tools, cooking materials, and hunting and fishing equipment using estimates provided by interviewees or from prices in the city of Iquitos, where most villagers purchased their goods. The value of buildings was not included because these were primarily constructed by family members using materials that were gathered from the forest. We performed Welch two-sample t-tests to compare differences in socioeconomic attributes between communities. In addition to the above interviews, we conducted daily interviews with the heads of household over an 11-day period, starting March 11, 2006 in Angora and March 23, 2006 in Unión, to assess the amount of time allocated to productive activities (hunting, fishing, farming, and forest gathering).

Finally, to explore their potential influence on patterns of species richness, we tested the relationship between species richness of homegardens, *chacras*, and both homegardens and *chacra*s (combined) and the following socioeconomic and farm size variables using linear regression: total area of *chacras,* total area of entire farm (*chacra* plus fallow fields), age and years of formal education by the heads of household (husband and wife averaged), number of children, number of kin in the community, years as resident in the community, number of poultry, and estimated wealth of household possessions. For each dependent variable of plant species richness, we modeled each socioeconomic/farm size variable along with the community of residency as main (fixed) effects in separate models (i.e., one socioeconomic/farm size variable per model). In each model, we explored both the additive (plant diversity ~ socioeconomic variable + community) and interactive (plant diversity ~ socioeconomic variable* community) relationships. Some variables were not normally distributed and were transformed so as to not violate model assumptions. To determine test statistics and significance of models, we ran an ANOVA on each linear model. All analyses outlined in the Methods section were conducted in R version 3.5.0 (R Core Team 2018).

Results

Size, Distribution, and Temporal Use of Landholdings

We found several significant differences between villages with regard to the spatial and temporal characteristics of the *chacras* and fallows (Supplementary Table 1). Though the number of fields per household was similar between villages, the mean amount of combined land in *chacra* and fallow per household was significantly greater ($T\ (9.94) = 2.381$, $P = 0.039$) in Angora (2.44 ha) as compared to Unión (0.97 ha). Angora farmers had nearly 50% more land in *chacras* and nearly five times as much land in fallow as Unión farmers (Supplementary Table 1).

Both communities practiced a modified shifting-agriculture cycle, where they plant plantains and bananas before burning the land, resulting in the following sequence: slash-first planting (plantains/bananas)-fell-burn-second planting (when herbaceous crops are planted). In terms of agricultural duration, Unión farmers maintained *chacras* in production for an average of 2.90 years compared to 2.19 years in Angora, though this difference was only marginally significant ($T\ (27.91) = 1.80$, P = 0.08; Supplementary Table 1). Within the shifting agriculture cycle, this time period represents the time from the first planting following the burn until the fields are left to fallow. The Angora farmers maintained their land in fallow longer than did the Unión farmers, at 5.60 years vs. 4.68 years, respectively, though the difference was not significant (Supplementary Table 1).

In addition to clearing fallow land to make *chacras*, farmers in both communities also continue to clear new land from primary forest. In 2006, 30% of Unión *chacras* were derived from primary forest, compared to 10% of those in Angora. However, given the smaller average size of Unión *chacras*, the total land area of first-time *chacras* recently cleared from primary forest was approximately the same in both communities (1.74 ha in Angora; 1.84 ha in Unión). In both communities, *chacras* and fallows were widely dispersed (Figure 2), although the Euclidean distance of *chacras* from the village centers was greater in Unión, averaging 0.94 km compared to 0.59 km in Angora ($T(40.0) = 2.09$, $P < 0.043$; Supplementary Table 1).

Botanical Diversity

We documented a total of 207 plant species (from 60 plant families) used by the villagers in Unión and Angora (see Supplementary Table 2 for a list of dominant species and Supplementary Table 3 for the complete species list). At a community level, Unión households used 25% more species (165 species from 55 plant families) than Angora households (132 species from 45 plant families) (Table 1). The higher diversity in Unión was true for both homegardens and *chacras,* as well as for each use category, including edible, medicinal, and other useful plants. Considering both communities, edible plants were the most common (97 species), followed by medicinal plants (60 species), and other useful plants (50 species) (Table 1). Of the species in the category "other," most were used for construction purposes, such as roofing (e.g., *Attalea butyracea*), flooring (e.g., *Iriartea deltoidea*), and framing of houses. This category also includes various tree species used for lumber and fuelwood, as well as species useful for hunting, fishing, crafted products, music, spiritual/cultural beliefs, and miscellaneous other uses (Supplementary Table 3).

At a household level, species diversity in homegardens was significantly higher ($P = 0.01$) in Unión (45.6 species) as compared to Angora (32.2 species) (Supplementary Table 4). Homegardens in this study did not supply large quantities of food, but rather served as a space for medicinals and supplemental nutrition, primarily fruits and vegetables, to the starchy staples produced in the *chacras* and fallows. Many species in the homegardens were perennial species, and filled multiple vertical strata (e.g., canopy

Table 1. Total plant species richness of edible, medicinal, and other species recorded for *chacras* and homegardens, by community and combined among communities.

	Unión		Angora		Combined
	Species	Proportion of total	Species	Proportion of total	
Total species	165		132		207
Total edible species	87	0.53	70	0.53	97
Total medicinal species	41	0.25	35	0.27	60
Total other species	37	0.22	27	0.20	50

trees, subcanopy trees, shrubs, vines, and herbaceous layers). Additionally, many homegardens housed each family's livestock animals.

Within *chacras*, the species richness (43.6 in Unión vs. 30.2 in Angora) and abundance-weighted diversity (54.1 in Unión vs. 40.1 in Angora) showed a trend of being higher in Unión, although the differences were not significant (Supplementary Table 4). The *chacras* were used primarily for production of the staple crops (see "major crops" in Supplementary Table 2). These crops provided most of the calories consumed in the household and served as a source of income when excess produce was sold to the market. With few exceptions, *chacras* were complex polycultures consisting of several of these major crop species, and they often included various other edible, medicinal, and miscellaneous ("other") plants that were scattered sparsely throughout the cultivated area (Supplementary Tables 2 and 3).

In terms of total species present in the combined homegardens and *chacras* for each farmer, with duplicate species counted only once, Unión had an average of 73.2 species and an abundance-weighted diversity of 83.8 per household, as compared to Angora's significantly lower richness of 51.9 species ($P < 0.008$) and diversity of 61.8 ($P < 0.016$) per household (Supplementary Table 4). The ratio of edible to medicinal to "other" useful species was fairly consistent across communities and field types, except that in Angora, relatively fewer "other" species were used, especially from homegardens (Table 1; Supplementary Table 4). Though we did not systematically survey plant diversity in the fallows (due to difficulty in traversing the thick vegetation through the entirely of the plots), they did contain several plants that continued to be harvested after *chacra* "abandonment," including plantains, bananas, and products from palm trees.

Socioeconomic Attributes and Relationship to Botanical Diversity

Several measures of household wealth differed between communities (Supplementary Table 5). Though heads of households (husbands and wives) were similar in age and non-significantly different in number of years of formal education and number of children, they did differ significantly in the number of chickens (6.8 Unión; 26.3 Angora) and pigs (0.1 Unión; 2.6 Angora). The combined value of total household assets, which included tools, hunting and fishing equipment, items, and livestock, but excluded buildings (which were built mostly from gathered materials), averaged an estimated US$495 per family in Unión vs. US$778 in Angora, though the difference was not significant. However, after excluding the three wealthiest villagers, the average assets dropped to US$113 for the remaining seven families in Unión vs. a significantly higher US$269 for eight families in Angora ($T(8.37) = 2.56$, $P = 0.032$; Supplementary Table 5).

The regressions between plant species richness and multiple socioeconomic and farm size variables revealed that the community to which a household belonged was consistently an important explanatory variable explaining the diversity of utilized plants (Supplementary Table 6). We found that the size of the *chacra* was positively correlated with species diversity—a species-area relationship. Kin size was negatively related to diversity in homegardens; more relatives equaled less diversity in their own homegarden. Farmer overall wealth and/or the number of poultry showed a significant interaction with the community of residency; for Unión, more wealth or poultry appeared to be related to fewer species in the combined homegarden and *chacra*, whereas in Angora, the opposite trend was observed.

From the data we gathered from daily interviews over an 11-day period, we found that households in Unión relied more on hunting and fishing than households in Angora, whereas Angora households spent more time with forest gathering and agricultural activities. Angora households averaged 2.7 (± 1.4 SE) total hours of hunting compared to 6.0 (± 2.3 SE) total hours in Unión during the entire period, whereas for fishing, Angora households averaged only 1.5 (± 1.0 SE) hours compared to 6.4 (± 2.9 SE) hours in Unión. Conversely, households in Angora spent an average of 19.4 (± 5.1 SE) hours on forest gathering, mostly collecting construction materials, compared to 9.0 (± 3.6 SE) hours in Unión, and Angoran households dedicated 45.5 (± 16.6 SE) hours to agricultural activities compared to Unión households at 22.4 (± 6.1 SE) hours.

Discussion

This study highlights the integral role that the plant diversity associated with a household's agricultural areas plays in the lives of both Mestizo and Urarina inhabitants in two communities of the Peruvian Amazon. Besides providing major food staples, these plants provide many other household resources for the villagers who depend on these managed landscapes for their sustained livelihood. Though the agriculture of both communities is outwardly similar, we reveal several distinct differences in utilized plant diversity and in agricultural practices, likely reflecting corresponding differences in their biocultural relationship to the land and in their market orientation.

Size, Distribution, and Temporal Use of Landholdings

Angora farmers had nearly 50% more land in *chacras* and nearly five times as much land in fallow as did Unión farmers at the time of our study. These data support the first hypothesis by providing evidence that the Mestizo community, Angora, may have larger landholdings as a result of selling more produce to markets. Several farmers from Unión do sell some produce, but less than Angora farmers, and the larger *chacra* sizes in Angora likely reflect this higher market orientation. Although we do not have data on how much of each household or community's agricultural production is ultimately destined for the market, interview data indicate that Angoran households dedicated considerably more time to agricultural activities compared to Unión households, also likely reflecting the higher market orientation of Angora. Mestizos first populated the Amazon in search of economic opportunities and this mindset may have continued for many Angora farmers. However, even in Angora, farms never reach very large sizes due to the labor-intensive nature of farming in the region and the limited labor force, which mostly consists of family members.

The Angora farmers also tended to keep their land in fallow slightly longer than Unión farmers (5.6 vs. 4.7 yrs), but these fallow times were substantially less than the 20 to 40 years traditionally practiced throughout the humid tropics (Sanchez et al. 2005). The sustainability of shifting agriculture depends on the ability of the soil to recuperate in fallow after losing significant fertility during its cultivation period (Sanchez et al. 2005). The short fallow times practiced in these communities may not be sufficient to allow adequate soil nutrient restoration nor to allow for other extractive activities, such as charcoal production or palm fiber extraction, which requires 10–15 year fallows, according to residents in a nearby region in Peru (Coomes et al. 2011). Such short fallow rotations have been referred to as a "poverty trap" (Coomes et al. 2011). Many Indigenous cultures were formerly nomadic and were able to practice a long-fallow system as they moved from location to location. However, with additional colonization and privatization of land, the formerly nomadic or semi-nomadic groups, such as the Urarina, have readjusted to a geographically static lifestyle. As declining land availability drives shorter fallow periods, farmers are forced to adjust the traditional slash-and-burn cycle, thus endangering the long-term soil fertility, biodiversity, and sustainability of the landscape (Coomes et al. 2011; Gehring et al. 2005; Metzger 2003). The trend toward shorter fallow periods has been reported elsewhere; for example, 3.6 and 3.2 years in Yurimaguas and Pucallpa (Peru), respectively (White et al. 2005), and 5–10 years among the Amuesha in Bolivia (Toledo and Salick 2006). Furthermore, a meta-analysis covering the period 1995–2010 showed that 49 of 59 sites reported a shortening of fallow times due to population growth and increasingly distant primary forest (van Vliet et al. 2012).

Though fallows were less actively managed than *chacras*, they were often not abandoned and the plots continued to serve as an important resource for farmers in both communities after letting the *chacra* turn into fallow. The value of these "productive" fallows corroborates other evidence from the Amazon (Denevan and Treacy 1987; Denevan et al. 1984). Many of the tree species that were originally spared or planted in the *chacras* were left to grow in the fallows, including valuable timber species (e.g., tropical cedar, *Cedrela odorata*) and edible species (e.g., peach palm [*Bactris gasipaes*]; *Citrus* spp.; red mombin [*Spondias mombin*]; avocado [*Persea americana*]; guava [*Psidium guajava*]). Farmers also continued to harvest fruits, such as plantains, bananas, and papayas (*Carica papaya*) from the fallows that were originally planted in the *chacras*.

The amount of total land area of *chacras* cleared from primary forest was similar in both communities, with the smaller total *chacra* area in Unión having a higher proportion being derived from primary forest. Therefore, it appears that the Unión farmers have adopted a strategy of using primary forest for a greater proportion of their agricultural production, with the additional fertility allowing them to keep their smaller *chacras* in production for a longer period. This characteristic may reflect a variety of factors. First, Unión is a more recent settlement (founded in 1993 vs. 1960s in Angora), so primary forest is generally more accessible than in Angora. Second, because the farmers of Unión tend to have smaller *chacras*, they are able to devote relatively more time to the labor-intensive clearing of primary land. Finally, the Urarina's historically semi-nomadic lifestyle could play a role in their preference for converting primary forest because this type of clearing would have historically been a critical component of settling a new area.

Botanical Diversity

Our survey of plant diversity supports the second hypothesis, that Unión, the Urarina village, has more plant species that they employ for multiple uses, including for food, spices, medicine, fuel, construction, hunting, fishing, crafts, music, and spiritual/cultural beliefs. The higher diversity in the Urarina community is present despite their village being younger than Angora; a notable finding, as Coomes and Ban (2004) found homegarden age to be the best (positive) predictor of homegarden plant diversity. The observed difference in useful plant diversity could be reflective of the higher market orientation in Angora and/or the difference in ethnic composition and biocultural relationships with plants between the villages. As the Urarina have been a part of the Amazonian ecosystem for centuries, they may have developed a stronger association with and dependence on their environment to meet their needs. Furthermore, the Urarina, as compared to the Mestizo community, are likely to have a different biocultural relationship with the Amazonian plants, as has been documented among many other Amazonian cultures (e.g., Baldauf 2020; Caballero-Serrano et al. 2019; Hanspach et al. 2020). Examples of plants with biocultural significance in the Urarina, but not Mestizo, community include *Banisteriopsis* *caapi*, a psychoactive plant used for ceremonial purposes, *Cissus ulmifolia*, which is believed to increase yields of cassava, and *Amaryllis* sp., which is believed to increase hair growth. Both communities cultivated *Brugmansia* sp., which is believed to help young children begin to walk. Though both communities had *Caladium* spp., which is believed to bring good luck during hunts, more species and a higher abundance overall were observed in the Urarina community. Some households in the Mestizo community, but not in the Urarina community, grew *Anthurium croati*, which is believed to help children grow.

Our results support other studies that document the high diversity of plants used by Indigenous Amazonians (Denevan et al. 1984; Lamont et al. 1999; Major et al. 2005; Padoch and de Jong 1991; Perrault-Archambault and Coomes 2008; Perreault 2005; Toda et al. 2017; Wezel and Ohl 2006). This botanical diversity represents the evolution of cultural and biological selection and transactions, as well as the accrued wisdom and insights of farmers who have interacted with their environment over centuries (Nair and Kumar 2006). Despite the high diversity of plants that are often utilized by Indigenous Amazonians, the influence of cultural background on farm and homegarden plant diversity in the Amazon is not always consistent. For one, communities of different Indigenous backgrounds may vary in the diversity of plants they use; Perrault-Archambault and Coomes (2008) found that Urarina gardens had less diversity than those of the Achuar, another Indigenous Amazonian group. On the other hand, Lamont (1999) found no differences in plant diversity used among Yagua and mixed Yagua-Mestizo communities, while Toda et al. (2017) showed Mestizo communities to use more medicinal plant species than Shipibo communities, though the latter tend to use the plants more frequently. Our study contributes to this body of literature, showing another example of higher diversity in an Indigenous community compared to a Mestizo community.

The role of market orientation on species diversity of farms or homegardens in the Amazon is not consistent in the literature. Some studies suggest that increased market pressures play a role in lowering species diversity over time (Hamlin and Salick 2003; Wray et al. 1996), which could help explain the lower diversity found in Angora. Other studies, however, have found that villages that are more closely linked to urban centers or higher market orientation have higher species diversity in homegardens or farms (e.g., Lamont et al. 1999; Padoch and de Jong 1991; Perreault 2005). Similarly, Wezel and Ohl (2006) report that Matsiguenka communities were observed to have a relatively low homegarden species diversity, likely because of their isolation that leads to a lower influx of plants from other regions or other cultures. Furthermore, Perrault-Archambault and Coomes (2008) found that villages that had a higher flow of outside visitors (i.e., being close to oil company bases) had higher species diversity in their homegardens, whereas another study did not find a significant difference in species diversity between a low-market and high-market orientation group (Major et al. 2005). Given the variability in the literature on the role of culture and market orientation on utilized plant diversity, our study contributes to the literature to help clarify where and why ethnobotanical differences may exist between communities.

Socioeconomic Attributes and Relationship to Botanical Diversity

Our results support the third hypothesis that socioeconomic factors at the household and community level contribute to the differences in species diversity patterns. Consistent with our discussion above, the community to which a household belonged had a strong influence on plant diversity in the models explaining the relationship between each individual socioeconomic variable and plant diversity (Supplementary Table 6). These results highlight the importance of community attributes in determining land management. The most salient differences between communities are their cultural background and market orientation and, although we do not have a way to directly test their influence, we interpret these to be the main drivers of differences in observed plant diversity patterns, as we explain above. Beyond the impact across communities, the number of kin was found to be negatively related to species richness in the homegardens. One possible explanation is that as the number of nearby relatives increase, there is more opportunity for familial sharing of resources from the homegardens such that individual households are not solely reliant on their own plants. These results contradict another study (Coomes and Ban 2004), though this study also reports kin group affiliation to be more important than kin group size in predicting plant diversity. Though we do not have data on the gender breakdown of the kinship networks, gender is an important consideration of how traditional knowledge of plants is transmitted; this dynamic may have played a role in our study as well (Camou-Guerrero et al. 2008; Díaz-Reviriego et al. 2016; Howard 2006).

Finally, we found an interaction with non-land wealth and/or the number of poultry and overall farm diversity by community. The Unión community showed decreasing species diversity in homegardens + *chacras* with increasing wealth or number of poultry, while the opposite was true with Angora. Perhaps, in Unión, increasing wealth provided an avenue to rely less on their Indigenous knowledge of plant products, decreasing the necessity to grow them. In Angora, whose residents in general rely less on plant diversity than their Urarina counterparts, increasing wealth may provide greater exposure to plant species diversity through enhanced social capital or travel.

Though all households relied to some degree on wild foods—whether hunted, fished, or gathered—we recognize that the degree of reliance undoubtedly varies across households and communities. Therefore, socio-economic indicators of wealth may not perfectly reflect true household livelihood. Some families may choose to focus more on wild foods, which we do not include in our wealth assessment, compared to rearing domesticated animals, which are included as wealth. Indeed, using data gathered from daily interviews, we found that households in Unión did rely more on hunting and fishing than households in Angora, whereas Angora households spent more time with forest gathering activities.

Our counts of species diversity in homegardens and *chacras* corroborate the findings of previous research documenting the rich diversity of utilized plants in the homegardens of Indigenous and Mestizo villagers in the Peruvian Amazon, with individual studies reporting between 71 and 307 species (Coomes and Ban 2004; Lamont et al. 1999; Padoch and de Jong 1991; Perrault-Archambault and Coomes 2008; Wezel and Ohl 2006). Our study documents that the Urarina and Mestizo communities we surveyed contain levels of plant diversity on the high end of what has been shown in the literature for this region of the Amazon. The rich botanical diversity recorded in the current study is even more appreciated when considering the likely diversity of varieties that was not assessed here. For instance, Wezel and Ohl (2006) found 56 varieties of cassava in a single Peruvian Amazonian community. As such, the managed landscape plays an important role in conserving local biodiversity, functioning as an in situ germ bank for many domesticated, wild, and varietal plants.

In addition to the immediate benefits of the plant diversity used in these communities, the high diversity may help farmers mitigate risk in the face of uncertain environmental and market influences (Hamlin and Salick 2003). Furthermore, their diverse agricultural areas, especially homegardens, function as important habitat for some wildlife species. For example, homegarden systems can be important for harboring birds due to their complex, multi-layered structure that is relatively stable and not often subjected to slash-and-burn practices (Montagnini 2006).

Our study reinforces the importance of Amazonian farmers, and especially Indigenous communities, for the conservation of both agrobiodiversity and traditional ecological knowledge in the tropics; indeed, it will be critical to work in tandem with these communities to reach conservation goals of biodiversity protection and sustained human livelihood. Sustaining the biocultural relationships between such communities and the biodiversity upon which they rely is a critical component of these conservation efforts; this consideration is especially vital in the face of potential loss through cultural assimilation, globalization, and ecosystem degradation exacerbated by climate change and deforestation.

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