Small-Scale Farmers as Stewards of Useful Plant Diversity: A Case Study in Portland Parish, Jamaica

LOGAN SANDER*,[1] AND INA VANDEBROEK[1,2,3]

[1]Yale University, School of Forestry & Environmental Studies, 195 Prospect Street, New Haven, CT 06511, USA
[2]The New York Botanical Garden, Institute of Economic Botany, 2900 Southern Boulevard, The Bronx, NY 10458, USA
[3]Biology PhD Program, Graduate Center, The City University of New York, 365 Fifth Avenue, New York, NY 10016, USA
*Corresponding author; e-mail: logansander@aya.yale.edu

For centuries, small-scale farmers in Jamaica have managed and cultivated a variety of plants for use as subsistence and market crops, fodder, construction materials, and medicine. Free-listing, casual conversations, guided visits to 35 farm plots and 16 homegardens, semi-structured interviews with 16 farmers, and quantitative analysis were used to identify the factors that most correlate with useful plant richness on these lands. Jamaican farmers reported on average 87 different useful plant ethnotaxa (ethnovarieties, including single-variety species as one ethnotaxon) of cultivated and wild plants growing on all their land holdings, across an average of 62 biologically distinct species. The cumulative acreage controlled by a farmer (total land size), consisting of their homegarden ("yard") and all their farm plots, explained 61% of the variation in useful plant richness recorded for each farmer ($r = 0.78$; $p < 0.001$). In contrast, there was no effect from the farmers' age, their level of farming experience, or household size. Overall, mean ethnotaxa richness was higher on farm plots than homegardens ($p = 0.012$) because of their larger size. However, on a per-unit area basis (0.1 acres), homegardens contained more useful plants than farm plots ($p = 0.005$). While homegardens were important repositories of wild plants that are commonly used as medicines and as regular teas for consumption in the morning, farm plots were important repositories of timber trees. This nuanced understanding of factors that contribute to useful plant richness may help to direct efforts to support local farmers and better utilize the capacity of those farmers who most promote useful plants. These results underscore the complexity of agrobiodiversity conservation in rural Jamaica.

Key Words: Agrobiodiversity, homegarden, swidden agriculture, ethnotaxonomy, ethnobotany, livelihood, food security, Caribbean, West Indies.

Introduction

Useful plant varieties and wild plants are considered a critical element of ecological sustainability and livelihood security for resource-poor subsistence and small-scale farmers (Delang 2006; Galluzzi et al. 2010; Thrupp 2000). In Jamaica, homegardens and farm plots incorporate a broad range of plants that provide essential food, medicine, construction materials, and the cash needs of households. Small-scale agriculture and homegardens are an especially important component of the livelihoods of economically marginalized community members, especially older people (Woodsong 1994). Furthermore, Jamaican farmers utilize useful plant diversity to cope with seasonal hunger (Rashford 2002), fluctuations in weather (Campbell et al. 2011) and markets

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(Davis-Morrison and Barker 1997), medical needs (Picking et al. 2011), as well as theft (Weis 2006).

Recent studies of factors influencing useful plant diversity in other locales have highlighted the effects of chemical fertilizer use, the number of plots utilized, household wealth, livestock number, membership in farmers' groups, altitude (Rana et al. 2007), the age and gender of the cultivator, the area under cultivation, ethnicity (Perrault-Archambault and Coomes 2008), spatial and seasonal variation (Cruz-Garcia and Struik 2015), a rural-urban gradient (Poot-Pool et al. 2015), soil type (Kawa et al. 2011), garden age, and levels of sharing and kinship affiliation (Coomes and Ban 2004). Previous research in Jamaica has described the strategies and characteristics of peasant cultivation (Barker and Spence 1988; Innis 1961, 1983; Weis 2006). This research has indicated that farmers may promote different types of plants at different ages (Spence 1999), assessed the role of local knowledge (Barker 2012; Beckford and Barker 2007), and observed the spatial arrangement of high maintenance plants and those susceptible to theft near homes (Barker and Spence 1988; Beckford and Campbell 2013). With the absence of considerable external agricultural investment, or the development of strong markets for agricultural produce, high-biodiversity small-scale agriculture and homegardens seem to be the most appropriate response to the needs of many rural Jamaicans. With mounting concerns over a changing climate (Taylor et al. 2012), and a struggling Jamaican economy, a more nuanced understanding of the maintenance of useful plant diversity may help to better direct resources to promote rural food and livelihood security.

Very few studies have quantitatively analyzed the factors contributing to the richness of useful plants on farm plots and homegardens in Jamaica (e.g., Thomas-Hope et al. 2000). Furthermore, few studies have compared useful plant species on both homegardens and farm plots (Thomas-Hope et al. 2000), and no local studies have conducted analyses at the level of plant varieties. In this study, we examine patterns of useful plant richness across farm plots and homegardens to different factors, including land use type (farm plot or homegarden), cumulative size of all plots and area managed, and the personal characteristics of the farmers. Those aspiring to support local food production and livelihoods will benefit from the identification of salient factors contributing to useful plant richness, including the roles of homegardens and farm plots in hosting different types of useful plants. We hypothesized that Jamaican small-scale (hillside) farmers will maintain and promote useful plants on an opportunistic basis as a consequence of social or biophysical factors related to a subsistence lifestyle. These have been identified and tested in the literature from other countries, and include access to land and labor, and the age of the cultivator (Perrault-Archambault and Coomes 2008; Rana et al. 2007).

In particular, we seek to answer three questions:

1) Which variables correlate with useful plant richness of ethnotaxa (ethnovarieties) promoted and maintained by farmers?
2) Is higher ethnotaxa richness maintained on farm plots or on homegardens?
3) How does ethnotaxa richness differ between farm plots and homegardens?

Materials and Methods

Study Area

This study was based in and near the community of Windsor Forest, Portland Parish, Jamaica (18° 6′ 34″ North, 76° 20′ 20″ West). This community of roughly 1000 people is approximately 2 kilometers (km) away from the eastern coast of the island, and about 30 km from the city of Port Antonio (Fig. 1). On average, Port Antonio, the administrative capital of Portland Parish, receives around 2700 mm of rainfall annually, with seasonally higher precipitation in May-June and October-December. The mean minimum and maximum air temperature is 19 and 28 °C, respectively, with high humidity throughout the year (Meteorological Service of Jamaica 2015). The community and surrounding farms are situated at around 120 m elevation on limestone hills. Soils are mostly Lucky Hill Clay loam over Bundo clay or Bonnygate stony loam and Carron Hill clay (Soil Survey and Research Department Regional Research Centre 1959). The land around Windsor Forest has been extensively modified by small-scale farming and is now a mosaic of active farm plots, secondary tropical hardwood forest, fallowed or abandoned farm plots, and former coconut groves. Several kilometers west of the community are state-owned forests of planted timber species (colloquially known as "Crown land," referring to historical political connections with Britain), including *Swietenia* spp. (mahogany), *Talipariti elatum* (Sw.) Fryxell (blue mahoe), and

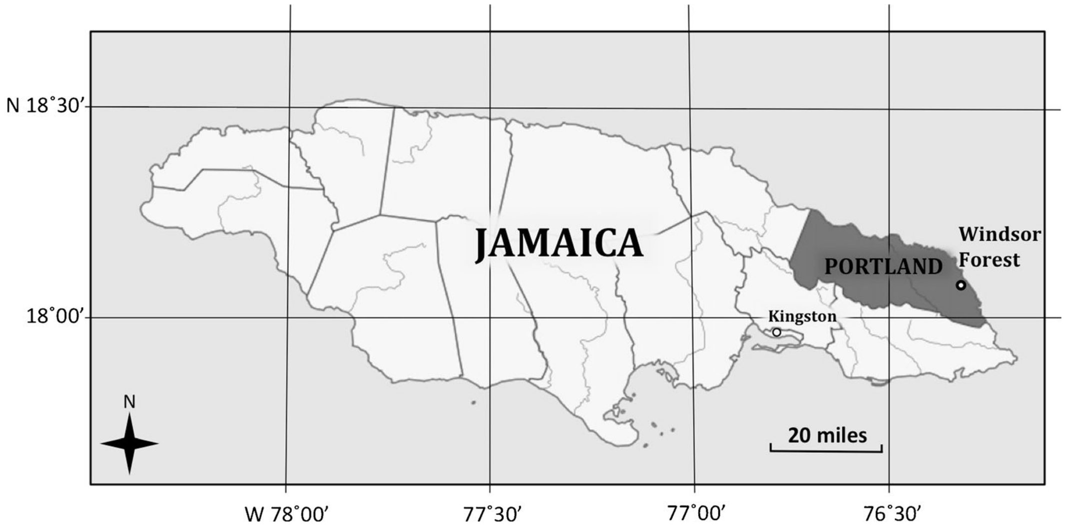

Fig. 1. Location of study site: Windsor Forest in Portland Parish, Jamaica. Base map from Wikipedia Commons (12 February 2016).

Cedrela spp. (cedar). Local residents utilize these forests and abandoned farm plots as places to hunt wild boar and procure bush plants for medicines (especially root tonics), for own use and sale.

Fifteen of the 16 farmers included in this study rely on hillside farming as their primary source of income. In general, farmers in Windsor Forest and the surrounding communities tend to participate in other income-generating activities on an opportunistic basis, including cooking, construction, housework, working on large farms near the coast that grow banana, plantain, ginger and yams, and to a lesser extent hotel work and other work in the capital of Kingston. Agricultural practices in Windsor Forest are typical of the rural Jamaican peasantry (Innis 1961, 1983; Weis 2006) and are best characterized as a mix of subsistence and opportunistic market-based activities on highly fragmented farm plots cumulatively smaller than 5 (mean, 3.1 ± 6.9) hectares. Most farmers cultivate at least one plot (mean, 2; range, 1–4), as well as tend a homegarden. We use the term "homegarden" to refer to what is locally called "yard" and what has been described in the Caribbean literature as "backyard gardens" (Barker and Spence 1988) and "kitchen gardens" (Brierley 1991). Homegardens are always adjacent to the farmer's home, tend to be smaller than farm plots, and often include areas dedicated to staple food crops, tree crops, managed wild plants for medicinal use, and ornamental plants. Homegardens are the primary site of farmer experimentation and are where children learn to grow food and distinguish useful plants (Beckford et al. 2007). Homegardens were observed to include small nurseries of newly obtained or propagated plants, or other plants that require more regular maintenance. In rural Jamaica, homegardens contribute to a balanced diet throughout the year, as well as to farmer income (Beckford et al. 2007). Farm plots are individual units of ownership or management that are defined by the farmer and usually consist of a mosaic of management systems (intensive annual cropping, orchards of tree crops, timber trees, fallows). Plots are inherited from family members, purchased, borrowed, or utilized in the customary arrangement termed "family land" (LeFranc 1974). Mostly, these plots have some form of active management when inherited by a farmer, but in a few cases farmers were actively clearing and burning abandoned overgrown plots or secondary forest.

Jamaican small-scale farmers utilize agrobiodiversity that is the legacy of global trade and migration, historic economic conditions, and a landscape modified by centuries of intensive agriculture (Rashford 1994). Jamaica's original indigenous inhabitants, the Taino, supplemented fishing and hunting with the cultivation of native and naturalized plants such as cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L.) Lam.), corn (*Zea mays* L.), and coco (*Xanthosoma sagittifolium* (L.) Schott). The early Spanish colonizers encountered a variety of local fruit trees, including pimento (*Pimenta dioica* (L.) Merr.), star apple (*Chrysophyllum cainito* L.), and papaya (*Carica papaya* L.), and introduced sugar cane (*Saccharum officinarum* L.), banana (*Musa acuminata* Colla), ginger (*Zingiber officinale* Roscoe), and citrus (*Citrus* spp.) (Food and Agricultural Organization 2008; Parry 1955). By the late seventeenth century, the English controlled Jamaica and transformed the island's economy toward the export of sugar, indigo (*Indigofera tinctoria* L.), and ginger (Barker 1993; Parry 1955). The large export-oriented plantations were worked by African slaves who grew their own food on "provision grounds" next to their dwellings or on land unsuitable for sugar cultivation (Brierley 1991). The techniques utilized to produce food on the provision grounds were the adaptation and refinement of thousands of years of experimentation in Africa (Innis 1961), and utilized a rich diversity of crops from around the world, including yams (*Dioscorea* spp.) and ackee (*Blighia sapida* K.D.Koenig) brought from Africa via the slave trade. Domestic food demands from a burgeoning slave population, the stresses of the war of American Independence, and the development of botanical gardens throughout the region contributed to the introduction of several other important sources of food on provision grounds, notably mango (*Mangifera indica* L.) and breadfruit (*Artocarpus altilis* (Parkinson) Fosberg) (Parry 1955; Rashford 1994). In response to Emancipation in 1838, most former slaves left plantation farming to start small hillside farms of their own, founding free settlements and initiating a Jamaican peasantry that continues to produce a significant degree of domestic food consumption (Barker 1993; Beckford and Barker 2007). Introductions of plants slowed after Emancipation, though Jamaican farmers have continued to contribute to the island's agrobiodiversity, including through the development of varieties of Scotch bonnet peppers (*Capsicum chinense* Jacq.), sorrel (*Hibiscus sabdariffa* L.), and callaloo (*Amaranthus viridis* L.) (Food and Agricultural Organization 2008).

Farmers' choice of crops in Windsor Forest is somewhat idiosyncratic; factors that likely influence this choice include market orientation, personal preferences, land use history, and the ecological suitability of the land they manage. In the relatively fertile soils on valley bottoms, farmers reported to cultivate tree crops such as breadfruit, ackee, pimento, nutmeg (*Myristica fragrans* Houtt.), plantain (*Musa* x *paradisiaca* L.), banana, june plum (*Spondias dulcis* G.Forst.), mango, coconut (*Cocos nucifera* L.), and lumber trees. All of these crops can be found growing on steep hillsides as well. Also, staple perennial crops such as yam (*Dioscorea* spp.), coco (*X. sagittifolium* (L.) Schott), and dasheen (*Colocasia esculenta* (L.) Schott) can be grown anywhere. On well-drained hillside areas with sunlight, sweet potato is planted. On hillsides closer to the forest, in areas described as having a "juicier soil," farmers grow labor- and resource-intensive annual vegetables such as cabbage (*Brassica oleracea* L.), carrot (*Daucus carota* L.), bok choy (*Brassica chinensis* L.), and callaloo (unpublished results).

Farmers typically interplant a diversity of both aboveground and belowground crops. This acts as a hedge against hurricane damage and price fluctuations, and may minimize crop diseases (Hills 1988; Innis 1961). Marketing opportunities for crops outside of the community are generally limited to street markets in the parish' capital, Port Antonio. Virtually all of the community's farmers have no access to irrigation and rely solely on rainwater or nearby springs for their crops, and most farm labor is done manually with machete or sometimes with the help of animals. Production of staple and annual crops is highly seasonal, and related to the availability of rainfall. Many of the farm plots included in this study are reachable by small roads into the surrounding hills, and typically take 15–60 min to reach on foot. In most cases, these roads have been degraded by hurricane damage and persistent lack of maintenance, to the point where they are now merely rugged footpaths.

Data Collection

The authors conducted fieldwork in Windsor Forest from May to August 2014. Sixteen farmers (14 men and 2 women) were interviewed by the first author and provided data related to a total of 35 farm plots and 16 homegardens. Selection of farmers relied on convenience and snowball sampling (Tongco 2007), in which each interviewed farmer was asked to recommend other farmers to interview. The average age of participants was 49 ± 10 years. Age and gender representation in our sample is roughly consistent with a record on Jamaican and Caribbean small-scale farming that consistently recognizes an older and male-dominated farming population (Beckford and Campbell 2013; SIOJ 2007; Spence 1999; Woodsong 1994). IRB exemption was granted for this study from Yale University (IRB #1404013698). Before each interview, verbal Prior Informed Consent (PIC) was obtained. Structured questionnaires were verbally administered by the interviewer who recorded responses. Data gathered included local useful plant names, type of agricultural inputs and practices, opportunities for produce marketing, access to labor, personal attributes of farmers such as age, number of years farmed, and problems faced with farming (Table 1). In addition, farmers were asked to estimate the acreage of each farm plot and homegarden, as well as the acreage currently under active management, including for activities such as harvesting, clearing, weeding and preparing land, maintaining trees, crops and pasture, or planting trees or crops. These questionnaire items were selected based on participant observation at the beginning of research and a review of the literature on small-scale agriculture and agrobiodiversity. This quantitative approach using structured surveys was supplemented with a qualitative approach, in which quotes were gathered by both authors through casual conversations and open-ended interviews in order to provide an explanatory context for the observed data.

Data on useful plant diversity of farm plots and homegardens were recorded as follows. The first author accompanied the farmers on a walk around most of their farm plots ($n = 35$) and homegardens ($n = 16$), where they were asked to report the local names of all the plants they used or promoted in any way (excluding purely ornamental use), including varieties of crops and plants that were sold, utilized for medicine or food, maintained for ecological or practical reasons, or produced into goods such as lumber or charcoal. In one case, several of a farmer's ornamental varieties were included because they were primarily intended for sale. Due to the initially abstract nature of this inquiry and the hesitation this sometimes created, the interviewer prompted the farmers at the beginning of the interview by naming a few common varieties and species as determined from preliminary interviews, participant observation, and the literature (Food and Agricultural Organization 2008; Hills 1988). Ganja (*Cannabis sativa* L.), an important but illegal plant to Jamaican farmers (Barker 1993), was excluded from data collection in order to protect the interests of the farmers and maintain trust between researchers and participants.

Our fieldwork took place during a period of prolonged drought. In order to address the bias this could have introduced in the data, farmers were asked to report plants that they intended to plant but were unable to because of the drought. All these were annual crops that farmers typically plant during the wet season (May to June, covering part of our fieldwork) and that represent a significant degree of market-oriented useful plant richness. We chose to include data about these plants because farmers commonly plan ahead for the crops they intend to plant and were regularly observed discussing their planting practices among each other.

This study relied on the ethnoclassification of plant varieties by means of common names. Voucher specimens were collected by the second author for most wild medicinal ("bush") plants growing on farm plots and homegardens, and are deposited at the Herbarium of the University of the West Indies-Mona (UWI) and The New York Botanical Garden (NYBG). Plants were identified with the help of Adams (1972) and Acevedo-Rodríguez and Strong (2007), consultation with plant specialists (Patrick Lewis, UWI; Richard Abbott and Robin Moran, NYBG), and comparison with herbarium voucher collections at these institutions. A permit for plant collection (2014–2015) was obtained from NEPA, the National Environment and Planning Agency. Scientific names follow The International Plant Names Index (www.ipni.org). For the other plants, mostly crop varieties, vouchers were not collected because this study aimed to compare relative useful plant richness to farmer and farm attributes, not to develop a definitive list of crop species for this region. We considered ethnotaxa (at the varietal level, in which single-variety species were counted as one ethnotaxon) to be the most appropriate level of classification for our analysis, as they are the unit of biodiversity perceived, and acted upon, by the farmers, and are not well represented in the region's literature.

Data Analysis

Reported useful plant richness (number of ethnotaxa; synonym, ethnovarieties) was classified by life form and plant type into the following functional groups (Fig. 2a, b): timber trees, perennial crops, annual crops, wild plants, and tree crops. Examples of ethnotaxa in these groups are found in Tables 4 and 5 (Electronic Supplementary Material—ESM).

Data were analyzed as follows: (a) the total number of different ethnotaxa (ethnovarieties) reported per farmer (growing in their homegarden or in any of their farm plots), or as the (b) mean or (c)

TABLE 1. SUMMARY OF STATISTICS FROM FARMERS PARTICIPATING IN THE STUDY ($N = 16$). TOTAL ETHNOTAXA REFERS TO THE TOTAL NUMBER OF DIFFERENT ETHNOVARIETIES REPORTED BY A FARMER IN THEIR HOMEGARDEN AND ALL OF THEIR FARM PLOTS (SINGLE-VARIETY SPECIES ARE COUNTED AS ONE ETHNOTAXON).

Farmer #	Gender	Age	# of years continuous farming	# of plots managed (including homegarden)	Cumulative acreage controlled by farmer (land size)	Cumulative acreage actively managed by farmer	Estimated # of timber trees planted (lifetime)	Household size
1	Male	48	23	2	1	1	5	1
2	Male	43	23	3	108	18	50	6
3	Male	54	45	4	12	2	400	1
4	Male	56	38	2	29	14	500	1
5	Male	57	32	5	11	6	20	1
6	Male	37	22	3	17	16	1000	5
7	Male	43	19	4	16	16	300	3
8	Male	63	2	3	4	3	500	1
9	Female	43	1	2	2	1	0	3
10	Male	38	16	4	15	15	1000	8
11	Female	42	1	2	4	0.3	0	9
12	Male	55	35	3	13	6	500	15
13	Male	64	49	3	10	10	50	4
14	Male	50	25	4	24	12	500	3
15	Male	60	46	3	4	4	20	2
16	Male	31	13	4	28	18	50	4

Farmer #	Total ethnotaxa	# of tree crop ethnotaxa	# of wild plant ethnotaxa	# of annual crop ethnotaxa	# of perennial crop ethnotaxa	# of timber tree ethnotaxa
1	43	20	3	7	4	4
2	104	43	12	26	7	7
3	109	48	10	19	14	14
4	142	50	27	32	11	11
5	111	46	10	24	10	10
6	67	29	3	12	9	9
7	101	50	8	12	12	12
8	70	29	5	18	8	8
9	39	17	3	10	3	3
10	103	44	11	16	15	15
11	40	15	2	11	1	1
12	70	29	2	16	9	9
13	95	39	7	24	9	9
14	116	47	11	27	11	11
15	54	16	4	20	5	5
16	123	47	9	37	10	10

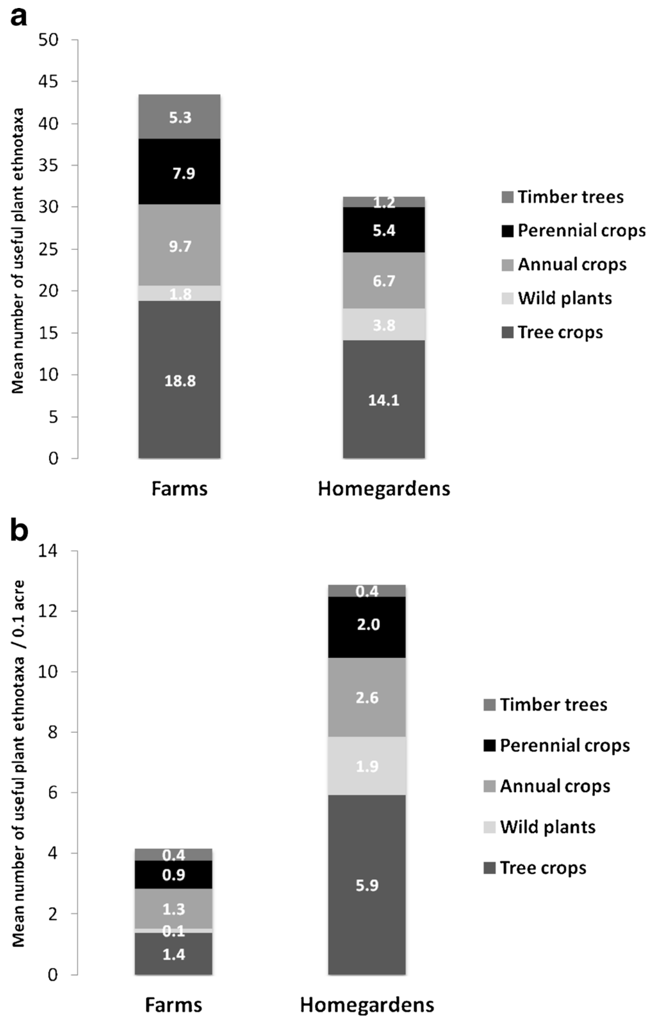

Fig. 2. **a** Mean number of useful plant ethnotaxa (ethnovarieties) by functional group in homegardens (*n* = 15) and farm plots (*n* = 34) in Windsor Forest, Jamaica. See Tables 4 and 5 (ESM) for a list of reported annual (or "short") crops, perennial crops, tree crops, timber trees, wild plants (including agrestals). **b** Mean number of useful plant ethnotaxa (ethnovarieties) per 0.1 acre by functional group in homegardens (*n* = 15) and farm plots (*n* = 34) in Windsor Forest, Jamaica.

cumulative number of ethnotaxa reported over all their farm plots or homegarden.

Pearson's product-moment correlation coefficients were calculated in SigmaStat (Jandell Scientific Software) to assess the relationship between useful plant richness and several farm and farmer variables. First, the correlation coefficient was calculated between the total number of different ethnotaxa (ethnovarieties) per farmer and the estimated number of different species maintained by a farmer, in their homegarden and in all of their farm plots. Since these two dependent variables were found to correlate highly, further analysis was done using the total number of ethnotaxa. Thus, a correlation matrix was created to test the following variables: (a) the total number of different ethnotaxa maintained by a farmer (in their homegarden and in all of their farm plots), (b) the household size of the farmer, (c) the age of the farmer, (d) the number of years the farmer had continuously been farming, (e) the cumulative acreage controlled by each farmer, including their homegarden and all of their farm plots (total land size), (f) and the cumulative acreage that each farmer was actively working on and managing (excluding fallows and abandoned land where no management occurred) (Table 1). Household size was defined as the number of people permanently residing in a participant's household at the time of interview. Data were checked for normality, and log transformation was used to compute statistics on total land size to meet normality requirements.

We conducted a two-sample *t* test to compare the mean ethnotaxa (ethnovariety) richness between farm plots and homegardens, and a Mann–Whitney rank sum test to compare the per 0.1-acre densities of useful plant ethnotaxa between farm plots and homegardens (calculated by dividing the total number of ethnotaxa reported for each farm plot or homegarden by its size, in 0.1-acre units). A Chi-square test and *Z*-test for proportions compared how cumulative ethnotaxa richness differed between farm plots and homegardens according to plant type.

Results

Figure 3 shows a visual representation of the farmer recommendation network in our study. It is assumed that farmers recommend their friends, social allies, neighbors, and farmers whom they view as especially successful. Many recommendations were to farmers who were not study participants, indicating that convenience and snowball sampling did not merely result in the participation of a group of close friends. Several farmers made no recommendations, instead expressing that younger people do not know much about farming, quoting: "dem [they] depend a different way" (farmer # 15, Fig. 3).

A homegarden (locally called "yard") was described as the place closest to the farmer's home where they plant "a few likkle [little] things fi [for] food and flowers, plants fi tea purpose, and things fi eat [and drink like] plum [*Spondias dulcis* G.Forst.] juice. Where you live is your yard." In contrast, a farm is located further away from the house and considered a "place where you plant things fi [for] sell to higglers [middlemen] and plant on a wider scale" (farmer #6; Table 1). Another farmer said: "you can pick a hand of banana or a piece of yam from your yard and do not need to go all the distance to the farm." He added that "you can plant the same things in your yard and farm because it goes by season" (farmer #7; Table 1).

Farmers in Windsor Forest listed on average 87 different useful plant ethnovarieties (including single-variety species counted as one variety or

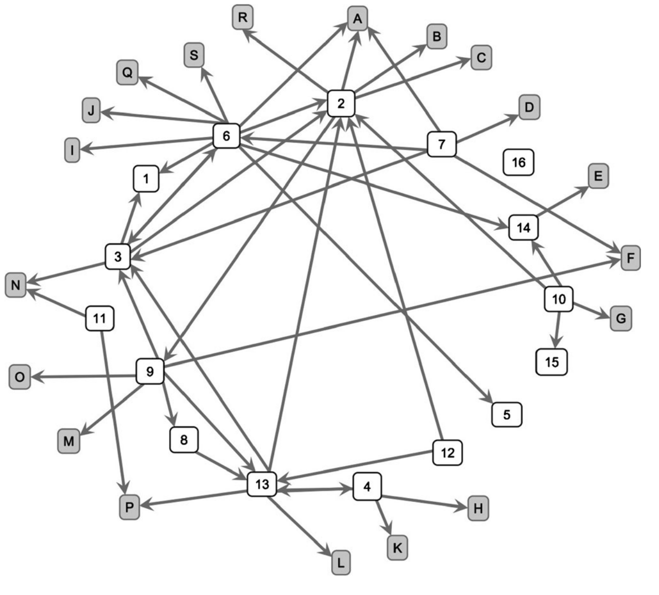

Fig. 3. Network map indicating participant recommendations from interviewed participants. *Numbered boxes* indicate farmers who were interviewed. *Lettered boxes* indicate non-interviewed farmers. *Arrows* originate from interviewed participants and are directed toward their recommendations.

ethnotaxon) on all their land holdings (range, 39 to 142; SD, 32), across an average of 62 biologically distinct species (range, 32 to 106; SD, 20). The total number of ethnovarieties reported was 349. The total number of biologically distinct species is lower (our best estimate is 174; Table 5), as many species have several varieties (for example mango), and some of the ethnovarieties mentioned by farmers are biologically indistinct from other ethnovarieties (ethnosynonymy), as has also been reported in this region by other authors (Kelly and Dickinson 1985). However, differences in naming between farmers do not impact the purpose of this study, as it was observed that individual farmers were consistent in their usage of names, therefore reported ethnovariety richness represents the relative agrobiodiversity managed and promoted by each farmer. The most important economic crops reported were coconut, plantain, yams, and annual "short" crops such as cabbage and peppers (*Capsicum* spp.).

The most prevalent farm problems cited by farmers were as follows (number of farmers between brackets): a lack of investment and capital (8 of 16), crop diseases (6 of 16), theft of crops from farm plots or homegardens (6 of 16), and livestock from neighboring farmers consuming their crops (3 of 16).

Farm plots in our sample were larger (mean, 7.8 ± 16.9 acres; range, 0.1–100) and more variable in size than homegardens (mean, 1.5 ± 2.5 acres; range, 0.05–10). The range of land managed (worked) to land controlled (total land size) varied between 8 and 100% (mean, 48%) (Table 1), which is consistent with other local studies (Meikle 1998). In Windsor Forest, useful plants continued to be harvested from fallow land, even though working on these lands was a lower priority for the farmer. Data on voucher specimens of "bush" medicinal plants are presented in Table 4 (ESM).

Factors Associated with Ethnotaxa Richness Managed by Farmers

There was a strong positive correlation between reported ethnotaxa (ethnovariety) richness and estimated species richness, $r(14) = 0.97$, $p = 2.27\text{E}{-}10$, with ethnovariety richness explaining 95% of species richness. As a result, we used ethnotaxa richness (number of different ethnovarieties per farmer) as the dependent variable in our correlation matrix. We selected the age of the farmer and total land size (log transformed) among the variables to be tested, as two other variables, namely the number of years the farmer had been continuously farming and the acreage under active management, were covariates ($r(14) = 0.56$, $p = 0.03$ and $r(14) = 0.83$, $p < 0.001$, respectively). Table 2 shows our correlation matrix in which total land size is the only significant correlate of the dependent variable ($r(14) = 0.78$, $p < 0.001$), explaining 61% of the variation in ethnotaxa richness in our sample. This result is significant even after Bonferroni correction for multiple comparisons, which in this case would require p values to be less than $0.05/6 = 0.008$ (for six comparisons between the number of different ethnotaxa, farmer age, total land size, and household size). Household size and the age of the farmer were not significantly associated with ethnotaxa richness.

Sharing, Transplanting, and Protecting of Plant Material

Several deliberate mechanisms were observed that facilitate the spread and protection of plant material throughout the community, including sharing, transplanting, and protecting crop and wild ("bush") plants. One farmer ran a small nursery near his home where he sold rare "bush" or horticultural varieties he had collected and propagated (farmer #4, Table 1). Another young farmer reported obtaining many useful plant varieties from his father who was widely known for having eclectic interests as a farmer and plant collector (farmer #16, Table 1). In the evenings, we commonly saw male farmers socializing in the community while discussing useful cultivated and wild plants. Farmers were also observed giving "suckers," or live vegetative propagules, to each other. One farmer explained this behavior as follows: "If you alone try to keep [a useful plant] and you fail, you will lose it. If you share it, you can get it back" (farmer #5, Table 1). Another farmer reported: "If a man takes a sucker or twenty, I have no problem." On another occasion, he said: "plantain tree carry 6 to 7 suckers, people share plantain [and] banana. It depends on the friendship, if you and the man no friend, [then] you have to buy it" (farmer #6, Table 1). Farmer #16's father explained that it is good to "exchange suckers to build up the breed [of the crop], that way you can catch it too." Social alliances were important in this regard. For example, callaloo (*Amaranthus viridis* L.) seed can be shared directly, or someone sows the seeds and may distribute plantlets to friends upon request. Farmer #6 (Table 1) explained sharing further: "Some people

TABLE 2. PEARSON'S PRODUCT-MOMENT CORRELATION MATRIX OF VARIABLES ASSOCIATED WITH REPORTED USEFUL PLANT ETHNOTAXA RICHNESS BY FARMERS ($N = 16$). NUMBER OF DIFFERENT ETHNOTAXA REFERS TO THE NUMBER OF DIFFERENT ETHNOVARIETIES REPORTED BY EACH FARMER AS GROWING IN ANY OF THEIR LAND MANAGEMENT UNITS (HOMEGARDEN AND FARM PLOTS) IN WINDSOR FOREST, JAMAICA.

		1	2	3	4	5	6
Variable:							
1. Number of different ethnotaxa	Pearson correlation	–	0.005	*0.78*	–0.213	*0.656*	0.366
	Significance	–	0.985	*<0.001*	0.429	*0.006*	0.163
2. Farmer age	Pearson correlation	–	–	–0.227	–0.26	–0.466	*0.555*
	Significance	–	–	0.397	0.331	0.069	*0.026*
3. Total land size (cumulative acreage controlled) (log)	Pearson correlation	–	–	–	0.196	*0.829*	0.255
	Significance	–	–	–	0.468	*<0.001*	0.34
4. Household size	Pearson correlation	–	–	–	–	0.111	–0.12
	Significance	–	–	–	–	0.684	0.657
Covariates:							
5. Cumulative acreage actively managed	Pearson correlation	–	–	–	–	–	0.075
	Significance	–	–	–	–	–	0.782
6. Years as a farmer	Pearson correlation	–	–	–	–	–	–
	Significance	–	–	–	–	–	–

Italic values are significant, $p \leq 0.05$. Total land size (cumulative acreage controlled) includes all farm plots controlled by a farmer and their homegarden. After controlling for Bonferroni correction of six comparisons with four variables (covariates excluded from analysis), significant p values would be $p < 0.008$.

just plant what they get, it depends on friends. We normally want the best to plant, for example *lacatan* banana [a variety] bears a better bunch [of fruits], but it depends on what plants your friends have, or maybe they [the farmers have to] go buy them [the plant material]." Social cohesion through friendships thus appears to be an important factor in the distribution of plant material.

When asked about the origins of several trees on larger farm plots, several participants responded that an ancestor had planted them. One farmer stated that "these things follow you" (farmer #5, Table 1), referring to fruits such as *Citrus* spp. that may originate from a discarded seed. Another farmer said: "me no plant no ackee tree (*Blighia sapida*) over there. They just blow and grow" (farmer #3, Table 1). We observed farmer #6 religiously keeping all the seeds of fruits or vegetables he had purchased as food to scatter them later freely on his land in the hope that they would "catch," including seeds from scotch bonnet pepper (*Capsicum chinense* Jacq.), pumpkin (*Cucurbita moschata* Duchesne), jackfruit (*Artocarpus heterophyllus* Lam.), tomato (*Solanum lycopersicum* L.), ackee (*Blighia sapida* K.D.Koenig), and cherry (*Malpighia glabra* L.).

In general, and regardless of their main function, trees are also appreciated for their ecosystem services. This includes roles such as providing shade and keeping the soil moist, which is illustrated by the following quotes from several farmers: "sun will kill you if you cut the trees" (farmer #12, Table 1). "[Trees] ease off sun, if you cut down the trees, it is like a desert" (farmer #13, Table 1). "The crop is failing without trees. Maybe because [when you] cut down too many trees, [the] soil does not have enough juice in it" (farmer #5, Table 1). "Trees control drainage, [then the] land becomes porous" (farmer #7, Table 1). These quotes illustrate the intricate knowledge that Jamaican farmers have about their land use systems.

On daily trips accompanying farmer #6 to his active farm, we regularly observed him transplanting plantlets that he had previously picked up from fallow farmland in the forest, or along community roadsides, including sweet orange (*Citrus sinensis* Osbeck), june plum (*Spondias dulcis* G.Forst.), and pear (avocado, *Persea americana* Mill.). He explained: "when farmers find useful tree plantlets in the forest, or useful suckers on non-active farms of other people, they can pick them up and transplant them on their own land." Farmer #6 also distinguished between useful trees and "waste trees"; the latter he described as trees that are "not useful to humans and bear no fruit that bird can eat." Waste trees were seen as trees that could be cut when managing the landscape, and included male plants of dioecious useful plants, such as nutmeg (*Myristica fragrans* Houtt.).

Finally, we observed farmers carefully tending spontaneous, self-seeded, or transplanted bush plants in their homegardens and farm plots to encourage their growth. As one farmer stated, "we do not destroy, because someday you might need it, most medicinal bush out of the yard" (farmer #5, Table 1). Another farmer said about a wild medicinal species: "when we see it, we clean it and we take care of it; we do not want it to die out" (father of farmer #16, Table 1).

Useful Plant Richness of Farm Plots and Homegardens

Mean ethnotaxa (ethnovariety) richness was significantly higher on farm plots (43.5 ± 17.2, N = 34) than homegardens (31.2 ± 13.8, N = 15) (two-sample t test, $t = 2.65$, $p = 0.012$). However, when calculated on a per-unit area basis (0.1 acres), median ethnovariety richness was higher on homegardens (8.4) than farm plots (2.3) (Mann–Whitney rank sum test, $t = 504$, $p = 0.005$). Farmer #4 (Table 1), who maintained a small but extremely diverse plant nursery in his homegarden (including several ornamental plants for sale), was excluded from this analysis as an outlier.

Mean species richness was also higher on farm plots than homegardens, even though the difference was less pronounced (33.9 versus 26.1 species; $t = 2.04$, $p = 0.05$). A comparison of the proportion of species in relation to varieties showed lower varietal richness on homegardens than on farm plots (85 versus 78%, $t = 2.08$; $p = 0.048$).

Table 3 represents the cumulative number of plant ethnotaxa (ethnovarieties) on farm plots and homegardens according to plant type (tree crops, wild plants, annual crops, perennial crops, and timber trees). Chi-square analysis shows that farm plots and homegardens differed according to the type of plants they contain (Chi-square: 77; 4 degrees of freedom; $p < 0.001$). Thus, homegardens contained proportionally more wild plants that are commonly used as medicines and bush teas ($z = 8.1$ with Yates correction; $p < 0.001$), whereas farm plots contained more timber trees ($z = 4.7$ with Yates correction; $p < 0.001$).

Discussion

The diversity of useful plants (349 ethnovarieties, 174 estimated species) recorded in our study compares to the number of species found in farms and homegardens in the nearby Lower Rio Grande Valley of Portland Parish that reported 235 different species (70% of which were used by local residents) (Thomas-Hope et al. 2003) and 245 total species (Reid 1999), respectively. For purposes of comparison, other locales in the Americas and the Caribbean reported the following number of species (using varied methodologies and sample sizes): Cuba (182 and 101 species in homegardens, 86 species in farm systems) (Buchmann 2009; Lores et al. 2008; Wezel and Bender 2003), Peru (168, 309, and 161 species in homegardens) (Lamont et al. 1999; Padoch and de Jong 1991; Perrault-Archambault and Coomes 2008), Brazil (80 total species and 86 species in homegardens) (Fraser et al. 2011; Kawa et al. 2011), Montserrat (85 species in homegardens) (Thomasson 1994), and Mexico (233 species and 316 species in homegardens) (Blanckeart et al. 2004; Poot-Pool et al. 2015). A review of the total number of species reported per geographical location in homegardens throughout Asia, the Americas (including the Caribbean), and "other regions"

Table 3. Comparison of cumulative number of ethnotaxa (ethnovarieties) in farm plots and homegardens (Chi-square: 77; 4 degrees of freedom; $p < 0.001$). *Z-test for comparison of proportions with Yates correction shows that farm plots contained significantly more timber trees than homegardens ($z = 4.7$; $p < 0.001$), whereas homegardens contained significantly more wild plants commonly used as bush medicines and regular teas ($z = 8.1$; $p < 0.001$).

Plant type	Farm plots	% of total	Homegardens	% of total
Tree crops	665	44	253	43
Wild plants	65	4	81	*14**
Annual crops	338	22	127	21
Perennial crops	276	18	101	17
Timber trees	182	*12**	29	5
Sum	1526	100	591	100

showed a wide variability in species richness according to region and location (range, 60–602 species, without distinction of their functionality as edibles, woody plants, or perennials). According to this review, homegarden diversity is comparable with that of adjacent forest formations, and classified as "intermediate" in diversity, as compared to "high diversity" of natural climax vegetation in the humid tropics, and "low diversity" of conventional agricultural systems (Kumar and Nair 2004).

Factors Associated with a Farmer's Useful Plant Richness

Authors in different countries found that useful plant richness was positively influenced by physical capital (access to land, diversity of habitats), social capital (household members of working age), or cultural capital (knowledge and experience with age) (Perrault-Archambault and Coomes 2008; Rana et al. 2007; but see also Coomes and Ban 2004 who found no correlation with plot size). We foresaw a positive association of a farmer's total land size (and thus land access) and useful plant richness because it is known that extensive areas in Caribbean small-scale farming systems are fallowed or unutilized at any given time and harbor many useful plants (Beckford and Campbell 2013). Farmers with greater landholdings had more total area under fallow management and were likely to maintain more useful plants as legacies of previous land use than other farmers. Furthermore, the landscape around Windsor Forest is highly heterogeneous. While not quantitatively measured in this study, a farmer controlling a greater land area is likely to have a higher degree of habitat diversity and therefore can grow more useful plant ethnotaxa. In our study area, larger farm plots were observed to simultaneously have several types of management systems, such as tree crop orchards, intensively cultivated annual crops, and perennial staple crops, all with the high degree of intercropping characteristic of Jamaican small-scale farming (Hills 1988; Innis 1983).

Although we expected a farmer's age (a covariate of farming experience) and household size, as forms of cultural capital, to correlate positively with useful plant richness, they were not significant variables in our assessment. Other research in Jamaica did not find that farmer age or household size was significant either (Thomas-Hope et al. 2000), nor that age was correlated to land holdings (Woodsong 1994). Furthermore, the effects of previous land use would likely diminish any effect of age. Farmers usually inherit, lease, or purchase land that has already been cultivated or managed at some point. Contemporary agrobiodiversity in this landscape has been influenced by generations of their predecessors' efforts at selecting for, introducing, and concentrating useful plant varieties that have naturalized or continue to exist as legacy trees. Farmers in Windsor Forest reported retaining existing useful trees and understory plants as they cleared land for cultivation. Perhaps mirroring a phenomenon observed throughout the tropics (see Clement and Junqueira 2010; Junqueira et al. 2010), farmers in Windsor Forest are likely beneficiaries of previous cultivation efforts. Our primary finding that useful plant richness only correlated significantly with land size (total acreage controlled or actively managed by farmers) suggests that previous land use resulting in "legacy plant diversity" may be a dominant factor influencing useful plant richness.

Farming experience (the number of years continuously farming) was not a significant correlate of useful plant richness in our study. This may be because many farmers come and go from farming as an occupation as they opportunistically respond to other work that becomes available to earn income. Often, only later in life do men become full-time farmers, as other opportunities for employment wane and the perceived stigma of farm work fades (Woodsong 1994). Alternatively, older farmers are likely to have less demands of financially supporting young children that would drive them to search for work opportunities.

Our qualitative data point to the important role of plant sharing within the community in promoting agrobiodiversity. Our study perceived a general lack of interest and participation in formal or official networks. However, as reported elsewhere, informal alliances and friendships appeared to represent an important mechanism contributing to local agrobiodiversity (see Aguilar-Stoen et al. 2008; Calvet-Mir et al. 2012; Coomes 2010; Pautasso et al. 2013).

Useful Plant Richness of Farm Plots and Homegardens

In Windsor Forest, useful plant richness was higher on farm plots than homegardens, a result that is contrary to other studies in Jamaica (Reid 1999; Thomas-Hope et al. 2000; but see also Thomas-Hope and Spence 2003 who showed that agroforestry plots and homegardens have a similar average species richness), Grenada (Brierley 1978, cited by Brierley 1991), and Latin America (Coomes and Ban 2004; Major et al. 2005). Mean reported homegarden richness in Windsor Forest (31 ethnovarieties, 26 species) was less than elsewhere in Jamaica (41 species; Beckford and Campbell 2013). Farm plots in our study were located farther away from homes than homegardens, in less intensively settled landscapes that displayed a significant degree of fragmented secondary forest cover, and were much larger. Their higher useful plant richness may be related to the presence of more timber trees and legacy species. Small-scale farms producing for domestic consumption have declined for years due to the effects of International Monetary Fund-mandated structural adjustment, the opening of domestic markets to highly subsidized-foreign produce, the degradation of marginal lands, and the stresses of a series of devastating hurricanes and droughts (Barker 2012; Weis 2006). As a result, there has been a precipitous decline in active farmland (SIOJ 2007). The higher richness that we reported on farm plots may reflect the legacy trees of homesteads and orchards from previous farming efforts, as well as an opportunity to grow timber trees that require less work on the part of the farmer (Fig. 2a; Thomas-Hope et al. 2000). However, because we compared overall ethnotaxa richness, our data also included the small patches of annual crops that continue to be grown within the matrix of perennial crops and tree species that now dominate the farming system.

Conversely, we found that useful plant richness on a per-unit area basis was far higher on homegardens than farm plots, the number of ethnotaxa per 0.1 acre approaching an order of magnitude more (Fig. 2b). This result is supported from elsewhere (Major et al. 2005). The observation that homegardens tend to be much smaller than farm plots and still contain a high degree of richness supports evidence for their role as important repositories of useful plants that people tend to manage for a broad variety of needs, including food, materials, and medicine (Kumar and Nair 2004). In Windsor Forest, homegardens contained significantly more wild plants known as traditional "bush" medicines. These plants are important to rural people throughout the Caribbean (Beckford and Campbell 2013; Mahabir and Guillford 1997; Quinlan and Quinlan 2007), as biomedical health services may be inaccessible, costly, or lacking in perceived quality (Vandebroek et al. 2011). On the other hand, farm plots held a higher proportion of timber tree ethnotaxa than homegardens, probably as a result of the relatively large spatial commitment and low degree of maintenance required by large trees. While trees were valued by local farmers for their role in provisioning ecosystem services such as shade and moisture retention, much of their value is economic and only realized when they are harvested for wood after many years of growth. "Bush medicines" in homegardens on the other hand fill a much more consistent role as a short-term source of nutrition (teas) and medicine.

Conclusions

Our results contribute to an understanding of the dynamic and complex nature of small-scale farmers' interactions with useful plant diversity in rural Jamaican hillside farm plots and homegardens. Farmers that controlled the most land promoted and maintained the most useful plant richness. Because of their greater size, farm plots contained higher useful plant richness than homegardens, which runs counter to conventional wisdom and the results of other research, and is an important consideration for policymakers and researchers working with agrobiodiversity conservation. However, because of their smaller size, homegardens held far more useful plant ethnotaxa per unit measurement. Finally, homegardens held a higher proportion of useful wild plants for medicine and regular teas, and farm plots had a higher proportion of timber trees. These differences likely represent a spatial optimization of the farmer's needs, with the frequent and time-sensitive use of wild "bush" plants necessitating their proximity to the home, and the infrequent and long-term nature of timber extraction facilitating these trees' location on more distant farm plots.

Agriculture in Jamaica is characterized by structural dualism, with the large farms of the fertile coastal plain receiving virtually all of the support from the government. Meanwhile, small-scale farmers largely fend for themselves (Barker 1993; Beckford et al. 2007). Even after the establishment of a free Jamaican peasantry in 1838, small-scale cultivators struggled for decades against the oppressive politics of an entrenched "plantocracy" (Knox 1977). It is a testament to small-scale farmers' creativity and skill that they have developed a highly sophisticated and distinctive tradition of farming that maintains high levels of useful plant richness and supplies a significant degree of domestic food consumption, despite receiving virtually no government support and being subject to droughts, hurricanes, and occupying some of the poorest lands (Barker 1993; Beckford and Bailey 2009). Today, Jamaica has begun to refocus on food security as a national priority. Food imports to the island have recently topped $1 billion USD and severely stress the economy of a nation with the world's eighth-highest debt to GDP ratio (123% of GDP). Researchers in Jamaica have defined expert farmers, in part, on the basis of the biodiversity of their farms (Thomas-Hope and Spence 2002). Officials aspiring to promote local food production will need to partner with expert local farmers who have knowledge of, and access to, useful plants for a wide range of needs.

We propose that future studies focus on the mechanisms of useful plant conservation in rural Jamaica. It is important to understand the intra-community transfer of useful plant varieties, and how this impacts local useful plant diversity (Coomes 2010; Pautasso et al. 2013). We showed evidence that farmers promote useful plant richness on an opportunistic and rational basis, and some farmers were identified through observation as contributing differentially to local useful plant diversity. A future study could use network analysis to evaluate the local exchange of plant material and the role of useful plant knowledge in promoting local agrobiodiversity (see Calvet-Mir et al. 2012; Pautasso et al. 2013). In addition, research could focus on household economics and useful plants, in particular the seasonality of income and risk associated with different functional groups of plants, and whether higher useful plant richness correlates with improved household economic and food security. This research could also assess the abundance of each useful plant ethnotaxon on farm plots and homegardens, as this is a critical factor in connecting plant diversity to livelihood strategies. This work would ideally include the study of ganja, as it is an important local "bush" medicine and was reported by farmers in Windsor Forest and in the literature (Barker 1993) to be an important source of income for communities. Also, the importance and dynamics of "legacy plants" from previous land use on useful plant diversity needs to be better understood, as well as the effects of natural disasters (droughts, hurricanes). Finally, future studies could also include a sample of female farmers large enough to compare to male farmers, in order to elucidate gender differences in agrobiodiversity maintenance and promotion.

The relevance of this research for the body of literature is that there currently exist few studies directly comparing on-site useful plant richness between homegardens and other types of land management units in small-scale farming systems throughout the tropics. More studies are needed because they can broaden the dialogue on the functionality and importance of homegardens. Moreover, since ethnovariety richness may be a more accurate representation of existing agrobiodiversity in tropical regions than species richness, and varieties play a central role in the life of small-scale farmers, it is hoped that other studies will compare ethnovariety versus species richness in different locales. In a highly variable climatic future, the endeavor of recording and preserving useful plant varieties will become all the more important.

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