INFLUENCE OF MARKET ORIENTATION ON FOOD PLANT DIVERSITY OF FARMS LOCATED ON AMAZONIAN DARK EARTH IN THE REGION OF MANAUS, AMAZONAS, BRAZIL[1]

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Major, Julie *(Department of Crop and Soil Sciences, Cornell University, Ithaca, NY 14853, USA; email: jm322@cornell.edu, phone: 607-255-1730, fax: 607-255-3207),* **Charles R. Clement** *(Coordenação de Pesquisas em Ciências Agronômicas, Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Brazil), and* **Antonio DiTommaso** *(Department of Crop and Soil Sciences, Cornell University, Ithaca, NY).* INFLUENCE OF MARKET ORIENTATION ON FOOD PLANT DIVERSITY OF FARMS LOCATED ON AMAZONIAN DARK EARTH IN THE REGION OF MANAUS, AMAZONAS, BRAZIL. *Economic Botany 59(1):77–86, 2005. Homegardens may serve as reservoirs of agro-biodiversity on highly fertile, anthropogenic Amazonian Dark Earth (ADE) soils of the Amazon basin. However, as these soils are used more intensively for market-oriented agriculture, we suspected a decrease in their agro-biodiversity. We present data obtained from surveys on 16 farms where ADE was present in the region of Manaus, Amazonas, Brazil. When farms were separated into two groups by market orientation, species richness on the farms was not significantly influenced by market orientation, but there was less dominance (i.e., more diversity) for homegardens in the low-market orientation group ($P < 0.1$). The proportion of native species was not affected by market orientation. Hence, while the most market-oriented farms retained high species richness, homegardens located on them contained higher proportions of commercially interesting species.*

Key Words: Agro-biodiversity; Amazonia; Amazonian Dark Earth; market orientation; *Terra Preta de Índio*; genetic erosion.

Although homegardens can take an infinite number of forms, they are usually characterized by high species diversity and complex multistrata architecture (Coomes and Ban 2004; Fernandes and Nair 1986) that constitute an important input to the diet of the household (Nair 1993), as well as spices, medicines, stimulants, etc. (Trinh et al. 2003). They also provide shade near living areas while reducing erosion in high-rainfall regions (Jose and Shanmugaratnam 1993). Homegardens can serve as key elements in the conservation of on-farm biodiversity (Eyzaguirre, Martin, and Barrow 2001; Trinh et al. 2003), for example by offering refugia for species whose importance is diminishing, and by serving as testing nurseries for new plant species or varieties (Eyzaguirre, Martin, and Barrow 2001).

Farms of traditional smallholder populations in Amazonia are usually composed of several swidden agriculture plots and a homegarden located close to dwellings. While cropping patterns in the swidden plots may vary from monocultures (e.g., manioc, *Manihot esculenta* Crantz) to multi-crop arrangements [e.g., manioc, maize (*Zea mays* L.), and dry beans (*Phaseolus* sp.) grown together, or manioc with a mixture of fruit trees], the diversity of these swidden plots is always less than that in the homegardens. Such cropping patterns are also found on farms located on areas of Amazonian Dark Earth (ADE, locally known as *Terra preta de Índio*). These are highly fertile soils formed at the location of indigenous settlements in pre-Columbian times (Smith 1980; Woods, McCann, and Meyer 2000). Their fertility is usually considerably greater than that of surrounding local soils; ADE soils exhibit higher pH, phosphorus, and organic matter contents, as well as higher cation exchange capacity (Kern and Kämpf 1989; Lehmann et al. 2003). The production of high-value crops (e.g., vegetables) is possible on ADE without the often prohibitive amounts of external inputs that would be necessary on sur-

[1] Received 13 September 2004; accepted 22 November 2004.

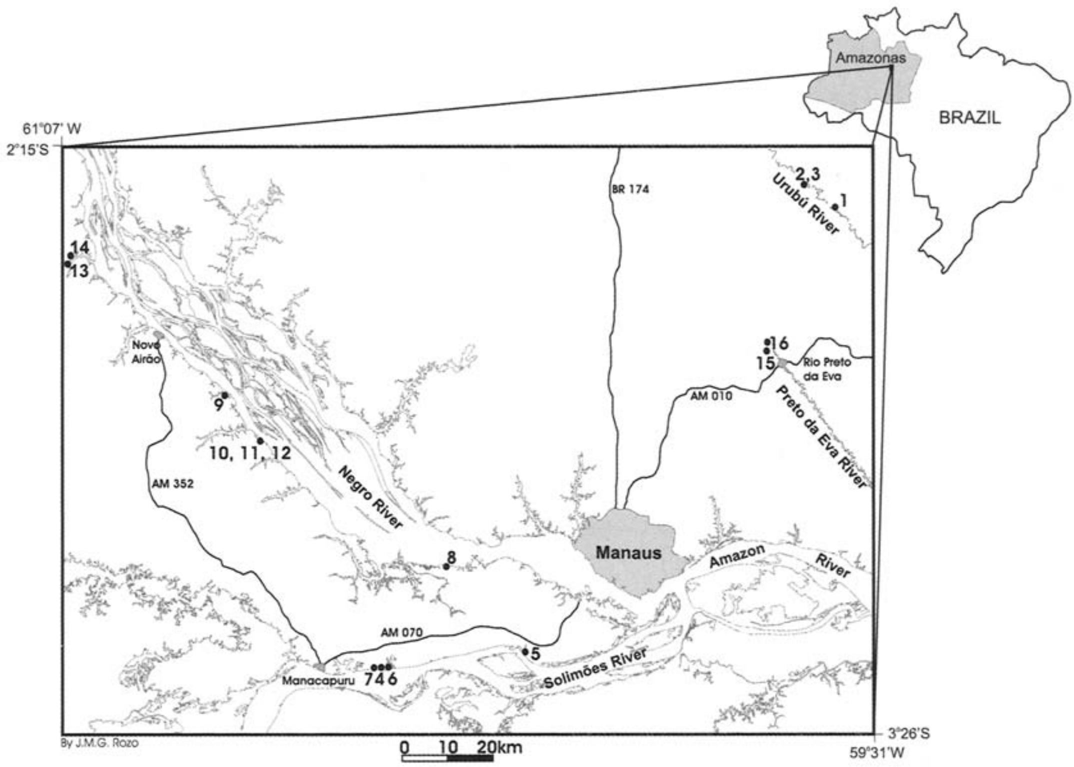

Fig. 1. Location of surveyed farms on Amazonian Dark Earth in the central Brazilian Amazon.

rounding Oxisols and Ultisols. Where access to market is good, ADE soils can be managed for permanent crop production (Hiraoka et al. 2003), including mechanized operations. In more remote areas, subsistence agriculture is practiced on these soils and a wide range of crops is produced, especially horticultural species.

Greater market orientation has been linked to greater soil nutrient deficits on small farms in Kenya (de Jager et al. 1998), to decreases in homegarden architectural complexity in Guatemala (Gillespie, Knudson, and Geilfus 1993), and to decreases in homegarden biodiversity in Indonesia (Soemarwoto 1987) and Mexico (Fey 1988). By offering the possibility to grow high-value crops more economically, ADE soils and the farms located on them may be at greater risk of losing agro-biodiversity as cropping activities become more market-oriented (Clement, McCann, and Smith 2003). We undertook this study to describe homegardens found on ADE and assess whether greater market orientation lead to losses of total and native food and condiment crop diversity on farms on which ADE soils occurred near the city of Manaus, the largest urban market in the central Brazilian Amazon.

Materials and Methods

Experimental Procedure

From January to June 2003, the primary author visited 16 households located on ADE in eight communities of the Manaus region (Fig. 1). Farms were chosen based on accessibility (i.e., farms were known and could be visited while carrying out other research activities involving surveys of agricultural weeds and controlled maize growth experiments, or during a three-day boat expedition) and the possibility to conduct the interview at the time the farm was visited. The market locations found near the sampled sites included Manaus, Manacapuru, Rio Preto da Eva, and Novo Airão (Fig. 1). On-farm diversity was assessed by surveying both the homegarden and all agricultural plots.

The area and number of crops grown on each farm plot were recorded, and the person who managed these and the marketing of produce was interviewed about the level of commercialization. Usually a man was interviewed, and in one case each a woman and a couple were interviewed. The homegarden of each farm was identified as an area adjacent to the dwelling, and defined in space by the owners when asked about their *quintal* (homegarden). It was analyzed in detail: food crop and condiment species were identified and numbers of individuals counted. Other agricultural plots were generally referred to as *roça* or *roçado* (forest clearing, plantation). Plants that served strictly medicinal or other purposes were omitted to avoid issues of access to traditional knowledge associated with Brazilian biodiversity laws, even though homegardens are rich in medicinal species.

Data Analysis

Market orientation has been defined in many ways that vary in rigidity and emphasis. Examples of definitions include the percentage of total output sold to outside markets (de Jager et al. 1998), and researcher perceptions of accessibility to markets via roads (Gillespie, Knudson, and Geilfus 1993). We calculated market orientation as the area planted to crops destined to be sold in outside markets [e.g., papaya (*Carica papaya* L.), bell peppers (*Capsicum annuum* L.), okra (*Abelmoschus esculentus* L. Moench)], divided by the total area of the farm under cultivation at the time of the visit, excluding land in fallow, which is similar to the definition of de Jager et al. (1998). In the cases where farmers reported selling manioc flour and surpluses of other subsistence crops (e.g., maize, beans), we included half the area of these plots in the calculation of the area planted to marketed crops. The proportion of subsistence produce sold from the agricultural plots varied with crops and among farms and harvests, and no specific data relating to marketed proportions were obtained. For this reason and based on observations, a value of one-half was used.

We did not consider distance or time to market because of high variability in the arrangements different farmers had. For example, some farmers knew transport agents that took their produce free of charge, others benefited from governmental programs for produce transport, while others traveled to different market locations according to the type of produce at hand or its quantity. The means of traveling to market also varied (e.g., river transport included paddling a canoe, small outboard motor-driven canoes, and larger boats with diesel motors).

Simpson's index of dominance (C) was calculated for the homegardens as:

$$C = \sum_{i=1}^{s} (p_i)^2$$

where p_i is the proportion of individuals represented by each species in the sample. Dominance relates to skewness in the representation of species in the sample, i.e., high dominance means a few species are represented by many individuals, while other species are represented by only a few individuals. This value was not computed for cropped plots due to the lack of individual counts.

Species richness (number of species observed) was calculated for the homegardens and for cropped plots. In the case of homegardens, species richness was also analyzed on a per 100 m^2 basis. For the majority of studied farms, the dwellings and the homegardens occurred on ADE, while agricultural plots often extended outside this area through regions of transitional soil (locally known as *Terra mulata*) and onto adjacent soils (non-ADE, *Terra comum, barro*). For whole-farm analyses, the total number of species found in the homegarden was added to the average number of species found on each cropped plot of the farms. We used plot averages because some farmers planted many small, monoculture plots of a number of species. Total species numbers for farmed plots would be high in this case, but the plots are not necessarily diverse. Immature and non-producing individuals were included in the analysis.

Linear regression analyses were performed using the GLM procedure in SAS (SAS Institute 2001). Data transformation for species richness was deemed unnecessary after evaluating diagnostic plots, and Simpson's index was logarithmically transformed to stabilize variance.

Results

A total of 79 food and condiment plant species were observed in the homegardens (Table 1), of which 35 are native to Amazonia and immediately adjacent regions. Three of the four most frequent species were exotics [mango (*Mangifera indica* L., frequency (f) = 15), coconut (*Cocos nucifera* L., f = 13), and citrus (*Citrus* spp., f = 13)]. The most frequent native

TABLE 1. FOOD CROP AND CONDIMENT SPECIES FOUND IN HOMEGARDENS AND AGRICULTURAL PLOTS ON AMAZONIAN DARK EARTH NEAR MANAUS, AMAZONAS, BRAZIL, WITH THEIR FREQUENCY OF OCCURRENCE (N = 16 FARMS). NATIVE SPECIES ARE AMAZONIAN OR NEOTROPICAL AND INTRODUCED TO AMAZONIA BEFORE 1500 A.D. (CLEMENT 1999).

Family	Local common name	English name	Native/ Exotic	Scientific name	Home-garden frequency	Agricultural plot frequency
Anacardiaceae	Caju	Cashew	N	*Anacardium occidentale* L.	11	2
Anacardiaceae	Manga	Mango	E	*Mangifera indica* L.	15	3
Anacardiaceae	Taperebá	Hog plum	N	*Spondias mombim* L.	5	—
Annonaceae	Condessa	Pond apple	N	*Annona glabra* L.	1	—
Annonaceae	Araticum	Mountain soursop	N	*Annona montana* Macf.	1	—
Annonaceae	Ata	Sugar apple	N	*Annona squamosa* L.	2	—
Annonaceae	Biribá		N	*Rollinia mucosa* Baill.	9	3
Anonaceae	Graviola	Soursop	N	*Annona muricata* L.	10	—
Apiaceae	Coentro (cheiro verde)	Cilantro	E	*Coriandrum sativum* L.	2	—
Apiaceae	Cominho	Cumin	E	*Cuminum cyminum* L.	1	—
Apiaceae	Cenoura	Carrot	E	*Daucus carota* L.	2	—
Apiaceae	Chicoria	Chicory	N	*Eryngium foetidum* L.	3	—
Araucariaceae	Pinhão	Parana pine	E	*Araucaria angustifolia* (Bertol.) Kuntze	1	—
Arecaceae	Tucumã		N	*Astrocaryum aculeatum* Meyer	9	5
Arecaceae	Babaçu		N	*Attalea speciosa* Mart.	1	—
Arecaceae	Pupunha	Peach palm	N	*Bactris gasipaes* Kunth	10	—
Arecaceae	Coco	Coconut	E	*Cocos nucifera* L.	13	2
Arecaceae	Dendê	African oil palm	E	*Elaeis guineensis* Jacq.	2	—
Arecaceae	Caiaué	American oil palm	N	*Elaeis oleifera* (Kunth) Cortes	2	1
Arecaceae	Açaí		N	*Euterpe oleracea* Mart.	7	1
Arecaceae	Buriti		N	*Mauritia flexuosa* L.	4	—
Arecaceae	Bacaba		N	*Oenocarpus bacaba* Mart.	3	—
Asteraceae	Alface	Lettuce	E	*Lactuca sativa* L.	—	1
Asteraceae	Jambu		N	*Acmella oleracea* (L.) R.K. Jansen	1	—
Bixaceae	Urucum	Annatto	N	*Bixa orellana* L.	5	—
Brassicaceae	Couve		E	*Brassica oleracaea* L.	3	3
Brassicaceae	Repolho	Cabbage	E	*Brassica oleracaea* L.	2	1
Brassicaceae	Rabanete	Radish	E	*Raphanus sativus* L.	1	—
Bromeliaceae	Abacaxi	Pineapple	N	*Ananas comosus* (L.) Merril	6	1
Caricaceae	Mamão	Papaya	N	*Carica papaya* L.	11	9
Clusiaceae	Bacuri		N	*Platonia insignis* Mart.	1	—
Convolvulaceae	Batata doce	Sweet potato	E	*Ipomoea batatas* (L.) Lam.	—	1
Cucurbitaceae	Melancia	Watermelon	E	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	—	1
Cucurbitaceae	Maxixe	West Indian gherkin	E	*Cucumis anguria* L.	3	2

TABLE 1. CONTINUED.

Family	Local common name	English name	Native/ Exotic	Scientific name	Home-garden frequency	Agricul-tural plot frequency
Cucurbitaceae	Pepino	Cucumber	E	*Cucumis sativus* L.	1	5
Cucurbitaceae	Abóbora	Squash	E	*Cucurbita moschata* Duchesne	6	7
Dioscoreaceae	Cará		N	*Dioscorea trifida* L. f.	2	1
Euphorbiaceae	Mandioca	Manioc	N	*Manihot esculenta* Crantz	1	7
Fabaceae	Ingá açu		N	*Inga cinnamomea* Benth.	1	—
Fabaceae	Ingá cipó	Ice-cream bean	N	*Ina edulis* Mart.	11	1
Fabaceae	Tamarindo	Tamarind	E	*Tamarindus indica* L.	1	—
Fabaceae	Amendoim	Peanut	E	*Arachis hypogaea* L.	—	1
Fabaceae	Soya	Soybean	E	*Glycine max* Merrill.	—	1
Fabaceae	Feijão	Dry beans	N	*Phaseolus vulgare* L.	—	5
Icacinaceae	Mari		N	*Poraqueiba paraensis* Ducke	5	—
Lauraceae	Abacate	Avocado	N	*Persea americana* Mill	15	2
Liliaceae	Cebolinha	Chives	E	*Allium schoenoprasum* L.	11	1
Malpighiaceae	Murici	Nancy	N	*Brysonima crassifolia* (L.) Rich	1	—
Malpighiaceae	Acerola	Barbados cherry	N	*Malpighia punicifolia* L.	6	2
Malvaceae	Quiabo	Okra	E	*Abelmoschus esculentus* (L.) Moench	1	2
Moraceae	Fruta pão	Breadfruit	E	*Artocarpus altilis* (Parkinson) Fosberg	1	—
Moraceae	Jaca	Jackfruit	E	*Artocarpus heterophyllus* Lam.	6	—
Moraceae	Figo	Fig	E	*Ficus carica* L.	1	—
Musaceae	Banana	Banana	E	*Musa* sp.	12	8
Myrtaceae	Castanha do Pará	Brazil nut	N	*Bertholletia excelsa* H&B	1	1
Myrtaceae	Araça-boi		N	*Eugenia stipitata* McVaugh	2	—
Myrtaceae	Araça-pera (goiaba araça)		N	*Psidium acutangulum* DC	3	—
Myrtaceae	Goiaba	Guava	N	*Psidium guajava* L.	11	3
Myrtaceae	Jambo	Malay apple	E	*Syzygium malaccense* (L.) Merr. & L.M. Perry	6	1
Myrtaceae	Azeitona	Jambolan	E	*Syzygium cumini* (L.) Skeels	1	—
Oxalidaceae	Carambola	Star fruit	E	*Averrhoa carambola* L.	2	—
Passifloraceae	Maracujá	Passion fruit	N	*Passiflora edulis* Sims.f.	4	2
Pedaliaceae	Jerjelim	Sesame	E	*Sesamum orientale* L.	—	1
Fabaceae	Guandu	Pigeon pea	E	*Cajanus cajan* (L.) Millsp.	1	—
Piperaceae	Pimenta do reino	Black pepper	E	*Piper nigrum* L.	4	—
Poaceae	Capim santo	Citronella	E	*Cymbopogon citratus* (DC) Stapf	6	—
Poaceae	Arroz	Rice	E	*Oryza sativa* L.	—	1
Poaceae	Cana de açucar	Sugar cane	E	*Saccharum officinarum* L.	6	2

TABLE 1. CONTINUED.

Family	Local common name	English name	Native/ Exotic	Scientific name	Home-garden frequency	Agricultural plot frequency
Poaceae	Milho	Maize	E	*Zea mays* L.	—	6
Portulacaceae	Carirú		N	*Talinum fruticosum* (L.) Juss.	3	—
Punicaceae	Roma	Pomegranate	E	*Punica granatatum* L.	1	—
Rosaceae	Abricot[1]	Apricot	E	*Prunus armeniaca* L.	1	—
Rosaceae	Pêssego[1]	Peach	E	*Prunus persica* (L.) Batsch.	1	—
Rosaceae	Cereja[1]	Cherry	E	*Prunus* spp.	1	—
Rosaceae	Pera[1]	Pear	E	*Pyrus communis* L.	1	—
Rubiaceae	Café	Coffee	E	*Coffea arabica* L.	5	1
Rubiaceae	Jenipapo	Genipap	N	*Genipa americana* L.	2	1
Rutaceae	Cítricos	Citrus	E	*Citrus* spp.	13	5
Sapindaceae	Rambutan	Rambutan	E	*Nephelium lappaceum* L.	1	—
Sapindaceae	Pitomba		N	*Talisia esculenta* (St.Hil.) Radlk	1	—
Sapotaceae	Abiu		N	*Pouteria caimito* (Ruiz et Pavon) Radlk	8	1
Solanaceae	Pimentão	Bell pepper	E	*Capiscum annuum* L.	—	1
Solanaceae	Pimenta de cheiro	Sweet pepper	E	*Capiscum* chinensis Jacq.	4	3
Solanaceae	Pimenta forte	Hot pepper	E	*Capiscum* chinensis Jacq.	7	—
Solanaceae	Tomate	Tomato	E	*Lycopersicon esculentum* Mill.	4	2
Solanaceae	Beringela	Eggplant	E	*Solanum melongena* L.	1	1
Sterliculiaceae	Cacao	Cocoa	N	*Theobroma cacao* L.	3	1
Sterliculiaceae	Capuaçu		N	*Theobroma grandifolium* (Willd. ex. Spreng.) Schum.	12	4

[1] Temperate species which are not expected to bear fruit in the Manaus region.

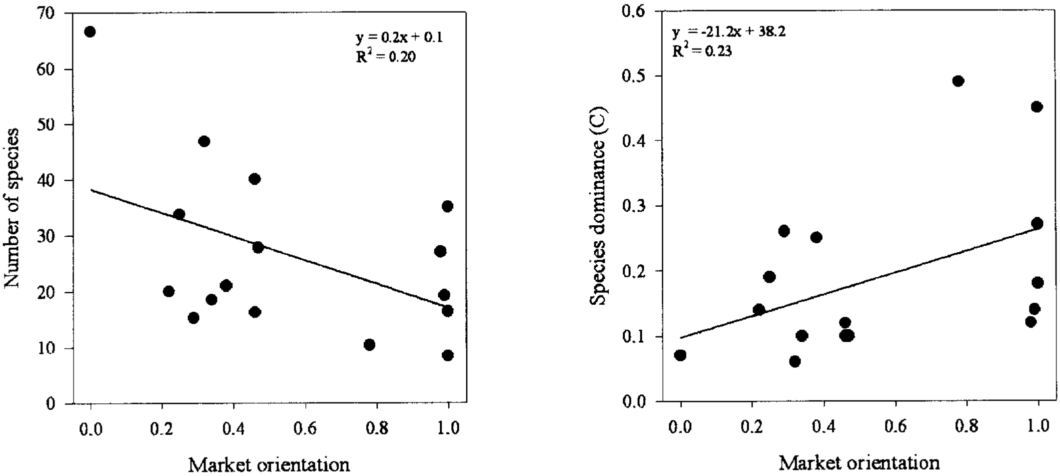

Fig. 2. Relationship between species richness for the whole farm and species dominance (Simpson's index C) in homegardens of 16 farms with different market orientation located on Amazonian Dark Earth in the region of Manaus, Amazonas, Brazil.

species were avocado (*Persea americana* Mill, f = 15), *cupuaçu* (*Theobroma grandiflorum* Schum., f = 12), guava (*Psidium guajava* L., f = 11), ice-cream bean (*Inga edulis* Mart., f = 11), and cashew (*Anacardium occidentale* L., f = 11). Avocado, guava, and cashew all arrived in Amazonia before European conquest (Clement 1999) and are thus treated as native species. On both whole-farm and homegarden bases, the proportion of native species was not significantly affected by market orientation, and was on average slightly above 50%.

Many species occurred at low frequencies, illustrating the variability in homegardens sampled. One homegarden contained numerous Eurasian exotics that the non-Amazonian owners hoped to adapt to Amazonia [e.g., peach (*Prunus persica* L. Batsch.), pear (*Pyrus communis* L. Sand)]. Another remarkably different farm is characterized by no market orientation, high species richness, and low dominance (high evenness in species representation) (Fig. 2). This household was composed of ideologically distinct individuals who strived to attain total self-sufficiency, and is hereafter referred to as the "self-sufficient" farm.

Forty-six species were observed on agricultural plots (including non-ADE). Of the total number of species observed (79), 48% appeared in homegardens but never in agricultural plots, while 11% appeared in agricultural plots but never in homegardens. The fact that more species appeared only in the homegardens supports the assertion that the latter are more diverse than agricultural plots, which was also observed in Amazonian homegardens of Peru (Coomes and Ban 2004). Species that appeared only in agricultural plots include staple foods [e.g., rice (*Oryza sativa* L.), maize, dry bean], as well as horticultural crops that are produced for market {e.g., bell pepper, lettuce [*Lactuca sativa* L.], and watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]}. The most frequently recorded species in agricultural plots were papaya (f = 9), banana (*Musa* sp., f = 8), maize (f = 0.6), manioc (f = 7), and squash (*Cucurbita pepo* L., f = 7). While banana and squash are often intercropped or planted on the edges of fields, papaya frequently appears voluntarily in plots and is tended.

With data from the "self-sufficient" farm included and farms not separated into groups, market orientation did not have a significant effect on species richness (for the homegarden alone, as a whole or on a 100 m^2 basis, or for the whole farm) or dominance. The other 15 farms can be separated into two groups according to market orientation (Table 2). With data from the "self-sufficient" farm removed, the "low" market orientation group (mean market orientation < 0.6) had a slightly higher mean species richness for the whole farm as well as for the homegarden only, although differences were not significant (Table 3). This group also had lower dominance,

TABLE 2. CHARACTERISTICS OF STUDY SITES IN CENTRAL BRAZILIAN AMAZONIA.

Farm[1]	Whole farm		Homegarden			Agricultural plots		Market orientation fraction[5]	Market orientation group
	Area[2] (ha)	# sp.[3]	Area (ha)	# sp.	C[4]	Area (ha)	Average # sp.		
1	0.84	39	0.04	32	2.14	0.80	1.8	0.25	Low
2	0.64	29	0.04	25	2.56	0.60	2.8	0.47	Low
3	0.40	46	0.09	43	2.48	0.31	3.8	0.32	Low
4	7.01	17	0.01	15	1.30	7.00	1.3	1.00	High
5	6.01	15	0.01	7	0.77	6.00	1.3	1.00	High
6	6.54	31	0.04	13	2.31	6.50	27.0	0.46	Low
7	3.86	17	0.04	9	1.12	3.82	1.3	0.78	High
8	5.04	23	0.04	18	2.08	5.00	1.2	0.99	High
9	1.04	23	0.09	20	1.86	0.95	1.0	0.38	Low
10	0.63	24	0.04	13	1.93	0.59	2.3	0.29	Low
11	0.74	19	0.04	17	2.45	0.70	1.5	0.34	Low
12	0.09	20	0.04	18	2.41	0.05	2.0	0.22	Low
13	1.80	23	0.13	14	2.46	1.67	2.3	0.46	Low
14	0.25	50	0.25	44	3.73	0.00	22.5	0.00	Low
15	56.04	36	0.04	34	2.39	56.00	1.0	1.00	High
16	5.60	27	0.10	26	2.41	5.50	1.0	0.98	High

[1] See Figure 1.
[2] Area under cultivation.
[3] Number of species.
[4] Simpson's index of dominance.
[5] Area farmed for market/total area farmed.

in the homegarden, compared with the "high" market orientation group ($P < 0.1$).

DISCUSSION

The homegarden food and condiment plant diversity obtained here (79 species) is greater than for a survey of 20 rural and 21 urban homegardens in the region of Santarém, Pará, Brazil (WinklerPrins 2002), and a study of 24 homegardens in a peasant village near Iquitos, Amazonian Peru (Coomes and Ban 2004), where 47 and 42 such species were identified, respectively. While the Peru study does not mention the presence of ADE, some gardens in the Pará study did contain such soils, although data are not presented or analyzed according to soil type, and no indication is given as to the frequency and extent of ADE in the sampled gardens. The high frequency of exotics in Amazonian homegardens has been observed in areas close to our ADE homegardens, for example in Rio Preto da Eva and Bela Vista (in Manacapuru) (Noda 2000) and further away on the upper Amazon River (Clement et al. 2001). In Rio Preto da Eva, avocado, *Citrus* spp., mango, and banana (*Musa* spp.) were most frequent; in Bela Vista, avocado, *Citrus* spp., mango, and coffee (*Coffea* spp.) were most frequent; along the upper Amazon,

TABLE 3. MEANS (± SE) FOR MARKET-ORIENTED AREA AS A PROPORTION OF TOTAL AGRICULTURAL AREA, SPECIES RICHNESS, AND SIMPSON'S DOMINANCE INDEX FOR TWO MARKET ORIENTATION GROUPS OUT OF 16 FARMS LOCATED ON AMAZONIA DARK EARTH SOILS IN THE REGION OF MANAUS, AMAZONAS, BRAZIL. DIFFERENT LETTERS REPRESENT SIGNIFICANTLY DIFFERENT VALUES ($P < 0.1$).

Market orientation	Market area/total*	Species richness	Dominance (C)
LOW (n = 10) "self-sufficient" farm included	0.32 ± 0.14	31 ± 17	0.14 ± 0.07
LOW (n = 9) "self-sufficient" farm excluded	0.35 ± 0.09	26 ± 12	0.15 ± 0.07[a]
HIGH (n = 6)	0.96 ± 0.09	20 ± 11	0.28 ± 0.16[b]

* Area farmed for market/total area farmed.

banana, jambo (*Syzygium malaccensis* L.), *Citrus* spp., and coconut were most frequent. Clement, McCann, and Smith (2003) observed that exotic species perform better on ADE than adjacent Oxisols and Ultisols because of better growing conditions. Our observations confirm this.

Others have reported declines in on-farm biodiversity as opportunities for commercialization increased (Fey 1988; Soemarwoto 1987). Our findings are in agreement with those of Trinh et al. (2003), who reported that despite anecdotal evidence from research sites in Vietnam that increased commercialization of homegarden products lead to decreases in agro-biodiversity, actual data did not support this hypothesis. However, Trinh et al. did observe a reduction in the number of species with increased market orientation, when species richness was compared on a per 100 m^2 basis. This was not the case here.

Although Trinh et al. (2003) did not report dominance measures in their study, they did allude to the increasing number of monocultures of commercially valuable species within the homegarden for households with a strong market orientation, a trend which results in increased plant dominance. An important difference between our assessment in this study and that of Trinh et al. (2003) is that the latter based their evaluation of market orientation only on the commercialization of products from the homegarden, and not from cropped fields, whereas we evaluated commercialization on a whole-farm basis.

The two farms in the "high" market orientation group with the highest species richness (Fig. 2) are both located in Rio Preto da Eva (Fig. 1, farms 15 and 16), a community with easy and rapid access to the metropolitan area of Manaus. The owner of one of these farms is originally from subtropical southern Brazil, and 21% of the species found in his homegarden are exotic to the Amazon and highly unlikely to bear fruit [e.g., grapes (*Vitis vinifera* L.), apricots (*Prunus armeniaca* L.), and cherries (*Prunus* spp.)]. The high market orientation farm with the second highest species number is characterized by an aging homegarden composed primarily of mature fruit trees. Little investment is made in planting new trees, except for a small monoculture of high market value soursop (*Annona muricata* L.). The garden was diverse when the present owner bought the property, and he was about to put the farm up for sale at the time of the interview. It is likely that a frequent change in ownership, combined with almost complete market orientation, will lead to the erosion of species richness at this location.

Conclusions

Hiraoka et al. (2003) suggested that species diversity in homegardens on ADE varies more according to the tastes of its owners and the availability of propagation material than with location, although favorable location is important for market orientation. We hypothesized that increased market orientation would decrease subsistence reliance on the homegarden for fruits and vegetables. Decreases in agro-biodiversity on ADE soils would be especially troublesome because a number of species are associated with them through their indigenous origin and are not valued in modern markets [e.g., *caiaué, Elaeis oleifera* (Kunth) Cortes] (Clement, McCann, and Smith 2003). While the diversity of other crops often remained high, our data indeed show that dominance in the homegarden is increased with increased market orientation, mostly because of the production of commercially interesting species.

Our study shows that commercialized home gardens can maintain species diversity, but they also tend to show increased dominance of highly marketable species. Our data set should be viewed as a snapshot of the dynamic interaction between traditional farmers and modern economies, and can serve as a baseline for future work.

Acknowledgments

We would like to thank the farmers who participated in this study, J. Max González Rozo for designing maps, and Dr. David R. Lee at Cornell University for guidance with writing this paper. Funding was provided by the Saltonstall Fellowship of the Department of Crop and Soil Sciences at Cornell University, the Fonds Québécois de Recherche sur la Nature et les Technologies, and travel grants from the Cornell International Institute for Food, Agriculture and Development and the Einaudi Center for International Studies, at Cornell University. Dr. Antoinette M.G.A. WinklerPrins of the Department of Geography, Michigan State University, and three anonymous reviewers provided valuable comments on earlier versions of the manuscript.

Literature Cited

Clement, C. R. 1999. 1492 and the loss of Amazonian crop genetic resources. Part 1. The relation between domestication and human population decline. Economic Botany 53:188–202.

———, **J. M. McCann, and N. J. H. Smith.** 2003. Agrobiodiversity in Amazonia and its relationship with Dark Earths. Pages 159–178 in J. Lehmann, D. C. Kern, B. Glaser, and W. I. Woods, eds., Amazonian Dark Earths: Origin, properties, management. Kluwer Academic Publishers, Dordrecht, The Netherlands.

———, **H. Noda, S. N. Noda, A. L. U. Martins, and G. C. Silva.** 2001. Recursos frutícolas na várzea e na terra firme em 11 comunidades rurais do Alto Solimões, Amazonas, Brasil. Acta Amazonica 31: 521–527.

Coomes, O. T., and Ban, N. 2004. Cultivated plant species diversity in home gardens of an Amazonian peasant village in northeastern Peru. Economic Botany 58:420–434.

de Jager, A., I. Kariuku, F. M. Matiri, M. Odendo, and J. M. Wanyama. 1998. Monitoring nutrient flows and economic performance in African farming systems (NUTMON). IV. Linking nutrient balances and economic performance in three districts in Kenya. Agriculture Ecosystems and Environment 71:81–92.

Eyzaguirre, P. B., P. Martin, and S. Barrow. 2001. Growing diversity, conserving plant genetic resources. UNESCO, Paris, WWF, Gland, Switzerland, and IPGRI, Rome.

Fernandes, E. C. M., and P. K. R. Nair. 1986. An evaluation of the structure and function of some tropical homegardens. Agricultural Systems 21: 179–210.

Fey, R. L. 1988. Diversity index usage in the geographic study of home gardens in Quitana Roo, Mexico. Ph.D. dissertation, University of Colorado, Boulder, CO.

Gillespie, A. R., D. M. Knudson, and F. Geilfus. 1993. The structure of four home gardens in the Peten, Guatemala. Agroforestry Systems 24:157–170.

Hiraoka, M., S. Yamamoto, E. Matsumoto, S. Nakamura, I. C. Falesi, and A. R. C. Baena. 2003. Contemporary use and management of Amazonian Dark Earths. Pages 387–406 in J. Lehmann, D. C. Kern, B. Glaser, and W. I. Woods, eds., Amazonian Dark Earths: Origin, properties, management. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Jose, D., and N. Shanmugaratnam. 1993. Traditional homegardens of Kerala: A sustainable human ecosystem. Agroforestry Systems 24:203–213.

Kern, D. C., and N. Kampf. 1989. Antigos assentamentos indígenas na formação de solos com terra preta arqueológica na região de Oriximiná, Pará. Revista Brasileira de Ciência do Solo 13:219–225.

Lehmann, J., J. J. Pereira da Silva, C. Steiner, T. Nehls, W. Zech, and B. Glaser. 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: Fertilizer, manure and charcoal amendments. Plant and Soil 249:343–357.

Nair, P. K. R. 1993. An introduction to agroforestry. Kluwer, Dordrecht, The Netherlands.

Noda, H. 2000. Pequena produção de terra firme no Estado do Amazonas, pp. 80, Série Documentos, 5. Instituto Nacional de Pesquisas da Amazônia, Manaus, AM.

SAS Insitute. 2001. SAS version 8e for Windows, Cary, NC.

Smith, N. J. H. 1980. Anthrosols and human carrying capacity in Amazonia. Annals of the Association of American Geographers 70:553–566.

Soemarwoto, O. 1987. Home gardens: A traditional agroforestry system with a promising future. Pages 157–170 in H. A. Steppler, and P. K. R. Nair, eds., Agroforestry: A decade of development. ICRAF, Nairobi, Kenya.

Trinh, L. N., J. W. Watson, N. N. Hue, N. N. De, N. V. Minh, P. Chu, B. R. Sthapit, and P. B. Eyzaguirre. 2003. Agrobiodiversity conservation and development in Vietnamese home gardens. Agriculture, Ecosystems and Environment 97:317–344.

WinklerPrins, A. M. G. A. 2002. House-lot gardens in Santarém, Pará, Brazil: Linking rural with urban. Urban Ecosystems 6: 43–65.

Woods, W. I., J. M. McCann, and D. W. Meyer. 2000. Amazonian Dark Earth analysis: State of knowledge and directions for future research. Papers and Proceedings of the Applied Geography Conferences 23:114–121.