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4 Home gardens as an alternative for sustainability: Challenges and perspectives in Latin America

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Abstract

Home gardens are productive systems associated with the home that contribute to the upkeep of important ecological functions and to the social and economic welfare of thousands of families. This chapter describes Latin American home gardens in terms of their ecological, economic and social sustainability;

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we also briefly review their history. We review and discuss the tendencies in the methodology used to study them, and we analyze their viability and limitations. The information available indicates that, without a doubt, these home gardens maintain the biological diversity of native and exotic as well as managed or wild species, and play an important role in improving the quality of life and the economic and social welfare of peasant and city dwelling families. A correlation analysis showed that the richness patterns of plant species are not associated to physical variables, suggesting, therefore, that these patterns are mainly due to idiosyncratic variables. The highest percentage of home garden species are used as foodstuffs, followed by medicinal and ornamental uses, among others. Therefore, although they are not a panacea, home gardens not only can help lessen the impact of poverty and malnutrition, they also contribute to spiritual wellbeing. Knowledge about the management of individual species and of the system as a whole, the family involvement and land and time availability, among other factors, are necessary for the system to last. Home gardens have been widely promoted in several Latin American countries, and there are proposals to establish them in other countries. Multidisciplinary studies are necessary to evaluate their sustainability, including an analysis of their ecological, social and economic dimensions.

1. Introduction

Sustainability is highly debated concept, which has generated various definitions and forms in which it is evaluated [1-3], and it has been defined within three dimensions: ecological, social and economical [4]. An ecologically sustainable system maintains production and consumption levels inside the limits that natural resource recuperation permits without deteriorating the environment [3]. From a social point of view, sustainability strives to meet basic human needs such as food, water, and shelter, as well as family integration, work, and recreation [5]. The economical focus looks to maintain equilibrium between economical and biophysical ecosystem limits [4]. To succeed reaching sustainability in every dimension depends on the relationship that exists between each dimension; however, each includes different aspects, which has made integration difficult. Until very recently, this has become important for scientists who have discussed the necessity to connect these topics. The proposals for sustainable actions by Kates et al. [1] emphasize the importance of recognizing the interaction between nature and society, also recognizing that these are complex systems that respond to factors that interact and provoke general, irreversible changes. In contrast to other agricultural systems (i.e. monocrops), home gardens (HG) are production models that combine, almost ideally, natural ecological functions with socioeconomic wellbeing of the families that maintain them. Some authors have considered these as sustainable systems [6-10].

The home garden is a space associated with the house in which trees, shrubs and herbs grow, mixed with annual crops and frequently with domesticated animals [10-15]. The space is divided into various management areas that vary in size, distribution and species composition and they are defined according to the owner's interests [7,16].

In this chapter, we succinctly look at the historical changes in Latin American gardens, and then analyze the sustainability of system from an ecological, social and economical perspective. We also discuss the methods used for their study and finally discuss the relevance of this system for development and natural resource use.

2. History of home gardens in Latin America

Some authors suggest that these gardens originated in America after the European Conquest with introduced species [17]. On the contrary, other authors have proposed that these systems have a pre-hispanic origin [18,19]. For example, Miller et al. [19] mentions that when the Spanish arrived, the Amazonian indigenous people lived in villas with great quantities of trees and animals around their houses and paths, which formed part of their productive system. The historical origin of these home gardens in America is a topic, which continues to be debatable.

The Spanish Conquest of America radically transformed social relationships with nature, especially distribution systems and production methods. In addition, the course of species domestication changed due to massive indigenous decimation, enslavement, and the fact that they were obligated to produce that which the conquerors imposed although later the gardens were enriched with the new introduced species [19,20]. In spite of the negative impact of the conquest, a rich exchange of useful species was allowed between the two continents. As consequence, tropical home gardens in the world actually share a group of species such as: *Mangifera indica, Coffea arabica, Cocus nucifera, Citrus* spp., *Musa* spp., *Saccharum officinarum, Dioscorea* spp., *Cajanus cajan* among others [21]. Examples of native species from America that are currently distributed in tropical home gardens are *Carica papaya, Gliricidia sepium, Leucaena leucocephala, Psidium guajava,* and also the diverse variety of the genus *Mimosa* and *Acacia* [13].

Historical changes can be observed in the systematic index of species found in current gardens. Introduced animals and vegetable species are evidence of this dynamic [17,19]. Animals such as pigs, hens, swans, and cattle, and plants such as mangos, banana, melon, lemon, orange, sugar cane and coffee [22] are still proof of these changes. Some of these species have influenced the world's and continent's economy, such as sugar cane, cattle, banana and coffee.

Other evidence of historical change is the size of the gardens, which involves the diminishing of area and reorganization. This phenomenon can be associated with urban life and the perception of development and modernity, which play an important role in the evolution of this system. Currently, these agro-systems are comprised of native and exotic species [19,23]. Their structure is the product of reorganization and retaking of pre and post-hispanic practices, and of market economy and transoceanic plant and animal trade [19,22,24].

3. Ecological sustainability of Latin American home gardens

According to Torquebiau and Penot [6] and Torquebiau [10], an agro-forest system is ecologically sustainable if it allows: biodiversity conservation and resources like water and soil (maintaining high organic material content, high levels of biotic activities, lessening temperature and humidity changes), maintenance of a closed nutrient cycle, efficient light use, appropriate waste management and reduced consumption of external resources. The following is a compilation and analysis of ecological information available from 29 Latin American communities, factors that effect species richness and 15 ethnobotanical studies to understand resource-use tendencies in Latin American gardens.

Structure, richness, and diversity characterization of the Latin American home garden

In Latin America, it is known that garden area can vary considerably from 0.05 ha [25] to 2.5 ha [26], although the average is generally between 0.1 and 0.25 ha (Table 1). This wide variation also exists for the quantity of species found in these gardens, which varies from 27 species in Costa Rica [27] to 405 species in Mexico (E.M. Pagaza, *unpublished data*) (Table 1). This demonstrates the complexity and the unpredictability of this system, as physical factors (i.e. altitude latitude, precipitation) that generally explain species richness patterns of natural ecosystems [28] are not determinant of species structure and diversity (Figure 1, Table 1). These properties are related with micro-environmental conditions created by man and are associated with other social (land ownership and control), cultural and economical (commercial crops) factors, which interact to determine garden structure and composition [9,11,14,16,29-32], suggesting that this variation is basically idiosyncratic, although marginally dependent of environment.

Table 1. Comparison of 29 studies showing the regional variation of the home garden in Latin America. For each study (labed by the first author) the location and ecological characteristics such as the number of gardens and plant stratum studied is shown. Each garden in each region is described in terms of its size and plant diversity that they contain. To characterize this diversity, total number of species data was used, and average species per garden and their range of variation was reported for each locality. Finally, the percentage of native species found in each region for each author is shown. The studies used in the correlation analysis shown in Figure 1 were marked with an asterisk (*); one of this studies is Pagaza *unpublished data*; n.a= not available; Ethnic group “mixed” means indigenous and mestizos.

References	Country (Vegetation type)	Ethnic group	Altitude (m)	Annual Rainfall (mm)	HG studied (#)/ Stratum studied	Area Interval (m^2)/ Mean area (m^2)	Average species (range)	Total plant species reported (#) (% native species)
33*	Brazil (Tropical dry forest)	n.a	n.a	599	31/ Woody perennials	100-3000/ 496	n.a	54 (50)
50*	Mexico (Tropical rain forest)	*Mestizo* (inmigrant)	0-400	4500	8/All	225-3400/ 1794	n.a	338 (15 -only woody perennials)
41	Guatemala (Subtropical Thorn forest)	Mixed	n.a	700	47/ All	90-2500/ n.a	33 (16-42)	276 (48)
41	Guatemala (Humid subtropical cold forest)	Indigenous	≤ 1200	2000-6000	31/ All	3200-5600/ 1900	56 (26-94)	252 (55)
41	Guatemala (Humid subtropical hot forest)	Mixed	≥ 20	2000-6000	46/All	400-2000/ 1000	50 (23-81)	280 (55)
57	Mexico (Tropical dry forest)	Indigenous	< 100 m	n.a	n.a/ Woody perennials	n.a/ n.a	n.a	92 (61)
26	Mexico (Tropical rain forest)	Indigenous	420-540	3000-4000	6/All	100-25,000/ 5393	65.57	295 (n.a)
34*	Mexico (Thorn scrub forest)	n.a	1217	394.6	30/All	n.a/ n.a	n.a	233 (n.a)
15*	Mexico (Deciduous & Subdeciduous Forest)	Indigenous	n.a	n.a	60/ Woody perennials	600 – 5000/ n.a	n.a	83 (32)
48	Mexico (Secondary forest)	Indigenous	n.a	n.a	80/All	n.a/ n.a	39	150 (n.a)
35*	Peru (Secondary forest)	*Mestizo*	110	2000-3000	24/All	195-10000/ 2944	16.3 (1 - 32)	82 (n.a)
87*	Mexico (Subtropical evergreen forest)	Indigenous	300	2110	40/All	n.a/ n.a	n.a	223 (n.a)
88*	Mexico (Tropical dry forest)	*Mestizo*	8	940	25/Trees	200 - 1000/ n.a	n.a	79 (45.57)
17*	Mexico (Tropical rain forest)	Indigenous	22	1232	9/All	2500 – 6400/ 3800	n.d.	339 (n.a)
2*	Honduras (Bosque húmedo premontano subtropical	*Mestizo*	900	1600	10/All	n.a/ n.a	60 (26 - 131)	253 (68.77)
4*	Belize (Tropical rain forest)	Indigenous	n.a	3100	18/All	n.a/ 0.65	30	164 (n.a)
46	Brazil (Tropical rain forest)	n.a	n.a	n.a	16/All (foods)	100-2500/ 650	21.75 (7 - 44)	79 (44.3)
25	Brazil (Tropical rain forest)	*Mestizo*	n.a	2893	n.a/All	< 50 – 5000/ 50 - 500	n.d.	n.a (n.a)
88	Honduras (n.a)	n.a	1340	910	10/All (foods)	n.a/ n.a	n.d.	206 (n.a)
88	Honduras (n.a)	n.a	700	620	10/All (foods)	n.a/ n.a	n.d.	172 (n.a)
7*	Nicaragua (Bosque húmedo premontano)	Indigenous	450	1500	20/All	200- 14000/ 3240	70 (22-106)	324 (n.a)
43*	Mexico (Tropical deciduous forest)	*Mestizo*	< 5 m	1141	n.a/All	800 - 4000/ n.a	n.d.	296 (n.a)
32	Peru (Tropical forest)	Mixed	n.a	n.a	21/All	67- 7322/ 300-700	18 - 74	168 (n.a)
32*	Mexico (Mountaine Cloud Forest)	Mixed	1343	2250	20/All	252-5000/ 1126	47.05	282 (53.55)

Table 1. Continued

32*	Mexico (Mountaine Cloud Forest)	Indigenous	1084	2250	20/All	271-23556/ 1738	39.35	238 (56.72)
32*	Mexico (Mountaine Cloud Forest)	Mixed community	926	2250	13/All	560-23576/ 5717	47.23	226 (56.64)
32*	Mexico (Mountaine Cloud Forest)	Mixed	n.a	2250	53/All	252-25376/ 2316	44.18	405 (51.85)
38*	México (Low tropical dry forest)	Indigenous	9-10	800-900	20/Trees & Shrubs	400 – 5000/2263	n.d.	135 (n.a)
38*	México (Tropical deciduous forest)	Indigenous	20	900-1000	22/ Trees & Shrubs	800 – 3200/ 1825	n.d.	133 (n.a)
98	México (Oak forest)	*Mestizo*	920-1100	700-800	10/All	380-4850/ n.a	n.d.	201 (48.3)
98	México (Pine-oak forest)	*Mestizo*	1000-1050	700-800	10/All	380-4850/ n.a	n.d.	181 (45)
99*	Peru (Tropical forest)	Indigenous	270 - 1700	6000	31/All (Food & comercial crops)	n.a/ n.a	n.d.	70 (n.a)
67	Mexico (Secondary forest)	Indigenous	n.a	970	22/ All (foods)	n.a/ n.a	n.d.	n.a (n.a)
36*	Mexico (Mountaine Cloud Forest)	Mixed	n.a	2500 - 3000	30/All	n.a/ 2025-2500	(25-82)	241 (20.75)
42*	Peru (Tropical lowland rain forest)	Indigenous	368	2000-2500	8/All (except ornamental & timber)	n.a/ n.a	n.d.	58 (n.a)
42*	Peru (Tropical lowland rain forest)	Indigenous	419	2000-2500	11 /All (except ornamental & timber)	n.a/ n.a	n.d.	49 (n.a)
21*	Cuba (Submontane evergreen forest)	*Mestizo*	n.a	2200	12/All	n.a/ 875	18 (7-29)	963 (n.a)
21*	Cuba (Submontane evergreen forest)	*Mestizo*	n.a	2200	8/All	n.a/ 875	22 (15-33)	51 (n.a)
21*	Cuba (Xeromorphic savannas)	*Mestizo*	n.a	400-500	11/All	n.a/ 875	24 (12-49)	81 (n.a)
63*	Brazil (Tropical rain forest)	n.a	n.a	850	21/All	350-10000/ 350 - 600 (urban HG) 500-1700 (rural HG)	n.d.	98 -only in urban HG- (n.a)
27*	Costa Rica (Lowland wet forest & Lower montane forest)	Indigenous	300	4000	83/ All (foods)	n.a/ n.a	4.5 - 8.6	46 (n.a)
27*	Costa Rica (Lowland forest & Lower montane forest)	Indigenous (inmigrant)	700-1700	3900	55/All (foods)	n.a/ n.a	3.8 - 6.8	27 (n.a)

Species richness and garden area variable do not appear to be related in the cases reviewed [33-38]. However, in Costa Rica, Lok [16] found that in small garden species diversity per area was not only greater in comparison to the large gardens, but also species density per hectare for small gardens was four times that of the larger ones. On the contrary, Padoch and Jong [32], and Fundora-Mayor et al. [39] found greater species richness and diversity in the larger gardens.

In gardens in arid zones, high species richness has been found, and it has been suggested that this is due to the rough, extreme environmental conditions, which has made the subsistence role of the gardens more relevant (Price [40] cited by Montagnini [13]). This is supported by the work of Wezel and Bender [21] for gardens in Cuba, Albuquerque et al. [33] in Brazilian Caatinga, Blanckaert et al.

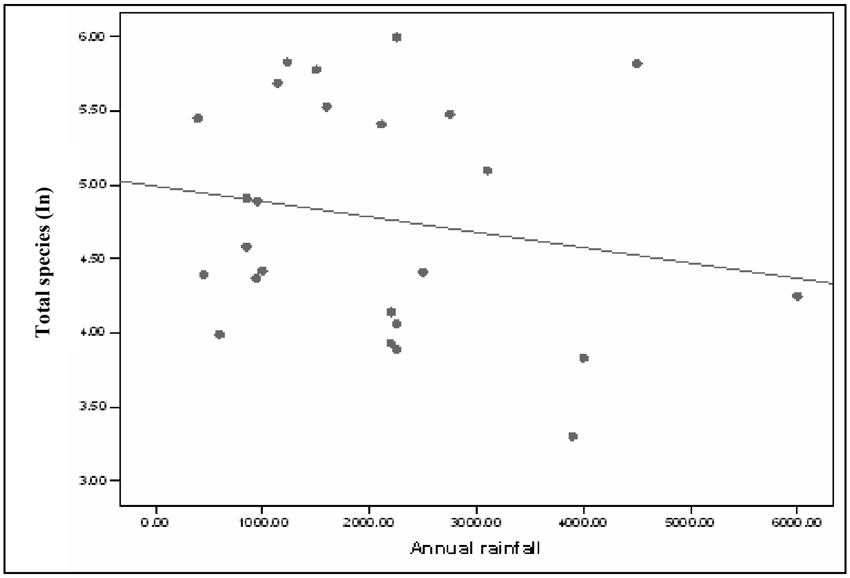

Figure 1. Correlation analysis between median annual precipitation and the natural logarhythm of the total plant species found in home gardens in Latin America. There was not a significant relationship (Pearson correlation coefficient = - 0.186, p = 0.58). The studies included to carry out this analysis are those marked with an asterisk (*) in Table 1.

[34] for a semi-arid zone in Mexico and Leiva et al. [37] for the arid region of Guatemala. However, in Guatemalan gardens, Azudia and Leiva [41] report that species number and structural complexity is greater in humid areas than arid.

With respect to alpha diversity, the work of Rico-Gray et al [38], Padoch and Jong [32], Vogl et al. [36], Mendez et al. [7] found high variation in floristic composition between gardens in the same location, converting each garden into a unique place. In terms of beta diversity, it has been reported that gardens that are geographically close tend to be slightly more similar than those situated at a greater distance [15,27]. This proves that for Latin American gardens, there is a high level of species interchange between gardens making each one unique. This implies that their contribution to species conservation has no meaning if they are not considered together at a regional scale.

At the landscape level, home gardens form part of a mosaic of agricultural systems mixed with the natural vegetation. The scarce evidence available suggests that when gardens are found close to primary and/or late-secondary vegetation, which are relatively abundant in the landscape, gardens are less diverse and have a different set of species than the adjacent vegetation. The proximity to forest resources facilitates collection and makes cultivating in the family garden unnecessary. For example: the Matsinguenka in Peru and the Mayas of Chunchucmil are accustomed to gather many medicinal species from the nearby forests, which explains the scarcity of medicinal species in their gardens [42,43]. In other cases, the proximity to the forest is such that there is not a clear delineation between the neighboring gardens, and a mosaic of different successional stages where species from every stage are put to use [7,31,32,44].

The location of home gardens with respect to urban centers, communication networks, and accessibility to markets and product demand also influence garden species composition [13,45]. It has been suggested that gardens located close to urban centers have a tendency to have less species diversity, more ornamental species, and species with commercial importance while gardens located in remote areas have greater species diversity and are orientated toward subsistence production [11,38]. However, the work of Wezel and Ohl [42], Padoch and Jong [32], and E.M.Pagaza [*unpublished data*] shows that urban gardens have high species diversity in spite of market influence and cultural characteristics of the population. On the other hand, if the destiny of the products is the market place, as in Manaos, Brazil, the number of species found in the gardens diminishes and dominance of commercially important species increases [46].

Functioning of the home garden

Home gardens are exceptionally dynamic spaces, as they go through phases of establishment, maintenance and abandon. During the establishment phase, due to their usefulness, some elements of the original vegetation are tolerated, which are converted into dominant canopy plants as Padoch and Jong [32] have documented in the Peruvian Amazon, Caballero [15] in gardens of the Yucatan Peninsula, Blanckaert et al. [34] in the semi-arid zone of the Tehuacan Valley in Mexico, Pinton [44] in Colombian indigenous gardens, and Azudia and Leiva [41] in humid regions of Guatemala. Nevertheless, the original vegetation can be used to construct houses as well as plant species brought there by migrants [6].

Once a home garden is established, the vegetative associations and environmental characteristics change over time. For example, in the Peruvian Amazon, the frequency of certain species (*Carica papaya*, *Manihot esculenta* and *Ananas comosus*) diminishes with garden age and there is a change in the frequency of others (*Inga edulis*, *Pouteria caimito*, *Citrus* sp., *Genipa americana*, *Citrus reticulata* and *Crescentia cujete*) [42]. Some crops (for example corn and rice) are initially mixed with young trees, but as solar radiation is diminished, these are replaced by crops tolerant of this condition such as beans and bananas [47]. Older individuals are continually replaced and the garden looks like a great mosaic of individuals of different ages [31]. It has been observed that as the garden grows older, the number of fruit and medicinal species, and species for construction increase [35]. Some authors propose that garden richness increases with the system's age [35,16,42], while other research demonstrates the contrary [32,34]. Other authors consider the number of strata-levels as an indicator of garden maturity [48].

Home gardens can be abandoned for a variety of reasons [32,44] and potentially return to the original natural vegetation state [49]. In other cases, the life of the garden can be prolonged until eventually modified into sections for inheritance or the land occupied for other uses.

The presence of numerous strata is one of the fundamental characteristics of the gardens; this organization facilitates the efficient use of light and space, maintaining relatively constant levels of temperature and humidity in the soil and diminishing the effect of the seasonal climate variation [13,44,48,50]. Simultaneously, resource production is maximized as in each stratus, species adapt according to their life form [48]. The majority of studies on water retention, incrementing organic material content, soil retention, pH regulation and incrementing of nutrient concentration have been carried out in Asia. In Latin America, it is known that soil fertility is maintained by the presence of litterfall, branches, and other organic waste such as food scraps and livestock waste [7,10,21,51,52]. Benjamin et al. [53] found nutrient concentration in leaves of predominant arboreal species of Mayan gardens contributed great quantities of nitrogen, phosphorus, and carbon to the system, nevertheless the litterfall production rate is considered to be low (1000 to 4000 kg/ha/yr). The presence of woody species from the Fabaceae family is very important in the gardens as they offer benefits of nitrogen fixation and improve soil fertility [54].

The contribution of home gardens to biodiversity conservation

Biodiversity conservation is a key aspect that determines ecological sustainability of HG. In this revision we found a correlation between "home garden hot spots" [6,55] and biodiversity hot spots [56]. This suggests the importance of gardens for conservation, especially if they are considered at a regional scale.

Gardens are recognized as reservoirs for conservation and manipulation of germoplasm for a wide variety of useful species [41]. In 15 of the 17 studies that contribute information on the geographic distribution of the species (Table 1), more that 40% were found to be native to America and in some cases, local vegetation types were used [37]. The research of Barrera [57] is interesting as it points out that before the Conquest, 80% of tree and bush species from the gardens of the Yucatan Peninsula were constituted by native elements selected by the Mayans. Additionally the gardens harbor high crop richness [39], and protect natural species that have been severely affected [32]. In extreme cases observed in Honduras, where species such as *Cnidoscolus chayamansa*, *Calathea macrosepala* and *Liabum* sp. are only found in these places [54]; *Couepia polyandra* is only found in home gardens in the city of Merida, Mexico, even though it used to be a common tree throughout the region [58].

Genetic manipulation is evaluated by Casas et al. [59], who mention that the continuous introduction and replacement of cacti such as *Stenocereus stellatus* in Mexican gardens increased genetic diversity for this species compared to the wild populations. Also, species management such as *Sideroxylon palmeri* and *Leucaena esculenta*, a fruit that is consumed and commercialized has improved its quality [60]. Garden species management also modifies population structure for certain resources, Martinez-Ballesté et al. [61] found that seedling survival of the palms *Sabal yapa* and *S. mexicana* incremented under management regimens, assuring the sustainability of the use of these native resources for roofs of homes in the Mayan area.

Even though there has been a greater focus on the benefits of home gardens on plant diversity, data on wild animal conservation also exists. Steinberg [62] registers the presence of 10 migratory bird species in Mayan gardens of Mopan in Belize, where the gardens function as food zones and refuge since the natural vegetation has been fragmented and transformed into *milpas*, pastures, and various types of secondary vegetation.

Ethnobotanical patterns in Latin American gardens

The primordial function of food production of home gardens has been frequently expressed [11,14,55], therefore we examined information from 15 studies (Table 2) regrouping reported data into nine use categories (edible, firewood, fodder, medicinal, ornamental, shade/fencing, ritual, wood, others). For details of the method used consult Appendix 1.

The results in the present analysis confirm that in Latin America food use species are dominant in this system (47%), with half being fruit, which demonstrates their contribution to food plant diversity (Table 2). Highlights the high percentage of food plants reported for El Recreo-Cuba by Crosby [22], which quite probably is due to the economic embargo that has forced this country to look for food security alternatives. The second most important use is medicinal (22%), in which the urban gardens of Santarem, Brazil stand out [63]. The ornamental plants are situated in third place are (14%) (Table 2); in three studies [7,34,43] these plants dominated even over food plants (Table 2). It has been suggested that this is due to cultural changes, modernization processes, and economic development that are associated with urban centers [23]. For example, in Merida (Mexico) 48% of the species registered had an ornamental use [58].

Table 2. Percentages of useful species for each use category reported for the 15 studies carried out in Latin America. To make this comparison, all the categories used by the authors were redefined in nine new categories (see details in Appendix 1). The column "edible" shows the percentage of edible species with the percentage of fruit in parenthesis (relative to the total). An asterisk (*) marks studies where the same specie is assigned to two or more use categories, for which the percentage sum is over 100%.

	Reference (locality)	County	Annual rainfall (mm)	Species (#)	Edible (fruit) (%)	Medicinal (%)	Ornamen. (%)	Wood (%)	firewood (%)	Shade / fencing (%)	Ritual (%)	Fodder (%)	Others (%)	% (sum)
10	Blanckaert *	Mexico	394.6	233	30 (0)	9	66	0	1	15	0	2	6	128
92	Wezel (Baitiquirí)	Cuba	400-500	82	61 (29)	39	0	0	0	0	0	0	0	100
1	Albuquerque	Brasil	599	54	26 (0)	26	12	16	0	8	1	3	5	100
96	Winklerprins	Brasil	850	98	47 (34)	45	0	0	0	0	0	0	8	100
15	Caballero	Mexico	1000	83	67 (55)	10	6	7	0	0	5	2	8	106
72	Ortega*	Mexico	1141	296	26 (0)	24	34	7	13	7	11	8	0	132
39	Herrera-Castro*	Mexico	1232	339	17 (0)	26	13	9	12	3	4	6	21	109
61	Mendez	Nicaragua	1500	324	16 (11)	7	56	4	0	0	0	0	17	100
40	House*	Honduras	1600	253	64 (15)	43	14	0	0	0	0	0	2	123
24	Del Angel-Pérez	Mexico	2110	223	35 (24)	21	17	5	0	0	9	0	13	100
92	Wezel (Nibujón)	Cuba	2200	63	68 (32)	32	0	0	0	0	0	0	0	100
92	Wezel (El Recreo)	Cuba	2200	51	86 (37)	14	0	0	0	0	0	0	0	100
93	Wezel (Yomibato)	Perú	2000-2500	58	57 (43)	26	0	0	0	0	0	0	17	100
93	Wezel	Perú	2000-2500	49	69 (45)	8	0	0	0	0	0	0	22	100
20	Coomes	Perú	2500	82	62 (49)	13	4	16	0	0	0	0	5	100
91	Vogl*	Mexico	2500 - 3000	241	49 (0)	33	20	13	6	17	4	4	16	160
51	Levasseur	Bélice	3100	164	40 (22)	5	4	18	17	0	2	0	15	100
	Pagaza *unpublished data*	Mexico	2250	406	25 (0)	24	23	3	7	3	1	2	6	96
	AVERAGE				47 (23)	22	14	6	3	3	2	1	9	

Considering the high number of medicinal species in some countries like Mexico, where more than 3000 species from all vegetative types (i.e. desert, tropical rain forest, tropical dry forest) are considered as part of this use category [64], and in spite of the great importance they have in home gardens [38], there is still little investigation about medicinal plants in home gardens. It is important to mention that a great number of plants have multiple uses and many species that are cultivated commercially possess medicinal properties, which are only taken advantage of at a local level by the family. In spite of their high potential and quality, medicinal plant species richness are not usually taken advantage to commercial purpose [65].

According to the case studies reviewed, the most frequent genus and species in Latin America are *Citrus* sp., *Musa* spp., *Inga* spp., *Psidium guajava*, and *Mangifera indica*, all with clear food use. Even though they are water-demanding species, it is interesting that they are present in humid zone gardens as well as semi-arid, suggesting that human management can overcome, at least partially, environmental limitations.

4. Social aspects that influence garden sustainability in Latin America

Social sustainability of home gardens (HG) is attributed to diverse factors related with subsistence. Aspects such as nutritional security, satisfaction of energy necessities, economic security and the form in which these can allow population level and appropriate socioeconomic maintenance have been used as indicators of sustainability. Evidence exists that HG improves diet and health of families in places such as Colombia and Mexico [44,66,67]. Psychosocial benefits have also been documented [29].

The study of the HG dynamic has been suggested as an indicator of adaptation capacity to social, economic and cultural changes. Aspects such as specialization or in productive activities in the market place could affect species composition such as those within the HG [15,45].

Even though the ecological sustainability of HG has been studied [6,7,68], the social aspects that affect the system have been analyzed less rigorously. For example, Howard [69] analyzed the social dynamics and gender in Latin American HG management, nevertheless the author does not dispute whether this fact could affect the sustainability of the garden management.

Socialization of home garden work

Equal to other parts of the world, in Latin America, the HG is a place of socialization where the family interacts establishing connections and exchanging management knowledge about useful species, which type of species to cultivate, as well as their distribution in the HG. The knowledge and abilities to maintain this type of agro-system can be distributed in a non-equitable way, reflecting factors such as age, gender roles and differences in learning opportunities [69].

Between men and women, knowledge amount resource management is related with the agricultural space where each gender carries out their activities and the time the invert in them [44,70-72]. In general, Latin American women spend much time in the home garden [44]. They are responsible for selecting and fostering the growth of useful food, medicinal, and ornamental species; while men are responsible to take care of the agricultural parcels, or hunting and gathering. Due to the previously stated, women obtain greater knowledge about herbaceous species that grow in the garden while men manage and have more knowledge about woody species of the area and species that grow inside the agricultural parcels [16,72]. Some authors have observed that men have greater knowledge about species destined for sale [30]; nevertheless, in other Central American locations, women are responsible for important commercial species propagation [16,69].

In some cases home garden species knowledge also increases with landowner age, in both men and women [72]. Even though in gardens in an arid zone in Mexico, [34] found no relationship between landowner age and species richness.

Family relationships are another important aspect of knowledge exchange in Latin America. Within this aspect, women play a very important role in maintaining knowledge during change processes [44,73-76]. In Mayan communities in Belize, mothers and close feminine relatives form important networks in this exchange [74]. According to Boster [77], species knowledge and management practices are part of physical and cultural capital that is transmitted between women and their descendents.

Intra and inter family relationships are important factors that effect productive activities in the home garden. Work time allocated for the tasks in this space directly affects species composition studies done in Nicaragua [7]. In Mexico, Torquebiau [10] found that the labor time inverted varied in accordance with garden size and occupation type of its inhabitants. Contact with other towns also favored species exchange, weather it was by gifts, sales, or inheritances. Ban and Coomes [70] found that the number of species exchange in the Peruvian Amazon was the most important variable related with the presence of certain species in the HG. Exchange and its interaction with the size and age of the home garden is reflected in crop richness.

Lastly, in home gardens other social actors exist, aside from the family, such as the intermediaries that link production with market [50], institutions that supply production materials [78] and agencies that certify organic products. These actors have the potential to affect the characteristics and complete system functioning.

Land possession

In Latin America, the majority of arable land is in the hands of elite land owners from large, unproductive rural estates, while small farmers that practice subsistence agriculture are concentrated in small or marginalized parcels of land. OEA [79] critiques the land policies of this region mentioning that: a great number of informal proprietors, lack of property rights security for women and indigenous people, political and administrative centralization, land conflicts, resistance from political and economic groups. The problem of land possession can create a limit on the efficient productivity of the home gardens.

In Latin America, interdependent relationships between families allows distinct access and land use forms, weather it be through land loans, collective management, or direct sale or inheritance under a private property regiment [80] the type of ownership for HG establishment is an important factor in management decisions about these systems [80]. In HG in Chiriquí, Panama, there was greater perennial species diversity found in land considered property than in those where the habitants were not owners or were renting; in the last two, people preferred to cultivate basic grains [80].

Changes in family structure often reflect changes in garden structure; for example, as families grow and children become independent, the garden is divided allocating to each son or daughter a portion of that space. This in conjunction with other factors, such as productive activities that the new owner performs, can have repercussions in species diversity in the home garden. Size reduction in this agro-system seems to have an inverse relationship with species number in them (see ecological sustainability section). Lok [16] found that in urban HG were smaller than rural gardens, nevertheless, the available space reduction incremented management intensity and specie density, which were promoted in urban systems. In spite of the greater superficial area in rural gardens, observed richness was less than urban gardens. In a rural population in the Peruvian Amazon the easy access to natural vegetative resources was the cause of this decrease [42].

Culture and cultural change

Culture is a conjunction of norms, habits, techniques, ideas, and learned values that are transmitted and that regulate social interactions [81,82]. Within this concept, it is expected that human actions for HG management and species selection are affected by elements that conform culture [83]. Even though various authors recognize the importance of culture in HG management, little about this has been studied in depth [30,84]. From the small farmer perspective in Latin America, the HG is an integral space in their lives [16] that is valued and continues to be an important structure, even in adverse economic conditions. Culture is reflected in garden structure, as in species selected and their associations [30].

Being a landowner and establishing a HG, in terms of culture, is a question of social status. The species that the owner decides to establish in their home garden indicate the socio-economic level of the family. In the Peruvian Amazon, the most respected and recognized people in the population were those with the most diversified HG [70]. Between indigenous and non indigenous people, there are differences in knowledge and management of HG as well as species diversity in them [18,44]. Among the Ngöbe of Panama, diversity and abundance of woody species in the HG is a part of their cultural identity. Trees play a very important role in connecting the Ngöbes and their land [80].

Soemarwoto et al. [85] suggests that people are not completely conscious of the knowledge rooted in their management practices; the processes of change involved in market or urbanization can provoke pressures and alterations in this knowledge. For the Mayas of Yucatan Mexico, the palm

Sabal spp. has been an important historic element in the HG for the construction of the traditional Mayan home. Nevertheless, the perception of the intrinsic value of this specie's management of within this system has been affected by changes in education levels, occupations, and Spanish language dominance of the habitants of this region [83].

Migration

HG management knowledge can be transformed by migration, catalyzing four distinct processes that alter the ecological surroundings. On one hand, the migrants can import their management techniques, adapting them to the new environment, enriching and altering the already existing management forms. For example, the Japanese community of Tomé-Açu established in the Brazilian Amazon and imported the acquired knowledge from agronomic schools in their country of origin. Currently, this community successfully manages HG resources, which are commercialized with the support of international institutions [78]. Secondly, migrants can learn appropriate techniques for resource management in the new ecological surroundings and in general, cultivating more commercially important species than subsistence species [36]. In other cases, it has been documented that the techniques applied by migrants can have negative effects on the natural environment [19,44]. Lastly, the migration process can also have effects on the community that is abandoned. Due to economic problems in countries like Mexico, the migration of men to other cities or countries has caused abandonment of agricultural land, and as consequence, women retake these spaces and obtain knowledge about cultivating techniques and the different plantings [86]. Sometimes, these crops are introduced at a smaller scale in the home gardens to better control their development [23].

5. Some aspects about the economic sustainability of home gardens

Economic sustainability is fundamental in considering weather or not home gardens are capable of providing diverse and stable income sources [6]. From our perspective, economic sustainability also involves the economic contributions that form part of personal use production. Therefore, economic sustainability includes satisfaction of material goods through the production for personal use, trading for other goods, giving gifts or in a market economy without destroying production sources.

In Latin America poverty is a severe problem: more than 60% of the population fits into this group. In some occasions, families subsist in poor conditions with a daily wage many times less than a dollar. Because of this, home gardens play a very important role in supplying products cultivated in their own land offering important economic and subsistence income.

Direct economic income

Home gardens generate a monetary contribution that can be significant for domestic economies. This contribution oscillates from 10 to 100%. In Nicaragua it represents from 10 to 100% with the average being 35% [7,87,88]. In Honduras this contribution varies between 10 and 26% [7]. In Belize, 62% of incomes obtained by the Mayan communities of San José come from agro-forest product sales [89]. In Cuba, small farmers organized in cooperatives or as private producers make 42 and 61% respectively higher than the incomes of State workers (Deere et al. [90] cited by Wezel and Bender [21]). In Peru, Niñez [66] found that in 40 gardens of an average size of 200 m^2 , with an investment of $2.80 USD, and 50 minutes of daily labor, the production per garden generates an average income of $28.33 USD in 5 months, which means a 10% gain. In terms of yearly income, with these same conditions and considering that a million families establish a small food garden, this would be $56,660,00 USD [66]. In some cases, fruit sale of the specie *Sideroxylon palmeri* generates an important part of family income as reported in Mexico (Chavez [91] cited by Gonzalez-Soberanis and Casas [60]); production of just three individuals of this species can surpass income generated for maize [60].

Animals can play a very important role and sometimes generate greater income gain than vegetable products [19]. Hens generate between 5 and 10% of income for egg, meat, and manure [92]. In Pará, Brazil, 50% of the production of animals is for sale and generates $35R (Reales) while for fruit they receive $30R [93 cited by 94]. On the other hand, it has been stated that in Murini, close to Belém, Brazil 30% of fruit, 15% of vegetable and 15% of the animals produced in the garden are commercialized. In gardens in Santarem, Pará, Brazil ducks are commercialized for special dishes and only 9.5% of families interviewed mention selling garden products [63].

Indirect economic income

Some of the contributions of home gardens cannot be evaluated as part of economic productivity. This is the case of the workforce, which can be product of individual or collective, family members or contracted. Family generates a large part of the labor required in these agro-systems [87]. The Ngöbe of Panama exchange work between families in an activity known as the *junta* (meeting) [80]. Daily required garden work time reported for Peru, Nicaragua and Honduras varies between 50 and 80 minutes [87,88].

Other indirect contributions that exist are satisfactory materials, which lessen market variations because the gardens are productive throughout the entire year and evade making purchases for products found in the garden. They balance the necessity for gain and subsistence as well as creating connections in the community because of the products that are gifted or traded [6,8,16,63,70,88].

It is worth mentioning that, in spite of the advantages that are presented by the incorporation of these gardens into the market system, globalization maintains market instability and the vulnerability of these agro-systems [6].

6. Methods applied for the study of Latin American gardens

In this chapter, our aim was to review the methods employed for the study of Latin American gardens. The majority of these was of inductive character, focused on system description, and seldom based on deductive methods that test hypothesis. This coincides with that pointed out by Kumar and Nair [11] in reference to gardens from diverse regions of the world. Within the descriptive articles, the majority use interviews and participatory observation techniques such as floristic studies and conventional ecological methods [7, 21,27,33-35,48,51,89]. Recently, some studies have applied multivariate statistic techniques in search of biodiversity patterns [24,33,34,72,83] and to evaluate the effect of cultural change on the system [72,83]. Other statistical methods used are correlation and linear regression [7,24,33,35,46,70,72], as well as descriptive statistics [95]. The application of eco-physiological and demographic methods for useful species is very rare [53,83,95]. On the other hand, and from a social point of view, there are few historical [19,24,45,96], archeological and landscape studies [94,97]. There are also few studies to evaluate garden health benefits [67], recreation, family relaxation, as well as social factors that affect gardens such as migration [42,50,78], cultural change [15,36,83, E.M.Pagaza *unpublished data*] and urbanization [8,25,42,63, E.M.Pagaza *unpublished data*]. There is no defined methodology to ponder the economic value of all that gardens contribute; ecological and social values are priceless. The security and resources that they offer are also not economically evaluated, nor is land ownership. Only one study has employed economic methods to evaluate the economic potential of the garden [88]. This is an incipient field of investigation, which should be stimulated.

Research methods employed for Latin American gardens show high heterogeneity in the data collection about the same topic, which makes it difficult to compare results. This makes it impossible to find tendencies or patterns of social, economic, and ecological aspects, on which system sustainability depends. The following are some suggestions from the authors' perspective, which could facilitate the creation of a robust theoretical framework.

On one hand, for biodiversity studies, it is suggested to show abundance of all life forms, since generally only woody species are considered. It is also suggested that with sufficient detail, the methods used for data collection and analysis should foster the formation and availability of regional and national databases. On the other hand, these use categories in ethnobotanical studies of home gardens should not be compared in the same manner. Study comparison with this information is difficult if similar categories or, at least detailed description of each category, are not used. Some studies consider numerous subdivisions in the category of "food" while in others they are more general. The "other" category should be clear about which uses are included. Unifying classification criteria would allow the carrying out of comparative studies about use patterns as well the search for new resources on Latin American gardens.

The interest in home garden sustainability study has had a recent boom [6,9,10,36,84]. Even though some studies in Latin America have only partially analyzed this topic, considering only some of their components [7,8,53]. Considering this, we suggest the necessity of carrying out multidisciplinary studies that include disciplines such as cultural anthropology, archeology, economy, history, and ecology, which will allow the amplification of sustainability perspectives of these systems.

In accordance with the previous statements, research topics that deserve greater attention for Latin American gardens are: soil dynamics (nutrient cycle, erosion rates, water retention capacity), environmental services (carbon sequestering capacity, biotic interactions), superficial area that the garden with respect to total vegetation cover, phytochemical studies of native medicinal species and the problems they solve, contribution of wildlife conservation, *in situ* genetic conservation studies, implications of land ownership on garden management, contribution to emotional well being and recreation, and effects of cultural change on the performance of these systems. In the economic realm, there is a lack of studies on economic importance of gifting and trade, labor time, system capacity to generate employment, as well as the evaluation of the effect of inserting the gardens in the market system.

Discussion and conclusions

This review shows that Latin American home gardens constitute a productive system, which is extensively distributed in diverse environmental and cultural conditions of America. They also present a wide range of variation in size, structure, floristic richness, socioeconomic characteristics, and owner ethnicity. Integral wellbeing of thousands of rural and urban families greatly depends on this system. Therefore, its long-term continuance prevails and is associated with the successful integration of the ecological, social and economical aspects. This implies autonomous ecological system functioning, biodiversity conservation, the satisfaction of material, economic, and recreation necessities and the strengthening of social networks, of which communal wellbeing depends.

In the ecological dimension, the characteristics widely vary, making it difficult to find clear patterns. Thus, the correlation analysis that we presented in this revision shows that the physical variables (i.e. precipitation) are not causal factors in explaining the variation of vegetative species richness in the garden. It seems that cultural, social and management factors explain more. One of the patterns that emerged from this revision is that the main use categories for Latin American gardens are in this order: food, medicinal, and ornamental; it would be interesting to be able to compare this pattern with gardens of other regions. Additionally, the overlap between geographic distribution of the biodiversity hotspots and the home garden hotspots compared in this chapter are evidence of the necessity to deepen the implications that this has for the conservation of natural anthropogenic systems in these geographic areas. Finally, the majority of the studies reports a high percentage of native species (frequently more than 50%) because of which the HG function as a reservoir of wild and cultivated germoplasm, as well as proportioning a number of environmental services.

From a social perspective, the garden is a reflection of use and management knowledge societies have of their natural environment. As aforementioned, even though their most important function is that of food production, the garden covers aspects related to health, work place, spiritual and recreation needs, strengthening social networks, as well as monetary income sources. As demonstrated in this chapter, social sustainability of home gardens depends on the processes of social and cultural change that can affect the continuation of this system. While the social benefits of the garden are clear, there has been practically no deep evaluation of the effects of social and cultural change on the maintenance of this system in Latin America.

In the economical dimension, the gardens are capable of lessening the effects of the market, reducing the necessity for cash to buy basic products as well as generating monetary income. The economic success of home gardens as a productive system depends on the way they are integrated into the global economy. Nevertheless, it is important to carefully analyze the impact that this integration into the market economy could have, as this phenomenon could reduce the diversity and richness of this system; to the extent that production obeys demand. Also, globalization as an integrative process has effects on markets in general, and these have impacts on home gardens and on local cultures.

In relation with historical aspects, various authors have pointed out that the origin of the gardens in America are in pre-hispanic times; nevertheless, the information available is not sufficiently forceful, which makes necessary further research. The effect of other historic processes (i.e. the conquest of America) on the gardens has been more apply documented, which permits the explanation of useful flora distribution patterns. The transoceanic species exchange explains the omnipresence of genus such as *Citrus, Coffea, Mangifera, Musa, Persea* in tropical gardens, even though their geographic origin is restricted.

In terms of methodological tendencies, it is suggested that methodological standardization to obtain data, as indicated by Landauer and Brazil [47]. This revision showed that there are information voids in various aspects of American home gardens in topics such as: useful species demography, the effect of cultural change and urbanization on the management of these resources, biophysical system functioning, environmental services, surface area they occupy with respect to other types of cover, phytochemical studies on medicinal species and psycho-social benefits among others

If the gardens disappear, accumulated traditional ecological knowledge will also disappear as well as the benefits; nevertheless, this system has demonstrated a large capacity to adapt to the goals of modernity and world market demands [9]. Even though the garden is not a panacea, these types of systems currently constitute a viable alternative to environmental and socioeconomic problems in Latin America, such as natural resource loss, urban population growth, marginalization and poverty, and the increased pressure on the earth and the increase of diverse satisfaction demands. Garden implementation is viable in Latin America due to the appropriate conditions such as: high diversity of useful species, maintained family structure, climate variation, cultural richness, the close relationship with the natural environment and the knowledge derived from this.

Independently of the advantages that this agro-forest system offers for Latin America, there are factors that affect its implementation and continuation; for example: landownership regimens, the availability and quality of water and soil, the lack and/or loss of knowledge, migration, schooling level and/or attitude, and the incorporation of a market system (intermediaries, competition, monopolies, lack of spaces to sell products, relationships with investment and gain). It is possible to overcome these limitations through the design of appropriate training and research programs from academic and governmental agencies based on community participation and adjusted to local environmental conditions.

In conclusion, we consider that home gardens constitute one of the most appropriate productive systems for the Latin American context. They should therefore be more amply stimulated, given their invaluable benefits in the ecological, social and economical dimensions. This could potentially contribute to the mitigation of poverty, food security problems, and environmental deterioration in America.

Appendix

Method used to compare the uses of plant species found in home gardens according to 15 Latin American ethnobotanical reports. Because each author has a different use category, and because we were interested in comparing the results, we re-grouped the original categories into new 9 ones. We have included, in each of the 9 categories, all of the names initially used by the authors as well as the original nomenclature.

1. *Edible*: food, alimento, edible, comestibles, alimento humano, human nutrition, food (crop), food (no fruit), arboles no frutales, food (fruit), fruit trees, fruit production (trees), frutales, food/spice (trees), spices, condiment, flavoring, saborizante, vegetable, vegetables and pulses, vegetables, beans and others, *Musa* spp., tubers. 2. *Medicinal*: medicinal, medicinales, medicina humana, medicinal herbs for humans and animals. 3. *Ornamental*: ornamental, ornamental plants, ornamentales, valor estético u ornamental. 4. *Wood*: wood, construction material, timber/construction (trees), timber, costrucción, construction. 5. *Firewood*: firewood, combustible, fuel wood. 6. *Shade/fencing*: shade, sombra y/o cerca, fencing. 7. *Ritual*: cultural, ritual, ceremonial, ceremonies, magic, mágico-religiosa, valor mágico religioso. 8. *Fodder*: fodder, forraje, forraje, forage. 9. *Others*: household utensils, tools, instrumental, utensilio, green manure, handicrafts, fibre, poisson, soap substitute, commercial, toy, juguete, beverage, shampoo, fertilizer, melífera y polinífera, multi-purpose (trees), multi-purpose (plants). The "others" cathegories also included the originally reported as others in each paper.

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