CHAPTER 5

HOMEGARDENS OF MESOAMERICA: BIODIVERSITY, FOOD SECURITY, AND NUTRIENT MANAGEMENT

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Abstract. The region of Mesoamerica is densely populated and it suffers from poverty and malnutrition both in urban and rural areas. It is home to the Mayan civilization that practiced sustainable agricultural systems, involving many native crops and soil conservation strategies, for centuries. The homegardens, which provide the household with a basic food source as well as high value products to generate cash income are important in Mesoamerica, and are often used as tools in development projects that promote food security, especially in the poorest areas of Mesoamerica. The Mesoamerican homegardens are quite diverse in vertical and horizontal structure and species composition. Both exotic and native plants are used, with emphasis on fruit trees. Domestic animals, especially chickens and pigs, add protein to a diet that is generally protein-deficient. Many indigenous communities (descendants of the ancient Maya) still manage these homegardens using techniques that include residue management and ash deposition, thus enhancing nutrient recycling and conservation. Carbon sequestration may be important due to the efficient capture of solar radiation in the multi-layered homegardens, although its global or regional importance is minimal due to the relatively small area under the homegarden system. Management strategies that promote nutrient recycling and maintain high species diversity should be encouraged to ensure sustainability of homegardens in the region.

1. INTRODUCTION

A vast area of what is known today as Mesoamerica was the home of the Mayan civilization. The remnants of Mayan culture are concentrated in southern Mexico,

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Guatemala, and Belize. The Mayan people are known to have practiced sustainable agricultural systems for centuries, cultivating a wide variety of native crops and applying indigenous knowledge on nutrient cycling and soil conservation (De Clerck and Negreros-Castillo, 2000; Benjamin et al., 2001). In regions such as the Tehuacán-Cuicatlán Valley in Central Mexico, human cultures have a history of nearly 10 000 years and at present several indigenous ethnic groups continue to follow cultural traditions in plant gathering and cultivation (González-Soberanis and Casas, 2004). The long history of interactions between human cultures and plant diversity has created a substantial body of traditional knowledge on the myriad uses of plants. The existence of nearly 1200 plant species utilized by local peoples for different purposes, most of them native wild plants, has been documented; many of these species are obtained through gathering, but several species are also under silvicultural management (Casas et al., 2001; González-Soberanis and Casas, 2004).

This rich tradition of sustainable agricultural practices in Mesoamerica justifies an extensive study of homegardens in the region. Several types of homegardens are practiced in the region by the descendants of Maya in present-day Mexico, Guatemala, Belize, and Honduras, by other indigenous groups, and by people of Hispanic descent in Nicaragua, El Salvador, Costa Rica, and Panama. Traditional agroecosystems, which include 'forest gardens' or 'homegardens,' contain combinations of trees with an understorey of annual and perennial crops and sometimes livestock. Villagers live within or adjacent to their gardens and maintain them over many generations. In present-day Mayan towns in the Yucatán Peninsula of Mexico, this type of forest gardens covers about 10% of the region's forested area (Noble and Dirzo, 1997). Small, scattered forest or agroforests can provide local or regional environmental services such as conservation of biodiversity (Guindon, 1996; Harvey and Haber, 1999). Thus, the practice of homegardens can meet forest conservation needs in regions where deforestation and population growth are constant threats, as is the case in much of the Mesoamerican region.

As in other regions of the neotropics, such as Amazonia (Miller et al., 2006), present-day homegardens of Mesoamerica represent the reorganization of original indigenous practices as a result of the changes brought by colonization, among which the most outstanding feature was the incorporation of non-native fruit trees and crops. Today, homegardens are of vital importance to the local subsistence economy and food security in the region, especially in regions that still carry the influence of Mayan culture (De Clerck and Negreros-Castillo, 2000; Méndez et al., 2001; Zaldívar et al., 2002; Wezel and Bender, 2003; Blanckaert et al., 2004; González-Soberanis and Casas, 2004).

This chapter describes the characteristics of homegardens in Mesoamerica, with emphasis on biodiversity, their importance in sustaining food security in rural areas, and their role in nutrient cycling. Information is presented on indigenous systems that have been practiced by descendants of the ancient Maya for many centuries in regions of Mexico, Belize, and Guatemala, as well as on systems currently being practiced in regions beyond the Mayan influence such as in Nicaragua, El Salvador, Honduras, Costa Rica, and Panama.

2. GENERAL ECOLOGICAL AND SOCIOECONOMIC CHARACTERISTICS OF MESOAMERICA

Culturally Mesoamerica joins the present-day middle and south Mexico, Belize, Guatemala, parts of Honduras, and El Salvador (Fig. 1). Geographically, the other three countries of Central America (Nicaragua, Costa Rica, and Panama) are also included in the region. Most geographers consider Central America to be part of the North American continent; however, they do not consider Mexico to be a part of Central America. The Caribbean islands are often considered separately from Mesoamerica because they are culturally very diverse. For the purposes of this chapter an example is drawn from Cuba, a country with a Hispanic tradition as rich as many of the countries of Mesoamerica, and with similar ecological and economic conditions.

Figure 1. *Map of Mesoamerica (source: www.biodiversityhotspots/mesoamerica/; last accessed: January 2006).*

2.1. Ecological setting

The climate, vegetation, and soils of Mesoamerica are very heterogeneous given the latitudinal expanse of the region and its montane relief. This results in high ecological heterogeneity that gives room to a whole variety of agricultural systems. The climate ranges from mild temperate-subtropical in north-central Mexico and Guatemala, to tropical in the rest of Central America (Richards, 1996). There is a general pattern of a more humid climate (annual precipitation 3000 to 5000 mm) along the eastern or Caribbean side due to the influence of the humidity brought by the trade winds. Winds reach the central volcanic mountain range in the region,

cause rains on the Atlantic side, and quickly lose much of their humidity. Consequently, most of the Pacific watersheds are drier with annual precipitation ranging from 300 to 2000 mm yr^{-1} and a marked dry season (November through April). The vegetation follows the climatic pattern ranging from subtropical and tropical rainforest in the Caribbean lowlands to dry forests and savannas in the Pacific watersheds (Richards, 1996).

The soil types cover a whole array from older, less fertile Oxisols and Ultisols (US Soil Taxonomy System), to younger Andosols and Inceptisols, especially in areas affected by past or present volcanic activity and in alluvial zones. Several other types of soils can be found due to the varied climatic and topographic conditions of the region (Sanchez, 1976; De Las Salas, 1987). In general, due to the recent volcanic influence, the soils of the region are relatively younger and more fertile than many soils of other regions of Latin America, such as the Amazon Basin.

The Mesoamerican region comprises an area with diverse plant and animal life. The varied topography, geology, vegetation, and drainage patterns within the region result in a rich array of vegetation types and animal communities. More than 24 000 plant species, 521 mammal species, 1193 bird species, 685 reptile species, and 460 amphibian species have been identified within Mesoamerica, many of which are endemic to the region[1]. Moreover, Mesoamerica is the third most biologically diverse region in the world; Myers et al. (2000) identified it as one of the world's 25 biological hotspots. Covering an estimated 0.5% of the world's terrestrial surface, it is home to roughly 7 to 10% of the world's plant and animal species (Harvey et al., 2005). Several trees that are currently planted worldwide in agroforestry combinations, such as *Leucaena leucocephala*, *Gliricidia sepium*, and some species of *Acacia* and *Mimosa*, have their centers of origin and diversity in Mesoamerica (NAS, 1979; 1980; Dommergues, 1987). Mesoamerican homegardens, in addition to meeting the immediate alimentary and economic needs of the people, also act as repositories of local biodiversity as they include a dynamic mixture of native and useful species.

2.2. Cultural setting

The region of Mesoamerica is culturally and socioeconomically diverse, sharing certain characteristics such as a strong Spanish colonial influence (with the exception of Belize) and a strong dependence on agriculture and natural resources (Harvey et al., 2005). In parts of Mesoamerica (southern Mexico, northern Guatemala, and Belize) homegardens and other types of agriculture carry the influence of ancient traditions from the indigenous Mayan groups that lived in this region prior to the arrival of European conquerors.

Several studies have reported and discussed sustainable land use practices that were used by the Maya, including terracing, using soil algae or wetland soil to enrich upland garden plots, and other soil conservation strategies (Barrera et al., 1977; Turner and Harrison, 1981; Beach and Dunning, 1995; Fedick and Morrison, 2004). Archaeological evidence of the use of homegardens by the ancient Maya include the location of residential sites within prime agricultural land, strategic placement of households to allow for gardening space, the addition of soil

amendments as indicated by nutrient enrichment within house lots, and the distribution of tools in the vicinity of residences (Fedick and Morrison, 2004).

The decline of the Maya civilization (~700 BC to 800 AD) has been attributed in part to complex economic, political, and social changes that led people to change their traditional sustainable agricultural practices to less diverse agricultural systems (Barrera et al., 1977; Turner and Harrison, 1981; Atran, 1993; Atran et al., 1999). A set of political and ecological factors apparently led some Maya groups such as the lowland Maya of Petén, Guatemala, to reject a diverse swidden-fallow management strategy for a more simple 'milpa' or shifting agricultural system that provided fewer forest products. This led to a less diverse agricultural landscape and a less diverse biological landscape (Atran, 1993; Steinberg, 1998; Atran et al., 1999). The milpa system consisted of 2 to 5 ha plots that were cut and burnt, and cultivated mainly with maize (*Zea mays*). In the traditional system, after a few harvests the plots were left to regenerate with a long fallow cycle, leaving tree species time to mature and bear fruits (15 to 40 years).

At present, many Maya groups such as the Mopan of Belize have shortened the fallow periods to about 5 years. With such a short fallow cycle, the vegetation regenerating in the milpas is much less diverse than in the traditional Mayan systems, with only a few useful species of shrubs and palms (Steinberg, 1998). However, some authors argue that only the most sophisticated and intensive type of Maya agriculture collapsed, while the oldest, simplest, and most ecologically stable type is still being practiced (Atran, 1993). The milpa system – as practiced today – with dispersed fruit trees and vegetable crops and livestock has the attributes of a productive homegarden.

2.3. Socioeconomic conditions

With a total land area of almost 2.5 million km^2 and a total population size of almost 140 million people, Mesoamerica is one of the most densely populated regions of not only Latin America but also the entire world (Harvey et al., 2005). The current population of Central America is approximately 38 million people, of which about 20% are indigenous (Harvey et al., 2005). With a yearly growth rate of about 2.6%, the population is expected to double within the next 25 years. The overall population density of the region is 56 people per km^2, with a range from 296 people per km^2 in El Salvador to just 11 in Belize (Table 1).

Despite its recent economic growth, Central America remains one of the world's poorest regions. About 50% of the population is poor (i.e., unable to cover basic needs such as nutrition and housing) and 23% is extremely poor (i.e., not able to cover even daily basic nutrition; Harvey et al., 2005). Particularly striking are the cases of Honduras and Guatemala with poverty levels of 74.5% and 78.5%, respectively (Harvey et al., 2005). The region's poverty has led to the massive exploitation of its natural resources. Large areas of forest have been cut down and burnt for firewood, used in the production of paper, and cleared for agricultural uses. Despite an equal distribution of population between rural and urban areas, rural populations are considerably poorer than their urban counterparts (Harvey et al., 2005).

Mesoamerica has diverse ecological, cultural, and socioeconomic conditions that have given origin to varied agricultural systems. The prevalent conditions of rural poverty and associated malnutrition call for the need of agricultural systems that can help fulfill urgent household needs. Homegardens, whose main function is to provide the household with a basic food source and marketable products, are extremely important—given the socioeconomic conditions prevalent today in Mesoamerica.

Table 1. *Area,population size and population density of Mesoamerica.*

Country	*Area (km²)*	*Population size*	*Population density (no./km²)*
Mexico	1,964,375	101,879,000	52
Nicaragua	131,847	4,918,000	37
Honduras	112,520	6,406,000	57
Guatemala	108,917	12,974,000	119
Panama	75,536	2,846,000	38
Costa Rica	51,113	3,773,000	74
Belize	22,965	256,000	11
El Salvador	21,046	6,238,000	296
Total	2,488,319	139,290,000	56

Source**:** Data update 2001 estimates, http://www.globalgeografia.com/north_america/nam_sup.htm (last accessed: January 2006).

3. COMPOSITION AND STRUCTURE OF HOMEGARDENS IN MESOAMERICA

As in other regions worldwide, the structure and composition of homegardens in Mesoamerica are quite complex. A full spectrum of homegarden practices can be found in different locations of Mesoamerica, ranging from near complete domination of woody perennials to homegardens where trees may account for less than 20% of the annual productivity. Plant composition in homegardens of Mesoamerica is influenced by access to water, owners' economic activities, labor availability, traditional social organization, modernization processes, and economic development (Blanckaert et al., 2004). In general, plant species composition within the homegardens is the result of continuous selection in which the family usually favors the planting of fruit trees with high productivity (Caballero, 1992).

Most homegardens of Mesoamerica consist of several vertical and horizontal strata in which plants are arranged according to their adaptability to the existing light conditions and nutrient resources (Fig. 2). The number of individual plants per stratum, however, varies among homegardens; older, more mature homegardens display more developed tree strata. Some homegardens resemble agricultural fields with an emphasis on herbaceous and low shrub strata, with a greater focus on agricultural crop production. Others have more trees, with architecture similar to

that of the native forests of the region (Gillespie et al., 1993; De Clerck and Negreros-Castillo, 2000; Méndez et al., 2001; Zaldívar et al., 2002; Blanckaert et al., 2004).

Figure 2. *Most homegardens of Mesoamerica consist of several vertical and horizontal strata, with plants arranged according to their adaptability to light and nutrient resources. A homegarden in Siquirres, in the Caribbean lowlands of Costa Rica showing vertical stratification with peach palm (* Bactris gasipaes*) in the top layer (right), coconut palms (*Cocos nucifera*) and plantains or bananas (* Musa *spp.) in the lower tree strata (left), sugarcane (*Saccharum officinarum*), and other herbaceous crops in the herb layer (Photo: R. González).*

3.1. Vertical stratification

The vertically stratified homegardens are potentially more productive on an area basis since they can capture more resources and exhibit tighter nutrient cycling, than those without a stratified arrangement. For example, in a study of four homegardens in the Petén, Guatemala, Gillespie et al. (1993) reported high structural complexity, with full canopy closure in the layers within the canopy. The garden architecture made efficient use of light and space, with intensive management for food and fuel production. The development of homegardens in the area utilized existing trees, leaving the most useful as residuals after thinning, and inserting other desirable trees and shrubs in the understorey and open space. This strategy seemed to maximize

light use, according to results of measurements of incident radiation at different canopy levels reported by Gillespie et al. (1993).

In most Mesoamerican homegardens, each stratum contains plant species that belong to a characteristic life form, much like in a native forest of the same region. In homegardens of the Zona Maya of Quintana Roo, Yucatán Península, Mexico, there were six strata: low herbs, low shrubs, tall shrubs, fruit trees, timber trees, and a stratum with vines (De Clerck and Negreros-Castillo, 2000). These authors studied the species composition of each stratum, and concluded that in these systems the efficient use of space and resources maximized the production of food, timber, medicinal plants, and non-timber products to cover the farmers' needs. They suggested that these systems (or analogs of these in terms of structure and composition) could be managed in a manner that protects the natural resource base of the region.

3.2. Plant species composition

The species composition of the homegardens in Quintana Roo analyzed by De Clerck and Negreros-Castillo (2000) was much like others in Mesoamerica and in other regions of Latin America as well, with a mixture of native and exotic species in each stratum fulfilling the farmers' needs. The herbaceous stratum (0 to 0.5 m tall) was comprised of herbs and creepers such as basil (*Ocimum basilicum*), squash (*Cucurbita* spp.), and sweet potatoes (*Ipomoea batatas*), containing an average of 14% of all species in the homegarden. The low shrub stratum (0.5 to 1.5 m tall) contained annual and perennial herbaceous plants such as tomatoes (*Lycopersicum esculentum*), maize or corn (*Zea mays*), ruda (*Ruta chalapensis*), and included several shade-tolerant species such as cassava (*Manihot esculenta*), ginger (*Zingiber officinale*), pineapple (*Ananas comosus*), and taro (*Colocasia esculenta*). The low shrub stratum contained 12% and the tall shrub stratum contained 15% of the total number of species of the homegardens. The low tree stratum was dominated by fruit trees, most frequently by *Citrus* spp., and contained 41% of the total number of species; this stratum was often dominant in the absence of the fifth stratum (tall trees). The presence of the tall tree stratum, with 15% of the species, was an indicator of the maturity of homegardens. It was composed of several species of palms, tall fruit trees such as mango (*Mangifera indica*) and avocado (*Persea americana*), and timber trees. The vine stratum started at ground level and rose up to the top of the canopy, with 4% of the total number of species, composed mainly of tuber-forming vines such as sweet potatoes and several species of yams (*Dioscorea* spp.). Many epiphytic species were found on trees and shrubs (De Clerck and Negreros-Castillo, 2000).

This complex horizontal and vertical structure allows for a variety of agricultural crops and tree products that are consumed in the household and sold in the local markets. Multistrata agroforests combining agricultural crops with high-value timber species, as described in the above example, can provide farmers with long- and short-term revenue with harvest distributed throughout the year.

In a study of homegardens located in eastern Cuba, Wezel and Bender (2003) found that species composition and structure were similar to "typical" homegardens

of other regions in Mesoamerica. The top layer (3 to 10 m) consisted mostly of trees such as avocado, coconut (*Cocos nucifera*), mango, and breadfruit (*Artocarpus communis*). In the middle layer (1 to 3 m), smaller trees like guava (*Psidium guajava*), soursop (*Annona muricata*), orange (*Citrus sinensis*), or papaya (*Carica papaya*) were found together with bananas and plantains (*Musa* spp.), sugarcane (*Saccharum officinarum*), pigeon pea (*Cajanus cajan*), and climber yam (*Dioscorea* spp.). In the ground layer (0 to 1 m), different vegetables, spices, and medicinal plants were cultivated while others grew spontaneously.

3.3. Horizontal structure

The horizontal structure of homegardens shows interesting patterns, governed by the uses/functions of the different plant species. For example, ornamental plants are often found in linear patterns around the house. They are also found along the roadside of the garden, reflecting their aesthetic purpose as well as their use for the delineation of property or sections thereof (Blanckaert et al., 2004). In general, edible plants are found a little farther away from the house, mostly in small groups to facilitate management such as weeding or pruning. In semiarid environments such as south-central Mexico (Blanckaert et al., 2004), central Nicaragua (Méndez et al., 2001), and in the Baitiriqui region of Cuba (Wezel and Bender, 2003), irrigation is frequently used. In these cases, edible plants are located downhill from the house and in close proximity to it so that they can be watered using the wastewater recycled from domestic uses. Medicinal plants are often found still farther away than ornamental or edible plants (Blanckaert et al., 2004). Homegardens are also important for providing additional living and working space to supplement small household structures (Lok, 1998).

In an effort to organize and systematize the study of this very complex type of agroecosystem, many authors have used statistical procedures to group descriptive characteristics of homegardens. For example, cluster analysis, correspondence analysis, and diversity indices have been used by several authors to explain the patterns of variations in floristic composition of the homegardens (Méndez et al., 2001; Zaldívar et al., 2002; Blanckaert et al., 2004). These procedures help in the description of the characteristics of the specific homegardens under study such as explaining differences in species diversity among homegardens of different settlements or localities in a region.

4. PLANT SPECIES DIVERSITY IN HOMEGARDENS OF MESOAMERICA

Results of several studies indicate that homegardens of Mesoamerica are rich in biodiversity, and need to be considered for *in situ* conservation and development programs. Table 2 shows a summary of studies on plant biodiversity in homegardens of different geographic regions of Mesoamerica. Several of the studies shown in Table 2 emphasize tree and shrub species and their uses and relevance for forest conservation, while others focus on the variety of plant species of all life forms and

Table 2. *Examples of studies on plant diversity of homegardens in Mesoamerica.*

Location	*Climate*	*Number of homegardens studied*	*Number of plant species*	*Source*
Tehuacán-Cuicatlán Valley, Puebla, south-central Mexico	semiarid to arid	30	233 (66% ornamental, 30% edible, 9% medicinal)	Blanckaert et al., 2004
Tixpeual and Tixcacaltuyub, Yucatán, Mexico	tropical humid lowland	not available	301 trees and shrubs (70% medicinal, 40% apiculture, 30% edible, 17% fuel, 19% building, 12% timber)	Rico-Gray et al., 1991
Tropical forests of nine states, south-southeast Mexico	tropical humid lowland	not available	278	Toledo et al., 1995
Totonac community in Coxquihui, Veracruz, Mexico	warm, subhumid, low elevation	40	223	Del Angel-Perez and Mendoza, 2004
Zona Maya of Quintana Roo, Yucatán Peninsula, Mexico	tropical humid lowland	78	80	De Clerck and Negreros Castillo, 2000
Maya community of San Jose, Toledo district, Belize	tropical humid lowland	18	164	Levasseur and Oliver, 2000
El Camalote, Copán, SW Honduras near the border with Guatemala	montane wet	10	253 (91 trees, 42 shrubs 90 herbs, 24 lianas, 2 palms, 2 mushrooms)	House and Ochoa, 1998

Nicoya, SW Costa Rica	tropical seasonal lowland wet	12	289 (63 varieties)	Lok et al., 1998
Five life zones (*sensu* Holdridge, 1987) of Costa Rica	tropical subhumid to humid	225	236 (excluding ornamentals)	Price, 1989
Eastern Costa Rica	wet tropical	45	133	Price, 1989
Talamanca, S. Costa Rica	wet tropical	83	46 cultivated species	Zaldivar et al., 2002
Coto Brus, S. Costa Rica	wet tropical	55	27 cultivated species	Zaldivar et al., 2002
Masaya, Nicaragua	semiarid to arid	20	334	Mendez et al., 2001
Eastern Cuba	semiarid	31	101	Wezel and Bender, 2003

their role in sustaining local livelihood needs. In a region with such broad geographic diversity as Mesoamerica, diversity of plants found in homegardens is expected to vary according to latitude, elevation, and rainfall. These trends are not evident from the data shown in Table 2, as similar numbers of species are reported for wet and for semiarid to arid locations. The number of species reported by the authors depends on the number of homegardens studied, types of species that were emphasized, size of the homegardens studied, reliance of homegardens for subsistence needs, and the traditional uses of the plants, among other factors as discussed below.

A number of the studies shown in Table 2 also emphasize plant uses and management. For example, in Yucatán, Mexico, Rico-Gray et al. (1991) reported the uses of trees and shrubs from the tropical deciduous forests by the Yucatecan Maya. Despite the lack of important timber species in these forests, the authors conclude that management could lead to sustainable production of honey, deer, and building materials for houses. In homegardens of the Tehuacán-Cuicatlán Valley in Puebla, Mexico (Table 2), plants were categorized into three main groups: cultivated (68%), protected (10%), or spared (22%) (Blanckaert et al., 2004). Cultivated plants are those that are sown or planted by the owner. Protected plants are those that are encouraged by the farmer, whether they are transplanted from zones outside the garden or grow spontaneously in the garden. The farmer may choose to protect or encourage the plant, for example, by supporting it or attaching it to a solid structure, or by putting stones around the plant. Spared plants are those that spontaneously grow in the garden and are not removed (Blanckaert et al., 2004).

The high diversity in plant species and uses reported by Blanckaert et al. (2004) were found at 1217 m above sea level with a climate classified as semiarid to arid (total annual precipitation 395 mm). Theoretically, these conditions would place the region at the low end of the spectrum of potential plant species diversity. The most represented plant families were Cactaceae, Araceae, Liliaceae, Solanaceae, and Crassulaceae, reflecting the climatic characteristics as well as the preferences of the local farmers. Members of both Cactaceae and Solanaceae families in the homegardens are important edible plants. For instance, nopal (*Opuntia* spp. and other species of Cactaceae), chilli (*Capsicum* spp.), and tomato (*Lycopersicum esculentum*) (Solanaceae) are important ingredients of the Mexican diet.

A possible explanation for the relatively large diversity of plants found in dry locations was advanced by Price (1989), who studied the characteristics of homegardens in five different ecological regions of Costa Rica (Table 2). The author found that homegardens were most important in regions of dry tropical forests because socioeconomic conditions were more difficult than in other regions of the country, making people rely more on homegardens for self-sustenance. In a semiarid region in eastern Cuba, Wezel and Bender (2003) also reported the importance of homegardens and their high species diversity (Table 2), with about 50% of the species consisting of fruit trees.

Locally, plant diversity of homegardens can also be influenced by size of the homegardens. For example, in Nicoya, Costa Rica, Lok et al. (1998) found that the size of homegardens ranged from 0.1 to 1.4 ha with an average of 0.5 ha (Table 2). The smallest homegardens considered in the study had the highest diversity, with

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205 to 745 species and an average of 348 species per ha. In contrast, the larger homegardens had only an average of 96 species per ha, with less variability among gardens in comparison to the smaller homegardens that exhibited higher variability in species diversity.

4.1. Importance for species domestication and conservation

The high plant species diversity of homegardens in Mesoamerica makes them an important resource for ethnobotanical studies. Since many species in homegardens are encouraged or cultivated, the process of domestication of useful species has long taken place in homegardens. This is true for homegardens in other regions of the neotropics where they are intensely managed and crops are carefully selected for specific purposes. For example, the homegardens of Japanese emigrants in the Tomé-Açu settlement in Pará, in the eastern Amazon region of Brazil, have served as "banks" of potential crop species that had been gathered and closely observed by the family members (Yamada and Osaqui, 2006). The homegardens of Tomé-Açu functioned as individual validation facilities for farmers making decisions about planting new crops in their farms. Farmers also used homegardens for improvement and propagation of nursery stock.

Several studies shown in Table 2 emphasize the role of homegardens as sites for domestication and preservation of useful species (Toledo et al., 1995; House and Ochoa, 1998; González-Soberanis and Casas, 2004, among others). In El Camalote, Copán (Honduras), House and Ochoa (1998) found several introduced species along with native species that belonged to natural forests of the region, and they stressed the importance of homegardens as genetic banks of ancient crops and as a research field for new varieties and cultivars. The diversity of traditional vegetables in the homegardens studied by these authors was outstanding, with many species that are also present in Guatemala and Mexico but that are absent in other parts of Honduras. They cite examples of several vegetables and fruits that today are almost exclusively found in the homegardens. Such is the case of the chayo (*Cnidoscolus chaymansa*), a popular green vegetable in Camalote (similar to spinach) but almost absent in the rest of Honduras. They also cite other unique species of vegetables and fruits that, again, are found only in the homegardens of Honduras and Guatemala.

Other examples of domestication of crop species can be found in regions such as the Tehuacán-Cuicatlán valley in central Mexico, where the Maya cultures have a history of over 10 000 years (González-Soberanis and Casas, 2004). These authors studied the management and domestication of a fruit of the Sapotaceae family, the tempesquistle (*Sideroxylon palmei*). This fruit is consumed and commercialized in large quantities in the villages studied. Apparently, management of this species in homegardens has resulted in larger, better quality fruits than those of the wild populations, demonstrating the importance of domestication of plant species by the owners and managers of homegardens. This is a good example of a process of selection by local farmers that may be true for many other species in other home-garden settings too.

Homegardens may have other positive effects on biodiversity, as they can serve as local refuges for plants and animals that otherwise may be threatened by human

or natural disturbances. For example, Griffith (2000) reported that during the 1998 fires in Petén, Guatemala, homegardens and other agroforestry systems might have served as critical refuges for many forest species. Apparently, agroforestry farms attracted birds by virtue of their complex structure – similar to that of intact forest patches – they harbor insects, provide nesting sites, and offer protection from predators (Griffith, 2000). They were also attracted by the cultivated fruit trees, which may have provided some of the only food sources in the region after fire destroyed most of the surrounding vegetation. Homegardens, thus, can provide additional services as buffers for protecting local biodiversity in times of stress.

5. SIGNIFICANCE FOR HOUSEHOLD FOOD SECURITY

Homegardens can enhance food security in several ways, most importantly through: (1) direct access to a diversity of nutritionally rich foods, (2) increased purchasing power from savings on food bills and income from sale of garden products, and (3) fall-back food provision during periods of temporary food scarcity. In many parts of the world, homegardens supplement food supply for people, but in some cases, homegardens can yield basic staples, when they are large enough to plant sufficient quantities of tubers or cereals (Eibl et al., 2000; Wezel and Bender, 2003). In this regard, homegardens fulfill a very important social function, especially in a region like Mesoamerica where poverty and malnutrition co-exist. For example, in the Maya community of San Jose, Belize, traditional agroforestry systems including milpa, cacao (*Theobroma cacao*) under trees, and homegardens almost entirely meet the family needs for food and wood, and generate 62% of family income (Levasseur and Oliver, 2000).

In contrast to other types of agroforestry and other productions systems, homegardens are very important for supplying the household with food products year-round (Budowski, 1990; Lok, 1998; Eibl et al., 2000). Their principal goal is not to optimize production, as it could be in the rest of the farm, but to guarantee a minimum supply of different food products at all times of the year, functioning as a buffer in times of low income and food scarcity. Often, high value products from homegardens can be sold to purchase staple foods during periods of scarcity. In Central America, women play an important role in the management, maintenance, and sale of homegarden food products (Lok, 1998; Howard, 2006).

5.1. Edible plant species

As seen in the previous sections, homegardens in Mesoamerica are planted with a variety of species used for various purposes, including food, medicinal, ornamental, timber, construction, crafts, among others (Zaldívar et al., 2002) . In addition to their use for self-sustenance, many studies have indicated that the potential for cash sales from homegardens is highly important in their composition and management. Frequently, excess homegarden production is given away to relatives working in urban areas, thereby supporting food security in both urban and rural areas.

The importance of homegardens for household food security becomes greater in more extreme situations of poverty and isolation. In present day Cuba, homegarden products have contributed additional food to the basic provision such as bread, oil, flour, meat, and other products sold cheaply in government stores. After 1989, when the Soviet Union collapsed and dropped aid to Cuba, the economic situation worsened and food distribution declined precipitously. As it was imperative to find alternative sources of food supplies, farmers intensified homegarden production in order to feed their families (Wezel and Bender, 2003).

Similar situations of low income and little assistance by government programs are common in several countries of Mesoamerica. In Nicaragua, one of the poorest countries of Central America, Méndez et al. (2001) found that families in Masaya obtained at least 40 different plant products from their homegardens (Table 2), as well as the benefit of space for working on handicrafts (a major source of income in Masaya), and socializing. People enjoyed meeting their neighbors and visitors in the homegarden because it was a pleasant area of their homes. Although dependence on homegardens varied according to specific conditions, they seemed to be a consistent, flexible resource used to meet a diversity of needs, although their main function was always to provide edible products for household consumption.

Although Costa Rica probably has the best conditions of Mesoamerica in terms of average per capita income and social welfare programs, rural poverty and malnutrition persist there, especially among some indigenous groups living in remote areas. Chibchan Amerindians (Bribris, Cabecares and Guaymis) who live in reserves located in Talamanca and Coto Brus, in the south-central part of Costa Rica, practice slash-and-burn agriculture, and maintain polyculture fields or homegardens adjacent to their dwellings with a high diversity of plants (Zaldívar et al., 2002; Table 2). Both Bribris and Cabecares have lived in territories within the Talamanca Reserve for centuries, while the Guaymi migrated about 60 years ago from their ancestral territories in Panama. Most edible crops common to all settlements studied by Zaldívar et al. (2002) were native to the region, with the exception of plantains and bananas, 'manzana de agua' (water apple, *Syzygium malaccense*), oranges and mangoes. In other regions of Costa Rica also, home-gardens are important for supplying food; they also serve as a buffer in times of harvest failures or economic depressions (Price, 1989).

In the Chiriquí province of Panama, Lok and Samaniego (1998) found that among the Ngöbe (or Guaymi) indigenous populations, the homegarden was the system that provided the largest cash income and number of edible products for household consumption when compared with other farm activities. They studied 10 farms with an average size of 6.7 ha each, of which about half a hectare was dedicated to homegardens. The Ngöbe grow annual food crops in plots where they also grow "fire-hardy" trees. These plots provide the basic food needs of the family (rice, maize, and beans) during much of the year. In the homegardens they grow about 100 plant species, of which 75 are woody species (trees, shrubs, and palms). Among the woody species most of them are fruit trees, including oranges, guayabas, avocados, and coconuts. Fruits are harvested for household consumption, and often are the sole source of food for the family in times of scarcity. Fruits are also a source of food for wildlife, especially birds that the Ngöbe hunt for food. About 80% of

land inhabited by the Ngöbe is of low productivity and is not suitable for commercial production of basic grains, as soils are low in organic matter and high in aluminium content. The cultivation of homegardens is one alternative that the Ngöbe families have successfully used to offset such edaphic constraints and/or to alleviate the problem of food shortage.

5.2. Domestic animals

Domestic animals are frequently found in the homegardens of Mesoamerica and Cuba. For example, in the Maya community of San Jose, Belize, poultry and pigs were found in about 80% of the households (Levasseur and Olivier, 2000). Likewise, in the Totonac backyard homegardens of Veracruz, Mexico, pigs, chickens, and small livestock were common (Del Angel-Perez and Mendoza, 2004). In a survey of 80 homegardens in the dry and humid regions of Costa Rica, Nicaragua, and Honduras, Wieman and Leal (1998) also noted chickens in 79% of the homegardens, pigs in 49%, and ducks in 10% of the households. In Cuba, animals such as pigs, sheep, chickens, and to a lesser extent ducks, rabbits, and turkeys abound in the homegardens (Wezel and Bender, 2003). Larger farm animals such as sheep, goats, and cows are often kept tethered on the nearby roadsides to permit grazing, or sometimes kept in small-fenced paddocks next to the house (C. Munford, pers. comm., October 2005).

Small animals, in particular, represent a source of production of low-cost protein in homegardens, especially for the low-income households (Wieman and Leal, 1998). Several small animals such as chickens, ducks, and rabbits also provide B-complex vitamins and minerals such as iron, calcium, and phosphorus. The small sizes of these animals also make their care and management, besides meat preparation (slaughtering, skinning, and cooking) relatively easy. Yet another advantage is the ease of selling the animals and their products in the local markets and their year-round production, unlike the orchard plant products which can be seasonal (Del Angel Pérez and Mendoza, 2004).

Chickens are particularly important in the homegardens of the developing countries worldwide, primarily for their ability to generate cash income from the production of eggs, meat, and chicken manure. They also contribute to biological pest control by preying on insects and grubs, and facilitating household waste recycling. In the Totonac backyard homegardens of Veracruz, Mexico, chickens roamed free in about half of homegardens surveyed, although they are often penned at night (Del Angel-Perez and Mendoza, 2004). The families in Central America also consumed most of the chicken meat and eggs produced by them. In contrast, duck meat is not as much appreciated, as ducks are often considered pets. Overall, the home-raised livestock has high priority among the Totonac farmers, presumably because of the high value of these animals in the open market.

Similarly, pigs are an important source of meat, despite the seasonality of production, mostly coinciding with festivities or special occasions. In the home-gardens studied by Wieman and Leal (1998), an average of seven pigs were

found in the larger homegardens of Limón, Costa Rica and Paraíso, Honduras, and a smaller number in the smaller-sized homegardens of Masaya, Nicaragua. Ornamental plant nurseries, wherever present, deterred pig husbandry because of the potential damage to nursery plants.

In general, local breeds of animals with high resistance to pests and diseases are used, and women take care of the animals (Lok and Samaniego, 1998). Whenever the domestic animals are likely to interfere with the cultivation of plants within the homegardens, they are enclosed or tied up. In the orchards dominated by trees, pigs and chickens roam freely, suggesting that the farmers disregard the understorey vegetation, while backyards in town often have animals in cages or in enclosed quarters to protect ornamental, medicinal, condiment, and ritual plants.

5.3. Promotion of homegardens in food security and development projects

Homegardens have long been used as a tool to promote household food security in many regions of the world, and especially as part of many educational and dissemination efforts by international aid agencies, local governments and non-government organizations (NGOs). For example, FAO has produced materials for their training package '*Improving Nutrition through Homegardening*' (FAO 2001), featuring homegardens for food security in many regions of the world, including specific projects in Nicaragua, El Salvador, and Honduras. In Nicaragua, government subsidies, in combination with international aid, have been used for decades to promote homegardens as a means to guarantee basic household food security. For example, the Plan Alimentario Nacional (National Food Plan) with financial support from foreign-aid and local logistic and technical support from NGOs working in the region, has distributed seeds, working tools, and cooking utensils to families in need, mostly from the rural areas of semiarid regions (El Nuevo Diario, Managua, Nicaragua, April 3, 2002). Similar promotion of homegardens to alleviate poverty and ensure basic food supply in rural and urban areas is underway in Panama and El Salvador, again supported by local NGOs and international assistance (e.g., Food Safety Program in Tacuba, El Salvador, sponsored by World Vision, Canada). In Nicaragua, the Peace Corps of the USA established the Food Security Program after Hurricane Mitch in 1998, while other organizations such as the Red Cross integrated homegarden projects into larger ones directed to address the post-Mitch needs including natural disaster mitigation efforts (D. Craven, pers. comm., October 2005).

In several locations of Mesoamerica, homegardens are often grown and managed as part of the communal development efforts. For example, in Diriamba, Nicaragua, community homegardens form part of a larger development program (POSAF, Program for Agroforestry Development and Environment) funded by the World Bank (Piotto et al., 2004). Similarly, in El Salvador and Nicaragua, homegardens are components of community development efforts in coffee cooperatives. They are assisted by local NGOs working on rural development and biodiversity conservation (Méndez and Bacon, 2005).

6. NUTRIENT CYCLING

Efficient nutrient cycling is a key to the ecological sustainability of traditional homegardens, and species and structural diversity are critical to maintaining it through optimum use and transfer of carbon, water, and nutrients. Many traditional homegardens in Mesoamerica have survived for centuries despite many ecological, social, and political changes, justifying the claim that they are a sustainable land use system (e.g., the Maya homegardens of Yucatán Peninsula; Caballero, 1992). However, this cannot be generalized to all systems practiced by traditional peoples of the region. A comparison of land use and land clearing by Maya descendants and Hispanic populations in the Sierra de Lacandón National Park in Petén, Guatemala, is a case in point; not only agricultural land use by these two groups is very similar but also the impacts on land clearing are comparable (Carr, 2004). Population pressure and changes in other socioeconomic conditions thus strongly influence nutrient management and recycling, affecting the sustainability of homegardens. Yet many traditional societies retain the conventional wisdom on sustainable land management.

In a study conducted in the northwestern and north-central regions of the Yucatán Peninsula of Mexico, Benjamin et al. (2001) hypothesized that Mayan farmers have been choosing tree associations and garden structures that maximize productivity and optimize nutrient cycling of the homegardens. At present, however, the Maya have ceased to use many of their earlier technologies that improved production, e.g., using raised beds and muck. Nevertheless, 'modern' Mayan homegardens still maintain relatively high yields using technologies of nutrient recycling such as mulching for residue management and fertilization (Benjamin et al., 2001). Soils in the region are very thin and contain rocks and calcium carbonates due to the shallow limestone bedrock. Low annual precipitation results in depleted surface and ground water resources, making large-scale irrigation a non-viable option. Benjamin et al. (2001) also noted that the Maya recognize appropriate tree species for such sites and know their growth characteristics; they also have the knowledge on appropriate nutrient management practices, which are applied in the design and management of homegardens. Irrigation timing, pruning, addition of ash to soils, and composting are some of the practices that Maya farmers use to enhance tree growth and survival, resulting in high fruit production with less investment in leaf biomass.

Sweeping and burning of litter in homegardens results in the export of substantial amounts of nutrients, decreasing the effectiveness of nutrient cycling. Ash is recycled in the homegardens, although not uniformly. However, soils had high concentrations of organic matter. If litter were not removed, potential nitrogen contributions from litter to the homegardens would be very high (Benjamin et al., 2001).

Nutrient addition through the litter of nitrogen-fixing species is also a practice used in many homegardens in Mesoamerica. The Maya communities of San Jose, Belize, use the litter of *Gliricidia sepium*, a tree species native to Mesoamerica, to fertilize their homegardens (Levasseur and Oliver, 2000). In addition, practices that are aimed to controlling soil erosion also contribute to nutrient recycling through

soil and nutrient conservation. The Totonacs in Coxquihui, Veracruz, Mexico, perceive soil loss as the most serious hazard to their traditional homegardens, and therefore, have sought to control erosion by retaining a continuous canopy cover, and using litter for mulching among other soil conservation practices (Del Angel-Pérez and Mendoza, 2004).

The small size of homegardens allows for the application of intensive management practices that can improve nutrient recycling and lead to higher productivity. In Tacuba, El Salvador, farmers often open small trenches (about 30 cm deep, few meters long, and set perpendicular to the direction of the slope) in their homegardens (Fig. 3). They drop household residues as well as prunings and other organic materials in the trenches. This avoids losses of residues that otherwise could be washed down the slope during the rains. They change the location of the trenches in the area of the homegarden so that eventually residues are recycled all over the homegarden area (pers. obs.).

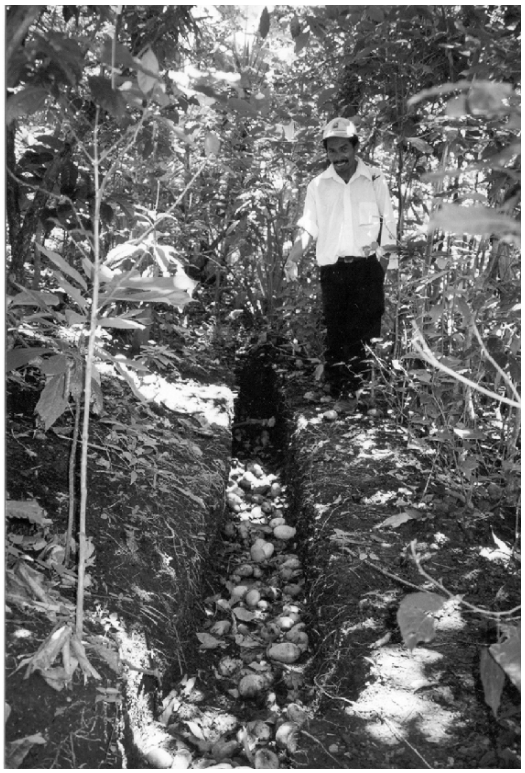

Figure 3. *Recycling of household residue in homegardens in Tacuba, El Salvador. Farmers dig small trenches set perpendicular to the direction of the slope, where they deposit household residues, prunings and other organic material, to avoid losses of residues down the slope.*

Manure of small animals is valuable as a nutrient source for the homegardens. This may be a localized effect as chickens or pigs often wander free in portions of the homegarden and their manure falls near cultivated plants. It can also be part of a specific management strategy, as chicken manure in regions of Costa Rica is used to fertilize small patches planted with corn that is used to feed the chickens as well as other animals of the homegarden (author's pers. obs.).

Vermiculture, or growing earthworms in worm boxes to use the castings for fertilizing homegarden soils, is used in many parts of Central America to increase the productivity of vegetable gardens and fruit trees. The high production of worm castings by certain earthworm species (e.g., the red Californian earthworm, *Allophora caliginosa*) is a source of cheap fertilizer for staple crops such as corn and sorghum (*Sorghum bicolor*). In rural areas of Nicaragua, some families sell the worm castings as organic manure (D. Craven, pers. comm., November 2005).

As mentioned above, in Mesoamerica the traditional agricultural knowledge existing in many regions that still carry the influence of ancient Mayan indigenous peoples includes management practices that improve nutrient cycling. Some management practices can be redirected or improved to optimize plant productivity in homegardens. Improved litter management and knowledge of the relative nutrient content of the litter from different species when used as mulch or compost may be one avenue for improving both water and nutrient cycling and homegarden production. Composting of homegarden litter, instead of burning it, would augment the amounts of nutrients recycled in the system. Water retention, by adding organic matter via compost, would help to improve water availability for plants, especially important in homegardens located in subhumid and semiarid regions of Mesoamerica.

Long-rotation production systems such as agroforests and homegardens can also sequester sizeable quantities of carbon in plant biomass and in long-lasting wood products (Albrecht and Kandji, 2003; Montagnini and Nair, 2004; Kumar, 2006). Many of the traditional homegardens already described share ecological characteristics and management practices that make them efficient in the use of solar radiation and carbon, and allow high levels of productivity. Soil carbon sequestration constitutes another realistic option achievable in homegardens.

7. CONCLUSIONS

The region of Mesoamerica suffers from social and environmental problems due to overpopulation and rural poverty. Under such conditions, homegardens have traditionally fulfilled and still provide an important function in terms of ensuring a basic food supply for the family. This is especially important in the remote areas such as in indigenous reserves or in other rural settings in the relatively more impoverished countries of the region.

Mesoamerican homegardens are quite diverse, with a complex vertical and horizontal structure that includes plants for food, ornamental, medicinal and other purposes. Mesoamerican homegardens are important reservoirs of local biodiversity and have a prominent role in the domestication of useful species.

Domestic animals in homegardens of Mesoamerica contribute to increased food security. Animal manure also contributes to nutrient recycling. The inclusion of domestic animals in homegardens is vital to ensure a more sustained protein supply. However, they require an investment for the care and management of animals that would be relatively large for the poor, rural households.

Mesoamerica was the home of the ancient Maya civilization, whose descendants still practice sustainable agriculture and manage homegardens in ways that increase the efficiency of the capture of solar radiation, increase productivity and improve nutrient cycling. Soil organic matter in homegardens can be increased by several practices of residue management. It is important that such sustainable management practices be retained to ensure homegarden sustainability. Homegardens of Mesoamerica also contribute to environmental services such as carbon sequestration, even though globally their role may be minimal due to their small land area.

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ENDNOTE

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