Tropical Homegardens

7

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Abstract

Agroforestry homegardens consist of multispecies combinations of a variety of economically useful plants including trees, shrubs, vines, and herbaceous species, often grown in association with livestock, in small landholdings around or adjacent to the home. These unique farming systems founded on generations of experience and traditional knowledge provide sustenance to billions of households in the humid and subhumid tropics and subtropics. Several types of homegardens have been identified according to their differences in size (area), form, layout, zonation pattern, species composition, management objectives, and the dominant plant species or the level of urbanization.

P. K. R. Nair et al., *An Introduction to Agroforestry*, https://doi.org/10.1007/978-3-030-75358-0_7

Some of the well-known homegardens, known by their locations, include those of Kerala (India), Java (Indonesia), Kandy (Sri Lanka), Chagga (Tanzania), Central America, and the Amazonia (Brazil), each with its unique historical as well as contemporary characteristics. Their enormous species diversity, which consists of food crops, medicinal plants, ornamentals, fruit trees, multipurpose trees, and fodder species, contributes to a variety of ecosystem services, and supports food-, and nutritional-, and livelihood security of millions of tropical smallholder farmers. Homegardens are also found in the temperate regions, but only to a limited extent in area and complexity compared to the tropics. Research on homegardens has mostly been limited to inventory and characterization of species diversity and descriptive accounts of ecosystem services. In the era of increasing emphasis on the market economy and yield maximization, the homegardens are not only being "ignored and left behind" but are also being transformed from their traditional subsistence outlook to market-oriented production enterprises.

7.1 Introduction

The term homegarden is used in agroforestry literature to denote a distinct form of land-use that represents one of the oldest forms of traditional land management in many tropical countries. Agroforestry homegardens should not be confused with ornamental gardens around homes, written as "home gardens" (two words).

Homegardens consist of multispecies combinations of a variety of economically useful plants including trees, shrubs, vines, and herbaceous species, often in association with livestock, in small landholdings around or adjacent to the home; photographs of two homegardens, one from Sri Lanka, and the other from Samoa are included as Figures 7.1 and 7.2, respectively. Considered a "time-tested example of sustainable agroforestry" (Kumar and Nair 2006), these unique farming systems founded on traditional knowledge systems and experiences acquired over generations have provided sustenance to billions of households in the tropics. In the humid- and sub-humid tropics where the homegardens are predominant, they account for a

Figure 7.1 A "typical" rural homegarden from Sri Lanka. (Photo: Focali: Forests, Landscapes and Livelihood research network – www.focali.se)

Figure 7.2 A multistory agroforestry homegarden in Samoa (Pacific Islands). The major species include *Artocarpus altilis* (breadfruit), *Cocos nucifera* (coconut), *Flueggea macrophylla* (bushweed), *Musa* spp. (banana/plantain), *Theobroma cacao* (cacao) and *Morinda citrifolia* (noni). (Photo: Craig Elevitch)

major share (up to 70% by some estimates) of contribution by smallholder farming systems to food production (see Chapter 8, Section 8.3; Chapter 23).

7.2 Global Distribution of Homegardens

Homegardens are most widespread in the tropics but can be found elsewhere too; a global distribution map is presented in Figure 7.3. South- and Southeast Asia; the Pacific islands; East-, West-, and Central Africa; the Caribbean and the Pacific Islands, and Mesoamerica are the major regions where tropical homegardens are common (Nair and Kumar 2006). Highly populated Java (population density: 1172/km^2: BPS 2018), Indonesia, and Kerala (population density: 860/km^2; https://www.census2011.co.in/census/state/kerala.html), India, are considered the two "hotspots" of tropical homegardens. In Java, the homegarden agroforests are estimated to cover about 20% of the arable land. In Kerala, it is critical to the local subsistence economy and food security for about 5.4 million small gardens (mostly less than 1.0 ha in area). Homegardening is also common in Central America, Amazonia, tropical and subtropical parts of China, the Mediterranean region of Catalonia, and many parts of Africa (Figure 7.3). *Streuobst*, a traditional multispecies gardening practice in several parts of Europe, is somewhat similar to tropical homegardening; see Chapter 10, Section 10.4.2: Herzog 1998). Indeed, EURAF (The European Federation of Agroforestry: see Chapter 10) has adopted the

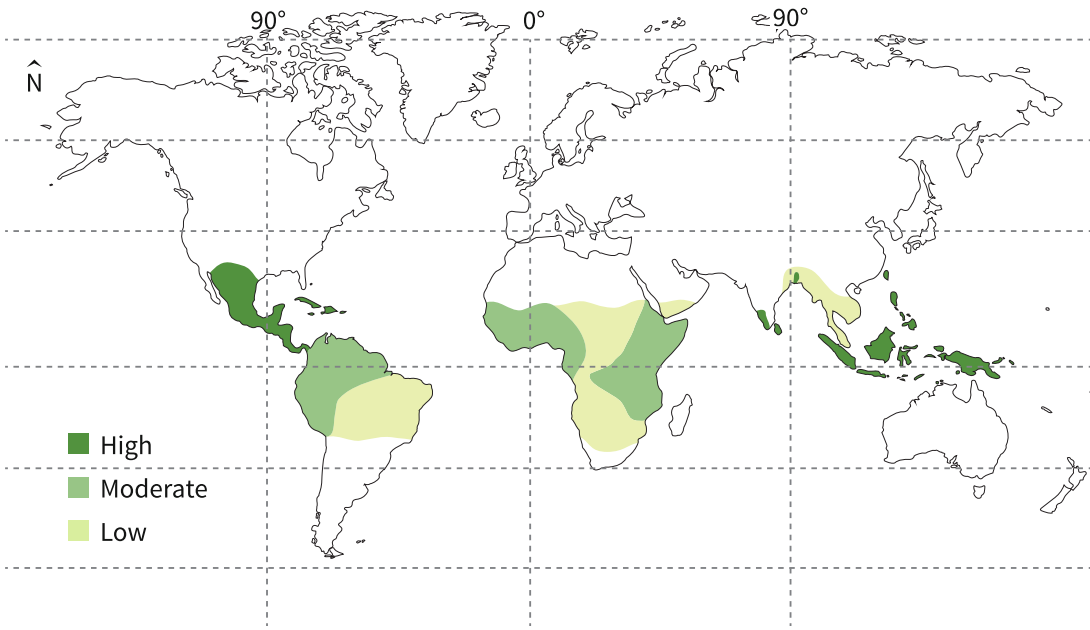

Figure 7.3 The global distribution of homegardens (Redrawn/Reprinted/Adapted by permission from Springer, Nair and Kumar (2006). European literature lists Homegardens as one (out of the five) of the major forms of agroforestry practices (see Chapter 3, Section 7). Some practices, described as *Streuobst* [Herzog (1998)] are also similar

term kitchen gardens as the synonym for homegardens and recognized it as one of the five agroforestry practices in Europe (Chapter 3, Section 3.8; Table 3.4). Although predominantly a rural practice, homegardening is gradually being extended to urban and peri-urban settings (see Section 7.4), with a commercial orientation (Nair 2006; Al-Kofahi et al. 2019). Despite the long history of economic and socio-cultural importance of homegardens for rural livelihood in many parts of the tropics, our understanding of the science underlying the practice is incomplete.

7.3 History, Evolution, and Distribution of Homegardens

Concrete evidence is not available on how, when, and where this land-use system originated. Archeological evidence from central India dating back to the Mesolithic period (10,000 to 4,000 BCE = BC) indicates that products from 63 species of fruit plants including *Phyllanthus emblica* (syn. *Emblica officinalis)*, *Mangifera indica*, *Ficus* sp., *Madhuca* sp., and *Ziziphus* sp. were consumed (eaten raw, ripe, roasted, or pickled) by the local inhabitants (Randhawa 1980). Literary evidence also suggests that homegardening in South Asia probably dates back to as early as 5,000 BCE (*cf.* Puri and Nair 2004). According to Wiersum (2006), homegardening was associated with the fishing communities inhabiting the moist tropical regions in Southeast Asia and it originated between 13,000 to 9,000 BCE, whereas Soemarwoto (1987) reported that the earliest available evidence of homegarden cultivation in Java, Indonesia, was around 3,000 BCE. Miller et al. (2006) suggest that the homegarden history in Amazonia corresponds with the evolution of agriculture and domestication of trees in ancient times, followed by the development of cultural complexes along the Amazon River and its main tributaries.

From the pre-historic and dispersed origins, homegardens have gradually spread to many humid and sub-humid regions especially in South- and Southeast Asia including Java (Indonesia), the Philippines, Thailand, Sri Lanka, India, and

Bangladesh. Suggesting the preponderance of homegardens in prehistoric India, Vatsyayana in his classical book – *Kamasutra* – a masterpiece of Sanskrit literature, written *ca*. 300 to 400 CE (= AD), portrays *house gardens* as a source of green vegetables, fig trees (*Ficus* spp.), mustard (*Brassica* spp.) and many other vegetables (*cf.* Randhawa 1980). Furthermore, Randhawa (1980) stated that early travelers (e.g., Ibn Battuta, Persian traveler: 1325–1354 CE) described homegardens with coconut (*Cocos nucifera*), black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), sugarcane (*Saccharum officinarum*) and pulses (grain legumes) in Kerala, India, in the early 14th century. Natural history studies in southern India during the late 1800s to early 1900s also suggest that societies habitually used their homesteads for a variety of needs such as food, energy, shelter, and medicines (Kumar and Nair 2004). Michon et al. (1983) allude that tree gardening systems were already widespread on the Indonesian island of Java in the tenth century CE.

Parallel to geographical expansion, the homegarden system has also evolved through successive generations of perpetual intensification of cropping in response to rising demographic pressure and the resultant scarcity of arable lands. In this context, the garden owners are often viewed as "perpetual experimenters" as they are persistently trying and evaluating new species, varieties, and technologies (Niñez 1987). A fresh species may be selected by the gardener because of its value in terms of food, wood, energy, medicinal, religious, ornamental, and based on self-instinct or knowledge passed on by kin and neighbors. This process eventually may have led to the development of complex multistory production systems in many parts of the tropics. Both the Javanese homegardens of Indonesia and the Kerala homegardens of India, the two prominent types of homegardens have seemingly developed over centuries of cultural and biological transformations and they represent the accrued wisdom and insights of farmers who have interacted with surroundings, lacking exogenous inputs, capital, or scientific skills (Kumar and Nair 2004). Socio-culturally also, agroforestry homegardens fit well with the prevailing farming systems and traditional village lifestyles, making it socially acceptable.

Homegardening is regarded as the earliest method of plant domestication. Domestication of fruit trees and tuber crops may have corresponded with one another as the hunter-gatherers used to collect both fruits and tubers from the forests. Gradually, however, the accidental dissemination of seeds became more purposive with key species planted to ensure their usufructs (Wiersum 2006). It is also probable that the prehistoric people may have impulsively selected trees with larger fruit size, better quality, or other desirable features from the wild, besides assisting in their regeneration. This, in turn, led to the cultivated populations becoming genetically distinct from their wild progenitors (Ladizinsky 1998).

While such "improvements" were occurring in the suite of cultivated species, the indigenous communities, over millennia, also interfered with the natural ecological processes of the forests in their subtle and persistent ways. For example, the pre-Columbian and contemporary Amazonian peoples managed the forest resources through practices such as species selection, tending, care, and management, thus promoting patches of domesticated forests around human settlements with one or a few useful species (Levis et al. 2018). This presumably must have given rise to the notion of "forest gardens," which is sometimes used synonymously with homegardens, as mentioned in the following section. Wiersum (2004) described forest gardens as "reconstructed natural forests, in which wild and cultivated plants coexist, such that the structural characteristics and ecological processes of natural forests are preserved, although the species composition has been adapted to suit human needs."

7.4 Types of Homegardens

Homegardens are known by various terms such as agroforestry homegardens, household or homestead farms, compound farms, backyard gardens, village forest gardens, dooryard gardens, and house gardens (Table 7.1). Some local names

Table 7.1 Homegarden terminology

Terms	Regions where it is predominantly used
Agroforestry homegardens	Most tropical and temperate countries
Backyard gardens	
Compound farms	
Dooryard gardens	
Homegardens	
Homestead farms	
House gardens	
Household gardens	
Kitchen gardens[1]	
Forest gardens or Village forest gardens[2]	Sri Lanka; Southeast Asia
Talun-Kebun[3]	Indonesia
Pekarangan[4]	
Shamba[5]	East Africa
Chagga homegarden[6]	
Huertos Familiare[7]	Mesoamerica
Food forests or Edible forest gardens[8]	Caribbean islands; Europe; North America
Streuobst[9]	Europe

[1]Vegetable cultivation areas adjacent to the kitchen
[2]Forest gardens or Village forest gardens are "intermediate" land-use systems in the nature-culture continuum and are defined as "reconstructed natural forests, in which wild and cultivated plants coexist, such that the structural characteristics and ecological processes of natural forests are preserved, although the species composition has been adapted to suit human needs" (Wiersum 2004)
[3]Rotational system between mixed gardens and tree plantations of Java
[4]The famous Javanese homegarden intercropping systems.
[5]A form of "taungya where agricultural crops are grown together with forest tree species, widespread in the high-potential areas of Kenya since the early 1900s" (Oduol 1986)
[6]A multi-storeyed cropping system practiced by the Chagga tribals on Mt. Kilimanjaro, Northern Tanzania
[7]Local name for homegarden systems in Mesoamerica
[8]Food forests are "low-maintenance and low-input agroforestry systems, characterized by a wide diversity of plant species" including fruit and food trees and also nonfood perennial hardwood trees (Beckford and Campbell 2013)
[9]A traditional system involving "tall trees of different types and varieties of fruit, belonging to different age groups, which are dispersed on cropland, meadows and pastures in a rather irregular pattern" (Herzog 1998) – similar to homegardens

such as *Talun-Kebun* and *Pekarangan* that are used for various types of homegarden systems of Java (Indonesia), *Shamba* and *Chagga* in East Africa, *Huertos Familiares* of Central America, and forest gardens in Sri Lanka, have also gained international acceptance because of the remarkable systems they symbolize. Although the nature and arrangement of components of the homegardens vary in different places depending on local ecology and socio-cultural traditions, they all represent complex, multispecies land-use systems that are intensively managed by the homeowner throughout the year for a variety of products that are mostly used for household consumption and sustenance. Figures 7.4 and 7.5 illustrate the diversity of species found in the homegardens of Kerala in southern India, and Jamaica in the Caribbean, respectively, which are just but two examples of the multispecies, multistory canopy configurations of tropical homegarden systems.

In general, differences in size, form, layout, zonation pattern, species composition, and management objectives abound in the homegardens. Accordingly, several homegarden types have been recognized, which generally reflect differences in size (area) of gardens and the dominant plant species or the level of urbanization. Based on zonation, diversity, total garden area, and socioeconomic functions, Mendez et al. (2001)

Figure 7.4 A multistory homegarden in Kerala, India. The ubiquitous coconut palms (*Cocos nucifera*) are a prominent component of the Kerala homegardens and are grown in association with several annual and perennial species of different forms; see also Chapter 8. (Photo: BM Kumar)

Figure 7.5 A multistory homegarden in Jamaica: Breadfruit trees (*Artocarpus altilis*) occupies the top tier of this multistrata canopy arrangement with cacao (*Theobroma cacao*), avocado (*Persea americana*), and other medium-tall trees in the next lower canopy tier. Below that layer are plantains (*Musa* spp.), papaya (*Carica papaya*), and similar other fruit plants. Fodder grasses (*Panicum* sp.), pineapple (*Ananas comosus*), and short-statured annuals such as tuber crops occupy the lowest canopy floor along the plot boundary. (Photo: PKR Nair)

attempted a cluster analysis to designate homegarden types. They recognized six types of Nicaraguan homegardens: ornamental, handcrafting (providing space and shade for handicraft manufacturing), subsistence, handcrafting and mixed production (for consumption and income), mixed production, and minimal management. Wiersum (2006) suggested four types of homegardens: survival, subsistence, market, and budget gardens. Based on a Hierarchical Ascendant Correspondence Analysis, Caballero-Serrano et al. (2016) grouped the Amazonian homegardens into three categories: small (recent), medium (established), and large (transitional) gardens. Proximity to urban centers is yet another criterion used to classify the homegarden systems into *urban* (within city limits), *peri-urban* (places on the fringes of urban areas), and *rural* (village) types. Some authors reported that the homegardens located near the urban centers contain fewer species and a larger number of ornamental and commercial plants than those in rural areas, implying that the focus of urban homegardens is more on provisioning services, e.g., production of marketable fruits, vegetables, and other edible products (Clarke et al. 2014). The urban homegardens unlike their village counterparts are also usually smaller in size. In general, the distinctions among the garden types mentioned above are somewhat fuzzy and such categorizations are arbitrary.

7.5 Ecology and Structure

Ecologists consider homegardens as "steady-state" systems, where photosynthetic production matches respiratory losses, i.e., inputs balance outputs, with structural attributes analogous to those of natural forest ecosystems (Kumar and Nair 2004). Selected ecological characteristics of homegardens concerning those of agricultural and forest systems are presented in Table 7.2, indicating the similarities between homegardens and natural forest ecosystems. Homegardens, especially of the so-called forest-garden type, which represents the "intermediate land-use systems in the nature-culture continuum" (Wiersum 2004), could resemble young secondary forests both in structure and total biomass store and may be considered as a man-made forest kept in a permanent early-successional state (Jensen 1993).

Homegardens are time-honored examples of sustainable agroforestry. Kumar and Nair (2004) described it as "the epitome of sustainability in managed land-use systems," implying that it is perhaps the most sustainable among all managed land-use systems. Their remarkable species- diversity, closed nutrient cycling, and low "nutrient export" through harvested products are the major traits that impart sustainability to these systems. Unlike monospecific production systems, homegardens combine the ecological functions with the socioeconomic welfare of the landowners, implying both ecological and socioeconomic sustainability. Ewel (1999) described such land-use systems "structurally and functionally the closest mimics of natural forests yet attained," while Nair (2017) deems the managed multi-strata tree + crop systems in the tropics (e.g., coconut-palm-based multispecies homegardens and shaded perennial systems) as an "agroecological marvel".

7.5.1 Floristic Diversity

A prominent structural attribute of tropical homegardens is the great diversity of species ranging from herbaceous plants to climbers and tall trees, consisting of food crops, medicinal plants, ornamentals, fruit trees, multipurpose trees, and fodder species (Table 7.3). Based on surveys in over 400 homegardens (with a total area of 45.2 ha) in southwestern Bangladesh, Webb and Kabir (2009) recognized as many as 419 species (59% native, 51% trees and shrubs) – of which six were on the IUCN Red List for Bangladesh[1]. Enormous variations also exist in homegarden species within and across regions, making each garden a unique entity (Kumar and Nair 2004). Many factors contribute to such

[1] The IUCN Red List – https://www.iucnredlist.org – provides the most comprehensive inventory of threatened biological species in the world.

Table 7.2 A comparison of the ecological attributes of climax forests, homegardens, and conventional agricultural systems (monocropping)

Parameter	Natural climax vegetation	Homegardens	Conventional agric. systems
Biogeochemistry	Nutrient inputs equal outputs	Inputs and outputs balance each other	Outputs far exceed inputs
Biotic stress	Low	Low	High
Canopy architecture	Multistrata	Multistrata	One- or two-layered
Disturbance regimes	Rare (except natural disturbances, such as tree fall)	Intermediate	High
Diversity	High	Intermediate	Low
Ecological succession	Normally uninterrupted; reaches a stable climax-stage	Consciously manipulated	Arrested, beyond the early stage
Entropy	Low	Low to high	High
Floristic spectrum	Shade tolerant and intolerant	shade tolerant to intolerant	Mostly shade-intolerant
Input use	No external inputs;	Low	High
Site quality	Progressive improvements (e.g. facilitation)	Progressive improvement	Steady decline
Standing biomass/net primary productivity (NPP)	Highest among the terrestrial ecosystems (mean NPP: 2000 g m^{-2} $year^{-1}$)	Comparable to climax formations, but NPP estimates are lacking (standing biomass stock in Kerala homegardens: 32.6 to 71.6 Mg ha^{-1}, Kumar 2011)	Low (mean NPP: 650 g m^{-2} $year^{-1}$; Leith 1975)
Sustainability	High	Medium to high	Low to medium

Source: Adapted from Kumar and Nair (2004)

Table 7.3 Commonly reported plants in homegardens of humid tropical lowlands

Category	Species in homegardens
Root and tuber crops	*Colocasia esculenta* (taro), *Dioscorea alata* (greater yam), *Dioscorea esculenta* (sweet yam), *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava), *Xanthosoma* spp. (tannia or cocoyam)
Other food crops	*Ananas comosus* (pineapple), *Arachis hypogaea* (peanuts), *Cajanus cajan* (pigeon pea), *Passiflora edulis* (passion fruit), *Phaseolus, Psophocarpus* and *Vigna* spp. (beans and other legumes), *Saccharum officinarum* (sugarcane), *Zea mays* (corn = maize), and various vegetables
Fruit and nut yielding perennials	*Anacardium occidentale* (cashew nut), *Annona* spp. (soursop and sweetsop), *Averrhoa carambola* (carambola), *Artocarpus heterophyllus* (jack fruit), *A. altilis* (breadfruit), *Carica papaya* (papaya), *Citrus* spp.(lemon, lime, orange, tangerin), *Cocos nucifera* (coconut), *Ficus* spp. (edible figs), *Mangifera indica* (mango), *Musa* spp. (bananas and plantains), *Persea americana* (avocado), *Psidium guajava* (guava), *Spondias dulcis* (vi apple, hogplum), *Syzygium malaccense* (Malay apple), *Tamarindus indica* (tamarind)
Spices, Social beverages, and stimulants	*Areca catechu* (betel nut), *Cinnamomum zeylanicum* (cinnamon), *Curcuma longa* (turmeric), *Cymbopogon citratus* (lemon grass), *Piper betle* (betel vine), *Piper methysticum* (kava), *Zingiber officinale* (ginger).

Source: Adapted from Nair (2006)

variations, the most important being the preferences of gardeners and the size and age of the gardens. Each species within a garden is chosen to fulfill a specific function or an ecosystem service (e.g., food, wood, medicinal, religious, ornamental values). The introduction of new species may also occur at any time of the year (Yamamoto et al. 1991), depending on the specific properties/uses of the species in question, and regardless of whether they are native or exotic. Serrano-Ysunza et al. (2018), in a longitudinal study on agrobiodiversity changes in homegardens of Tabasco, Mexico, found that species that disappear at some periods may reappear with time.

Some reports are available on the relationships between the number of woody species and the homegarden's size and age (e.g., Tolera et al. 2008). The direct relationship between the size of the garden and woody species richness (total number of species) is understandable because larger areas available allow the landowner to grow more species. However, the relationship between the age of the garden and species richness is more complex. The term age of the garden by itself is difficult-to-explain unless the garden is of the "first-generation" type, i.e., established directly after forest clearance. Tolera et al. (2008) determined the age of crop fields and homegardens since conversion from the natural forest using a chronosequence approach based on information from key informants combined with interpretation of aerial photographs of the area. Kumar (2011) reported, however, that while the woody species richness of homegardens within a region may increase with the size of the holding, the scenario will be different when the species richness is considered on a unit area basis. As shown in Figure 7.6, the total species (plant)

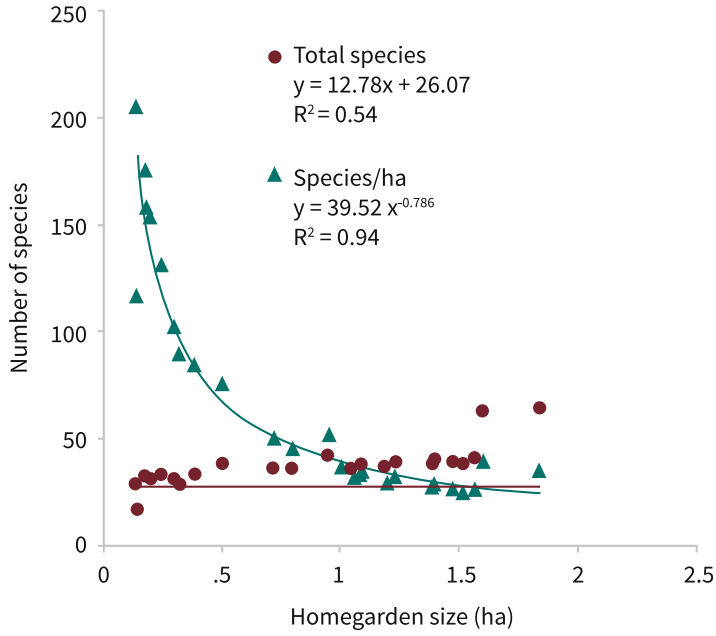

Figure 7.6 The relationship between species richness and the size of homegardens in Kerala, India. Species richness is the number of species, or simply a count of the botanical species; it does not represent the abundance of the species. In the figure, "Total species" means the total number of species (botanical) in a garden, and "Species/ha" means the number of botanical species per ha (estimated by dividing the total number of species per garden by the size of the garden and extrapolating to a hectare-basis). Note that although the total number of species per garden is somewhat similar between the smaller (< 0.5 ha) and larger (>1.0 ha) gardens, the total number of species per hectare is much more in the smaller gardens than in the larger gardens. Source: Adapted from Kumar (2011) with permission from Elsevier

count or richness expressed on a unit area (hectare) basis was considerably higher in smaller gardens although the total number of botanical species (on a unit-area basis) is somewhat similar between the smaller (< 0.5 ha) and larger (>1.0 ha) gardens. This shows that owners of the small homegardens grow a wide spectrum of plants at higher planting density compared to owners of the larger homegardens. Increased plant density as well as diversity may be the smallholder farmers' strategy to maximize total farm production.

Species composition of homegardens depends both on its position in the overall farming system and the livelihood strategies of the farmers (Wiersum 2006). Specific needs and preferences of the household and nutritional complementarity with other major food sources, besides ecological and socioeconomic factors, are key processes in this respect. Das and Das (2015) suggested that factors such as proximity to urban areas, market access, and geographical and social isolation, besides the size of the homegardens play a major role in determining the diversity of homegardens. Other socioeconomic and sociocultural aspects such as ethnicity, education level, gender, occupation of the owners, and biophysical attributes such as altitude may also impact homegarden floristics. Another important factor that influences species diversity is the intensification of agricultural production and the associated introduction of species with high commercial value, especially near urban centers. Proximity to urban centers and the propensity of farmers to introduce species with high commercial value are generally regarded as drivers of the homegarden diversity decline phenomenon.

A shift from subsistence agriculture to market economy often underlies homogenization (i.e., transformations generally aimed at simplified cropping systems) of the homegarden structure and increased use of external inputs (Kumar and Nair 2004). Homogenization of agricultural landscapes owing to commercial simplification is a widespread concern in many parts of the world. Indeed, Abebe et al. (2013) observed that the introduction of new cash and annual food crops into the homegardens of southern Ethiopia "could jeopardize the integrity and complexity of the system, which has been responsible for its sustenance." Societal processes of rural transformations and globalization, therefore, may alter homegarden floristics and their contribution to agrobiodiversity conservation (Serrano-Ysunza et al. 2018). Such changes in homegarden species composition and richness are sometimes viewed as reflections of the homegardeners' ability to continuously refine and adapt their livelihood strategies and preferences in the wake of quick social, economic, and cultural transformations of rural territories (e.g., Zimmerer 2007; Buchmann 2009; Hecht 2010).

Another remarkable attribute of the homegardens is the great diversity of *landraces* and cultivars that highlight intraspecific variability of species. In a study on Amazonian Dark Earth homegardens (see also Chapter 20, Section 20.6.1), Junqueira et al. (2016) reported that the farmers recognized different landraces for 33 species, and some species such as banana (*Musa* spp.) had as many as 20 landraces, signifying the existence of enormous diversity at the intraspecific level in the homegardens of Amazonia and elsewhere. Moreover, homegardens are reported to help conserve many rare and endangered species (Watson and Eyzaguirre 2002; Gunawan et al. 2004). Webb and Kabir (2009) suggested that the profound variability in homegarden floristic richness across sites and regions generally indicates that "under some circumstances tropical homegardens exhibit high levels of plant diversity and serve as a repository for rare and threatened species." The complex vegetation structure of homegardens may also provide habitat for different bird species (Parikesit et al. 2004) as well as wildlife (Perfecto and Vandermeer 2008). Overall, tropical homegardens are splendid illustrations of maintaining species diversity in cultivated and managed landscapes.

7.5.2 Vegetation Structure

Vegetation structure refers to the arrangement of various floristic elements of the gardens and the age- or size-class distribution of the woody

components. Two aspects of structure are often recognized: vertical (i.e., how the tree and crop strata are vertically oriented) and horizontal (i.e., how the various components of the garden are placed or zoned laterally). Indeed, the structure and composition (diversity and the nature of components involved) of homegardens are tightly interrelated and influenced by numerous socioeconomic and biophysical factors. The multi-tiered and judiciously managed canopy architecture (Figures 7.4 and 7.5) is perhaps the most distinguishing feature of humid tropical lowland gardens. Most authors delineate a three-to-six-strata system, with about three quarters to full ground coverage (Kumar and Nair 2004; Mohri et al. 2018). The vertical stratification provides a gradient in light and relative humidity, which produces diverse niches allowing many species assemblages to flourish, with the shade-tolerant species occupying the lower stratum, shade-intolerant trees in the upper layer, and species with varying degrees of shade tolerance in the intermediate levels. Variations from this general pattern of multi-tiered canopy architecture also exist. For example, in the Mediterranean (Catalonia, Spain) and the arid tropical (Soqotra island, Yemen) gardens, stratification is typically restricted to a lower stratum of herbs and shrubs and a higher one of trees (Agelet et al. 2000; Ceccolini 2002). The Vietnamese *Vuon-Ao-Chuong* system (VAC or Garden-Pond-Livestock pen systems) is another case in point with a simple vertical structure (Mohri et al. 2018). Garden age and management are cardinal factors that impact the vegetation structure. Older gardens, regardless of size, may evolve a multistrata canopy structure, while younger gardens may have a simpler vertical stratification.

Discrete horizontal zonation patterns also occur in the homegardens, and their position, extent and species composition reflect careful managerial approaches. For example, the Javanese and Kandyan homegardens not only exhibit a complex horizontal zoning but also a multilevel vertical structure with a variety of species (Mohri et al. 2013). The number of such management zones per homegarden is also variable: it may range from two to six, with a mode value of three (Kumar and Nair 2004). In general, food- and fruit-producing species dominate the zone adjoining the residential quarter and working areas, and small plots of annual crops separate this part of the garden from the more distant parts usually allocated to woody perennials. Medicinal and ornamental species are typically cultivated in small areas or pots surrounding the house, and vegetables in areas adjacent to the kitchen. Multipurpose tree and shrub species used as live fences are usually planted on farm boundaries regardless of holding size. Trees also may be scattered throughout the homestead or at specific points to offer or elude shade, essential or detrimental to various plants, besides providing support for climbers (e.g., *Piper nigrum*). Plants that are included in different zones generally mirror the farmer's management priorities and socioeconomic needs. Possibly, a large number of species are planted in distinctive patterns unique to each homegarden to optimize space, light, water, and fertilizer requirements. On another note, while an archetypal homegarden may characterize a delineated area (fenced-in or bounded by field risers), often it is not easy to differentiate the homegarden boundaries from the adjoining arable cropping area (Figures 7.7, 7.8, and 7.9).

7.5.3 Ecosystem Services

The role of agroforestry systems in providing a range of ecosystem services is well recognized; the nature and extent of such services provided by different agroforestry systems including homegardens are discussed in Section V of this book, Chapters 19–22. Briefly, these include various provisioning services such as the production of food, fuel, fodder, medicines, ornamental plants, green manure, and timber resources; regulating services including the maintenance of soil fertility, erosion control, watershed protection, and microclimate modification, as well as the provision of shade and fencing, pest regulation, pollination, and climate and environmental resilience; and cultural services such as aesthetics, recreational and spiritual values. The most significant

Figure 7.7 Terraced rice fields in the foreground and coconut-dominated homegardens in the background in Bali, Indonesia. (Photo: Craig Elevitch)

Figure 7.8 Rice in the foreground with a multistory homegarden consisting of various short and tall species in the elevated field behind the rice field in Bangladesh. (Photo: PKR Nair)

Figure 7.9 Homegarden-rice paddy continuum – Vietnam. (Photo: ICRAF/Southest Asia, and Prasit Wangpakapattanwong, FAO)

role of homegardens, however, is in ensuring food and nutritional security for millions of tropical smallholder farmers who are the major practitioners of homegardening; these issues are discussed in Chapter 23.

7.6 Commercialization of Homegardens

Commercialization refers to the production of crops for sale in the market rather than for household consumption. While the traditional homegardens mostly represent smallholder production systems of the subsistence or non-commercial type, large homegardens with a higher proportion of commercial crops have also become common lately. Adoption of input-intensive, new technologies to maximize productivity is an intrinsic feature of the commercial systems. This, in turn, has transformed many traditional (subsistence) homegardens into production systems that are designed primarily to meet the need for more cash income. For example, commercialization has caused a decline in the structure and functions of the Indonesian *pekarangan* and *talun-kebun* systems (Abdoellah et al. 2006). Commercial gardens are characterized by lower species diversity and a greater number of plants (usually of the same species) per garden (Table 7.4; see also Section 7.5.1). Consequently, a few plant species dominate such homegardens, which may gradually acquire the characteristics of monocultures. Examples include the gardens containing commercial crops such as vegetables that are in high demand in urban markets of West Java, Indonesia (Abdoellah et al. 2006). Mellisse et al. (2018) reported that transition

Table 7.4 Plant diversity parameters in commercial and non-commercial homegardens in Sukapura village, West Java, Indonesia

Structural attributes	Commercial homegardens (n = 35)	Non-commercial homegardens (n = 59)
Area (m^2)		
Average	461.5	270.7
Range (min.–max.)	120–2000	85–1400
Number of species		
Total	145	181
Average	15.71	15.37
Range (min.–max.)	4–49	4–41
Number of all plants		
Average	1227	66
Range (min.–max.)	95–8388	6–159
Shannon–Wiener diversity index		
Average	1.11	2.03
Range (min.–max.)	0.16–2.00	0.96–3.12
Pielou's evenness index		
Average	0.42	0.78
Range (min. –max.)	0.07–0.86	0.39–0.95

Source: Adapted from Abdoellah et al. (2006). For the vegetation survey, the authors randomly selected 94 households out of 3433 and recorded the species name, number of individuals of each species per plot/farm, number of structural layers based on plant height, and the plant category based on the main use (Vegetable, Ornamental, Food, Fruit, Spices, Medicinal, Building material and other species). Homegardens were defined as "commercial" (if more than half of the products from the homegarden were sold for cash) or "non-commercial" (if more than half of the products were consumed by the family). Cash crops such as vegetables were usually found in the lowest layer (less than 1 m tall; 88.6% of the total). "Range" under "Number of all plants" represents the total number of plants per garden

Table 7.5 Annual dry matter yield of different crops, farm-level energy productivity of food crops, and total revenue for the different homegarden systems in southern Ethiopia

Homegarden systems	Total crop yield (annual dry matter kg ha^{-1})	Energy productivity of food crops (GJ ha^{-1})	Revenue (US$ ha^{-1})
Khat-based (n = 18)	$2438^{b} \pm 427$	$20^{b} \pm 8$	$6817^{a} \pm 1842$
Enset-cereal-vegetable (n = 9)	$3021^{a} \pm 813$	$21^{b} \pm 6$	$1675^{b} \pm 567$
Enset-based (n = 9)	$2864^{ab} \pm 426$	$43^{a} \pm 17$	$719^{c} \pm 346$
Enset-coffee (n = 18)	$1817^{c} \pm 372$	$17^{b} \pm 7$	$1763^{b} \pm 843$
Enset-livestock (n = 9)	$2540^{b} \pm 701$	$20^{b} \pm 7$	$2368^{b} \pm 1305$

Khat = *Catha edulis*, Enset = *Enset ventricosum* and coffee = *Coffea arabica*
Values in cells represent mean followed by standard deviation (n = 63). Means with different superscripts within a column are significantly different between homegarden types at $P < 0.05$
Source: Adapted from Mellisse et al. (2018)

from the traditional enset (*Enset ventricosum*) + coffee (*Coffea arabica*) homegarden systems to *khat* (*Catha edulis*)-based and enset-cereal-vegetable systems (commercial) in the southern highlands of Ethiopia has led to a decline in livestock herds and a shift from organic manure to inorganic fertilizer use. Despite this, the latter two systems (i.e., *khat*-based and enset-cereal-vegetable systems) showed better productivity and provided better food security than the traditional enset-coffee systems (Table 7.5), partly because of the superior purchasing power it offers to the owners of such gardens. Wiersum (2006) describes that such changes in homegarden characteristics may mirror the quest for a new equilibrium in the relationship between urban and rural areas. On the other hand, others (e.g., Parikesit et al. 2004) perceive such changes as a

loss to traditional characters of the system that are rooted in history and culture and demand the need for revitalizing them.

7.7 Major Tropical Homegarden Systems

As mentioned, species composition, management practices, age structure, and size of homegardens are profoundly variable, even within a region, making each garden a unique entity. As a result, the homegardens of different geographical regions show considerable variations. But multi-functionality, multi-tiered canopy architecture, complementary resource use, agrobiodiversity conservation, predominantly subsistence nature of the system, and the role of women in land management are the underlying principles that bind them. Some of the prominent homegarden systems around the world are briefly described in the ensuing section.

7.7.1 Homegardens of Kerala (India)

As stated, the southern Indian state of Kerala is one of the two "hotspots" of tropical homegardens. Although homegardening is popular elsewhere in India too, particularly the eastern and north-eastern regions, the Kerala homegardens have become more widely known. Since time immemorial, these multifunctional homegardens have continued to be a ubiquitous feature of Kerala's landscape. Despite the drastic changes in the land-use patterns in Kerala since the mid-1900s, the homegardens are still important for providing subsistence and cash returns to farm families. The coconut palms form the dominant, central component occurring in 97% of the homegardens, and other components – both perennial and annual species – are integrated with the palms (Nair 1983, Jose and Shanmugaratnam 1993; Fox et al. 2017). Other common tree crops in the gardens include commercial species such as the areca palm (*Areca catechu*) and Para rubber tree (*Hevea brasiliensis*). Banana, jackfruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*), and other multipurpose trees are also important components.

7.7.2 Javanese Homegardens of Indonesia

The Javanese words *Pekarangan* (homegarden) and *Talun-kebun* (bamboo-tree gardens) are often used synonymously with the word homegarden. Just as in the case of Kerala homegardens, the Javanese homegardens are legendary, centuries-old constituents of the rural ecosystems in Java and involve a mixture of annual and perennial plants harvested on a daily or seasonal basis. According to ancient records, homegardens of Java started as community spaces linked to temples, palaces, and homes (Mohri et al. 2018). Homegardening is popular elsewhere in the Indonesian archipelago too (e.g., Sumatra). With the government-policies to promote transmigration of families from the heavily populated Java to other islands, the Javanese homegardens are being "replicated" in other regions of the Indonesian archipelago by the Javanese peasant settlers.

Apart from their economic and ecological functions, the homegardens also play important social and recreational roles in rural societies. For example, the Javanese homegarden is an important locale for socialization with family, friends, and neighbors (Soemarwoto 1987). In Java, homegardens and bamboo-tree gardens are an important status symbol too. People who do not have a homegarden are generally not ranked high in social esteem. The homegardens also play an important role in the inheritance system of the Javanese society; being a family asset inherited through generations, such gardens are seldom alienated (Parikesit et al. 2004).

Damar agroforests of Sumatra: The damar (*Shorea javanica*) agroforests of Sumatra and elsewhere in Indonesia are a variant of the homegarden system (Figure 7.10). The farmers have established these forest gardens by planting damar trees in upland swidden rice fields. The damar tree yields a resin, locally known as *damar mata kucing* in Sumatra. It is used in the production of incense, varnish, paint, and

Figure 7.10 Damar (*Shorea javanica*) agroforestry gardens in Sumatra, Indonesia. (Photo: E. Torquebiau)

cosmetics. Traditionally, the resin used to be collected from the damar trees in the natural forests. However, as the wild resources were dwindling, attempts were made to establish damar gardens. Kusters et al. (2008), while describing the system, stated that it is "a showcase win-win example of a land-use system with both economic and environmental benefits". Harvest of resin from damar trees constitutes the principal source of household cash income (see also Chapter 11, Section 11.5.9).

7.7.3 Polynesian Homegardens

Homegardens are pervasive in the Pacific island landscapes, from the very densely populated urban areas in atoll microstates, such as South Tarawa, Kiribati, Fogafale Islet on Funafuti Atoll, Tuvalu, and RETA in northeast Majuro Atoll, Marshall Islands to rural villages and plantations in areas of low population density in Fiji, Vanuatu, and Papua New Guinea (Thaman et al. 2006; Elevitch 2007, 2011). They generally involve an array of food trees, non-tree staple and supplementary food plants, medicinal plants, and other non-food trees and plants of cultural and commercial significance (Figures 7.2 and 7.10). As in other homegarden systems, ornamental plants, medicinal and aromatic plants, sacred plants, and other culturally valuable multipurpose plants, are common components of the system.

Agrodeforestation (loss of tree cover from the agricultural landscape) has been a critical problem in the urban and peri-urban areas of these islands (Thaman et al. 2006). The principal drivers for exacerbating the problem include rising population pressure, poverty, and the need for fuelwood; expanding squatter settlements; nonexistence of rules for regulating tree removal; increasing dependence on root crops such as cassava and sweet potatoes (*Ipomoea batatas*); and the loss of traditional knowledge on the importance of trees in the context of rapid urbanization. In the rural areas, promotion of a wide range of export cash crops (e.g., coconut, banana,

cacao (*Theobroma cacao*), sugarcane (*Saccharum officinarum*), coffee (*Coffea* spp.), ginger (*Zingiber officinale*), and butter pumpkin (*Curcurbita maxima*) has led to clearing of diverse agroforests (Thaman et al. 2006).

7.7.4 The Shamba and Chagga Gardens of East Africa

The *Shamba* and *Chagga* are two types of traditional homegardens that are popular in East Africa. The *Shamba*, which is also considered a form of *taungya* system (Chapter 5, Figure 5.12), involves growing agricultural crops together with forest tree species; it used to be widespread in the high-potential areas of Kenya, but is less popular now. The *Chagga* homegardens, on the other hand, are still widespread on the slopes of Mt. Kilimanjaro, especially on the upper southern slopes. These gardens have been nurtured by the *Chagga* tribe for more than a century. Much like the other homegarden systems, the *Chagga* homegardens are also located close to family dwellings (Figure 7.11). Just as the Javanese homegardens (Section 7.7.2), the *Chagga* gardens play important social and recreational roles too apart from their economic and ecological functions (see Chapter 22, Figure 22.7). The gardens mostly involve cultivation of perennial crops such as banana and coffee, and some annual crops such as maize (*Zea mays*) and beans (*Phaseolus vulgaris*). Trees and shrubs are planted both on the farm boundaries and as scattered trees inside the homegardens. A. Hemp (2005a) and C. Hemp (2005b) have reported that the typical feature of the *Chagga* homegardens is their multilayered vegetation structure similar to a tropical montane forest with trees, shrubs, lianas, epiphytes, herbs. The boundary planted trees are also intensively lopped and pruned (Chapter 11, Figure 11.4). Livestock such as cattle and goats form an integral part of the garden, which are usually stall-fed (Fernandes et al. 1984; Fernandes and Nair 1986; Hemp 2005a, 2005b; Ichinose et al. 2020). The crop residues and tree leaves serve as feedstock for livestock, and the animal dung, feed residues, and crop residues are recycled as organic manures – the only source of soil nourishment in the homegardens and other smallholder farm production systems of Africa (Zingore et al. 2007; Ichinose et al. 2020). The conversion of these traditional homegarden areas into maize production has become widespread since the 1990s following the crash in coffee

Figure 7.11 The *Chagga* homegardens in the foothills of Mt Kilimanjaro, Tanzania are a unique homegarden system. (Photo: Andreas Hemp)

prices in the international markets (Soini 2005), an oft-cited example of a shift in the land-use dynamics of the traditional homegardens as a function of market forces.

7.7.5 The Sri Lankan Homegardens

Homegardens account for about 14.8% of the total land area in Sri Lanka and provide approximately 42% of the country's wood and wood products (FAO 2009). A subset of the Sri Lankan homegarden is the *Kandyan* homegardens (Figure 7.1), which originated in the historical *Kandyan* Kingdom and the adjoining regions. As elsewhere, the Sri Lankan homegardens are smallholder production systems providing a multiplicity of goods and services. These multi-strata systems, involving associations of annual and perennial crops, livestock, and occasionally fish, function as a supplemental source of food and income for households at low input costs daily. According to Mattsson et al. (2018), homegardens in Sri Lanka, "are the poor farmers' insurance and safety-net in dire food situations, giving additional nutrition and calories". Several governmental programs in Sri Lanka, therefore, have incorporated homegardening as a key element to support food and nutritional security. Besides, homegardens figure prominently in Sri Lanka's Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change, UN REDD+ program to reduce emissions from deforestation and forest degradation and the National Adaptation Plan for Climate Change (NAP) 2016–2025 (Mattsson et al. 2018).

7.7.6 Central American Homegardens

The Mayan civilization, which practiced sustainable agriculture for centuries, involving many indigenous crops and soil protection approaches, evolved in Mesoamerica. Within this region in the Mayan domain, diverse native groups, descendants of the ancient Maya, established multi-strata homegardens to fully exploit the available solar radiation. Montagnini (2006) has acclaimed them as the world's most diverse homegardening system. This region is also heavily populated; poverty and malnutrition co-exist both in the urban and rural areas. The Mesoamerican homegardens also exhibit widely varying vertical and horizontal structure and species composition (Rico-Gray et al. 1990). Conventionally, households establish several agricultural subsystems such as "milpa" (outfield extensive slash and burn agricultural areas), homegardens, beehives, irrigated orchards, and hunting areas. Furthermore, the Mayan lowland orchards and homegardens have been considered crucial for the semi-intensive production of commercial crops such as cacao, annatto (*Bixa orellana*), and vanilla (*Vanilla planifolia*) during the 16th and 17th centuries (Castro et al. 2018). In recent decades, however, owing to the social and economic changes in the Yucatan Peninsula (Mexico) caused by tourism, improved roadways, and expanding urban centers, the Mayan homegardens are undergoing major changes (Martínez-Ballesté et al. 2006).

7.7.7 Homegardens in the Brazilian Amazon

Homegardens constitute a dominant land-use system in the Brazilian Amazon since time immemorial. Recent archeological studies have indicated the importance of polycultures (homegardens) in the pre-Columbian land use of eastern Amazon (Maezumi et al. 2018). Indeed, the adoption of polyculture agroforestry – combining the cultivation of multiple annual crops with progressive enrichment of edible forest species and the exploitation of aquatic resources – was associated with the development of complex societies in the Amazon region, as early as ~4,500 years ago. This legacy of pre-Columbian land use on the modern vegetation composition of Amazonia, however, has been a source of debate for long. Some authors argue that the hyper-dominance of edible plants in the modern forests of eastern Amazon presumably is an enduring legacy of the persistent anthropogenic landscapes for the past 4,500 years (ter Steege et al. 2013). Anthropological and ethno-

biological literature reviewed by Miller and Nair (2006) also indicates the existence of a great variety of indigenous agroforestry practices in Amazonia, ranging from deliberate planting of trees in homegardens and fields to the management of volunteer seedlings of both cultivated and wild species. These practices result in various configurations of agroforestry systems, such as homegardens, tree/crop combinations in fields, orchards of mixed fruit trees, and enriched fallows.

7.8 Research on Homegarden Systems

Despite being one of the oldest land-use systems in the tropics, research on homegardens is of relatively recent origin. The first available report dates back to the 1940s when Terra (1953, 1958) initiated investigations on mixed-garden horticulture in Java, Indonesia. Following that, Ruthenberg (1980) evaluated tropical mixed-species cropping systems in the 1970s and similar work was pursued at many institutions around the tropics; for example, The Institute of Ecology, Bandung, Indonesia (Soemarwoto 1987); the Central Plantation Crops Research Institute, Kasaragod, Kerala, India (Nair 1979); and elsewhere (e.g., Michon et al. 1983). The global inventory of agroforestry systems by ICRAF (International Centre for Research in Agroforestry) gave a further fillip to such efforts (Nair 1987), and several descriptions and syntheses of traditional homegarden systems followed (Nair 1989). Kumar and Nair (2004) summarized the patterns and trends in homegarden research during the previous 25 years and concluded that quantitative data on the biogeochemical and physiological processes in tropical homegardens are severely inadequate. Although tropical homegardens are a hot topic of discussion in most agroforestry conferences especially those covering humid tropical lowlands, focused research on the topic has, unfortunately, not gathered momentum possibly due to lack of institutional and policy support. Some notable publications on the topic include the proceedings of two international workshops: Landauer and Brazil (1990) based on the 1984 workshop in Bandung, Indonesia; and Watson and Eyzaguirre (2002) based on a 2001 workshop in Witzenhausen, Germany. Yet another collection of papers on the focal theme of this chapter is by Kumar and Nair (2006), based mostly on the presentations in a technical session on the topic at the First World Congress on Agroforestry, Orlando, Florida, 2004.

Historically, homegarden research mostly dealt with system descriptions and inventories. Agroforestry literature is replete with references to such accounts. Structural complexity and multifunctionality are intrinsic features of tropical homegardens, which received some attention. Other focal themes include food and nutritional security of the gardeners and other ecosystems services provided by the homegardens. Besides recording the local practices and species inventory, studies over the past 3 to 4 decades also highlighted the need for conservation of biocultural diversity (i.e., diversity exhibited by coupled or interacting natural systems and human cultures) and highlighted the sociocultural dimensions of agrobiodiversity conservation, and the conventional uses of various plants.

7.9 Concluding Remarks

Homegardens have been globally recognized as harbingers of agrobiodiversity and providers of ecosystem services. They have also been acclaimed to mimic the structural and functional attributes of natural ecosystems, but that has been mentioned as a probable reason to "frustrate the development community that seeks out replicable models of development" (Nair and Kumar 2006). Furthermore, in the era of increasing emphasis on the market economy and yield maximization, the homegardens are not only being "ignored and left behind" but are also being transformed from their traditional subsistence outlook to market-oriented production enterprises. Such a drastic transformation will, unfortunately, lead to irreparable loss of

genetic resources, biodiversity, traditional knowledge, and all such values of the homegardens that cannot be simply described by a price tag. All is not doom and gloom, however. There is a very welcome development that the message of homegardens seems to be getting recognized and appreciated in some industrialized countries and mega-urban centers of the world. Interest in sustainable land-use and organic farming is increasing rapidly in such industrialized societies. Urban food gardens are getting popularized under various labels in several megacities around the world as an approach to reconnect urban societies to nature. Perhaps the message and lessons that can be learned from the traditional homegardens hold their rightly deserving bright future.

References

Abdoellah O, Hadikusumah H, Takeuchi K, Okubo S, Parikesit P (2006) Commercialization of homegardens in an Indonesian village: vegetation composition and functional changes. Agrofor Syst 68:1–13. https://doi.org/10.1007/s10457-005-7475-x

Abebe T, Sterck FJ, Wiersum KF, Bongers F (2013) Diversity, composition and density of trees and shrubs in agroforestry homegardens in southern Ethiopia. Agrofor Syst 87:1283–1293. https://doi.org/10.1007/s10457-013-9637-6

Agelet A, Angels BM, Valles J (2000) Homegardens and their role as a main source of medicinal plants in mountain regions of Catalonia (Iberian peninsula). Econ Bot 54:295–309. https://doi.org/10.1007/BF02864783

Al-Kofahi SD, Gharaibeh AA, Bsoul EY, Othman YA, Hilaire RS (2019) Investigating domestic gardens' densities, spatial distribution and types among city districts. Urban Ecosyst 22(3):567–581. https://doi.org/10.1007/s11252-019-0833-7

Beckford CL, Campbell DR. (2013) Food Forests and Home Gardens: Their Roles and Functions in Domestic Food Production and Food Security in the Caribbean. In: Domestic Food Production and Food Security in the Caribbean. Palgrave Macmillan, New York, pp 95–107. https://doi.org/10.1057/9781137296993_8

BPS (2018) Proyeksi Penduduk Indonesia. 2015–2045. isbn: 978-602-438-189-9. No: Publication: 04110.1801. Jakarta, Indonesia

Buchmann C (2009) Cuban home gardens and their role in social-ecological resilience. Hum Ecol 37:705–721. https://doi.org/10.1007/s10745-009-9283-9

Caballero-Serrano V, Onaindia M, Alday JG, Caballero D, Carrasco JC, McLaren B, Amigo J (2016) Plant diversity and ecosystem services in Amazonian homegardens of Ecuador. Agric Ecosyst Environ 225:116–125. https://doi.org/10.1016/j.agee.2016.04.005

Castro A, Lascurain-Rangel M, Gomez-Dıaz JA, Sosa V (2018) Mayan homegardens in decline: the case of the pitahaya (*Hylocereus undatus*), a vine cactus with edible fruit. Trop Conserv Sci 11:1–10. https://doi.org/10.1177/1940082918808730

Ceccolini L (2002) The homegardens of Soqotra island, Yemen: an example of agroforestry approach to multiple land use in an isolated location. Agrofor Syst 56:107–115. https://doi.org/10.1023/A:1021365308193

Clarke LW, Li L, Jenerette GD, Yu Z (2014) Drivers of plant biodiversity and ecosystem service production in home gardens across the Beijing Municipality of China. Urban Ecosyst 17:741–760. https://doi.org/10.1007/s11252-014-0351-6

Das T, Das AK (2015) Conservation of plant diversity in rural homegardens with cultural and geographical variation in three districts of Barak Valley, Northeast India. Econ Bot 69(1):57–71. https://doi.org/10.1007/s12231-015-9299-6

Elevitch CR (ed) (2007) Traditional trees of Pacific Islands: their culture, environment, and use. Permanent Agriculture Resources, Holualoa, 800 p

Elevitch CR (ed) (2011) Specialty crops for Pacific Islands. Permanent Agriculture Resources, Holualoa, 558 p

Ewel JJ (1999) Natural systems as models for the design of sustainable systems of land use. Agrofor Syst 45:1–21. https://doi.org/10.1023/A:1006219721151

FAO (2009) The state of food and agriculture. www.fao.org/3/i0680e/i086e.pdf

Fernandes ECM, Nair PKR (1986) An evaluation of the structure and function of tropical homegardens. Agric Syst 21:279–310. https://doi.org/10.1016/0308-521X(86)90104-6

Fernandes ECM, O'Kting'ati A, Maghembe J (1984) The Chagga homegardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro, Northern Tanzania. Agrofor Syst 2:73–86. https://doi.org/10.1007/BF00131267

Fox TA, Rhemtulla JM, Ramankutty N, Lesk C, Coyle T, Kunhamu TK (2017) Agricultural land-use change in Kerala, India: perspectives from above and below the canopy. Agric Ecosyst Environ 245:1–10. https://doi.org/10.1016/j.agee.2017.05.002

Gunawan B, Takeuchi K, Tsunekawa A, Abdoellah OS (2004) Community dependency on forest resources in West Java, Indonesia: the need to re-involve local people in forest management. J Sust For 18(4):29–40. https://doi.org/10.1300/J091v18n04_02

Hecht S (2010) The new rurality: globalization, peasants and the paradoxes of landscapes. Land Use Policy 27:161–169. https://doi.org/10.1016/j.landusepol.2009.08.010

Hemp A (2005a) The banana forests of Kilimanjaro: biodiversity and conservation of the Chagga homegardens. Biodivers Conserv. https://doi.org/10.1007/s10531-004-8230-8

Hemp C (2005b) The Chagga homegardens – relict areas for endemic Saltatoria species (Insecta: Orthoptera) on Mount Kilimanjaro. Biol Conserv 125:203–209. https://doi.org/10.1016/j.biocon.2005.03.018

Herzog F (1998) Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe. Agrofor Syst 42:61–80. https://doi.org/10.1023/A:1006152127824

Ichinose Y, Nishigaki T, Kilasara M, Funakawa S (2020) Central roles of livestock and land-use in soil fertility of traditional homegardens on Mount Kilimanjaro. Agrofor Syst 94:1–14. https://doi.org/10.1007/s10457-019-00357-9

Jensen M (1993) Soil conditions, vegetation structure and biomass of a Javanese homegarden. Agrofor Syst 24:171–186. https://doi.org/10.1007/BF00706890

Jose D, Shanmugaratnam N (1993) Traditional homegardens of Kerala: a sustainable human ecosystem. Agrofor Syst 24:203–213. https://doi.org/10.1007/BF00706892

Junqueira AB, Souza NB, Stomph TJ, Almekinders CJM, Clement CR, Struik PC (2016) Soil fertility gradients shape the agrobiodiversity of Amazonian homegardens. Agric Ecosyst Environ 221:270–281. https://doi.org/10.1016/j.agee.2016.01.002

Kumar BM (2011) Species richness and aboveground carbon stocks in the homegardens of Central Kerala, India. Agric Ecosyst Environ 140:430–440. https://doi.org/10.1016/j.agee.2011.01.006

Kumar BM, Nair PKR (2004) The enigma of tropical homegardens. Agrofor Syst 61:135–152. https://doi.org/10.1023/B:AGFO.0000028995.13227.ca

Kusters K, Ruiz Pérez M, de Foresta H, Dietz T, Ros-Tonen M, Belcher B, Manalu P, Nawir A, Wollenberg E (2008) Will agroforests vanish? The case of damar agroforests in Indonesia. Hum Ecol 36 (3):357–370. https://doi.org/10.1007/s10745-008-9168-3

Ladizinsky G (1998) Plant evolution under domestication. Kluwer, Dordrecht, pp 4–9

Landauer K, Brazil M (eds) (1990) Tropical homegardens. United Nations University Press, Tokyo, 257 pp

Leith H (1975) Primary production of major vegetation units of the world. In: Leith H, Whittaker RH (eds) Primary productivity of the biosphere, Springer-Verlag, New York, pp 203–215

Levis C, Flores BM, Moreira PA, Luize BG, Alves RP, Franco-Moraes J, Lins J, Konings E, Peña-Claros M, Bongers F, Costa FRC, Clement CR (2018) How people domesticated Amazonian forests. Front Ecol Evol 5:171. https://doi.org/10.3389/fevo.2017.00171

Maezumi SY, Alves D, Robinson M, de Souza JG, Levis C, Barnett RL, Almeida de Oliveira E, Urrego D, Schaan D, Iriarte J (2018) The legacy of 4,500 years of polyculture agroforestry in the eastern Amazon. Nat Plants 4(8):540–547. https://doi.org/10.1038/s41477-018-0205-y

Martínez-Ballesté A, Martorell C, Caballero J (2006) Cultural or ecological sustainability? The effect of cultural change on Sabal palm management among the lowland Maya of Mexico. Ecol Soc 11:27. https://doi.org/10.5751/ES-01803-110227

Mattsson E, Ostwald M, Nissanka SP (2018) What is good about Sri Lankan homegardens with regards to food security? A synthesis of the current scientific knowledge of a multifunctional land-use system. Agrofor Syst 92:1469–1484. https://doi.org/10.1007/s10457-017-0093-6

Mellisse BT, Descheemaeker K, Giller KE, Abebe T, van de Ven GWJ (2018) Are traditional home gardens in southern Ethiopia heading for extinction? Implications for productivity, plant species richness and food security. Agric Ecosyst Environ 252:1–13. https://doi.org/10.1016/j.agee.2017.09.026

Mendez VE, Lok R, Somarriba E (2001) Interdisciplinary analysis of homegardens in Nicaragua: micro-zonation, plant use and socioeconomic importance. Agrofor Syst 51:85–96. https://doi.org/10.1023/A:1010622430223

Michon G, Bompard J, Hecketsweiler P, Ducatillion C (1983) Tropical forest architectural analysis applied to agroforests in the humid tropics, the example of traditional village agroforestry in West Java. Agrofor Syst 1:117–129. https://doi.org/10.1007/BF00596353

Miller RP, Nair PKR (2006) Indigenous agroforestry systems in Amazonia: from prehistory to today. Agrofor Syst 66:151–164. https://doi.org/10.1007/s10457-005-6074-1

Miller RP, Penn JW Jr, van Leeuwen J (2006) Amazonian homegardens: their ethnohistory and potential contribution to agroforestry development. In: Kumar BM, Nair PKR (eds) Tropical homegardens: a time-tested example of sustainable agroforestry. Springer, Dordrecht, pp 43–60. https://doi.org/10.1007/978-1-4020-4948-4_4

Mohri H, Lahoti S, Saito O, Mahalingam A, Gunatilleke N, Irham, Hoang VT, Hitinayake G, Takeuchi K, Herath S (2013) Assessment of ecosystem services in homegarden systems in Indonesia, Sri Lanka, and Vietnam. Ecosyst Serv 5(4):124–136. https://doi.org/10.1016/j.ecoser.2013.07.006

Mohri H, Landreth N, Lahoti S, Saito O, Hitinayake G, Gunatilleke N, Irham, Thang HV, Takeuchi K (2018) Ecosystem services of traditional homegardens in South and Southeast Asia. In: Takeuchi K et al (eds) Resilient Asia, science for sustainable societies. Springer, Tokyo, pp 95–121. https://doi.org/10.1007/978-4-431-56597-0_6

Montagnini F (2006) Homegardens of Mesoamerica: biodiversity, food security, and nutrient management. In: Kumar BM, Nair PKR (eds) Tropical homegardens, Advances in agroforestry, vol 3. Springer, Dordrecht, pp 61–84. https://doi.org/10.1007/978-1-4020-4948-4_5

Nair PKR (1979) Intensive multiple cropping with coconuts in India: principles, programmes and prospects. Verlag Paul Parey, Berlin, 147 pp

Nair PKR (1983) Agroforestry with coconuts and other tropical plantation crops. In: Huxley PA (ed) Plant research and agroforestry. ICRAF, Nairobi, pp 79–102
Nair PKR (1987) Agroforestry systems inventory. Agrofor Syst 5:301–317. https://doi.org/10.1007/BF00119128
Nair PKR (ed) (1989) Agroforestry systems in the tropics. Kluwer, Dordrecht, 664 pp
Nair PKR (2006) Whither homegardens? In Tropical homegardens: a time-tested example of sustainable agroforestry. In: Kumar BM, Nair PKR (eds) pp. 355–370. Springer, Dordrecht. doi: https://doi.org/10.1007/978-1-4020-4948-4_20
Nair PKR (2017) Managed multi-strata tree + crop systems: an agroecological marvel. Front Environ Sci 5:1–5. https://doi.org/10.3389/fenvs.2017.00088
Nair PKR, Kumar BM (2006) Introduction. In: Kumar BM, Nair PKR (eds) Tropical homegardens: a time-tested example of sustainable agroforestry. Springer, Dordrecht, pp 1–10. https://doi.org/10.1007/978-1-4020-4948-4_1
Niñez VK (1987) Household gardens: theoretical and policy considerations. Agric Syst 23:167–186. https://doi.org/10.1016/0308-521X(87)90064-3
Oduol PA (1986) The Shamba system: an indigenous system of food production from forest areas in Kenya Agroforest Syst 4:365–373. https://doi.org/10.1007/BF00048108
Parikesit TK, Tsunekawa A, Abdoellah OS (2004) Kebon tatangkalan: a disappearing agroforest in the Upper Citarum Watershed, West Java, Indonesia. Agrofor Syst 63:171–182. https://doi.org/10.1007/s10457-004-1182-x
Perfecto I, Vandermeer J (2008) Biodiversity conservation in tropical agroecosystems: a new conservation paradigm. Ann N Y Acad Sci 1134:173–200. https://doi.org/10.1196/annals.1439.011
Puri S, Nair PKR (2004) Agroforestry research for development in India: 25 years of experiences of a national program. Agrofor Syst 61:437–452. https://doi.org/10.1023/B:AGFO.0000029014.66729.e0
Randhawa MS (1980) A history of Indian agriculture, vol. 1 (Beginning to 12 century) & vol 2, (Eighth to eighteenth century). Indian Council of Agricultural Research, New Delhi, vol 1:414–415; vol 2:67–68; 98–99
Rico-Gray V, Garcia FJG, Chemas A, Puch A, Sima P (1990) Species composition, similarity, and structure of Mayan homegardens in Tixpeual and Tixcacaltuyub, Yucatan, Mexico. Econ Bot 44:470–487. https://doi.org/10.1007/BF02859784
Ruthenberg H (1980) Farming systems in the tropics, 3rd edn. Clarendon Press, Oxford, 424 pp
Serrano-Ysunza AA, van der Wal H, Gallardo-Cruz JA, Ramos-Munoz DE, Vaca RA (2018) A 6-year longitudinal study on agrobiodiversity change in homegardens in Tabasco, Mexico. Agrofor Syst 92(6):1485–1494. https://doi.org/10.1007/s10457-017-0094-5
Soemarwoto O (1987) Homegardens: a traditional agroforestry system with a promising future. In: Steppler HA, Nair PKR (eds) Agroforestry: a decade of development. ICRAF, Nairobi, pp 157–170
Soini E (2005) Land use change patterns and livelihood dynamics on the slopes of Mt. Kilimanjaro, Tanzania. Agric Syst 85:306–323. https://doi.org/10.1016/j.agsy.2005.06.013
ter Steege H, Pitman NCA, Sabatier D et al. (2013) Hyperdominance in the Amazonian tree flora. Science 342:325–347, 1243092. https://doi.org/10.1126/science.1243092
Terra GJA (1953) Mixed-garden horticulture in Java. Malayan J Trop Geogr 1:33–43
Terra GJA (1958) Farm systems in Southeast Asia. Neth J Agric Sci 6:157–182
Thaman RR, Elevitch CR, Kennedy J (2006) Urban and homegarden agroforestry in the pacific islands: current status and future prospects. In: Kumar BM, PKR N (eds) Tropical homegardens: a time-tested example of sustainable agroforestry. Springer, Dordrecht, pp 25–42. https://doi.org/10.1007/978-1-4020-4948-4_3
Tolera M, Asfaw Z, Lemenih M, Karltun E (2008) Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. Agric Ecosyst Environ 128:52–58. https://doi.org/10.1016/j.agee.2008.05.001
Watson JW, Eyzaguirre PB (eds) (2002) Homegardens and in situ conservation of plant genetic resources in farming systems. Proceedings of the second international homegarden workshop, 17–19 July 2001, Witzenhausen, Germany; International Plant Genetic Resources Institute, Rome 184 pp
Webb EL, Kabir ME (2009) Homegardening for tropical biodiversity conservation. Conserv Biol 23:1641–1644. https://doi.org/10.1111/j.1523-1739.2009.01267.x
Wiersum K (2004) Forest gardens as an 'intermediate' land-use system in the nature–culture continuum: characteristics and future potential. Agrofor Syst 61:123–134. https://doi.org/10.1023/B:AGFO.0000028994.54710.44
Wiersum KF (2006) Diversity and change in homegarden cultivation in Indonesia. In: Kumar BM, Nair PKR (eds) Tropical homegardens: a time-tested example of sustainable agroforestry. Springer, Dordrecht, pp 13–24. https://doi.org/10.1007/978-1-4020-4948-4_2
Yamamoto Y, Kubota N, Ogo T, Priyono (1991) Changes in the structure of homegardens under different climatic conditions in Java Island. Jpn J Trop Agric 35:104–117
Zimmerer KS (2007) Agriculture, livelihoods, and globalization: the analysis of new trajectories (and avoidance of just-so stories) of human-environment change and conservation. Agric Hum Values 24:9–16. https://doi.org/10.1007/s10460-006-9028
Zingore S, Murwira HK, Delve RJ, Giller KE (2007) Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. Agric Ecosyst Environ 119:112–126. https://doi.org/10.1016/j.agee.2006.06.019