Chapter 6
Ecosystem Services of Traditional Homegardens in South and Southeast Asia

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Abstract Among homegarden research, few studies assess and compare ecosystem services provided by different systems. This chapter discusses the similarity and differences in structural characteristics, functions, ecosystem services, and biodiversity of different homegarden systems across Indonesia, Sri Lanka, and Vietnam. A case study on Sri Lanka highlights how we can apply ecosystem service

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assessments to better understand drivers of changes for these homegarden systems and adapt them to economic, social, and environmental changes to continue to enhance rural livelihoods.

Keywords Homegardens · Ecosystem assessment · Ecosystem services · Agrodiversity · Adaptation

Contents

6.1 Introduction

A homegarden is a small-scale agricultural system that provides various goods and services, including secondary sources of food and income, and often also mimics aspects of natural forest systems (Hoogerbrugge and Fresco 1993). Soemarwoto and Christanty (1985) define a homegarden as *a land-use system with a structure resembling a forest that combines the natural architecture of a forest with species fulfilling the social, economic, and cultural needs of people*. Soemarwoto and Conway (1992) also define homegardens as agro-socio-ecological systems with plants and animals as an integral part of the system along with humans. They produce a variety of fruits, vegetables, fibers, and non-timber products to support family diet and provide additional income. Homegardens are distributed around the world, but are predominantly a tropical phenomenon, considered among the oldest type of land-use system after shifting cultivation (Kumar and Nair 2004).

Past research on homegardens has typically focused on functional, ecological, or structural components specific to a study area (e.g., Phong et al. 2010; Kehlenbeck et al. 2007; Abdoellah et al. 2006; Phong et al. 2006; Ueda 1996; Soemarwoto and Conway 1992; Karyono 1981; Wiersum 1977). Some recent research on agroforestry and traditional production systems has also begun to consider the capacity of homegardens to help adapt to ecosystem and climate change-related challenges (Rao et al. 2007; Takeuchi 2010). However, the uniqueness of households and their homegardens has made it difficult to implement commonly accepted research frameworks and methods for understanding homegardens, despite their structural and functional similarities (Kumar and Nair 2004). The objective of this paper is to apply a common ecosystem services-based framework to homegarden research, including:

(a) To investigate the diversity of scale, structure, and function in homegarden systems of South and Southeast Asia
(b) To understand drivers of changes and some strategies to enhance these homegarden systems based on a case study of Sri Lanka

6.2 Methodology and Materials

6.2.1 Methodology

To evaluate the interactions between different ecosystem services provided by homegarden systems and to identify the drivers of change, the study used the Millennium Ecosystem Assessment (MA) framework (MA 2003, 2005). The framework focuses on linkages and dynamic interactions between ecosystem services and human well-being (MA 2005).

An extensive literature review examined 104 books, peer-reviewed journal articles, and conference papers (Mohri et al. 2013). The distribution of publications was diverse in terms of publication year and theme, and almost equal numbers of literature for study areas were referenced to identify components, spatial layout, temporal/spatial scales, diversity, and functions of each system by country. Additionally, field observation and professional workshops were conducted between 2011 and 2012 in each country, as shown in Table 6.1. The case study focuses on Sri Lanka to identify the role of homegardens and potential strategies to enhance homegarden systems. Two major field surveys were conducted in the Kandy area, and the northern part of Sri Lanka. Details of surveys are described later in this paper.

6.3 Traditional Homegarden Systems in Indonesia, Vietnam, and Sri Lanka

As a traditional land-use system, homegardens have evolved from prehistoric times through ancient civilizations to the modern era (Mohri et al. 2013). This study focuses on one particular kind of homegarden in three countries: the Pekarangan (Java, Indonesia), Kandyan (Sri Lanka), and VAC systems (Vietnam). Each has different characteristics reflecting their socioeconomic and geographic conditions.

Indonesia is the world's largest island nation with diverse land-use systems and bio-production systems. In this study, we focus on Pekarangan, a traditional homegarden system in Java, which is generally managed by individuals who grow various products for subsistence purpose (Wiersum 2006). Ancient records indicate the homegardens of Java originated as public space associated with temple precincts and have been attached to palaces and homes (Mohri et al. 2013).

Sri Lanka has the highest rural population among Asian nations (World Bank 2011). Kandyan homegardens play a key role to link agricultural and natural landscapes and provide a secondary source of income in the country's midlands (Pushpakumara et al. 2010). Historic evidence of gardens similar to present-day Kandyan homegardens can be found in the ancient epic Ramayana (Puri and Nair 2004; Kumar and Nair 2004). Kandyan homegardens are multi-structured plots

Table 6.1 Biophysical and socioeconomic features of homegardens in the study area

Characteristics	Javanese homegardens	Kandyan homegardens	VAC system
Location/ country	Indonesia	Sri Lanka	Vietnam
Local name	Pekarangan	Kandyan gardens	VAC system
Population density (km²)	700[1]	500–699	1.1–13.9 (person/ha)[5]
Eco-zone	Humid; medium altitude and lowlands	Humid; medium altitude	Red River Delta, tropical to subtropical; midlands, tropical and subtropical; lowlands, tropical; Mekong Delta, tropical
Rainfall (mm)	1800–2400	2000–2500	1388–1900
Altitude range (m amsl)	0–600[1]	400–1000	1–80
Temperature (°C)	22–29	24–26	26–29.5
Relative humidity (%)	Average 75	65–80 (day) and 75–90 (night)	82
Number of vertical canopy	5[1]	3–5	N/A
Dominant soil type	Reddish brown latosol to brown latosols	Reddish brown latosol to immature brown loam	North, loam and sandy loam; central, Bazan; south, alluvial clay; Mekong Delta, clay
Slope of land (%)	Varied	10–40	Varied
Land tenure	Privately owned[2]	Mainly privately owned	Privately owned (allocated by government)
Typology	Traditional and commercial		Traditional, commercial, mixed
Market orientation	Subsistence/commercial	Commercial with subsidiary subsistence	Subsistence/commercial
Net income	6.6–55.7% of total income with an average of 21.1% depending on size, family needs, and composition of homegardens[3]	30–50% of household income[4]	30–60% of family income

Adapted from Mohri et al. (2013)
Sources: [1]Fernandes and Nair (1986), [2]Wiersum (1982), [3]Soemarwoto (1987), [4]Pushpakumara et al. (2010), [5]General Statistics Office of Vietnam (2013)

established around rural homes, with a deliberate mix of indigenous and exotic species providing multiple uses and ecosystem services (Gunatilleke et al. 1993).

Vietnam is a large rice-exporting country with rapid economic growth. Changing economic policies have driven significant change in rural land-use and traditional bio-production systems, including the Vuon-Ao-Chuong system (VAC system, or Garden-Pond-Livestock pen in English, also known as traditional integrated agriculture-aquaculture, or IAA). The VAC system originated in the Red River Delta and midlands of Northern Vietnam and uses household land for various agri-aquaculture activities (Trinh et al. 2003). Implementation of the national government's Doi Moi policy in 1986 promoted the VAC system to improve and stabilize the nutritional and dietary standards of the rural poor (Luu 2001). This policy resulted in extensive coverage of integrated VAC farming across Vietnam, especially in irrigated lowlands, rain-fed uplands, and semi-urban areas (Luu 2001; Nguyen 1997; Phong et al. 2003; Phong et al. 2010).

6.3.1 Diversity in Scale, Structure, and Function of Homegarden Systems

Each homegarden has different characteristics that typically vary by geographic location, climate, culture, government policy, and socioeconomic context.

6.3.1.1 Spatial Scale: Homegarden Size

Homegarden land area differs depending upon the climate, soil type, topography, rainfall, economic activity, and culture of the study area (Mohri et al. 2013). Twenty percent of total area in Java is occupied by homegardens (Wiersum 1980; Terra 1954). Around 70% of households in the Kandy area have homegardens (Mohri et al. 2013), covering around 30% of Kandy District (Forestry Sector Master Plan 1995). Almost 44% of households now have a VAC system. The average homegarden area is 0.6 ha and 0.4 ha in Java and Kandy, respectively. In Vietnam, the VAC system has spread irregularly across the country, and so the average size is difficult to establish. Vietnam's Mekong region typically has larger homegardens and pond sizes than the northern part (Trinh et al. 2003).

6.3.1.2 Temporal Scale: Labor and Time

Homegardens require little time and labor relative to primary farming activities and are mostly maintained by household members during free time to flexible schedules. Labor time differs by size, farming intensity, number of family members, and their primary occupation (Torquebiau 1992). In Kandy, additional labor is hired for skilled operations (Jacob and Alles 1987) such as harvesting cash crops. VAC homegardens are maintained by family members.

6.3.2 Structure of Homegarden Systems

The vertical and horizontal structures of homegardens vary according to the sociocultural, economic, and ecological attributes of communities (Abdoellah et al. 2001). The Javanese and Kandyan homegardens have a complex horizontal zoning and multilevel vertical structure with a variety of species, resulting in a virtually closed canopy structure (Mohri et al. 2013). VAC systems have a simpler vertical structure. The vertical structure and main species present at different levels of the homegardens is shown in Table 6.2. A large number of species are planted in patterns unique to each homegarden to maximize space, light, water, and fertilizer requirements (Christanty et al. 1986).

6.3.3 Homegarden Functions

Wiersum (2006) highlighted the importance of livelihood conditions and household economy in determining the structure and composition of Javanese homegardens. Wiersum suggested four types of homegardens: survival, subsistence, market, and budget gardens. In Kandy, homegardens may be forested areas near the house or also include small areas of paddy in nearby valleys (McConnell 1992). In Vietnam, VAC systems vary by geography, the local commune's policy, and personal decisions (Edwards 2010). For example, coastal VAC systems focus on aquaculture, and mountainside VAC systems focus on farming and forestry (An 1997). Some VAC systems have diversified by improving commercial productivity ("improved VAC") (Edwards 2010) or incorporating forestry (RVAC) and biogas (VACB) (Ueda 1996; Zhu 2006).

6.3.4 Ecosystem Services Provided from Homegarden Systems

Homegardens are managed and modified ecosystems providing a range of services that directly benefit households but are also an important habitat for maintaining and conserving local biodiversity and source of other regulating and supporting services. The below section briefly describes the provisioning, regulating, cultural, and supporting services provided by homegardens.

Table 6.2 Vertical stratification in homegarden systems

Stratum	Height in meters (m)	Javanese homegardens	Kandyan homegardens	VAC
Level 1 – ground level	<3 m	Starchy food plants, vegetables, and spices – Languas, ganyong, *Xanthosoma*, cassava, sweet potatoes, taro, chili peppers, egg-plant, spinach, and wing bean	Vegetables, medicines, species, fruits trees, subsistence, and cash crops – okra, eggplant, beans, tea, cassava, ginger, turmeric, *Anthurium*, pineapple, and chili peppers	Flowers, medicinal plants, herbs, spices, fruits, plants in the pond (or on the banker), and vegetables
Level 2 – lower stratum	3–10 m	Fruit trees and cash crops – bananas, papayas, mango, jack-fruit, and other fruit trees; soursop, jack-fruit, pisitan guava, and mountain apple; or other cash crops such as cloves	Medicines, food staple, subsistence, and cash crops – vanilla, banana/plantain, cacao, coffee, passion fruit, betel vine	Fruits trees – *Lucuma mammosa*, orange, tangerine, grapefruit, longan, rambutan, kapok, and water apple; Bamboo, cashew, *Acacia aneura*
Level 3 – lower-middle stratum	10–15 m	Other trees for build-ing material and fuel wood – coconut trees and other trees (e.g., *Albizia*)	Subsistence food sta-ple, seasonal fruits, and cash crop – papaya, pepper, avocado, man-gosteen, breadfruit, rambutan, citrus	Coconut, areca, bam-boo, eucalypts, caje-put, and *Calophyllum inophyllum*
Level 4 – upper-middle stratum	15–25 m		Fruits, timber, medi-cines, cash crops – mango, bamboo, areca palm, nutmeg, clove, rubber, wild breadfruit, kitul palm	
Level 5 – upper stratum	25–30 m		Timber, cash crops, fiber, and oil seed crops – durian, talipot palm, jak, coconut palm, kapok, pepper	

Adapted from (Mohri et al. 2013)
Sources: Christanty et al. (1986), McConnell (2003), Trinh et al. (2003), An (1997)

6.3.4.1 Provisioning Services

Provisioning services are the resources supplied by homegardens to human communities, such as food, timber, fuel wood, water, and natural medicines (Mohri et al. 2013). Table 6.3 summarizes the various provisioning services and species composition found in homegardens.

Table 6.3 Provisioning services provided from homegarden systems

Provisioning services			Javanese homegardens	Kandyan homegardens	VAC system
Food	*Crops*	*Major food crops*	Rice, maize, coconuts, taro, sweet potato, cassava, yam, ganyong, spinach, wing bean, eggplant, leafy vegetables, etc.	Rice, maize, green gram, cowpeas, cassava, coconut, jackfruit, sweet potato, taro, yam, juggary, and treacle from fish tail palm	Rice, corn, sweet potato, citrus, black bean, cassava, yam, banana, coconut, jackfruit, banana, luffa, orange pomelo, longan, kumquat, spinach
		Major cash crops	Coconut, banana, orange, mango, jackfruit, papaya, guava, coffee, clove, etc.	Cacao, cloves, cocoa, coconut, banana, coffee, jackfruit, mahogany, nutmeg, pepper and other spices, teak, jak, etc.	Bamboo, pineapple, jackfruit, guava, papaya, banana, lime, orange, pomelo, lychee, pear chilies, kangkong (in the fishpond), etc [8]
	Livestock		Chickens, cows, goats, and sheep[7]	Poultry and cattle[5]: 15% of householders rear livestock[1]	Buffalo, cow, pig, chicken, duck[10]
	Aquaculture		Fishpond as a part of system	NA	Carps, robu, mrigal, mud carp, tilapia (limited number of case), soft shell turtle, frogs, snakehead fish, and catfish[8]
	Wild plant and animal food products		Weed species used for herbal medicine, roofing, vegetables, and fodder[7]	Local breeds of chicken, eggs, goat, and cow milk[4]	Guava, vegetables, longan, lychee, chilies, cassava, bamboo [9]
Fiber	*Timber*		Important source of building material, e.g., *Sandoricum koetjape*, *Crescentia cujete*, jackfruit	Supplies 48% of the total sawlog demand of the country[3]	Importance source of building materials and sawlog
	Fuel wood		Supplies 40–80% of the rural fuel wood [6], e.g., Laban, bamboo, *Muntingia calabura*	Supplies 38% of the total biomass fuel demand of the country[3]	Block wattle, *Litchi*, guava, *Melia azedarach*, *Casuarina equisetifolia*, *Mangifera*, and bamboo[8]
Genetic resources			Provides habitat for small wild animals such as birds, reptiles, and amphibians	Provides habitat for a wide range of species, from soil micro life to insects, including pollinators, and from crops, trees to mammals, birds, and other wildlife[4]	Provides habitat for small wild animals such as birds, reptiles, amphibians, and insects and plant crops

(continued)

Table 6.3 (continued)

Provisioning services	Javanese homegardens	Kandyan homegardens	VAC system
Natural medicines	Extracts from medicinal plant provide treatment against various diseases and are consumed as a way of healthy life style	Most herbs and trees are used medicinally[1], e.g., turmeric, ginger, vanilla, areca palm, clove, nutmeg, etc.	Plenty herbs and medicinal plants used medicinally such as ginger, clove, *Artemisia*, etc.
Nutrition	Supplies 18% calories and 14% proteins [2], and provides vegetable proteins, carbohydrates, vitamins, and minerals	NA	NA

Adapted from (Mohri et al. 2013)
Sources: [1]Pushpakumara et al. (2010), [2]Ochse and Terra (1937), [3]Gunathilleke (1994), [4]Pushpakumara (2000), [5]Perera and Perera (1997), [6]Wiersum (1977), [7]Soemarwoto et al. (1985), [8]Vien (2003), [9]Trinh et al. (2003), [10]Luu (2001)

Livestock are an integral part of some homegardens, and their selection is determined by sociocultural, environmental, financial, and religious concerns (Soemarwoto 1987). These mainly provide nutritional security but also a source of additional income. Waste is also used for manure to maintain soil fertility and sustain production. The livestock component has relatively less importance in Javanese and Kandyan homegardens (McConnell 2003) but plays an important role in VAC systems. VAC systems often also include aquaculture ponds.

Homegarden fiber is an important source of fuel wood and timber for rural households. Wiersum (1977) found that homegardens are important to fulfill energy demands of rural households. In Sri Lanka, Kandyan homegardens are considered the most important source of fiber in non-forest land (Gunathilleke 1994). Northern mountainous areas in Vietnam typically have a VAC system combined with forestry.

High homegarden species diversity suggests a strong potential gene pool for future breeding programs that can strengthen crops and improve agricultural productivity (Soemarwoto 1980; Karyono 1981; DoA 2007).

Homegardens are also an important source of production and in situ conservation of medicinal plants. Although the economic values of homegarden medicinal plants are not commonly exploited, they are widely used within households and communities for medicinal values (Rao and Rao 2006). In VAC gardens the diversity of medicinal plants is higher than vegetables, fruits, and other plants (Trinh et al. 2003). A key role of homegardens is to supply nutritional and food security to households by a steady supply of necessary vegetable proteins, carbohydrates, vitamins, and minerals, particularly during lean periods (Abdoellah 1985).

6.3.4.2 Regulating Services

Global and local climate regulation, erosion control, pest control, and pollination are some of the key regulating services provided by homegardens (Jose 2009; Mohri et al. 2013; Rao et al. 2007).

6.3.4.2.1 Climate

A basic characteristic of homegardens is a multilayered structure, which regulates microclimate by influencing air temperature, solar radiation flux, soil moisture, wind speed, and maintaining ambient temperature (Rao et al. 2007). Homegardens also contribute to global climate regulations by storing carbon and mitigating greenhouse gas emissions. According to James (2002), Indonesian homegardens store equivalent carbon to secondary forests in the same area. The UNFCCC's Clean Development Mechanism (CDM) can provide additional income for further enhancing or protecting homegarden carbon stocks (Mohri et al. 2013), especially in Sri Lanka (Szott and Kass 1993; Mattsson et al. 2009). Homegardens cover a third of Kandy region and provide a central source of carbon storage for the country (Pushpakumara et al. 2010). On the other hand, while shifting to homegardens has encouraged some tree planting in Vietnam, new VAC systems may have a net negative impact on climate regulation as they generally use more fossil fuels than the swidden cultivation or forestry they often replace because of increased livestock activities and rice cultivation (Leisz et al. 2007; Mohri et al. 2013).

6.3.4.2.2 Soil Erosion

Soil erosion is a critical issue for many farmers, especially in steep lands (McConnell 2003). Multilayered canopy structure and dense root architecture of homegardens can mitigate erosion risk (Torquebiau 1992). Homegarden plants and trees are rarely harvested completely, further minimizing erosion risk compared to more intensive agriculture (Gajaseni and Gajaseni 1999). In Sri Lanka, where landslides and soil erosion are a widespread danger, typical homegardens have a soil erosion rate comparable to native forests, a rate less than 1% of conventional annual cultivation systems (Wagachchi and Wiersum 1997; Pushpakumara et al. 2010).

6.3.4.2.3 Pest Regulation

Livestock is often used to control pests. For example, in Javanese homegardens peanuts are planted near the house to attract insects and make it easy for chickens to find and eat them (McConnell 2003). High homegarden biodiversity is likely to reduce the risk of pests and plant diseases compared to monoculture farming, but further scientific evidence is required to better assess homegarden pest regulation services (Mohri et al. 2013).

6.3.4.2.4 Pollination

Homegardens are likely to have an important role in pollination, natural hybridization, and seed dispersal (Mohri et al. 2013). Kandyan homegardens are home to many animals and insects which maintain these services (Pushpakumara et al. 2010; Mendis et al. 1985), but further research is needed on pollination services provided by Javanese homegarden and VAC systems (Mohri et al. 2013).

6.3.4.3 Cultural Services

Homegardens are also a major part of culture for rural communities. Many plants selected for cultivation reflect cultural preferences, such as ornamental and eating preferences, rather than productive purposes. Homegardens also play an important social role. In Java, homegardens are a social status symbol and can enhance social networks in communities. For example, traditional homegardens are generally bordered by shrubs or small trees that allow easy access for neighbors to fetch water, collect medicines, and pass through. In Indonesia, the traditional concept of free sharing of homegarden products among relatives and neighbors (*rukun tetangga*) fosters social equity and social fabric. In Vietnam, homegarden products are used for various ceremonies, especially fruits for Vietnamese New Year and competitions for the best cultivated homegarden products (Trinh et al. 2003; Mohri et al. 2013).

6.3.4.4 Supporting Services

Homegardens provide biomass production, nutrient cycling, soil formation, and habitat services that support other ecosystem services. In Java, homegarden litter production, decomposition, and biomass cycling can occur at higher rates than typical forests (Gajaseni et al. 1999). In Vietnam, homegardens return waste from the home, garden, pond, and livestock as fertilizer and biomass energy (Mohri et al. 2013). Further study is needed to better highlight the importance of homegarden systems in nutrient cycling and soil formation (Mohri et al. 2013).

6.3.4.5 Biodiversity

Homegardens provide habitat for a large number of flora and fauna, including many endangered species, helping conserve biodiversity (Soemarwoto and Conway 1992;

Pushpakumara et al. 2010; Mohri et al. 2013). They often provide refuge in areas where urban development or agricultural intensification is having negative impacts on overall biodiversity. In Kandy, homegardens often link agricultural and natural landscapes, reducing risks of population fragmentation and enabling vital gene flow and seed dispersal (Pushpakumara et al. 2010).

6.3.5 Drivers of Change in Homegarden Systems

The flexibility and diversity of homegardens make them flexible and adaptable to environmental and socioeconomic change (Peyre et al. 2006). However, some homegardens are responding to change with more commercial systems that have reduced diversity (Peyre et al. 2006; Wiersum 2006; Mohri et al. 2013). Wiersum (2006) identifies the main drivers of change in homegardens as socioeconomic changes, commercialization, population growth, changes in farming systems, scientific innovations in the healthcare sector, invasive alien plant species, inheritance, urbanization, climate change, overexploitation, and pollution. Market demand also drives more cash crop production and monoculture (Soemarwoto and Conway 1992; Kumar and Nair 2004; Abdoellah et al. 2006). Seed exchange among homegardens may be one of the major sources of invasive alien plant species threatening floristic diversity (Marambe et al. 2003; Kumar and Nair 2006). Population growth and urbanization fragments and reduces homegarden size, decreasing income and driving farmers to off-farm employment (Christanty et al. 1986; Mohri et al. 2013). In a Javanese village near Yogyakarta, fish ponds are one of the typical components of homegardens, but overexploitation and pollution have caused some to be abandoned or converted to other use such as livestock (cattle) production due to deterioration of water quality (Mohri et al. 2013). The price increase of feedstock was also a major factor (Mohri et al. 2013).

Climate change is also considered to significantly threaten homegarden systems (Pushpakumara et al. 2010). Local farmers in the study areas pointed out recent changes in rainfall pattern, temperature, sea level, and extreme events like floods and drought at local scale, but only a few scientific assessments of the climate change impacts on homegarden systems have been conducted (Mohri et al. 2013).

6.4 A Case Study: Strategies to Enhance Homegarden Systems in Kandy, Sri Lanka

A case study was conducted in Kandy, central Sri Lanka, to better understand the drivers of change and potential strategies to make homegarden systems and household livelihoods more resilient to negative drivers of change. This section will also consider how lessons from this case study could be applied in other contexts.

6.4.1 Land Management Changes and Their Drivers: Study Area and Method

In 2012 and 2013, a biodiversity stocktake (70 households) and follow-up survey (31) of homegarden households were undertaken in five villages in the mountainous Kandy District of Sri Lanka's Central Province (Fig. 6.1, Landreth and Saito 2014). The biodiversity stocktake measured biophysical features and biological diversity in different homegardens. The follow-up survey identified how households perceived their homegardens to have changed over the last 10 years and why. In-depth literature review and interviews with village and national government officials and international development organizations complemented the survey. These were used to identify how different government and market-driven interventions could help homegardens meaningfully contribute to contemporary sustainable development issues at local, national, and global scales. The surveys provided information on drivers of land management choices, perceived climate and ecosystem change, performance of current intervention strategies, homegarden productivity, market dependency, and how households value ecosystem services for their well-being (Landreth and Saito 2014).

6.4.2 How Are Kandyan Homegardens Changing?

Land management is the key characteristic of homegardens that determines whether the ecosystem will transform into secondary forest or be driven to more intensive agriculture, both of which have positive and negative consequences for ecosystem services (Landreth and Saito 2014). Homegarden changes in Kandy fell under three broad categories:

1. Fifty-five percent were shifting some or all of the homegarden toward commercial simplification of cultivated species, resulting in less diverse agroforests.
2. Thirty-six percent were shifting some or all the homegarden toward partial (29%) or total (7%) abandonment of homegarden management, resulting in secondary forest succession.
3. Nine percent were maintaining homegarden management with no significant change to labor, crop diversity, or other key features of the system.

6.4.2.1 Simplification

All households that shifted toward commercial simplification reported an increase in income over the last 10 years. This simplification was typically done by replacing fruit trees and diverting labor to spices (typically nutmeg in Kulugammana, pepper

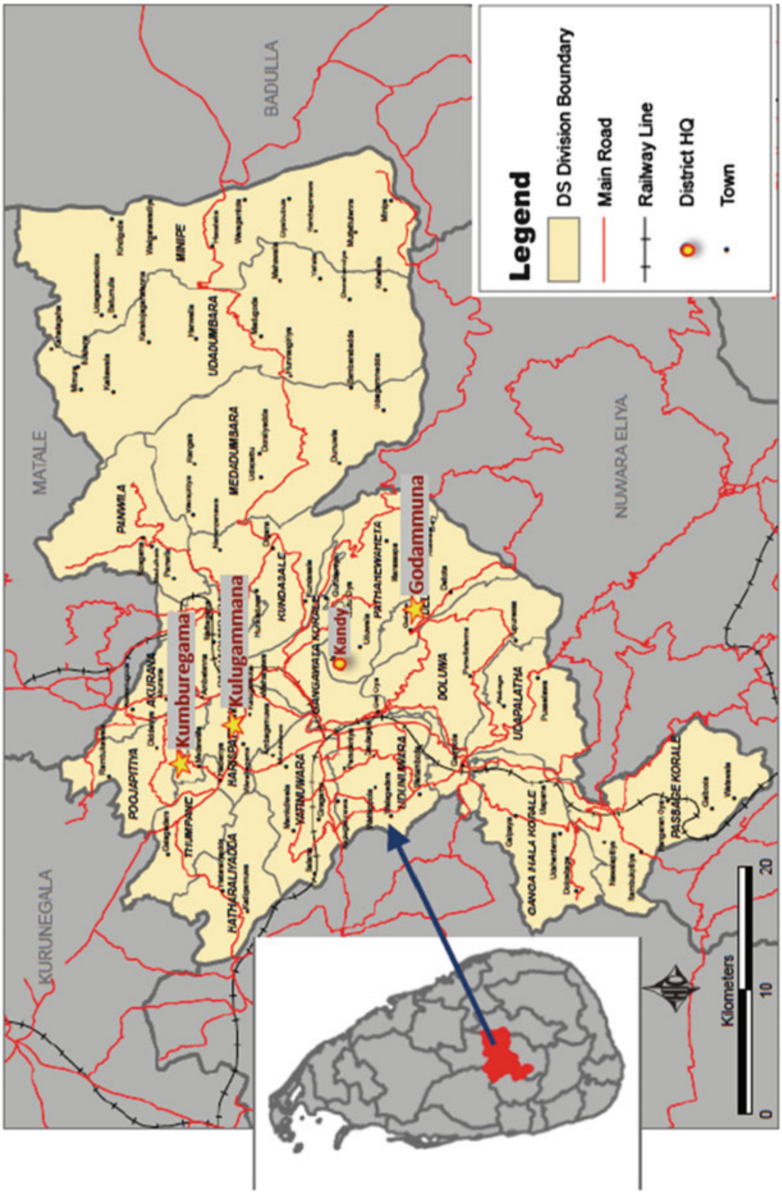

Fig. 6.1 Field survey sites in Kandy District, Central Province, Sri Lanka

in Godammuna, and to a lesser degree organically certified nutmeg and turmeric in Kumburegama). Some households also reported this simplification was driven by drought resilience as well as income. Simplification increased revenue and in some Kumburegama households drove an increase in homegarden cultivation area. However, it also had impacts to reduce food security, resilience to weather impacts, biodiversity, and all noneconomic ecosystem services identified by households as being important for long-term well-being. Households with diverse sources of income beyond the homegarden had lowest incidences of commercial simplification.

6.4.2.2 Abandonment

The benefits of abandoning homegarden cultivation included some improved environmental conditions and freed-up labor for other activities. Full or partial abandonment gave way to secondary forest succession, which still provides sources of fuel, timber, wild forage, and small amounts of market crops that can persist untended, such as pepper (Landreth and Saito 2014).

However, many of the homegarden species identified in the biodiversity stocktake relied on active human management and were outcompeted for soil space or sunlight when secondary forest took over. In Sri Lanka, secondary forests typically provide "depauperate" habitats for a less diverse number of dominating or invasive species (Pethiyagoda 2012), such as coffee, and increase habitat for destructive wild animals, amplifying existing damage problems from monkeys, boars, and porcupines.

6.4.2.3 Impacts of Simplification and Abandonment

The field survey found that, on average, homegardens provided around a quarter of household food staples. This ranged from a low of 12% in Kulugammana, where commercial simplification to increase spice production was highest; to 30% in Godammuna, where partial abandonment due to drought was highest; and to 47% in Kumburegama, where high market values for smaller amounts of organic crops had allowed households to maintain a balance of commercial and subsistence homegardening. Commercial simplification and abandonment reduce food production and increase dependence on markets for food. Households with greater dependence on markets were found to have limited diet diversity (usually less vegetables) and consume a greater proportion of processed foods, such as sweetened powdered milk or low-quality white bread that can have negative impacts on the spread of diabetes.

Simplification and abandonment also reduced the pool of local knowledge and genetic stocks, especially vegetables and other annuals, increasing reliance for some newer homegardeners on commercial seeds unsuited to local conditions and at higher risk of failure, especially during drought.

While secondary forests have lower average erosion rates than conventional agricultural landscapes, homegardens in Kandy typically include community-managed “lock-and-spill” drains that catch and redirect heavy water flows down steep hillsides. Abandoning homegardens also means abandoning components of this drainage system, which in recent heavy rains had resulted in heavier water flows damaging neighboring homegardens and silting lowland paddies.

6.4.3 Drivers of Change in Kandyan Homegarden Systems

Table 6.4 below shows main drivers of change identified in homegardens across the study area.

6.4.3.1 Increasing Wild Animal Damage

Wild animals had the greatest impact on maintaining the resilience of homegarden diversity and ecosystem services. All but one household reported wild animal incursions (primarily macaques, boars, and porcupines) had increased over the past 10 years to a level that was driving change in homegarden cultivation, and three households reported they had fully abandoned homegarden cultivation due to unmanageable animal incursions. Two households also responded by removing trees to limit macaque access (Landreth and Saito 2014).

Boar damage was most common, although macaques had a greater impact due to their greater mobility throughout the canopy. In the worst affected homegardens, recurring damage from boars and porcupines digging for tubers and worms or feeding on fruit tree bark had made cultivation of vegetables or new plants

Table 6.4 Drivers of change in Kandyan homegarden systems

Driver	Households (%)	Impact on land management choices
Increasing wild animal damage	84	Abandonment
		Simplification to spices and animal-resilient nonfood crops (e.g., nutmeg and pepper)
Water scarcity, including changing climate patterns	58	Abandonment
		Simplification to drought-resistant crops
Better market prices and access	55	Simplification to spices and organically certified commercial crops
Eating and/or ornamental preferences	71	Full or partial maintenance of multi-crop homegardens
National support programs	74	No impact
		Full or partial maintenance of multi-crop homegardens

Adapted from Landreth and Saito (2014)

untenable. Monkeys, primarily macaques, also damage established fruit trees. Nearly all households reporting increased macaque incursions were no longer able to harvest enough fruit from homegardens to meet household needs. Animal damage was the main reasons given for high average market dependency for coconuts (51% of households sourced entirely from market), fruits (83%), vegetables (91%, specifically due to boars and porcupines), fresh chili (81%), and coconut oil (92%).

By making it difficult to establish new plantings, wild animals made it difficult to maintain homegarden diversity, adapt to water scarcity and climate change, or recover from extreme weather events (typically increasingly heavy rains and drought). Kulugammana households reported that macaques had recently uprooted new plantings, tore unripe fruit from trees, and often stripped leaves from trees once fruit had been consumed. One Kumburegama household replanted around Rs. 200 of cabbages and chilies to replace those destroyed in recent extreme rains. Within a week boars and porcupines had destroyed the replacement plants.

Partial or full abandonment of homegarden management driven by wild animals, especially reduced undergrowth clearing and canopy pruning, has feedback impacts by increasing secondary forest succession that amplifies ideal boar and macaque habitat and feeding grounds.

6.4.3.2 Water Scarcity, Including Changing Climate Patterns

Fifty-eight percent of households attributed lower homegarden productivity to more unpredictable and extreme rainfall patterns. Traditional strategies for predicting and responding to weather, such as bird calls and flying ant mating habits, were reported as no longer reliable by households that used to apply this local knowledge (Landreth and Saito 2014). Some participants were able to specify when rainfall patterns noticeably changed (typically between the last 3–10 years).

Unpredictable rainfall reduced the security and productivity of crops for food and income, driving simplification to more drought- and rain-resilient species and driving some homegardeners to seek alternative incomes.

During the research period, an elongated drought broke in December 2012 with the heaviest rain reported in parts of the study area since 1953 (East Godammuna Grama Niladhari, pers. Comm., January 2013). For one household, the drought destroyed one season's harvest, and the following season was destroyed by the extreme rainfall. While extreme rainfall was considered by all households to be part of conventional homegarden management, abandonment of neighboring homegardens also reduced substantial benefits from lock-and-spill drainage techniques to manage erosion – only 3 of the 18 households employing these techniques reported erosion damage in the extreme rain.

6.4.3.3 Better Market Prices and Access

Surveyed households had an average monthly income of between Rs. 30,000 and Rs. 40,000, comparable to the national mean at the time of Rs. 36,451 (Central Bank of Sri Lanka Statistics Department 2012). On average, homegardens provided around 24% of household income, but this was across a wide range. Thirty-six percent reported homegardens as their primary source of income, and 23% reported no income from homegardens at all.

Fifty-five percent of homegardens had changed species composition in the last 10 years to generate more income. This primarily involved replacing ground cover annuals and fruit trees with valuable spices, especially nutmeg which has increased market value substantially in recent years.

Before an organic certification program arrived in the Kumburegama area in 2006, vegetables were the main source of income for the 18 households in the program. Nutmeg is now the leading source of income (President, Kumburegama Farmers' Association, pers. comm., Jan. 23, 2013). Sixty percent of surveyed Kumburegama homegardens reported minimal change to homegardens due to increased market value, increasing the profitability of existing crops rather than encouraging major changes to species composition. Turmeric cultivation had increased significantly in 60% of households but was not deemed to have significantly displaced previous crops in the area. Two households had cleared some timber and cloves to intensify nutmeg production, although similar and more intense changes in Kulugammana, where no homegardens are organically certified, indicate nutmeg intensification is a symptom of overall trends in increased market value rather than simply due to organic certification.

6.4.3.4 Eating and Ornamental Preferences

Cultural ecosystem services are still a major countervailing driver for households to maintain and increase multi-crop diversity in homegardens in the face of substantial pressure for change driven by animals, climate change, and market values. Seventy-one percent of households at least partially maintained diverse homegardens for eating preferences and 68% for ornamental preferences (Landreth and Saito 2014).

6.4.3.5 National Support Programs

At the time of the study, Sri Lanka's *Divi Neguma* policy was seeking to improve food security in one million "domestic economic units" (households) across Sri Lanka. Divi Neguma included the *Api Wawamu Rata Nagamu* program (National Campaign to Motivate Domestic Food Production, referred to here as Api Wawamu). Its core activities were targeted at maintaining the contribution of homegardens to sustainable livelihoods, Sri Lankan cultural values, and national economic development. The program provided education and information on better natural resource management, subsidies for seeds, and postharvest technology and coordinated farmer organizations to improve irrigation and market access.

Seventy-four percent of households reported voluntarily participation in *Api Wawamu* programs. However, only between 10% and 30% of households reported national interventions as successful in improving homegarden cultivation and productivity, depending on the initiative, suggesting these programs may have limited effectiveness in the Kandy region.

6.4.4 Strategies to Address Drivers and Enhance Homegarden Systems in Kandy

Homegarden systems offer a range of ecosystem services that have adapted over the centuries to provide ecosystem services still relevant in a contemporary development context. Households, governments, and markets are responding with strategies to address drivers and enhance the services these systems can provide to human well-being and the broader environment.

6.4.4.1 Wild Animal Strategies

Traditional strategies at the household scale to protect against wild animals often required people to be constantly at home to fend off animals, repair fences, or set up cages. This becomes more difficult as contemporary Sri Lankan rural livelihoods become more diverse (58% of surveyed households had another source of off-farm employment) and children are educated at schools rather than staying at home. The low required maintenance of homegardens is one of the reasons they can adapt to changing employment preferences, as homegardeners can take off-farm employment without upsetting land management too significantly. Solutions to wild animals may not be successfully taken up if people must consistently watch the homegarden.

Over 50% of surveyed households had instead responded by accepting cohabitation with increased numbers of wild animals. These households had replaced easily damaged crops with commercial spices or more timber, considered resilient to most wild animal damage and delivering greater income benefits. This strategy resulted in significant loss of agricultural and biological diversity, provisioning services, and cultural services.

Preventative strategies for dealing with wild animals were limited by Sri Lanka's *Flora and Fauna Protection Ordinance* (1937, s3.44) that states no animal shall be hunted, killed, or taken unless caught harming crops. However, illegally caught porcupine and boar meat is sold and consumed throughout Sri Lanka (FAO 2002), and boar meat has potential to be a significant sustainable livelihood opportunity to sell in urban markets (Samaraweera et al. 2011).

With proper targeting and training, hunting permission could be extended to licensed operators in the Kandy District while keeping with the spirit of the Flora and Fauna Protection Ordinance allowance of population control to prevent future crop damage, not just limited to capture and trapping of animals caught in the act. If monitored sustainably, the sale of boar meat could provide significant additional income for local communities while reducing the number of boar incursions on valuable and new crops (Samaraweera et al. 2011).

For endangered macaques, translocation to reinvigorated habitats in reforested former tea plantations or underutilized state forests far uphill from affected homegardens could be a more appropriate strategy. This has been trialed in the Kandy region at a small scale, but the success of this strategy has yet to be evaluated.

6.4.4.2 Water Scarcity and Climate Change Strategies

Households with access to reliable water sources or stable alternative incomes were less likely to consider climate change responses necessary, applying existing lock-and-spill drainage as the main response to mitigate risk of increasing or more frequent heavy rainfall damage. Traditional knowledge was applied in other households to change the mix of species to more drought-resilient species, including mango, nutmeg, pepper, vanilla, tamarind, brinjal, and jak. Four households were increasing timber and sandalwood to provide income security in anticipation of future climate stress on their regular commercial and food crops. However, climate impacts and homegarden changes made in response reduced diversity, increased the need for additional sources of income, and increased expenditure on market-sourced food (especially vegetables). Reduced diversity has also been found to reduce resilience to weather fluctuations (Marambe et al. 2012; Weerahewa et al. 2012).

An important village-scale response is to improve water infrastructure. Fifty-three percent of households reported they did not have year-round access to nearby water sources, restricting their capacity to diversify into more commercial or resilient species.

6.4.4.3 Market Strategies

Homegardens already use limited agrochemicals and labor and so are well suited to organic and fair-trade certification that can attract high premiums if produce can be delivered at scale and consistent quality. Other ecosystem services that homegardens provide of value to global organic and fair-trade markets include biological diversity, global climate regulation, protection of nature, agricultural biosafety, consumer health, and "fair-trade" working conditions (Landreth and Saito 2014).

While some organic and fair-trade certification bodies require biodiversity conservation plans, these may be of low sensitivity to local conditions. Some certified households reported increased simplification to take advantage of commercial crops. Certification standards could consider relaxing some requirements in place of better safeguards to avoid perverse outcomes of commercial homegarden success, such as to prevent reduced agrodiversity that may lead to greater reliance on expensive and unhealthy market-sourced food and reduced species important for pollination.

6.4.4.4 National Support Programs

Api Wawamu programs had a broad reach into surveyed households but could be a more effective driver of homegarden resilience. The promotion of container gardens with free seeds for kitchen use, usually in gunny sacks or coconut husks near the home, was taken up by around 30% of respondents. No households reported container garden damage due to wild animals, suggesting these smaller plantings could be useful fallbacks for small-scale food cultivation or to meet eating preferences in homegardens with heavy animal incursions.

Twenty-six percent of households reported that *Api Wawamu* instructors provided advice that improved productivity, including to introduce households to organic certification programs, suggesting education could be a significant driver for improved home gardening. Only one household that implemented instructor advice reported it was poor advice. However, 58% reported that they were not offered instructor advice, and 26% of all households indicated they would not trust national instructor advice if it was offered.

Around 52% of households did not bother with *Api Wawamu* distributed seeds and plantings. For many of these households, local knowledge was considered superior for local conditions compared to advice from instructors. Improving the quality and local sourcing of *Api Wawamu* distributed seeds and plantings could improve outcomes of this type of program in other situations. While around 60% of households that propagated *Api Wawamu* plants reported they were successful, they were mainly for small container gardens. Other households criticized the program for distributing commercial hybrids that could not be organically certified and thus worth less in export markets. Distributed seeds and plantings were also typically commercial varieties engineered for intensive production, not suited to household eating preferences and local conditions.

6.4.5 Lessons from Kandyan Homegardens

This research found that homegardens deliver a range of ecosystem services with substantial potential to adapt to and complement contemporary sustainable development priorities. However, rapid changes, particularly increased wildlife conflicts, market access, and climate change, are driving commercial simplification and abandonment with often unintended trade-offs. National and international interventions to maintain homegardens have typically focused on cost barriers (such as through subsidies) and developing natural resource management skills (such as through agricultural instructors). The ecosystem services-based analysis applied in this research can enhance these strategies by helping them identify and adapt to positive drivers, such as changing seed distribution programs to reflect local eating preferences, or build safeguards against negative drivers, such as including local biodiversity plans in organic certification guidelines or adjusting agricultural instruction to focus on responding to wildlife conflict.

6.4.6 Reestablishing Homegardens in Northern Sri Lanka

Lessons from the above studies on homegarden ecosystem services and the case study in Kandy could be applied in other places like the Northern Province of Sri Lanka, where people suffer from harsh environmental conditions and socially unstable situations. Since the 25-year civil war ended in 2009, the Northern Province in Sri Lanka has progressed from destruction to reconstruction through economic and infrastructure development, but still people in the region struggle to sustain their livelihoods. A number of field surveys were conducted in the area to evaluate the current agriculture practices and farmer livelihoods and propose some recommendations to improve livelihoods in Northern Sri Lanka. One hundred and two samples were collected from a household survey conducted in four divisions in Kilinochchi District, Pooneryn, Pachchilaipalli, Kandawali, and Karachchi. Northern Sri Lanka is heavily dependent on the agriculture sector. Poverty rates in the region are relatively high compared to other parts of the country, and people have limited access to the land and other natural resources. Many farmers depend on their limited land to have homegardens but during the war were separated from their land and have lost homegarden knowledge and management skills. As demonstrated in assessments from other regions discussed in this chapter, reestablishing homegardens has great potential to improve not only livelihoods but also the damaged natural environment around the region. As this research showed, the Kandy homegardens maintain high biological diversity and contribute significantly to livelihoods. Kandyan strategies could be incorporated into the development plans in the Northern Province to build homegarden knowledge and skills, integrated into agricultural development efforts such as training programs, water management efforts, and government subsidies for fertilizers.

6.5 Conclusion

This chapter shows the multitudinous benefits of homegardens and potential strategies to enhance the contribution of homegardens to livelihoods and resilience against environmental, climatic, and social changes. This found substantial scientific research has been conducted on homegarden systems, with some notable gaps in socioeconomic aspects of the systems (Kumar and Nair 2004; Mohri et al. 2013).

Homegardens provide many services for people in rural areas: an income source, a place for communication, a livelihood protection from environmental and economic shocks, and a means of conserving traditional culture, biodiversity, and agrodiversity. While this paper found similarities in components, spatial layout, temporal and spatial scales, diversity, and functions of homegarden in the study areas, characteristics and functions differ at regional and local scales. This diversity and multifunctionality of homegardens reflect their adaptability and how they can play an important role in providing *general resilience* against social, economic, climatic, and ecosystem changes. *General resilience* is a system or function that has the capacity to recover from different types of shocks and cope "with uncertainty in all ways" (Folke et al. 2010) which can be distinguished from *specific resilience*, that is more specialized on a specific event or disturbance (Carpenter et al. 2001; Folke et al. 2010; Mohri et al. 2013).

In the study areas, homegardens generally still exist in some form despite substantial impacts and change. One of the main challenges will be to integrate such traditional homegardens with rapid changes to modern technology and global economy to enhance the resilience of the system against new issues. The longevity and adaptability of Kandyan homegardens provide an example of how mixed-crop smallholder agriculture can be positioned positively in contemporary sustainable development for other communities vulnerable to or recovering from climate change and socioeconomic and political instability impacts.

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