

A REVIEW OF RESEARCH ON HOMEGARDENS IN SRI LANKA: THE STATUS, IMPORTANCE AND FUTURE PERSPECTIVE

**D. K. N. G. PUSHPAKUMARA^{1*}, B. MARAMBE¹, G. L. L. P. SILVA²,
J. WEERAHEWA³ AND B. V. R. PUNYAWARDENA⁴**

¹ Department of Crop Science, Faculty of Agriculture,
University of Peradeniya, Sri Lanka

² Department of Animal Science, Faculty of Agriculture,
University of Peradeniya, Sri Lanka

³ Department of Agricultural Economics and Business Management, Faculty of
Agriculture, University of Peradeniya, Sri Lanka

⁴ Natural Resources Management Centre, Department of Agriculture, Sri Lanka.

ABSTRACT

Homegardens in Sri Lanka are dynamic sustainable food production systems, and presumably the oldest land use activity, next to shifting cultivation. It is still one of the major forms of land use in the island that has continued to evolve through generations within the Sri Lankan landscape to suit the socio-economic, cultural and ecological needs. In most cases, transferred from one generation to the next, the gardens are maintained as a family property. This land use system has existed in Sri Lanka for centuries, and in 1995 accounted for 13.1% of the total land area of the country. However, it started receiving the national recognition only recently. This review summarizes the current status of knowledge on homegardens, their importance to the society and environment, and potential for improving them. In this endeavor, about 90 published documentary evidences were reviewed. As revealed the homegarden research in Sri Lanka dates back to 1973 and during the past four decades, the research focus was mainly on providing system description on localized homegarden systems. It was further attempted in this review to highlight the significance of the homegarden land use system and its dominant contribution in maintaining agricultural and environmental sustainability of the country. In this context, the importance of classification of homegardens, present status of homegarden agroforestry in terms of area under homegardens and their distribution, contributions of homegardens to timber and fuelwood production, food and nutritional security of householders, biodiversity conservation, and in managing landscape sustainably through environmental services, are discussed in detail. Further, the critical gaps in available information and way forward in homegarden research are identified.

KEYWORDS: Homegardens, Species diversity, Food, nutritional security, Timber, fuelwood, Environmental conservation, Research gaps.

*Corresponding author is the ICRAF Country Liaison Scientists. Email: ngpkumara@pdn.ac.lk.

INTRODUCTION

Homegardens have been identified as the oldest land use activity, next only to shifting cultivation in the tropics (De Silva, 1981; McConnell, 1992, 2003; Kumar and Nair, 2004). It is suggested that almost all homegarden systems have evolved to provide food and other requirements of households through generations under the influence of resource constraints in respective countries such as population pressure, physical limitations like remoteness of the living area, inadequate market facilities, and shortage of arable lands and capital (Nair and Kumar, 2006).

In Sri Lanka, homegardens have been an integral part of the landscape and culture for centuries (Mahawamsa, *undated*; De Silva, 1981; Jacob and Alles, 1987; MFE, 1999). They still remain as one of the major forms of land use in the island having evolved to suit the socio-economic, cultural and ecological needs of the island's diverse communities and landscape (FSMP, 1995; MFE, 1999; Pushpakumara et al., 2010). The land use systems in Sri Lanka at present are challenged as never being before with mounting concerns of environment on one hand and pressure of economic development on the other. Hence, as stated by Nair and Kumar (2006), the land use systems today are evaluated based not only on their ability to fulfill any single objective such as production of a selected commodity, but also on how best they fulfill the sustainability criteria. In this respect, homegardens are considered as one of the popular and sustainable land use systems in Sri Lanka. This system in most cases involves the optimum utilization of land and resources around the household, satisfying both the production and environmental functions (Nuberg et al., 1994; FSMP, 1995; Pushpakumara et al., 2010).

However, the term "homegarden" is loosely defined in literature. Kumar and Nair (2004) and Nair and Kumar (2006) suggested that it includes the concept of intimate plant associations of various trees and crops, sometimes in association with domestic animals, and consequent multi-storey canopy configuration around homestead. More recently, Weerahewa et al. (2012), while providing a detailed description of homegardens, defined it as a complex sustainable land use system that combines multiple farming components, such as annual and perennial crops, livestock and occasionally fish, of the homestead and provides environmental services, household needs, and employment and income generation opportunities to the households.

Over the years, the number and total area of homegardens have been increasing annually, with little policy support. However, homegardens are now increasingly recognized as an example of traditionally developed agroforestry systems with excellent promise for facing present and future challenges. Having realized the importance of homegardens, the national development policy framework of the government of Sri Lanka now includes strategies to expand and improve food and timber productions in such landscapes of the country (Mahinda Chintana, 2010). The policy framework further includes establishing of dairy villages in order to improve the dairy production, and promoting poultry production activities at village levels as a mean of ensuring village empowerment.

The *Haritha Lanka* program established under the National Council for Sustainable Development, which is chaired by H.E. the President of Sri Lanka, also promotes the process of sustainable development while recognizing the importance of homegardens in achieving sustainable development in Sri Lanka (NCSD, 2009). In addition, the National Agriculture Policy of 2007 (MADAS, 2007) also highlights the need for promoting homegardens, especially focusing on the urban sector, and the role play of women on homegardens. Improvement of homegardens in Sri Lanka has been the priority of many development programmes implemented in the country over the past five years where development of 375,000 homegardens were aimed under the “*Api Wawamu Rata Nagamu*” (Let us grow and uplift the nation) programme launched in 2007, and strengthening of 1.5 million homegardens is the target of “*Divi Neguma*” (Livelihood Development) programme in order to achieve self-sufficiency in vegetables and to reduce vegetable prices (Government of Sri Lanka, 2011).

Various research studies carried out since 1973 have contributed to the present understanding of the structure and functions of this dynamic production system in Sri Lanka. However, many of those findings still remain as student reports and abstract publications with limited access for researchers, policy makers and general users. Most of these publications has limited access and also carry limited details on methodologies used. This situation on one hand is leading to inadvertent repetition of research areas, while on the other hand several critical research areas remain untouched. Nevertheless, policy decisions are made without concrete evidence from the research carried out. Given these circumstances, this review attempts to compile the current status of homegarden agroforestry systems in Sri Lanka, in order to specifically highlight the importance of this land use system

HOME GARDEN RESEARCH IN SRI LANKA

to the country, the research gaps and the research needs with a future research directive on the system. The present review has captured only the published and verifiable information at national and international levels. Several undergraduate and postgraduate research projects, directed studies of postgraduate work and abstracts published based on findings of student reports have not been used in this review due to lack of information gaps exist in methodology, sample size etc., and also due to limitation in access.

HISTORY AND CLASSIFICATION OF HOME GARDENS IN SRI LANKA

A typical peasant farm in Sri Lanka combines three kinds of holdings: paddy, backyard home garden and highland plot (de Silva, 1981). Construction of a house and its surroundings including the home garden, termed as *vasthu*, though date back to period over 6,000 years, became more common after introduction of Buddhism to the country in 247 BC (Mahawamsa, *undated*; Attanayake, 2006). Though early establishments of home gardens are largely based on native food, timber, medicinal and ornamental plants, some exotic annual and perennial flowering plants have been introduced to home gardening through traders and the National Botanic Gardens during the colonial occupation in Sri Lanka (Ceylon Administrative Reports, various years). The colonial rulers have viewed peasant agriculture as primitive, unproductive and backward, hence paid little attention to the food producing peasant sector and in some instances destroy the traditional nature of the system, including fruit and food trees in home gardens. After independence, with many new introductions of ornamental plants, vegetables and fruit species, home gardens have evolved to present level.

As Pulido et al. (2008) suggested development of home gardens includes phases of establishment, maintenance and in some cases abandoning. In general, transferred from one generation to the next, the gardens are maintained as a family property. Experience in Amazonian home gardens, has revealed that age of home garden influence the plant diversity, and usually older home gardens tend to be more diverse, especially with respect to perennial fruit trees, medicinal plants, and plants that provide materials for construction (Coomes and Ban, 2004). However,

58

historical changes of species composition and dynamism of homegardens in Sri Lanka are little studied, hence evidences are scanty.

Homegardens are diverse and complex and individual homegardens are unique in structural, compositional and functional basis. However, they share common traits and forms within bio-cultural eco-zones and different geographical areas (Hitinayake and Sinclair, 1998; Kumar and Nair, 2004; Nair and Kumar, 2006). To establish a proper management for a systematic improvement of homegarden systems, a proper identification of its components and appropriate classification based on acceptable parameters is required. Size, structure, socio-economic value, climatic area, geographical region, and dominant species have been used by various authors as the criteria in classifying homegardens. Hitinayake and Sinclair (1998) suggested classifying homegardens based on the analysis of indigenous ecological knowledge such as the knowledge-based system approach. However, no accepted scheme is used currently and no firm guidelines have been given or widely adapted in Sri Lanka or elsewhere.

The homegardens in Sri Lanka can be classified based factors given in Table 1, and such information can be considered as essential basic background information for any homegarden research in Sri Lanka which facilitates sharing and comparing of information among studies. The composition and structure of homegardens depend on agro-ecological regions yet homegarden distribution based on agro-ecological regions and their impacts on diversity and structure have not been properly estimated yet. In planning for improving the homegarden systems, the agro-ecological basis can be used as suggested in literature (Premakantha et al., 2008; Punyawardena, 2010). Homegarden can also be categorized based on analytical methods such as cluster analysis. Such analysis offer good opportunities to identify similar clusters which provide systematic insights to grouped homegardens as they elaborate the importance of individual homegardens at the district, provincial, regional and the national landscape levels. However, at present, analysis based on clustering or grouping are lacking in homegarden research in Sri Lanka. This type of analysis and classification will be useful in development of management guidelines for homegardens with uniform criteria for different parameters which facilitates comparison among studies.

HOME GARDEN RESEARCH IN SRI LANKA

Table 1. Factors affecting the structure and composition of homegardens.

Factor	Condition	Examples and remarks
Environmental condition	Agro-ecological region; Soil parameters	Wet zone homegardens are diverse, dense and structurally more complex than that to Dry zone homegardens; Low soil fertility reduces diversity of crops and density of vegetation.
Geographic location	Urban vs rural; Adjacent to and away from natural forests	Urban homegardens often smaller and more aesthetically oriented; Homegarden adjacent to natural forests may consist of more endemic species.
Dominant trees or crops	Annual, perennial nature of dominant crop; Density of species; Degree of complementarity to open field cultivation; Level of dynamism; Level of stratification; Presence or absence of animal components	Coconut based, spice crop based, tea based homegardens; Presence of animal component and crop components; Incipient gardens first dominated by annual crops followed by increased incorporation of tree crops; Stratification based on common forest type of the area.
Socio-economic condition of households	Size of homegarden; Wealth status of owner; Access to market; Access to off-farm employment; Gender related issues; Contribution to household economy	Smaller size more species per unit area included to achieve various food items; With increase of wealth increased importance of commercial and aesthetic plants; Commercial crops stimulated by good market access; Financially lucrative employment decreased importance of commercial crops; Gardens of female headed households often more household use oriented.
Maturity of homegarden	Age of homegarden	Mature homegardens are structurally more complex than recently established gardens.
Cultural factors	Food preferences of owner or community	Cultural preferences in respect to consumption of vegetables and spices.

Source: Modified from Wiersum (2006).

AREA UNDER HOMEGARDENS AND THEIR DISTRIBUTION

The land use pattern of Sri Lanka is dominated by agriculture (including paddy, tea, rubber, coconut and other perennials, non-perennial crops), close canopy and sparse forests, forest plantations and homegardens as shown in Figure 1 (DCS, 2010). The extent under homegardens in Sri Lanka is reported as 781,000 ha in 1983 and 858,100 ha in 1995 (FSMP, 1995). The latter represents 13.1% of total land area in the country (FSMP, 1995). However, the area under homegardens has been reported and widely quoted as 14.3% based on the reports of Ariyadasa (2002) and FAO (2009). It is important to note that statistics in the latter reports have been derived only from 20 districts, excluding Jaffna, Kilinochchi, Mannar, Mullaitivu and Vavuniya districts. According to the DCS (2002), the land extent covered by homegardens in 2002 has been 76,484 ha or just 1.2% of total land area of the country, which has been quoted by ME (2010). However, this latest figure has been derived considering only the homegardens of less than 40 perches (approximately 0.1 ha). This indicates that there is an ambiguity over the extent of homegardens in Sri Lanka.

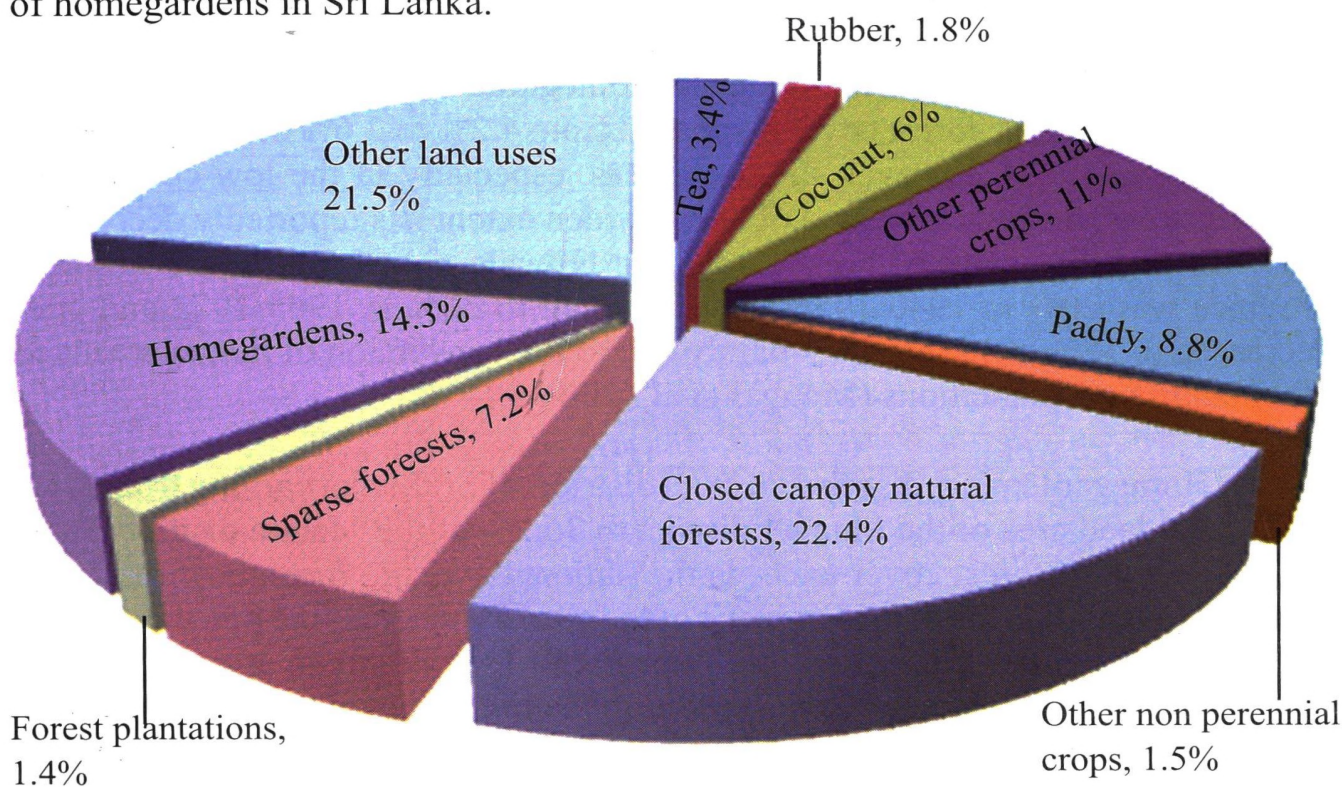


Figure 1. Area of homegardens in Sri Lanka in relation to forests, agriculture and other land uses. Sources: DCS, 2010.

HOME GARDEN RESEARCH IN SRI LANKA

The area under homegardens in Sri Lanka has been increased by about 1% (8,000 ha) annually since 1980 to 1992 (FSMP, 1995). There were about 1.42 million homegardens in Sri Lanka in 2002 with a holding size below 40 perches (approximately 0.1 ha; DCS, 2002). The total number of homegardens has also continued to grow at a rate of 1.6% annually. The size of homegarden area can vary considerably from 0.05 ha to several hectares (over 2.5 ha) (Pushpakumara et al., 2010). A comparison of land use data from 1956 to 1980 also revealed that the area under homegardens has steadily increased during that period. A similar trend in change of homegarden area has been reported in the upper Mahaweli catchment area also (FSMP, 1995). FAO (2009) reported that both the number of homegardens and the total land extent under homegardens is increasing in Sri Lanka due to establishment of new settlements and fragmentation of some of the existing homegardens. Perera and Tsuchiya (2009), in their assessment of land cover and its change from 1987-2006 in south eastern Sri Lanka also revealed that during these two decades, the forest cover has reduced by 50% while the area of homegardens has doubled.

Further, Starkloff (1986) also shown that in highland village of Kitulwatta in the Uva province, the total land extent of homegardens has increased from 11.8% to 24.9% whereas the forest cover decreased from 4.2% to 2.6% during the period from 1954 to 1988. However, in some areas, especially in the low country tea growing areas, the total area area of homegarden extent has reportedly decreased. For example, the extent of homegardens in Nilwala river basin in the southern province was 20% in 1940-1956, and increased to 26% in 1965-1972 and later decreased to 15% in 1985-1995, mainly due to the conversion of homegardens to monoculture tea plantations (Mungai et al., 2004).

Homegardens are distributed in all districts of Sri Lanka varying from 2.4% of the total land area of the Manner district to 36.2% of the Matara district (Table 2). The extent of forest cover exceeds the national average forest cover (22.4 or 23.5%) only in the areas of the Dry zone of the country whereas the percentage area of homegardens exceeds the national average (13.1%) largely in areas of the Wet zone of Sri Lanka (Table 2). Homegardens in the highly populated Wet zone have suffered a considerable degradation in the past two decades due to fragmentation and urbanization (FSMP, 1995; MENR, 2009; ME, 2010; Dela, 2011). Starkloff (1998) reported that the fragmentation of homegardens is serious in Kitulwatta area in the up country of Sri Lanka. In addition, Starkloff (1998) further revealed that during the previous three decades, people have cleared the centres of the old

homegardens to grow more cash crops such as vegetables and eucalyptus trees and customary homegarden species have receded to the hedges along the property boundaries. Similarly, it has been observed in some areas, though high canopy fruit trees and multipurpose trees are the dominant type of trees reported in the homegardens, owners prefer to have medium canopy cash crops and multipurpose trees to fulfill their basic needs in the gardens. This transformation from forest utility trees to mono crop vegetable and cash crops has disturbed the mixed and multi-storied nature and reduced the environmental and other social benefits of homegardens.

Table 2. Statistics on land area, population density, forest cover and homegarden area of administrative districts of Sri Lanka.

District	Area (sq km)	Population density (per sq km)	Forest cover (%)	Homegarden cover (%)*	Tree canopy cover (%)
Ampara	4,318	143	37.5	4.1	41.6
Anuradhapura	7,034	111	35.0	8.0	43.0
Badulla	2,803	294	19.0	17.7	36.7
Batticaloa	2,686	204	21.0	4.2	25.2
Colombo	656	3,631	2.8	13.1	15.9
Galle	1,635	629	13.0	22.1	35.1
Gampaha	1,386	1,523	0.3	25.2	25.5
Hambantota	2,579	210	20.5	15.1	35.6
Jaffna/ Kilinochchi	2,218	337	1.1	26.5	27.6
Kalutara	1,588	688	13.0	20.1	33.1
Kandy	1,906	704	17.0	30.4	47.4
Kegalle	1,693	468	9.5	23.2	32.7
Kurunegala	4,813	311	5.0	15.1	20.1
Mannar	1,985	50	60.0	2.4	62.4
Matale	1,993	233	40.5	11.7	52.2
Matara	1,282	620	16.0	36.2	52.2
Moneragala	5,545	75	40.5	9.9	50.4
Mullativ	2,517	56	60.0	6.6	66.6
Nuwara Eliya	1,720	423	24.5	5.3	29.8
Polonnaruwa	3,224	117	38.0	10.6	48.6
Puttalam	3,013	245	25.0	21.5	46.5
Rathnapura	3,255	325	20.0	15.8	35.8
Trincomalee	2,631	147	48.0	7.2	55.2
Vavuniya	1,967	74	51.0	10.1	61.1
Sri Lanka	65,610	314	23.5	13.1	40.8

Note: Tree canopy cover is defined by adding only the areas of forest and homegarden covers.

Sources: IUCN and MENR (2007) and *FSMP (1995).

HOME GARDEN RESEARCH IN SRI LANKA

The currently available estimates of homegardens and forest area (Table 2) are mainly based on the data found in FSMP (1995), Jewell (1995) and Legg and Jewell (1995). The national statistics on homegarden area therefore, need to be updated as the isolated studies done in different areas have produced an ambiguity in different estimates. For example, in Nuwara Eliya district, the area of homegardens was estimated as 9,172 ha or 5.3% of the total area by Jewell (1995) and Ariyadasa (2002) using Landsat Images. However, in a recent assessment using the same methodology, Premakantha et al. (2008) suggested that the area of homegardens in Nuwara Eliya district was 27,440 ha or 16% of the total land area indicating a substantial difference. This may be due to the different definitions used in homegardens leading to a change of the inclusion or exclusion of certain areas to match with the definition that was followed and technology available at a given time. Thus, the area under homegardens needs to be identified accurately as suggested by Premakantha et al. (2008) and is vital for national planning for activities on improvement and development of homegardens in Sri Lanka. In this regard, updating Sri Lanka's forest cover map of 2012 to include homegarden extent as well is urgently required.

RESEARCH ON HOME GARDENS IN SRI LANKA

General overview and methods applied

Though the homegarden system existed for centuries in Sri Lanka, pioneering research and documentation dates back to early 1970s when McConnell and Dharmapala (1973) reported on the economic structure of Kandyan homegardens. During the past four decades, there are over 90 locally or internationally published documentary evidences related to research carried out or information generated on homegardens in Sri Lanka, of which 54% are found in peer reviewed journal. Peer reviewed books or book chapters published related to homegardens in Sri Lanka accounts for 15% of the documentary evidences. Eight percent and 23% documents are peer reviewed reports and proceedings of workshops/seminars, respectively. In addition, 22 remain as undergraduate research reports at the Faculty of Agriculture, University of Peradeniya alone. There may be more with other Faculties of University of Peradeniya and other universities, too which we have not been able to use for this review. Further, many remains as abstracts published in various places.

Although many studies have been conducted on Kandyan homegardens and homegardens in the Wet zone (over 50% studies reviewed), there are limited studies carried out to understand the homegarden practices in the Dry zone (21%) and Intermediate zone (15%). These studies, too, are not representative enough to capture the essential and critical aspects of diverse homegarden systems. Majority of studies have considered only homegardens whereas only 12% of studies have considered the landscape gradient including homegardens and natural vegetations. Over 40% studies assessed only plant category whereas only 12% and 14% used animal category only and both plant and animal categories, respectively. No island wide studies have been carried out except that of Ariyadasa (2002) covering 87% of the land area of the country. However, Ariyadasa (2002) has documented only the timber production potential of homegardens. Only two reviews have been published on homegardens in Sri Lanka to-date, but limited to Kandyan homegardens (Pushpakumara et al., 2010) and homegardens in the village tank systems (Marambe et al., 2012a).

According to the literature, system description using plant community has been the most common aspect of homegarden research in Sri Lanka and these studies seldom based on of testing hypothesis. The majority of studies have used interviews and participatory observation techniques such as floristic studies and conventional ecological methods along with statistical techniques such as descriptive statistics, correlations and linear regression. Raheem et al. (2008) and Weerahewa et al. (2011) have used multivariate analysis and ecological approaches for calculation of species area curve, while Marambe et al. (2012b) used only ecological approaches in computing diversity indices and assessment of species area curve those are relatively new approaches in homegarden studies. Using an ecological approach, Raheem et al. (2008) assessed diversity of land snails in homegardens and adjacent land uses to identify conservation potential of homegardens. Very recent studies by Kudavidanage et al. (2012a; 2012b) used a multi-taxon approach (butterflies and amphibians) with environmental variables to identify conservation potential of natural forests, homegardens and Pinus plantation and habitat quality assessment using dung removal activity by dung beetles, respectively. However, both Raheem et al. (2008) and Kudavidanage et al. (2012a; 2012b) did not report the structure and composition of plant communities in different land use systems.

Issues related to food and nutritional securities and dietary diversity were recently addressed but limited to three districts of Sri Lanka (Weerahewa

et al., 2011; Marambe et al., 2012b). The resilient features of the homegardens have recently been addressed in the context of change of climate in Sri Lanka (Marambe et al., 2012b, 2012c; Weerahewa et al., 2012). Few studies have been conducted on economic assessment of homegardens but limited to Kandyan homegardens (McConnell and Dharmapala, 1992; Batagalla et al., 1998). Social aspects of homegardens and process of homegarden development especially in the Mahaweli settlement of the Dry zone was reported by Wickramasinghe (1993; 1995a). However, there are no historical, archaeological and landscape level studies. Similarly, no studies have been carried out to evaluate the health benefits and recreational value of homegardens and their impacts on family relaxation to-date. Further, almost all the documented information has been generated from short-term studies on randomly selected homegardens in different locations whereas long term studies using permanent sampling techniques has not been reported to-date.

System description

The published inventories suggest that plant species in homegardens are used for many purposes and hence, they are categorized based on uses such as edible species (food, fruit, vegetable, leafy vegetable species, spices), timber trees, multipurpose species, ornamental species, shade trees, fodder species and medicinal plants. Woody components generally include timber trees, fruit trees, fuelwood species, and palms, and may include native as well as exotics, and wild as well as domesticated plants (McConnell and Dharmapala, 1973; Jacob and Alles, 1987; Perera and Rajapakse, 1991; Hitinayake and Ekanayake, 1999; Pushpakumara et al., 2010; Marambe and Silva, 2012; Marambe et al., 2012a; 2012b; Weerahewa et al., 2011, 2012). Kandyan homegardens consists of 9, 10, 13, 13, 30 and 25% of food, fruit, cash, wood, medicinal and no use species, respectively (Perera and Rajapakse, 1991). Kumari et al. (2009) reported that urban homegardens in Negambo area consists of 51, 36 and 12% of ornamental, food and medicinal plants, respectively. Many researchers categorized homegarden species into these categories but not in the same manner. The presence of many crops have also been recorded, but the occurrence of animal component in homegardens is limited to the maximum of 30% of the homegardens studied (McConnell and Dharmapala, 1973; Perera and Rajapakse, 1991; Marambe et al., 2012b; Weerahewa et al., 2012). Although early and many present investigations on homegardens are largely based on species diversity of trees, crops and food plants, the recent investigations

considered faunal categories such as land snails, butterflies, amphibians, ants, etc. (see Bambaradeniya, 2003; Karunaratne and Edirisinghe, 2008; Karunaratne et al., 2008; Raheem et al., 2008; Kumara and Ukuwela, 2009; Amarasinghe, 2010; Kudavidanage et al., 2012a; 2012b).

Floristic and faunal composition of homegardens

Similar to the homegardens in Bangladesh, India and Indonesia (Kumar et al., 1994; Kumar and Nair, 2004; Ali, 2005; Wiersum, 2006), homegardens in Sri Lanka are also characterized by high species diversity. As Nair (2006) suggested species diversity of homegardens is an appealing feature to the homegardeners for variety of reasons, and has been identified as a major driving force in the maintenance of the gardens for centuries. Species diversity of different floral and faunal components of Sri Lankan homegardens recorded by researchers during the past four decades is summarized in Appendix, and depict that a wide variation exists in species assemblages of different geographic/agro-ecological regions.

According to Ariyadasa (2002), there are more than 400 different woody species in homegardens and 120 of these species are common while some species are planted the others are naturally regenerated. A total of 153,493 million trees have been recorded from homegardens in 20 districts of Sri Lanka of which Wet, Intermediate and Dry zone homegardens consists of 49, 37, and 14% of trees, respectively. The average density of trees in homegardens of Sri Lanka is recorded as 200 trees/ha although there is a wide variation from 20 to 475 trees/ha. The Wet zone homegardens are significantly smaller in extent than those of the Dry zone of the country, but the total number of trees recorded within the Wet zone is much higher due to the higher tree density (average of 260 trees/ha) than those in the Dry zone (average 125 trees/ha). Further, higher species density has been reported in small homegardens than that of large homegardens (McConnell and Dharmapala, 1973; McConnell, 1993).

The common tree species based on frequency of occurrence in homegardens of Sri Lanka are *Cocos nucifera* L. (38.616 million), *Hevea brasiliensis* (A. Juss.) Muell. Arg. (17.101 million), *Artocarpus heterophyllus* Lam. (10.437 million), *Areca catechu* L. (9.697 million), *Swietenia macrophylla* King. (6.410 million), *Alstonia macrophylla* Wall. Ex G. Don (5.968 million), *Mangifera indica* L. (5.607 million), *Albizia falcataria* (L.) Fosberg (5.607 million), *Eucalyptus* spp. (4.061

HOME GARDEN RESEARCH IN SRI LANKA

million), *Tectona grandis* L.f. (3.293 million; Ariyadasa, 2002). Agriculture census conducted in 2002 recorded 17.464 million trees of *C. nucifera*, 4.605 million trees of *A. heterophyllus*, 3.286 million trees of *M. indica* in Sri Lanka (DCS, 2002). Highest occurrence of *C. nucifera* and *A. heterophyllus* are due to their multiple uses especially food, nutritional, medicinal, and timber uses among households. Ariyadasa (2002) reported that the important home garden tree species are well distributed over the country and found in all three climatic zones, and 22 such species are distributed in excess of 50% of the land area. Similar observations have also been made by Hitinayake et al. (1996) in the mid country Intermediate zone (Kundasale), mid country Wet zone (Galagedara) and up country Wet zone (Galaha) areas; Weerahewa et al. (2011) in Kandy, Kurunegala and Batticaloa districts, and Marambe et al. (2012b); and Weerahewa et al. (2012) in Kandy (Pilimathalawa) and Anuradhapura (Sivalakulama and Keeriyagaswewa) districts. Wezel and Bender (2003) stated that species such as *M. indica*, *C. nucifera*, *Coffea arabica*, *Citrus* spp. and *Musa* spp. are common in tropical homegardens in the world, too.

Inventories on domestic animals are given in Perera and Rajapakse (1991) Marambe et al. (2012c), and Weerahewa et al. (2012). Diversity of butterflies, birds, small mammals, amphibians, and reptiles are given by several authors and discussed elsewhere in this review. In terms of plant diversity, the Dry and Intermediate zone homegardens are less diverse compared to that of the Wet zone homegardens in general, although there are exceptions exist in some areas (see Weerahewa et al., 2012). The Dry zone homegardens (Dharmasena, 1993; 1994; 1997) and homegardens adjacent to natural forests (Nuberg et al., 1994) consist of higher diversity of endemic species compared to Kandyan homegardens (Pushpakumara et al., 2010). In term of diversity of animal species, Kudavidanage et al. (2012) revealed that amphibian species found in homegardens adjacent to Sinharaja forest are mostly common and widespread species, and endemic species are largely concentrated to forest communities. Similar trends have also been reported in birds and small mammals of Sinharaja forest by Wijesinghe and Brooke (2005). However, an island wide study on this aspect is not reported to date and some available information needs further verification.

Comparison among different studies on homegardens in Sri Lanka is however difficult due to the different criteria employed for preparing inventories by the researchers. Lack of uniform methodologies, and also variation of the

perspectives in the process deriving data make it impossible in some cases for direct comparison. Further, definitions of homegarden, age and developmental stage of homegardens (Plate 1) have not been uniform or not reported in many cases. Thus, the information needs to be interpreted with caution. These situations lead it difficult to identify whether diversity and density of homegardens have changed favorably or unfavorably during the last four decades. Many studies carried out on floristic richness of homegardens are, unfortunately deficient in the information on degree of heterogeneity in the study areas. Little attention has been paid to relate the floristic richness to ecosystem processes.

Homegardens are recognized as reservoirs of conservation and use of germplasm for a wide variety of useful species (Eyzaguirre and Linares, 2004; Pushpakumara and Silva, 2008). Although homegarden in general, and Kandyan homegardens in particular have been identified as repositories of germplasm of numerous species (Perera and Rajapakse, 1991; Jayasuriya and Rajapakse, 2004; Pushpakumara and Silva, 2008), studies on genetic diversity of homegarden floral and faunal species have not been reported in Sri Lanka.

Vertical structure of homegardens

The multi-tiered canopy structure is another distinguishing feature of homegardens in the humid tropical lowlands as homegardens consist of a mixture of species whose canopies are arranged in different vertical layers (Kumar and Nair, 2004). They are carefully structured systems with every component having a specific place and function. Several layers of plants occupy the available space both horizontally and vertically and resources are widely used due to its arrangement on different canopy configurations. In general terms, all homegardens in Sri Lanka consist of a herbaceous layer near the ground (1-1.5 m height), a tree layer at upper canopy levels (approximately over 25 m), and one or more intermediate layers in between depending on the area of occurrence (Perera and Rajapakse, 1991; Pushpakumara et al., 2010). The vertical profile reported in homegardens of Sri Lanka, categorization of stratification and associated species are given in Table 3. Accordingly, the Wet zone homegardens, particularly Kandyan homegardens are structurally more complex than the Dry zone homegardens. As expected, the newly established homegardens are structurally simpler than the well established mature homegardens (Plate 1; McConnell and Dharmapala, 1973; Jacob and Alles, 1987; Perera and Rajapakse, 1991; Pushpakumara et al., 2010).

Table 3. Vertical profile reported from homegardens in different areas of Sri Lanka.

Location	Climatic Zone	Sample Size	Number of vertical layers and associated height and species.	Source
Kandy	MCWZ	1	Three vertical layers identified (top canopy layer->10 m height, middle layer-between 5-10 m height and bottom layer < 5 m height)	Costa et al. (2006)
Matale district (spice gardens)	MCWZ	127	Five canopy layers reported. The highest canopy layer (> 15 m) dominated by jackfruit, coconut, durian and mango, the second highest layer (9-15 m) dominated by arecanut, nutmeg, clove, kitul palm, the third or middle layer (5-8 m) dominated by pepper, avocado, and giricidia, the lower layer (1-4 m height) dominated by coffee, vanilla) and the ground layer (< 1 m) where ginger, is common.	Lindara et al. (2006)
Hambantota district	LCDZ	150	Three vertical layers recorded (herbaceous <1 m height, intermediate-between 1-15 m height and tree layer-about 15-25 m height)	Sivananthawerl et al. (2004)
Kandy	MCWZ	10	Trees taller than 2/3 of top height are classified as upper storey, trees within 2/3 and 1/3 of top height as the middle storey and trees less than 1/3 of top height as the lower storey.	Hitinayake and Sinclair (1998)
Mirahawtaa, Welimada (Uva basin)	UCIZ	60	Canopy height ranged from 15-25 m and five vertical layers (emergent, canopy, sub canopy, shrub layer and ground cover) recorded (stated that not in clear tiered arrangement).	Everett e, (1995)

Table 3 Continue

Central Sri Lanka, Kandy	MCWZ	30	<p>Five vertical strata reported. Level 5-Canopy (15-30 m height and dominated by durian, talipot palm, jakfruit, coconut, kapok), Level 4-upper middle layer (9-18 m height and dominated by bamboo, arecanut, nutmeg, clove, rubber, wild breadfruit, kitul palm, mango), Level 3-lower middle layer (6-12 m height and dominated by pepper, avocado, mangosteen, breadfruit, rambutan, citrus, papaw), Level 2-Lower layer (1-6 m height and dominated by cacao, coffee, passion fruit, betel vine, vanilla) and Level 1-ground layer (< 1 m height and dominated by tea. Cassava, ginger, turmeric, anthurium, pineapple, vegetables, yam and grass/fodder).</p>	McConnell (1992)
Central Sri Lanka, Kandy	MCWZ	50	<p>Four vertical strata identified. Canopy (>10 m height and dominated by <i>Alstonia</i>, coconut and jackfruit), third layer (2.5-10 m height and dominated by <i>Gliricidia</i>, fishtail palm, arecanut, cloves, avocado, mango), second layer (1-2.5 m height and dominated by papaw, coffee) and ground layer (<1 m height).</p>	Perera and Rajapakse (1991)

Note: Arranged according to the published year; MCWZ=Mid country Wet zone; LCDZ=Low country Dry zone; UCIZ=Up country intermediate zone

The presence of numerous strata facilitates the efficient use of light and space, maintaining relatively constant levels of temperature and humidity in the soil and diminishing the effect of the seasonal climatic variation (Montagnini, 2006). Further, in homegardens utilization of resource and production is optimized in each stratum where species adapt according to their life form (De Clerck and Negreros-Castillo, 2000). There is no significant association between age of the homegardens with the number of tree species recorded. It is suggested that the structure and composition of the homegardens determine the level of production (Kumar and Nair, 2004; Montagnini, 2006), although the information on this aspect under Sri Lankan condition is limited. With regards to vertical structure of homegardens also comparison among studies cannot be made due to the different criteria used to define vertical stratification. Attention on vertical and horizontal structural profiles of homegardens of different ecological regions of Sri Lanka is scanty. Therefore, it is worth in future studies to stratify homegardens on the basis of the appropriate forest type in the area and sketch-record the common homegarden types at least by means of a line diagram.

Management of homegardens

Traditional management of homegardens in Sri Lanka is characterized by low inputs and simple technology (McConnell and Dharmapala, 1973; Perera and Rajapakse, 1991; Pushpakumara et al., 2010). One reason for the low level of management in homegardens is the lack of labour availability due to involvement of family members in other jobs (Jayawardena and Jayatilaka, 1998). Though the management of homegardens is less intense, some of the management related activities are naturally looked after. For example, cover crops and mulching are rarely practiced to control soil erosion but a dense cover of dead litter is found on the floor of most homegardens providing the same function.

A close relationship between the management and functions of homegardens has been suggested. However, there have been very few studies carried on this aspect, specifically on the management of homegardens in Sri Lanka. It is also reported that homegardens are associated with abundant knowledge on how to manage plants and their sustainable use, but only a few researchers have documented the local practices, traditional uses and management of various plants besides the species inventories (see for example Hitinayake and Sinclair, 1994; Nuberg et al., 1994; Sinclair and Hitinayake, 2000).



Plate 1. Different developmental stages of homegardens in Sri Lanka.

Note: A=Well managed Kandyan homegarden can provide a similar environmental services as natural forests with well-stocked, multi-strata species of jackfruit, coconut, arecanut, kitul, ginisapu etc., although garden owned by individuals as neighboring gardens blend together an area seen from above appears as a forest island; B=Well managed Kandyan homegardens is useful to maintain a pleasant environment around the house; C=Dry zone homegardens are structurally simpler than that to Wet zone homegardens; D and E=Well stocked homegarden with annuals (many vegetables) and perennials (kathurumurunga, coconut, mango, banana etc.) can support family food and nutritional security; F=Early stage of development of homegarden.

HOME GARDEN RESEARCH IN SRI LANKA

Level of management and role of gender in homegardens have been investigated by Wickramasinghe (1991) and Jayawardena and Jayatilaka (1998) in Kandyan homegardens and reported that both the males and females are equally engaged in managing homegardens. In allocating space and selecting species for homegarden hedges, fences, both male and female members of the family go through a series of reasoning. The contribution of males and females varied with the type of management practices, which include land preparation planting, pruning of branches, construction of drains, application of organic fertilizer and pesticides and harvesting of products by climbing trees. The female dominance was mainly observed in activities such as removal of excess seedlings in nurseries, weeding, watering the plants and processing of harvested products (Wickramasinghe, 1991; Jayawardena and Jayatilaka, 1998). Marketing of products is mainly attended by males who are the main cultivators of trees in homegardens whereas, women often are responsible in growing most of the secondary crops that provide the diversity needed for a healthy diet, thus play a major role in ensuring nutrition and food quality.

As reported by Hitinayake and Sinclair (1998) and Jayawardena and Jayatilaka (1998) the management practices such as pruning and thinning are not performed adequately in the homegarden systems largely due to misconceptions about effects of pruning on tree growth. According to findings of their study, the composition and structure of understory of homegardens in Kandy district most species and individuals in the understory have self established and are rarely managed. These evidences indicate opportunity to increase production and productivity of homegardens by expansion, replacement, substitution and management of plant and doemtic animal species. However, the dynamism of the homegarden overstorey or understory has not been adequately addressed so far.

Wijesinghe et al. (2010) and Egodawatta et al. (2011) reported that higher organic matter incorporation in homegardens compared to crop fields, has enhanced soil chemical and physical properties and crop yield of both maize and mung bean. Based on these results they suggested that in order to develop a sustainable land use system in slopy landscapes, homegardens can be used as a benchmark for upgrading the land use systems. However, homegardens also require soil erosion control under continuous cultivation. The same authors further suggested agronomic, social and economic characteristics could also have an influence over the sustainability of homegardens in Meegahakiula area of Badulla district in Sri Lanka.



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Socio-economics of homegardens

Attempts have been made to identify the major socio-economic conditions associated with Kandyan homegarden systems in several studies. The basic function of a homegarden in Sri Lanka has been identified as, to provide the subsistence needs of household, irrespective to the changes in economic development of the country. Economic benefits, generation of employment opportunities and social impacts of homegardens have been addressed in few studies. However, these studies are also not comparable as different definitions, tools and techniques have been used.

Batagalla et al. (1998) proved that the profits gained in agroforestry homegarden systems are superior to the profits of monoculture systems such as tea and cloves. The study has revealed that 95% of the farmers have increased their income by engaging in homegardening and helped themselves minimizing of risk, maximizing leisure and production of subsistence needs. Changing the composition of trees to have more income generating crops is one of the options for increasing the profit margin. The study further showed that the income from Kandyan homegardens is positively and significantly related to the number of species grown, family labour available, capital used, land extent and tree density. However, the average homegarden income earned varies and difficult to compare due to differences in methodologies used in the reported studies. Further, a common problem of assessment of economic benefits of homegardens is lack of widely accepted procedures to measure intangible benefits of homegardning (Nair, 2006).

Homegardens are also significant sources of mineral and other nutrients. However, assessments on the contribution of homegardens to food and nutrient security of families are yet to be comprehended as there are only selected areas on this aspect have been addressed to-date (Weerahewa et al., 2011). Weerahewa et al. (2011) showed that the intake of vitamin A, vitamin C, calcium and iron from homegarden sources enable an individual to meet 11%, 71% and 11% of the Recommended Daily Allowance (RDA) of these nutrients. They suggested that diversification and intensification of homegardens would help in achieving nutrition security of the household. Detailed descriptions on micronutrients provided by homegarden food and tree crops are depicted in Marambe et al. (2012b), too. The dietary diversity of household members can be enhanced through intensification

of homegardens by introducing selected underutilized fruit and vegetable species based on nutrient composition of species, and by awareness creation among householders with regard to their nutritional value (Jeevika Weerahewa - *Personal Communication*).

Quality of homegarden products and their impact on health of household members have also been predicted (Pushpakumara et al., 2010), but no evaluation has been done to-date. Impacts of tsunami in 2004 and the subsequent recovery of homegarden ecosystem in the coastal area have been reported by IUCN (2005). Changes of homegardens due to government interventions such as fertilizer subsidy for food crops, national agriculture development programs like 'Divineguma', are yet to be assessed and need attention of the researchers. Only a status report has been published in this respect by Fonseka et al. (2010) so far.

Other research information

Krishnarajah and Sumanarathne (1988) reported that the estimated soil erosion in well-managed homegardens (0.05 t/ha) is almost comparable to the annual soil loss under natural forest. The soil chemical conditions of Kandyan homegarden systems developed on reddish brown latasolic soil are reported by Kendaragama and Jayasundara (2012) and indicated that soil is slightly acidic (pH range from 5.2-5.8) in nature with above average organic matter content (ranging from 2.6-3.7, where the average for ultisols is 2%), with low level of available phosphorus (ranging from 1-3.8 mg/kg) and moderate levels of exchangeable potassium (ranging from 93-124 mg/kg). Siddique et al. (2007) revealed that the practicing of Kandyan homegardens for a long period of time in marginal lands have led to improve soil physical and chemical properties resulting in rehabilitation of the soil conditions. Introducing proper management practices and appropriate extension services to enhance the efficient resource utilization and other aspects of homegardens management would help increasing the production of homegardens (Siddique et al., 2007).

An investigation of 25 homegardens in sub-urban Colombo area by Fernando (2009) revealed the occurrence of 36 wood-inhabiting agaric fungi. The highest species richness was found on timber of *C. nucifera*, recording 16 agaric species. *A. heterophyllus*, *T. grandis*, *S. macrophylla* and *Vitex altissima* L.f. showed resistance to macro-fungal attack. *Schizophyllum commune* Fries fungus

was observed on 16 wood species as the most common agaric species while 17 other agaric species recorded their preference for one particular wood species. However, diversity of soil micro- and meso-flora and fauna, and lower plants of homegardens are little studied.

Nutrient cycling and safety net mechanism in the tropical homegardens have been reviewed by Seneviratne et al. (2006) and revealed that such studies help improving the homegarden production and services rendered to the inhabitants while sustaining the system. It is proposed that maintaining plant structural diversity and density are fundamental to nutrient recycling (Nair, 2006; Seneviratne et al., 2006). Agronomic practices such as root and branch pruning, fertilizer and manure applications should be optimized for enhancement of productivity with a least depletion of the system. However, empirical evidence on this area is scanty in Sri Lanka.

Wagachchi and Wiersum (1997) suggested that the inclusion of ponds in homegardens increases the multi-functional nature of the homegardens, especially in relation to water availability, erosion and sedimentation management and animal husbandry. They further added that the presence of a pond in the homegarden optimizes the complementary nature of homegardens in the farming systems of Badulla district in Sri Lanka.

The only reported study on physiological aspects of homegarden tree species in Sri Lanka has been carried out by Costa et al. (2006) focusing on water uses of different species at different canopy layers. Despite the limited sample size and limitation in selection of species in different layers, they suggested that water use of Kandyan homegardens is dominated by the large upper canopy trees and largely determined by the incident solar radiation. However, no such studies have been reported for other homegarden systems in the country.

Studies conducted by Gunawardena et al. (1994) and Hall et al. (1995) reported that the water loss from Kandyan homegardens is substantial and comparable to natural forests. Effects of climate change on homegarden adaptation strategies in Sri Lanka have been investigated recently by Marambe et al. (2012b; 2012c) and Weerahewa et al. (2012) who reported that despite the fact that there is evidence of climate change in the past 20 years, the composition of homegardens in Sri Lanka has not changed substantially, but the different management strategies

adopted by home gardeners have enabled them to cope up with changes in the climate.

A study on the sub-surface pot irrigation system and a sub-surface irrigation system with specially designed clay emitters established in home garden vegetable field with curry chilies have revealed that compared to manual irrigation, the yield obtained from the crop under designed irrigation was two times higher (Navaratne et al., 2006). The use of water under sub-irrigation system with clay emitters has been considerably low when compared to the sub surface pot irrigation. Both designed irrigation systems have automatically control the water intake of the soil when the soil is wet (Navaratne et al., 2006). Navaratne et al. (2003) has also described a methodology to determine the system of cropping calendar and planting time for home garden vegetables by minimizing the risk associated with the dry spell in cropping season.

SIGNIFICANCE OF HOMEGARDEN AGROFORESTRY TO SRI LANKA

A summary of goods and services provided by home garden agroforestry and status of the relative attributes of home gardens in relation to a land use continuum in the tropics are given in Table 4 and 5, respectively.

Table 4. Summary of goods and services provided by home garden agroforestry.

Major category	Goods or services provided
Provision of goods	Fruits, vegetables, spices, medicine, staple food items, stimulus, timber, fodder, fishery products, livestock products, poultry products, bee honey,
Provision of regulating services	Carbon sequestration, flood control, ameliorating micro-climate, water quality, soil erosion, pest and disease control, symbiotic relationships,
Provision of cultural services	Aesthetic, employment, social status, pleasure, pride, sacrifices, benefit sharing, building up mutual relationships
Provision of supporting services	Habitat for wild flora and fauna including pollinators, nutrient cycling, nutrient dispersal, seed dispersal, resource utilization

Table 5. Summary of the relative attributes of a land use continuum in the tropics.

Attributes	Type of land use					
	Intensive monoculture		Poly culture		Secondary forests	Primary forests
	Annual crop	Perennial crops	Simple agroforests	Homegardens		
Diversity	Low	Low	Medium	High	Very high	Very high
Soil biota	Low	Low	Medium	High	High	Very high
Ecosystem services	Low	Low-medium	Low-high	Medium-high	High	Very high
Loss rate of soil carbon (decomposition)	High-very high	Medium	Medium	Low-medium	Low-medium	Low
Nutrient outputs (leaching/other losses)	High	Medium	Medium	Low	Low	Very low
Fossil fuel inputs/subsidies (Carbon costs)	High	Medium-high	Low-medium	Low	Zero	Zero
Above ground C stock	Low	Low-high	Low-high	Medium-high	Medium-high	Very high
Below ground C stock	Low	Low-high	Low-high	Medium-high	Medium-high	Very high

Source: Adapted from Kumar (2006).

Homegardens as a source of timber and fuelwood

In Sri Lanka, forests and forest plantations account for about 75% of the wood production. However, most of this wood is inaccessible due to the ban on logging in natural forests since 1990 (FSMP, 1995). Further, the forest plantations have not substantially expanded even after imposing the logging ban in natural forests and has not contributed substantially to the demand for timber or fuelwood supply of the country compared to other sectors (Table 6). Trees are managed in areas other than the natural forests and forest plantations in the country. In terms of products and services, homegarden agroforestry systems have contributed substantially to the Sri Lankan economy, and are the major sources of timber (42%) and fuelwood (27%) (Table 6). For example, according to FSMP (1995), homegardens produce about 0.95 m³ of sawlogs and 0.5 m³ of poles/ha/year, on average. In some areas, homegardens provide over 75% household fuelwood requirements (Everett, 1995). Homegardens will become crucial for Sri Lanka in future as the sawn wood demand from 1993 to 2020 is projected to grow by 12,600 m³/year, which correspond to the annual average growth rate of 2%. Similar trends have also been projected for the demand for fuelwood, which is the highest in the areas of estate sector in the upcountry (FSMP, 1995).

Table 6. Contribution of national timber and fuelwood supply of Sri Lanka from various sources.

Source	Timber supply (%)	Fuelwood supply (%)
Homegardens	42	27
Rubber plantation	18	19
Coconut plantation	11	19
Forest plantation	11	4
Imports	10	-
Other sources	8	14
Natural forests	-	7
Crop residues	-	7
Processing residues	-	3

Source: FSMP (1995); Ariyadasa (2002); FAO (2009).

As Ariyadasa (2002) estimated, 22 out of 25 administrative districts of Sri Lanka consist of 124 million timber trees in homegardens dominated by *C. nucifera*, *H. brasiliensis*, *A. heterophyllus*, *S. macrophylla*, *A. macrophylla*, *M.*

indica, *A. falcataria*, *Eucalyptus* spp. and *T. grandis*. Accordingly, homegardens in Sri Lanka are capable of producing over 1.3 million m³ of industrial timber and fuelwood. This indicates that management of trees outside forests particularly in homegardens could be a priority option for sustainable development. In the global scale, too, smallholder timber production is increasingly appreciated in many countries (Garrity, 2004). However, achieving the national timber and fuelwood demand from homegardens is hampered to some extent due to fragmentation of homegardens. Fragmentation leads to loss of canopy trees, especially in the areas of highly populated Wet zone (MENR, 2009; Dela, 2010) and decreases the timber production potential. Further, the ban on logging imposed on some timber species and requirements of permits for transportation of timber which are commonly grown in homegardens have negatively impacted on the timber production (MFE, 1999; Pushpakumara et al., 2010). Hence, the regulations need to be revised or alternative homegarden certification systems should be developed if further expansion of timber production from homegardens and other sources outside forests are anticipated. In addition, the availability of quality planting material of timber trees is another prerequisite. The true potential of timber production and alternative strategies for timber production in homegardens has however, not been updated in Sri Lanka after the Forestry Sector Master Plan completed in 1995 (FSMP, 1995). Thus, updating of timber production and demand under the current scenario is critically needed.

Homegardens as a source of household income

Homegardens provide a considerable amount of household income, and it varies from a very low value to almost the total income for some families. If Kandyan homegardens are taken as an example, the percentage contribution to the total household income within the range of 30-50% is common, and this contribution comes mostly from the cash crops such as spices and timber trees (McConnell and Dharmapala, 1973; Perera and Rajapakse, 1991; Batagalla et al., 1996; Lindara et al., 2006). One of the key factors in Kandyan homegardens is the occurrence of several species of spice crops (McConnell and Dharmapala, 1973; Perera and Rajapakse, 1991; Lindara et al., 2006), such as cloves (1.084 million trees), nutmeg (0.151 million trees), and pepper vines (4.746 million vines; DCS, 2002). These species are high value crops and provide a significant income for householders (McConnell and Dharmapala, 1973; Perera and Rajapakse, 1991; Lindara et al., 2006). According to the consumer finance and socio-economic surveys, homegardens in the rural sector provide a higher contribution to the

HOMEGARDEN RESEARCH IN SRI LANKA

household income compared to those in the urban and estate sectors (Table 7). A gradual decline in such contributions has been observed over the years in both rural and urban sectors. Research carried out on market gardens in elsewhere has shown that a 10 m x 20 m vegetable plot for small farm families can increase the family income by 30% (Chadha and Oluoch, 2003; 2007).

Table 7. Contribution of homegarden induced income by sectors.

Year	Cash Income (million Rs)	Urban	Rural	Estate	All Sectors	
1986/ 1987	1 Month	Income (%)	0.30	2.30	0.40	1.60
		Total income	5.35	10.97	0.95	17.26
1987	6 Months	Income (%)	0.30	1.80	0.40	1.20
		Total income	31.87	60.65	5.35	97.87
1996/ 1997	1 Month	Income (%)	0.10	2.00	0.30	1.60
		Total income	14.24	50.59	2.24	67.07
1997	6 Months	Income (%)	0.10	1.60	0.20	1.30
		Total income	82.15	287.52	12.56	382.23
2003/ 2004	1 Month	Income (%)	0.11	1.75	0.98	1.37
		Total income	36.14	127.67	4.82	168.62
2004	6 Months	Income (%)	0.08	1.26	0.62	0.98
		Total income	213.77	721.75	27.09	962.61

Note: One month and 6 months cumulative income are given. Income (%) refers share of income from homegardens. Total income refers total cash income earned by all the households in the receptive sector. Sources: CBSL (1986-2004).

Homegardens as a way of reaching household food and nutritional security

Montagnini (2006), Pushpakumara et al. (2010) and Weerahewa et al. (2011) suggested that the homegardens can enhance food security by (a) providing direct access to a variety of nutritionally rich foods, (b) increasing purchasing power from savings on food bills and income from sale of garden products, and (c) providing fall-back food during periods of temporary food scarcity. It is a well established fact that the increasing agricultural productivity on small holdings is one of the most effective strategies to ensure people, especially the poorest people, to have an accessible food supply (Yang and Hanson, 2009). One effective way of ensuring access to a healthy diet that contains adequate macro and micro-

nutrients is to produce diverse kinds of foods in farming systems. This is further supported by the present analysis as it revealed that in Sri Lanka homegardens are dominated by food use species demonstrating their contribution to food plant diversity (Table 8). Marambe et al. (2012a) investigated expenditure patterns of households in a poverty stricken rural village in the Dry zone (Keeriyagaswewa) and in a middle-income village in the Wet zone (Pethiyagoda) in Sri Lanka to identify the contribution from the homegardens to household food security. The results showed a household, on an average, spends Rs. 6,179/= and Rs. 10,909/= per month to purchase food from the market and the market values of homegarden-produce were Rs. 1,155/= and Rs. 970/= per month (equivalent to 16.6% and 28.8% of the household food expenditure), respectively. The principle goal in homegardening is not to optimize production of a single crop but to guarantee a minimum supply of different food products at all times of the year. High value products from homegardens such as timber can be sold to purchase staple foods during the periods of food scarcity (Montagnini, 2006).

In a review on Kandyan homegardens, Pushpakumara et al. (2010) pointed out that the sustainable production of various foods and direct access to them is helpful in achieving the nutritional quality of meals and diet of the households. Similar idea has been highlighted by Weerahewa et al. (2011) for selected homegardens in Kandy, Kurunegala and Batticaloa districts. In all cases, homegardens provided a low cost, sustainable strategy for increasing household food and nutritional level by providing a steady supply of various types of edible products and more importantly direct access to them. They are traditionally designed to provide the basic complementary food and material products necessary for daily life (Table 8). The combination of trees, crops and livestock with different production cycles and rhythms provides a relatively uninterrupted supply of food products, which helps to increase the self-reliance of households (Pushpakumara et al., 2010). There may be peaks and slack seasons for harvesting various products from the homegardens depending on the climate and other environmental characteristics. However, there is usually something to harvest daily from most of the homegardens as they contain a large number of crop, tree and animal species (Table 8). A significant characteristic of tree and crop components in homegardens is the diversity of fruits, leafy vegetables, spices, and other food producing plants and trees (Table 8; McConnell and Dharmapala, 1973; Jacob and Alles, 1987; Perera and Rajapakse, 1991; Attygalle, 1996; Hitinayake et al., 1996; Pushpakumara and Silva, 2008; Pushpakumara et al., 2010). It has been

estimated that homegardens in Sri Lanka produce 50-60% of leafy vegetables, and 20% of all vegetables consumed by the household under urban conditions (Kumari et al., 2009). Homegardens scattered in the country also constitute the most significant production system for fruits in Sri Lanka (Weerakkody, 2004; Pushpakumara et al., 2007).

Table 8. Common species reported from homegardens of Sri Lanka.

Products	Examples
Food (some cases staple) species	<i>Artocarpus incisus</i> L. f. (breadfruit), <i>Artocarpus heterophyllus</i> Lam. (jackfruit), <i>Cocos nucifera</i> L. (coconut), <i>Colocasia esculenta</i> (taro), <i>Dioscorea</i> spp. (raja ala, sweet yam, greater yam), <i>Ipomoea batatas</i> (L.) Lam. (sweet potato), <i>Manihot esculenta</i> Crantz. (cassava), <i>Xanthosoma</i> spp. (coco yam), <i>Zea mays</i> L. (maize).
Fruit species	<i>Aegle marmelos</i> (L.) Correa (bael), <i>Anacardium occidentale</i> L. (cashew), <i>Ananas comosus</i> (L.) Murr. (pineapple), <i>Annona</i> spp. (soursop and sweetsop), <i>A. heterophyllus</i> (jackfruit), <i>Averrhoa carambola</i> L. (carambola), <i>Baccaurea motleyana</i> Mull. Arg. (gaduguda), <i>Borassus flabellifer</i> L. (palmyrah palm), <i>Carica papaya</i> L. (papaya), <i>Citrus</i> spp. (lemon, lime, sweet and sour orange, pommelo, mandarin), <i>Durio zibethes</i> Murr. (durian), <i>Elaeocarpus serratus</i> L. (weralu), <i>Garcinia mangostana</i> L. (mangosteen), <i>Limonia acidissima</i> L. (woodapple), <i>Mangifera indica</i> L. (mango), <i>Manilkara zapota</i> (L.) P. van Royen (sapodilla), <i>Muntingia calabura</i> L. (jam), <i>Musa</i> spp. (banana), <i>Nephelium lappaceum</i> L. (rambutan), <i>Passiflora edulis</i> Sims (passonfruit), <i>Persea americana</i> (avocado), <i>Phyllanthus emblica</i> L. (nelli), <i>Pouteria campuchiana</i> (Kunth) Baehni, <i>Psidium guajava</i> L. (guava), <i>Punica granatum</i> L. (pomegranate), <i>Spondias dulcis</i> Sol ex Parkinson (amberella), <i>Syzygium</i> spp. (rose apple, dan, madan), <i>Tamarindus indica</i> L. (tamarind).
Ornamental species	<i>Aglaeonema</i> spp., <i>Anthurium</i> spp., <i>Begonia</i> spp., <i>Bougainvillea</i> spp., cacti, <i>Caladium</i> spp., <i>Chlorophytum</i> spp., <i>Coleus</i> spp., crotons, <i>Cyperus</i> spp., <i>Dieffenbachia</i> spp., <i>Dracaena</i> spp., ferns, <i>Impatiens</i> spp., jasmine, <i>Maranta</i> spp., orchids, palms, <i>Peperomia</i> spp., <i>Philodendron</i> spp., roses.
Timber and fuelwood trees	<i>Albizia falcataria</i> (L.) Fosberg., <i>Alstonia macrophylla</i> Wall. ex G. Don, <i>A. heterophyllus</i> , <i>Azadirachta indica</i> A. Juss., <i>Berrya cordifolia</i> (Willd.) Burret, <i>C. nucifera</i> , <i>Eucalyptus</i> spp., <i>Filicium decipiens</i> (Wight & Arn.) Thw., <i>Gliricidia sepium</i> (Jacq.) Walp., <i>Gmelina arborea</i> Roxb., <i>Melia azedarach</i> L. s.l., <i>Michelia champaca</i> L., <i>Pterocarpus marsupium</i> Roxb., <i>Swietenia macrophylla</i> King, <i>Tectona grandis</i> L. f.

Medicinal plants	Over 200 species are recorded. Most herbs and trees in homegardens are medicinally used.
Vegetables (including leafy vegetables)	<i>Abelmoschus esculentus</i> (L.) Moench (okra), <i>Amaranthus</i> spp. (various thampala), <i>Basella alba</i> L. (spinach), <i>Capsicum annuum</i> L. (miris, malu miris), <i>Cardiospermum halicacabum</i> L. (penela), <i>Centella asiatica</i> (L.) Urban (gotukola), <i>Cocinia grandia</i> (L.) J. Voigt (kowakka), <i>Lasia spinosa</i> (L.) Thw. (kohila), <i>Luffa acutangula</i> (L.) Roxb. (wetakolu), <i>Lycopersicon esculentum</i> Miller (tomato), <i>Momordica charantia</i> L. (bittergourd), <i>Moringa oleifera</i> Lam. (moringa), <i>Olex zeylanica</i> L. (mella), <i>Phaseolus</i> spp. (beans), <i>Physalis micorantha</i> Link (andibatu), <i>Psopocarpus tetragonolobus</i> (L.) DC., <i>Sesbania grandiflora</i> (L.) Poir (kathurumurunga), <i>Solanum melongena</i> L. (brinjal), <i>Solanum violaceum</i> Ortega (thibbatu), <i>Syngonium angustatum</i> Schott (wel kohila), <i>Trichosanthes anguina</i> L. (snakegourd), <i>Vigna</i> spp. (me).
Spices, beverage and stimulant plants	<i>Areca catechu</i> L. (puwak), <i>Capsicum</i> spp. (chillies), <i>Cinnamomum verum</i> (L.) Presl (cinnamon), <i>Curcuma longa</i> L. (turmeric), <i>Cymbopogon citratus</i> (DC) Stapf (lemon grass), <i>Elettaria cardamomum</i> (L.) Maton (cardamom), <i>Garcinia quaesita</i> Pierre. (goraka), <i>Murraya koenigii</i> (L.) Spreng (curry leaf), <i>Myristica fragrance</i> Houtt. (nutmeg), <i>Pandanus amargllifolius</i> Roxb. (rampe), <i>Piper betel</i> L. (pepper), <i>Piper nigrum</i> L. (pepper), <i>Syzygium aromaticum</i> (L.) Merr. & Perry (cloves), <i>Theobroma cacao</i> L. (cocoa), <i>Zingiber officinale</i> Roscoe (ginger).
Animal species	Village and local breeds of <i>Bos Taurus</i> Linnaeus, 1758, <i>B. indicus</i> Linnaeus, 1758 (cattle), <i>Bubalus bubalis</i> Linnaeus, 1758 (buffalo), <i>Capra hircus</i> Linnaeus, 1758 (goat), <i>Sus scrofa</i> Linnaeus, 1758 (pigs), <i>Gallus domesticus</i> Linnaeus, 1758 (chicken).

Sources: McConnell and Dharmapala, 1973; Jacob and Alles, 1987; Perera and Rajapakse (1991); Attygalle, 1996; Hitinayake et al., 1996; Pushpakumara and Silva (2008); Pushpakumara et al. (2010); Weerahewa et al. (2011); Marambe et al. (2012a; 2012b), Weerahewa et al. (2012).

The production from most homegardens is used for home consumption or for sharing with neighbors, which is one of the important principles of achieving food security in rural villages (Wickramasinghe, 1993; Pushpakumara et al., 2010). As stated earlier, any marketable surplus can provide a security against future crop failures and also a source of additional income, which is particularly useful during the off seasons and droughts. Fuelwood, the major domestic energy source for over 90% of rural people, is becoming scarce in some locations, resulting in a substantial increase in time and energy spent on fuelwood collection, increased prices of fuelwood and use of low energy substituted fuelwood species

for high energy species (Ulluwishewa, 1997). The use of low energy fuelwood species for cooking also means spending longer hours by the side of fireplaces, usually ill-ventilated kitchens where the inhalation of smoke is difficult to avoid (Ulluwishewa, 1997). Further, lack of fuelwood impedes cooking and can contribute to only partial cooking, which in turn reduce the digestibility of food and partial boiling of water may increase health hazards (Pushpakumara et al., 2010; Ulluwishewa, 1997). Improvement of homegarden agroforestry with adequate number of fuelwood species help to minimize such problems by providing enough fuelwood to householders. Hence establishment of adequate fuelwood stock in homegarden agroforestry is suggested for new rural settlement and development projects (Ulluwishewa, 1997).

A recent study conducted in Bangladesh, Cambodia, Nepal and the Philippines showed that household food consumption can be improved through promotion of homegardens along with provision of education on nutrition (Talukder et al., 2010). According to Marsh and Talukder (1994) even a small mixed vegetable garden can provide a significant percentage of the recommended dietary requirement of protein, iron, calcium, vitamin A and vitamin C. Similar information has also been reported by Chadha and Olouch (2003) using a 4 m x 4 m plot with a family of five.

Although land is one of the limiting factors for agriculture, development of urban homegardening revealed that such problems can be overcome with technological interventions. In areas where homegarden land extent is limited, technologies such as vertical gardening, roof top gardening, establishment of cultivation tower and cultivation bags can be introduced. Further, landscaping of homegardens with edible species (edible landscape) is ideal for such situations where space arrangement for livelihood development, application of plant growing techniques and integration of edible plants into homegarden landscaping can be done. However, how such technologies have an impact on homegardening, both in urban and rural areas where land is limited, has not been specifically assessed in Sri Lanka.

Krishnal et al. (2012) used coping strategy index to identify food security of home gardeners and showed that multi-layered homegarden system with well-mixed annual and perennials are essential to reduce food insecurity. Analysis of actual food and nutrient supply from homegarden products in Sri Lanka and their

temporal changes are however relatively sparse, and only a few analysis has been initiated recently (Weerahewa et al., 2011). Analysis of availability of nutrients of homegarden products is particularly useful in determining appropriate composition of trees, crops and livestock in the system that will be useful in reducing poverty and malnutrition rather than maintaining a collection of different species in the homegarden. It is also considered that rearing small animals such as chicken will be useful in reducing malnutrition especially for the low income households (Montagnini, 2006). Poultry and cattle are the common livestock components in homegardens, but depending on the area, only 15-30% of householders keep livestock as a component of homegardens (Perera and Rajapakse, 1991; Marambe et al., 2012b; Weerahewa et al., 2012). Rearing of animals in homegardens of Sri Lanka is rather limited compared to other countries in the region (Marambe et al., 2012b; Weerahewa et al., 2012).

As evidence above suggests, if food and nutritional security is to be achieved through homegardening, the fundamental issues to be tackled are (i) improveing the understanding of the system and planned introduction and utilization protocol for plant/tree/animal species, (ii) understanding the reasons for leaving animal component out in the majority of homegardens in Sri Lanka and take appropriate measures to include them into the system, (iii) selection of species based on unique problems of the area (i.e. malnutrition due to vitamin A or iron deficiencies or poverty), and (iv) integrating homegarden skills training with health and nutrition education.

Homegardens and biodiversity conservation

Sri Lanka, despite its small size, is rich in diversity of natural and man-made ecosystems, species diversity among different groups of flora and fauna, and their genetic diversity and culture (Table 9). Further, Sri Lanka is identified as one of the 34 biodiversity hotspots in the world (Mittermeier et al., 2005). Under this situation and given the high population density and low forest cover (Table 2) in the biodiversity-rich Wet zone areas of the country, as Kabir and Webb (2008) suggested the important question arises whether the homegardens in Sri Lanka help conserve biodiversity? The presence of 13.1% of the country's area under tree-dominated habitats of homegardens (Table 2) makes this question very reasonable.

HOMEGARDEN RESEARCH IN SRI LANKA

The first step in assessing the conservation value of homegardens is to review the comparative floral and faunal surveys carried out in homegardens and natural vegetations. Three hypotheses have been proposed on how agroforestry systems such as homegardens could help conserve biodiversity (Schroth et al., 2004). Firstly, agroforestry can help reducing pressure on natural forests due to deforestation if agroforestry systems such as homegardens are adopted as an alternative to more extensive and less sustainable land use practices, or it can help the local people to cope up with the limited availability of forest land resources. Secondly, agroforestry systems such as homegardens can provide habitats and resources for partially forest-dependent native or endemic plant and animal species that would not be able to survive in the purely agricultural landscapes. Thirdly, in landscapes that are mosaics of agricultural areas and natural vegetation, the conservation value of the natural vegetation remnants (which may or may not be protected) is greater if they are embedded in a landscape dominated by agroforestry elements than if the surrounding matrix consists of crop fields and pasture largely devoid of tree cover.

Table 9. Species diversity of some invertebrates, vertebrates and plants in Sri Lanka.

Category	Number of species recorded	Number of endemic species
Bees	148	21 (14.2)
Dragon fly	120	57 (47.5)
Aphids	84	2 (2.4)
Ants	181	NA
Butterflies	243	20 (8.2)
Ticks	27	NA
Spiders	501	NA
Fresh water crabs	51	51 (100)
Land snails	246	204 (82.9)
Fresh water fish	82	44 (53.7)
Amphibians	106	90 (84.9)
Reptiles	171	101 (59.1)
Birds	482	33 (6.8)
Mammals	91	16 (17.6)
Flowering plants	3,771	960 (25.5)
Pteridophytes	348	48 (13.8)
Mosses	566	63 (11.1)
Liverworts	222	NA
Lichens	661	NA

Note: NA = Not available; values given in parenthesis represent Percentage endemism. Sources: MFE (1999); IUCN and MENR (2007).

Forest cover in Sri Lanka has declined from 70% at the beginning of the last century to 44% in 1956. Forty years later in 1997, the forest cover was only 21% (IUCN and MENR, 2007). Despite all efforts by both the government and non-governmental organizations, deforestation continues to threaten the country (FSMP, 1995; IUCN and MENR, 2007). The estimates indicate a further decline of the forest cover to 20% (Mattsson et al., 2012a), and up to 17% by the year 2020 (FSMP, 1995). The consequences of deforestations are serious and well-known. Similar to natural forest systems, homegardens also consist of high diversity of floristic and faunal elements (Appendix) and multi-layered structure dominated by trees as emergent in the canopy layer and small trees, shrubs and herbs in the other layers (Table 3).

As highlighted earlier, homegardens in Sri Lanka are helpful to ease pressure exerted on the natural forests. Homegardens are the most important single source of timber and fuelwood amongst the non-forestlands (Gunathilake, 1994; FSMP, 1995) and may prevent the forests from deforestation by providing forest products. Hence, as Schroth et al. (2004) suggested, under Sri Lankan conditions, the hypothesis that agroforestry would reduce deforestation appears to be valid although more empirical work is needed to clarify the range of social and economic conditions under which its validity is maintained.

Homegardens are typical examples for the conservation of trees, crops, herbs and other species, including livestock, through their sustainable utilization or *circa situm* conservation. Such homegardens provide a variety of habitat niches. Rotting logs, large amount of leaf litter, scrubs, presence of various levels of shade, the abundance of prey items (insects), conservation and storage of water, and interconnected homegardens occupying a large area, are the typical examples of attributes to the high level of niche specialization found (Karunarathna et al. 2007; Pushpakumara et al., 2010). In areas where highly fragmented natural forests exist, value of homegardens in connecting natural forests is significant (Senanayake, 1987; Gunatilleke et al., 2005; Karunarathna et al. 2007; Gunatilleke et al., 2008; Raheem et al., 2008; MENR, 2009; Dela, 2011; Kudavidanage et al., 2012). One advantage claimed by homegardens is that they can bring some biodiversity benefits associated with natural forests into the homegarden land use system by often being refuges and providing shelters for plants species, small mammals, birds, bats and insects, which play an essential role in ecosystems services such as pollination, natural hybridization, and seed and fruit dispersal.

McConnell and Dharmapala (1973) and Jacob and Alles (1987) suggested that the species density and diversity of Kandyan homegardens are comparable to that of natural forests in similar elevations and climates. However, from the data presented in the earlier section of this review, it is evident that, despite the exceptionally high species diversity for agricultural systems and the occasional presence of threatened and endemic species, homegardens are a poor substitute to natural forests because many forest-dependant species are missing or under-represented (Pushpakumara et al, 2010; Kudavidanage et al., 2012a). Dela (2011) and Moore et al. (2010) reported that the majority of one of the world's 25 most endangered primates in Sri Lanka, *Trachypithecus vetulus nestor* (Colobinae), are now living predominantly in homegarden ecosystem of the country, outside the forest ecosystems. The broader understanding of complex interactions that take place between humans and animals living in sympatry is of paramount importance to the survival of species (Moore et al., 2010; Dela, 2011) as well as continued existence of homegardeners.

Based on the assessment of amphibian and butterfly diversity of Sinharaja forest and adjacent anthropogenic habitats including homegardens, Kudavidanage et al. (2012) stated that homegardens at the periphery of forests require realistic management recommendations to support the species inhabiting, visiting or migrating through them. Kudavidanage et al. (2012) also suggested that decision making requires a multi-taxon approach as homegardens provide a favorable habitat complexity for butterflies but not for amphibians.

Many authors (Schroth et al., 2004; Gunatilleke et al., 2005; Webb and Kabir, 2009; Pushpakumara et al., 2010) have suggested that homegardens cannot be seen as a substitute or replacement but only as a complement to areas of natural forest habitat. However, as Pethiyagoda (2012) suggested when ideal conservation option of primary forests is no longer achievable, given rising human population pressure, there is no choice but to make the best of the second best. In this respect, homegardens and other agroforestry systems can play integral role in future tropical biodiversity conservation. Enhancing the quality of homegarden habitats when in proximity to forests should be prioritized as they can provide habitats to forest species and some non-forest species. Further, in order to protect the multi-storied and multi-species nature of the homegardens under increasing intensification of land use practices, it will be increasingly important to find ways to increase the

profitability of homegarden systems while maintaining, as much as possible, their biodiversity benefits. The presence of natural faunal categories in some instances may also complicate homegarden management due to the damages done to crops/trees/animals. For example, mongoose, monkeys, pigs, porcupines, giant squirrels and palm cat may damage homegarden species/products, which need to be handled carefully if desirable benefits are to be reaped through biodiversity conservation in homegardens.

It is widely accepted that the homegardens involve biodiversity-friendly land use practices, which helps conserving agrobiodiversity (Perera and Rajapakse, 1991; Hitinayake and Ekanayake, 1999; Jayasuriya and Rajapakse, 2004; Pushpakumara and Silva, 2008; Pushpakumara et al., 2010; Marambe et al., 2012a; 2012b). For example, the Kandyan homegardens are not isolated management units but, they always complement other agricultural activities such as permanent rice farming and further contribute to a landscape mosaic, which link agricultural land and wild areas (Bambaradeniya, 2003). Though the Kandyan homegardens provide an expanded habitat for a wide range of species, from soil micro-life to beneficial insects including pollinators, and from crops and trees to mammals, birds and other wildlife, little information is available on this aspect in published form. In addition, they also provide a vital refuge for native flora and fauna. Perera and Rajapakse (1991) reported that out of 39 fruit species recorded from the Kandyan homegardens, 32 have been lesser-known, while Hitinayake and Ekanayake (1999) reported 20 fruit species as underutilized. Further, 30% of the plant species have no apparent uses (Perera and Rajapakse, 1991), but attempts to intensify the garden's productivity by replacing these with productive plants have not been made (Hitinayake and Sinclair, 1998). Above cases indicate the conservation potential of homegardens. Furthermore, well interconnected homegarden systems in Sri Lanka may contribute to the conservation of biodiversity by enhancing landscape connectivity, reduce edge effects and improve local microclimates, and could make a substantial contribution to the long term viability of plant and animal populations in the tropical mosaic landscapes (Schroth et al., 2004). However, evidence in proving such contributions need to be collected largely in Sri Lanka as reported evidence cannot be adequately found to-date.

Although scientific evidence for homegarden based tree domestication in Sri Lanka is hard to find, the ancient literature (such as Mahawamsa, *undated*;

HOME GARDEN RESEARCH IN SRI LANKA

Ceylon Administrative Reports, various years) provide some indication about the diversity of trees around the homegardens. In this respect, homegarden owners may have instinctively selected trees with desirable characters such as large fruits, better quality fruits with other desirable traits from the natural forests. These garden owners constantly try out and test new species and varieties, including methods to improve their management which mirrors a substantial indigenous knowledge base (Kumar and Nair, 2004). Therefore, the homegardens not only provide locations for initial domestication of wild crops, trees and animals but also act as a principal hub of evolution of crops, trees and animals and their diversity. Eyzaguirre and Linares (2004) in their global survey of homegardens documented many cases where homegardens serve as sites for continuing crop domestication. The maintenance of agrobiodiversity in the form of crop and tree varieties, many of which are genetically important for adaptation and formation of new products, is among the environmental services that homegardens provide (Eyzaguirre and Linares, 2004), that are not present in larger fields or commercial orchards and horticulture. While progress in modern agriculture has been through mono-specific stands, sometimes described as biological deserts, the homegardens can be considered as spectacular examples of crops, trees and animal rich and diverse communities. Further, these systems also provide cultural identity as the traditional systems based on indigenous species and associated knowledge is part of the cultural patterns of the community.

It is clear that the homegarden network of Sri Lanka provides a complementary resource base for conservation of crop/tree/animal genetic resources and acts as a complementary option to mediate *in situ* - *ex situ* gap, and a platform for continuation from natural vegetation to monoculture fields. The system can also play an important role in the *circa situm* conservation of germplasm selected by farmers over generations providing field gene banks. It is important to note that conservation of endemic species is limited even in Kandyan homegardens. Thus, due to the lower level of presence of endemic and rare plants in homegardens compared to exotics, the value of homegardens to native and endemic plant conservation remains unresolved. Further, comprehensive analysis of floral and faunal components along the gradient of different landscapes is rare (see Raheem et al., 2008; Kudavidanage et al., 2012a) or even few done have lapses due to limited sample size or lack of information on plant community (see Appendix).

Adequate attention has not been paid on the assessment of existing stocks of trees, crops and domestic and other animal species and their contribution to crop, forest and animal genetic resources conservation and facilitation of gene flow in Sri Lanka. As Webb and Kabir (2009) suggested there is a need for a paramount shift in the research focus beyond the present trend of species compilation into landscape level investigations of multidimensional ecological process. Such an approach exemplified by Raheem et al. (2008) and Kudavidanage et al. (2012) in homegardens and adjacent natural vegetations has helped identifying whether homegarden is a viable conservation option for native biodiversity.

Homegardens and sustainable management of landscape through other environmental services

The contribution of homegardens to sustainable management of land has been reviewed mainly focusing on the Kandyan homegarden system. Pushpakumara et al. (2010) reported that the Kandyan homegardens, apart from contributing to food and nutritional security and biodiversity conservation, provide environmental conservation such as protection of natural forests, increase multi-layered vegetation cover leading to pleasant living environment, erosion and pollution control, and fertility replenishment. Though it is well speculated that the homegardens and agroforestry systems provide ample products and environmental benefits at landscape level in Sri Lanka, it is clear that one of the major constraints in employing homegardens to provide environmental benefits is the absence of comparative quantitative data on landscape health, soil micro flora, carbon sequestration, soil erosion control, tranquility of human mind and aesthetic beauty of the area (Tables 4 and 5). There is no economic feed back to homegarden systems that facilitate these benefits, and thus need to be urgently addressed.

Homegardens and tree cover maintenance

The natural forest cover together with homegardens provide a reasonable tree-dominated vegetation cover for almost all districts of Sri Lanka, which is of high value (40.8%; see Table 2) in terms of associated environmental benefits of the perennial crops in the area (Tables 4 and 5; Pushpakumara et al., 2010). For example, the forest cover in Kandy district (including the Mahaweli catchment

HOME GARDEN RESEARCH IN SRI LANKA

area but excluding homegardens) has been estimated to be 17% whereas the tree cover including homegardens exceeds 47% of the total land area. The presence of Kandyan homegardens has a significant advantage as Kandy district is one of the most important watershed areas in the country. Similarly, the tree cover in highly populated Colombo and Gampaha districts are 15.9% and 25.5%, respectively, where the forest cover represents only 2.8% and 0.3%, respectively (see Table 2). Both these examples indicate the relative importance of an inter-linked homegarden system in the Wet zone areas of Sri Lanka in terms of perceptible role in maintaining canopy cover and impacts of homegardens on the landscape. However, in Sri Lanka, the real ecological contribution of homegardens in landscape level sustainability has not yet been assessed, which is a priority research need in the homegarden agroecosystem.

Homegardens and control of soil erosion

Soil erosion and land degradation are widespread problems in Sri Lanka and occur in all climatic zones at different intensities. However, soil erosion is more acute in many parts of the Wet zone, especially in the mid and hill country, where slopes are often very steep with high population density (NEAP, 1999). Soil erosion in the hilly watersheds has multifaceted consequences such as harming local crops and leading to abandoned land, causing costly investments in fertilizer application and most importantly decreasing power generation and irrigation capacities by changing water storage capacity due to siltation (Nuberg and Evans, 1993; Nuberg et al., 1994; MFE, 1999; NEAP, 1999). The major causes of soil erosion in the mid and up country areas of the Wet zone are the cultivation of crops on steep slopes without any soil conservation measures, inappropriate land use systems, slapdash soil and water management practices, deforestation, and mining activities. The process of degradation is further aggravated due to increasing human population reducing the land to man ratio. Hence, a proper land use planning and a desirable land management system are required. Studies on specific sites have indicated that the soil erosion is minimal (only 0.05 t/ha) in well-managed Kandyan homegardens under different slopes and is comparable to the value obtained for natural forests (Krishnarajah and Sumanarathne, 1988). This evidence suggests that Kandyan homegarden is one of the best land management systems to minimize soil erosion. The multi-strata canopy of the Kandyan homegarden protects the soil from the direct impact of rain. Their dense mixed vegetation, ground cover and accumulated litter layer also help reducing

runoff and thereby controlling soil erosion. However, comparative figures of soil erosion under different ecological zones are not available and need attention.

Homegardens and soil physical and chemical properties

It is also reported that managing Kandyan homegardens would lead to improve soil physical and chemical properties with the rehabilitation of relatively degraded soil within a reasonable period of time (Siddique et al., 2007). According to Siddique et al. (2007), the soil pH (one unit higher), CEC (nearly double), total soil nitrogen (40% higher), and top soil gravel content (less than half) have changed favorably in homegardens compared to the adjacent common land use practice of grasslands. The practice of Kandyan homegardens is also helpful in preventing fires as the lower vegetation (*i.e.* dry grasslands), where fires usually take place, is controlled in these systems. Thus, establishment of homegardens will be one of the options for rehabilitation such degraded lands.

Homegardens and carbon sequestration

As in the case of tropical forests and forest plantations, tropical homegardens have a special role in carbon sequestration (Albrecht and Kandji, 2003; Marambe and Silva, 2012) due to their ability to store carbon in the standing biomass and soil. As Kumar (2006) suggested, homegardens sequester carbon in soil and vegetation, reduce fossil fuel burning by promoting fuelwood production and help in the conservation of carbon stock in existing forests by alleviating the pressure on natural forests. It is also suggested that homegardens are never clear-felled and relatively permanent making the system remarkably resilient (Kumar, 2006; Weerahewa et al., 2012) thus, the carbon storage would last for a longer period.

Kumar (2006) reviewed the carbon sequestration potential of tropical homegardens and indicated that multi-layered woody perennial systems such as homegardens have a higher carbon sequestration potential than other comparable systems. Javanese and Sumatran homegardens accumulated carbon is reported to be within the range of 55.8 to 162.7 Mg/ha (Mg=tons) (Roshetko et al., 2002). In some cases, the above ground carbon in homegardens is in par with the carbon stocks reported for similar aged secondary forests (Jensen, 1993), but lower than that accumulated by the mature forests in the region (114-500 Mg above ground carbon/ha) (Kumar, 2006). Roshetko et al. (2002) reported that soil organic carbon content of Indonesian homegardens ranged between 10.4 to 103.7 Mg of

carbon/ha. The carbon sequestration potential of homegardens in Sri Lanka has received relatively little attention compared to that of plantation forestry (Costa and Suranga, 2012) and natural forests. SNC (2011) stated that the net CO₂ stock change in homegardens in Sri Lanka as -109.33 Gg/year. However, only recently, Mattsson et al. (2012b) and Premakantha et al. (2012) took a landscape level approach to assess the biomass and their contribution to carbon sequestration potential in the homegardens. Premakantha et al. (2012) showed in their detailed study that the total carbon stock in homegardens of Nuwara Eliya district as 2.114 million tons at the level of 154 Mg/ha above ground biomass and 77 Mg/ha of carbon. The amount of carbon in the homegardens of the district was highest in any agriculture systems of the district and depends on agro-ecological region. As the UNFCCC (2007) suggested, in terms of benefit sharing, it is necessary to develop mechanism to bundle homegardens by connecting individual unit to make a landscape level impacts, which is so far not practice in Sri Lanka and need immediate attention.

Homegardens and human health

The presence of homegardens in highly populated areas creates healthy, comfortable, attractive and pleasant micro climatic conditions. Hot humid climates and pollution have been identified as some of the salient factors for over exertion, fatigue and depression (Pilapitiya, 1994). Thus, the management of homegardens, which consist of an atmosphere appropriate for relaxation, minimized pollution and high amenity and aesthetic value, is a cost-effective strategy to improve human health (Pilapitiya, 1994; Pushpakumara et al., 2010). Nair (2006) also stated that an increasing number of homegardeners are finding pleasure in growing plants for various uses and deriving satisfaction from such integrated system. Further, in most cases, almost all the products of homegardens are chemical and contamination free, hence important for healthy diet and lifestyle. In addition, the productivity of homegardens can also be systematically increased through eco-friendly practices, which also reduce some health and environmental issues such as solid-waste management commonly experienced in Sri Lanka. A good household waste management program through improvement of the homegarden system can convert homegarden waste into fertilizers and mulch through various composting methods. Tranquility of human mind can also be achieved through arrangement of in-door and out-door landscaping using ornamental plants. However, research and extension on this important aspect is limited in Sri Lankan condition.

Homegarden as a business venture

Many Kandyan homegardens are attractive places for tourists, an aspect that has already been exploited and termed as “Spice Gardens” where the owners introduce tourists to plants and their products, which include spices, local ayurvedic treatments and herbal drinks, medicinal plants and related treatments that are popular among visitors (Lindara et al., 2006). This is an example of the ability of local people to respond to business opportunities by using traditional tree-growing customs (Pushpakumara et al., 2010). Assessment of spice gardens has revealed that the system is operating at a technical efficiency of 84% (range from 30-97%) indicating the potential for further improvement of this homegarden agroforestry system (Lindara et al., 2006).

HOMEGARDEN AND SUSTAINABILITY

Sustainability has been defined within three dimensions or pillars, namely environmental (ecological) protection, social progress and economic growth (Goodland, 1995; Kates et al., 2001; Nair, 2006; Marambe and Silva, 2012c). An ecologically sustainable system maintains production and consumption levels within the limits that natural resource recuperation permits without deteriorating the environment (Mangel et al., 1993). In this respect, as Pulido et al. (2008) suggested, in contrast to other agricultural systems (mono cropping), homegarden agroforestry systems are production models that combine, almost ideally, the natural ecological functions (Table 5) with socio-economic wellbeing of the families that maintain them (Table 4), though empirical evidence on these aspects are lacking in Sri Lanka. It is important to note that all activities of homegardens are carried out at individual levels, yet the benefits of the system arises at the individual, district, provincial, regional and the national levels. However, assessments of system sustainability at different levels, especially at the level of landscape are not addressed yet.

GAPS IN RESEARCH AND FUTURE RESEARCH AND EXTENSION – THE WAY FORWARD

A well developed homegarden is a stable and partially self-generating ecosystem. Several studies have demonstrated that the functions and composition of homegardens depends greatly on socio-economic conditions as well as

household livelihood strategies (Abdoellah et al., 2006; Nair, 2006; Peyre et al., 2006; Torquebiau and Penot, 2006; Wiersum, 2006). These studies recognized that the home garden systems are dynamic, and over the years, gradual changes have taken place in species composition and structure based on socio-economic changes of the family and society. There is a significant societal benefit that could be obtained by improving the system. Despite the fact that several attempts have been made during the past four decades, the research needs still remain in order to fulfill the knowledge gaps that exist in critical aspects of the system. Further, research methods employed for assessment of homegardens show high heterogeneity in the data collection even on the same aspect. This not only makes it difficult to compare the results but also impossible to find tendencies or pattern of social, economic and ecological aspects, on which the system sustainability depends. Thus, the suggestions given in this review will help creation of a robust theoretical framework with the methodological standardization to obtain data.

Many studies have been conducted on homegardens in Sri Lanka, yet a comprehensive assessment of the true potential of homegardens to supply industrial timber, fuelwood and other benefits such as family food and nutrient supply and environmental services including landscape potential for carbon sequestration and other environmental functions are missing in home garden research in Sri Lanka. Even at the global scale, economic and social sustainability attributes of homegardens are little studied compared to the ecological sustainability attributes (Nair, 2006). In Sri Lanka, only Ariyadasa (2002), Premakantha et al. (2008), Weerahewa et al. (2011); Marambe et al. (2012b), Mattsson et al. (2012a) and Weerahewa et al. (2012) have addressed some of these aspects partially. This is a priority research area since homegardens are considered as the main source of timber and fuelwood and also helpful in achieving food, nutritional and environmental security in Sri Lanka. However, as Torquebiau and Penot (2006) suggested, the performance of homegardens cannot be fully assessed by using conventional economic criteria and approaches and hence, an innovative economic analysis such as micro- and meso-level economic analysis (at farming systems and upper level system) are required to capture the economic, ecological and social benefits of homegardens. These types of analysis are scanty for Sri Lankan context.

The below ground architecture of homegardens has not yet received any attention, including pattern of root distribution, soil fertility management,

mycorrhizal and soil carbon contents. Understanding the nutrient, energy, and water balance in the homegardens is crucial in providing scientific foundation for better designing and management of the system to permit efficient uses of resources, to avoid loss of energy and to increase production. Further, the diversity assessment of soil fauna and flora and their compressions with natural vegetations in the respective areas have not been reported.

The question of regeneration dynamics of trees and temporal variation of crops in homegardens has been examined, but only in few isolated studies on crop component (Senanayake et al., 2009; Wijesinghe et al., 2010; Egodawatta et al., 2011) and only one study on the tree component (Ariyadasa, 2002). An architectural analysis has not been employed to understand the essential characteristics of the major types of homegardens in comparison with relevant natural vegetations common in the area. No researchers have used appropriate statistical analysis such as multivariate analysis and ecological approaches to identify diversity of trees and crops and their ecological relationships.

Research attention on production potential and quality of biomass from homegardens has been modest and evaluation of the functional diversity of homegardens is not available. The diversity of all different functional groups have not been considered in the assessments reported to-date, instead, those reports are largely based on plants and few other functional categories such as butterflies, birds, land snails, etc. The reasons for comparatively low representation of domestic animals in homegardens in Sri Lanka needs to be properly investigated as the incorporation of animals to the crop-driven agricultural system is well-known to strengthen the approaches in achieving long-term food and nutrition security (Marambe and Silva, 2012). In addition, the litter decomposition and nutrient dynamic studies of homegardens in Sri Lanka are scanty. More studies on biodiversity assessment using different taxonomic groups simultaneously similar to that conducted by Kudavidanage et al. (2012) using amphibians and butterflies, are important as such studies are the fundamental to identifying the responses of biodiversity to various land use changes. Further, as Sinclair and Hitinayake (2000) suggested the development of new and innovative management strategies, especially for pruning of trees through a systems and participatory approach is needed and should be incorporated to homegarden system to reach the maximum benefit levels.

Homegarden researchers in Sri Lanka are largely specialists in a discipline. Thus, in order to bring true values of homegardens a multi-disciplinary research with a system approach at landscape level is a must as suggested by Nair and Kumar (2006), with the assessment of biological, environmental and socio-economic aspects. This assessment should be based on a detailed account of sustainable attributes of multi-strata agroforests as summarized by Torquebiau and Penot (2006), at the level of individual homegardens as well as the level of landscape.

There are many examples of introduction of higher inputs such as chemical fertilizer and pesticides, improved technology and improved planting material to homegardens. As Soemarwoto (1987) suggested, many home gardeners have benefited from these types of developments. However, these developments need to be assessed in detail as such introductions could carry risks, mainly in the form of changes in the structure and composition of homegardens. Further, everywhere in the country as well as the world, it is the general phenomenon that from generation to generation, homegardens are subjected to fragmentation due to human population growth, commercialization and use of high yielding crop/tree varieties. However, relatively little attention has been paid on studies related to the dynamics of homegardens under the influence of rural transformation to commercialization and fragmentation. Nevertheless, impacts of those transformations on resilience nature of the system and social, cultural and ecological sustainability in the homegardens as well as how people can cope up with such changes need to be assessed. In this regard, authors propose to build district, provincial and national level databases to capture the dynamics of homegardens in different aspects using the above criteria (with a multi-disciplinary team). This type of database would allow monitoring the changes in the system and also facilitate the sharing and comparisons of information with possibility of prediction/adapting for different situations.

It is generally agreed that the homegardens help to strengthen local communities and their surrounding environments leading to build conducive and peaceful communities (Wickramasinghe, 1991; 1995a; 1995b; Pulido et al., 2008). In this regard, assessment of current status of the homegardens of the northern and eastern provinces of Sri Lanka, where long term civil war had detrimental impacts on the social structure, is a timely need. This may offer a viable platform to institute solidarity, social justice and equity, especially for the disadvantaged and vulnerable sections of the population.

It is also clear that addressing the issues related to homegardens need capacity on trans-disciplinary concerns across agriculture, forestry, health, nutrition, socio-economics, food security, biodiversity and climate change. Training of professional and extension officers on such direction need greater attention that would form a critical mass of human resources to lead an effective and efficient response to these important issues. In addition, proper training of farmers with respect to the importance and uses of homegardens for socio-economic and environmental benefits is also imperative, which in turn would lead to sustainability of the system.

CONCLUSIONS

Homegardens, as discussed in this review, will continue to be an important land use system for Sri Lanka in terms of percentage of land area occupied, timber and fuel wood production, and food and nutritional security of the household. Further, homegardens help to support biodiversity conservation and achieve many other environmental benefits. Scientific evidence on this important land use system is unfortunately limited and unbalanced. Even the limited available information is scattered failing to reach the masses. Thus, conclusions and recommendations leading to strengthening of the national homegarden development programs have not been made. Scientists who are not familiar with the traditional systems have not realized the importance and potential contribution of homegardens to agricultural development. Others, who are under the influence of the conventional outlook of monoculture systems or forestry, consider homegardens to be very specialized systems adapted to subsistence land-use.

There are various studies conducted with detailed investigations on homegardens, which have recognized and appreciated the value of the systems. Yet some of the important aspects of homegardens have been neglected. Despite the fact that the wealth of information generated through these studies provides evidence on the behavior of plants and animals in homegarden system, the knowledge gap on certain critical aspects of homegardens still exist. Homegarden systems are structurally highly complex to be suitable for manipulation and improvement. Thus, research and development activities in homegardens should receive priority attention through a multi-disciplinary team approach in order to fill the knowledge gaps for further understanding of the system and maximizing environmental services, and support economic and social development of the country.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Ms. Caroline M. Mobogo, Administrative Assistant, World Agroforestry Centre (ICRAF), Nairobi, Kenya for her quick response in providing necessary literature, Dr. V.P. Singh, Regional Coordinator, World Agroforestry Centre, South Asia, New Delhi for encouragements of writing the manuscript and providing critical comments on the manuscript, Prof. H.P.M. Gunasena, senior ICRAF Fellow for his comments on the manuscript, Dr. Ruchira Samaraweera for providing literature on animals in homegardens of Sri Lanka, Ms. D.L.L.H.A. Subashini of ICRAF-Sri Lanka program for typesetting the manuscript. This paper is dedicated to the homegarden practitioners of Sri Lanka.

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Appendix: Diversity of floristic and faunal elements reported from homegardens in different areas of Sri Lanka.

Location	Climatic zone	Sample Size	Number of species recorded from homegarden and their description	Source
Singharaja forest and peripheral areas	LCWZ	32 and 25 transects	Out of 120 recorded butterfly species from primary and selectively logged forests and homegardens and <i>Pinus</i> plantations, homegardens recorded 109 species with 1,413 individuals (with the highest diversity among 4 habitats). Out of 32 amphibian species recorded from 4 habitats, homegardens recorded 19 species with 1,276 individuals which represent the second highest diversity among 4 habitats. However, amphibian communities of homegardens are dominated by common and widespread species which has been remarkably different to natural forests. Unlike in butterflies, all identified amphibian species restricted to forest habitats are endemic.	Kudavidanage et al. (2012a)
Delwala and Kudumeria	LCWZ	50	A total of 9 and 11 plant species recorded from Delwala and Kudumeria, respectively with density of 478 and 688 plants/ha, respectively. 23% and 10% forest birds recorded from homegardens of Delwala and Kudumeria, respectively.	Wijesekara et al. (2001)
Multi-locations	LCDZ & MCWZ	148	116 woody plant species, 4 domestic animal species, 28 woody species are reported from three sites.	Weerahewa et al. (2012); Marambe et al. (2012b)
Sivalakulama	LCDZ	30	A total of 48 woody plant species and 4 domestic animal species recorded.	Weerahewa et al. (2012)
Keeriyagaswewa	LCDZ	59	A total of 84 woody plant species and 4 domestic animal species were recorded.	Weerahewa et al. (2012)

Pethiyagoda	MCWZ	59	A total of 75 woody plant species, but no domestic animal species recorded.	Weerahewa et al. (2012)
Multi-locations	LCDZ, LCIZ & MCWZ	643	A total of 283 plant species recorded from all three districts of which 149 (53%) are food related species. 19 out of 149 species are common to all three districts.	Weerahewa et al. (2011)
Batticaloa	LCDZ	206	Only 21 food related species recorded with the mean Shannon Weiner Index of 0.04.	Weerahewa et al. (2011)
Kurunegala	LCIZ	219	116 food related species recorded with the mean Shannon Weiner Index of 1.75.	Weerahewa et al. (2011)
Kandy	MCWZ	218	132 food related species recorded with the mean Shannon Weiner Index of 2.38.	Weerahewa et al. (2011)
Mattakele area of up country (tea landscape)	UCWZ	?	Out of seven habitat observed highest avifaunal diversity was recorded from homegarden (Shannon Index of 3.03, 38 species or 62% of all bird species recorded) habitat followed by secondary forests, seasonal stream, small scale reservoir, tea field, eucalyptus plantation and Wetland habitat.	Kottawa-Arachchi et al. (2010)
Nawalapitiya	MCWZ	1	A typical homegarden of 0.4 ha recorded 21 ant species in 7 sub families. A total of 1,363 nests belonging to 18 species have been recorded. In terms of number of genera (21), single homegarden represented one third of ant genera recorded from Sri Lanka.	Amarasinghe (2010)
Meegahakiula	MCIZ	30	Homegardens established on steep, moderate and flat sites have been assessed and found that all slope categories plant species diversity is not statistically different in terms of mean number of species and Shannon Weiner Index.	Senanayake et al. (2009)
Ambagamuwa (multi-habitats)	MCWZ	6	Homegarden, paddy field, secondary forest, primary forest and tea plantation habitats have been observed for species diversity of amphibians and homegarden habitat consists of 16 of 19 species recorded from all habitats.	Kumara and Ukuwella (2009)

Colombo suburbs	LCWZ	25	Thirty six homegarden wood-inhabiting agaric fungal species reported.	Fernando (2009)
Thimbirigaskatuwa (western province and largely urban homegarden)	LCWZ	106	289 plant species (51, 36 and 12% of ornamental, food and medicinal plants, respectively) recorded. Average diversity per household was 45 and ranged from 14-95. 85% of species are identified as perennial species where as 14% and 1% represent annuals and biannual. 49% of plant species are identified as herbs, whereas 21, 18, 6% and 45 are identified as shrubs, trees, herbaceous vines and woody vines, respectively.	Kumari et al. (2009)
Bangamunkanda estate of south western Sri Lanka - Galle district	LCWZ	1	A total of 197 plant species from 63 families (39% endemic species) and 207 species of vertebrates [23 fish species (48% endemic species), 17 amphibians (24% endemic species), 25 snakes (24% endemic species), 17 tetrapod reptiles (41% endemic species), 90 birds (15% endemic species) and 34 mammals (15% endemic species)] recorded.	Liyanage et al. (2009).
Knuckles forest, associated vegetation and homegardens	LCWZ, MCWZ, UCWZ		The highest number of bee species has been recorded from rice field, homegardens and scrub land (RHS) habitat at 150 m elevation (46 species), followed by cultivated homegardens at 455 m elevation (CHG; 41 species), patna grassland at 850 m elevation (PG; 16 species), natural forest at 1,350 m elevation (NF; 10 species) and managed cardamom plantation at 1,065 m elevation (MCP, 3 species). The highest bee diversity was observed in CHG (S-W index of 2.9), followed by RHS habitat (2.77), PG (2.317), NF (1.59) and MCP (0.799). Only four species, namely <i>Lasioglossum carnifrons</i> , <i>L. alphenum</i> , <i>L. aulacophorum</i> and <i>L. bidendatum</i> (Halictidae) are endemic to higher altitude of Sri Lanka and <i>Normada priscilla</i> (Apidae) was recorded from NF but not from homegardens.	Karunaratne and Edirisinghe (2008).

Homegardens and other habitats of Nilgala forest area	LCDZ	NR	Homegardens are with mixed cropping with woody plants such as <i>M. indica</i> , <i>Chloroxylon swietenia</i> , <i>Schleichera oleosa</i> , and <i>T. indica</i> . Trees grow up to 15 m, shade is about 50% and leaf litter content is high and Wet. Among 11 habitats observed in Nilgala forest area, homegardens represented highest species richness (20.8%) of amphibians, followed by roadside habitat (19.5%) and riverine forests (13%).	Karunaratna et al. (2008)
Southern Sri Lanka close to Sinharaja forest	LCWZ	12	Home garden and forest habitats have been investigated and suggested that a substantial number of widespread and localized forest land snails can survive in homegardens (28 species or 52% of total species recorded from homegardens though such habitat had proportionately fewer endemic species (17 species out of 41 species). An endemic species that occurs in homegardens was not recorded from the forest.	Raheem et al. (2008)
Kandy district	MCWZ	5 reps	Mean of 15 tree species reported from gardens (with total basal area of 21.6 m ² /ha) whereas adjacent grassland had a few species (with total basal area of 0.004 m ² /ha).	Siddique et al. (2007)
Matale district (spice gardens)	MCWZ	127	Mean of 42 species reported with a range of 31-62 species. Five canopy layers reported.	Lindara et al. (2006)
Pitigala, Elpitiya, Galle district (analogue forest)	LCWZ	1	A total of 206 species of vertebrates belonging to 74 families were recorded of which, 58 species are endemic (18 species of amphibians, 25 species of snakes, 17 species of tetrapod reptiles, 23 species of fish, 89 species of birds and 34 species of mammals).	Gamage et al. (2006)
Various habitats of Nuwara Eliya district	UCWZ		The lowest bird diversity recorded from home garden habits compared to primary montane, secondary montane, grasslands.	Wijesundara and Silva (2005)

Hambantota district	LCDZ	150	More than 400 woody species recorded from three agro-ecological regions in Hambantota district.	Sivananthawerl et al. (2004)
Kandyan homegardens	All zones	NA	Out of 610 species of vertebrates in Sri Lanka 250 species have been recorded from homegarden rice field ecosystem. This includes freshwater fish (20 species out of 78 in Sri Lanka), amphibians (25 species out of 60 in Sri Lanka), reptiles (35 species out of 155 in Sri Lanka), birds (133 species out of 226 in Sri Lanka) and mammals (37 species out of 91 in Sri Lanka).	Bambaradeniya (2003)
All island	All zones	87% of the country covered	A total of 482 species was recorded, however only 76 species used in analysis due to low level of frequency of other species and categorized as timber (46 species), timber (17 species) and food (13 species).	Ariyadasa (2002)
Kandyan homegardens	UCWZ, MCIZ, MCWZ	NA	A total of 39 fruit trees were recorded; 7 are present in all three regions, 20 species are underutilized, and 12 mammal species, 35 bird species, 28 species of butterflies were also recorded.	Hitinayake and Ekanayake (1999)
Central Sri Lanka	MCWZ	NA	Encountered 640 species of trees, shrubs and herbs with mean and range of 53, 22-170 species per homegarden	Hochegger (1998)
Multi-location Kundasale, Galagedera and Galaha	MCIZ	12	The number of tree species per homegarden at an average was 48±20, and ranged from 27-82. The total number of tree species recorded was 98 of which 55% are food trees.	
	MCWZ	12	The number of tree species per homegarden at an average was 67±8, and ranged from 60-81. The total number of tree species recorded was 100 of which 54% are food trees.	Hitinayake et al. (1996)
	UCWZ	12	The number of tree species per homegarden average at 39±10, and range from 27-56. The total number of tree species recorded was 85 of which 61% are food trees.	

Mirahawtaa, Welimada (Uva basin)	UCIZ	61	A total of 143 tree species was reported of which 37% are native species. Species richness varied from 8-53 species per homegarden with a mean of 29 species and 250 individual of woody plants. 5 canopy layers identified.	Everett et al. (1995)
Pitakele (close to Sinharaja)		19	A total of 55 edible species was recorded.	Caron (1995)
Welimada, bandarawela - Uva Basin	UCIZ	NA	Homegardens recorded the highest number of bird diversity (53 species) compared to even the forest remnant (45 species) (abundance of birds has been 441 in homegardens compared to 340 in forest remnants).	Nuberg et al. (1994)
Anuradhapura	LCDZ	15	A total of 140 plant species with 11 prominent species in all homegardens. It is reported that equal number of endemic and introduced species (but definition here is not clear on endemic species, probably represent native or indigenous species). The maximum plant density is reported as 10 plants per 100 square meters.	Dharmasena (1994)
Anuradhapura	LCDZ	27 covered 8 ha	Only perennial species inventoried. About 4,000 plants surveyed, 140 plant species recorded with 11 prominent species in all homegardens (of which 7 are fruit trees). The majority are multipurpose species. Plant density was 525 plants per hectare and ranged from 160-860. Average number of plants per farm was 30 and ranged from 9-56.	Dharmasena (1993)
Mahawli H - Kithsirigama	LCDZ	22	A total of 29 species recorded (of which only 10 are non food producing), average number of perennials per garden was 24 and ranged from 12-48.	Wickramasinghe (1993)
Central Sri Lanka, Kandy	MCWZ	30	A total of 187 plants per acre was reported.	McConnell (1992)

A total of 125 of which 93 are usable and 52 are medicinal species (61 trees, 12 shrubs, 10 climbers and 42 herbaceous) plant species belongs to 61 families recorded. Average number of plant species per homegarden ranges from 37-65 with a mean of 46 species. Tree density ranges from 92-3,736 trees per hectare.

Perera and Rajapakse (1991)

Central Sri Lanka, Kandy

MCWZ

50

A total of 27 species was reported at 4-18 species per homegarden. The plant density varied from 56-315 per 0.4 ha.

Jacob and Alles (1987)

Central Sri Lanka, Kandy

MCWZ

30

A total of 29 plant species was recorded from all homegardens with 4-18 main economic species on individual farms. The tree density varies from 78-1,053 per homegarden.

McConnell and Dharmapala (1973)

Central Sri Lanka, Kandy

MCWZ

30

Note: Arranged according to the published year; NA=not available or not reported. MCWZ=Mid country Wet zone; MCIZ=Mid country Intermediate zone; LCDZ=Low country Dry zone; LCIZ=Low country Intermediate zone; LCWZ=Low country Wet zone; UCWZ=Up country Wet zone; UCIZ=Up country Intermediate zone.