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Characteristics of South Asian rural households and associated home gardens - A case study from Sri Lanka

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Abstract: Home gardens form an essential component of South Asian rural farm households. Although South Asia presents a wide variety of climates, there is no information yet on the diversity of farm households and associated home gardens in the different climatic regions of South Asia. The objective of this study was to compare demographic and home garden characteristics in the three climatic zones of Sri Lanka (wet, intermediate and dry zones). The study surveyed 300 households over a period of four months. The households of the three climatic zones of Sri Lanka managed their home gardens for food and/or income generation using mostly family labor, but differences could be observed between the 3 zones. The climatic conditions of the wet zone allowed growing a high diversity of annual and perennial species and to obtain a high crop production. Our results suggest that in this zone home gardens were managed in first priority for economic reasons. On the contrary the biomass production was constrained by the lack of moisture in the dry zone, leading to lower yields and a weaker ability to replenish soil fertility by organic matter inputs. Most home gardeners from this zone perceived the production of their units as being declining. The first priority for managing home gardens in the dry zone was food security. The diversity of households and associated home gardens observed across different climatic zones strongly suggests that any policies aiming at improving the productivity of home gardens will need to take into account the biophysical and socio-economic diversity of the context in which they are embedded.

Key words: Climatic zones, food security, income generation, home gardens, South Asia, traditional ecological knowledge.

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Introduction

Tropical home gardens have been defined as units occupying a part of the homestead land, engaging family labor and having high agricultural productivity (Dash & Misra 2001). They are considered to be well developed sustainable agricultural systems, which maximize beneficial interactions among crop plants, while minimizing unfavorable interactions (Kumar & Nair 2004). They are complex in nature due to species richness and are managed sustainably over long periods of time, ranging from decades to centuries. In many densely populated tropical nations, these home gardens appear like little forest islands surrounded by large tracts of staple food crops such as rice and maize (Kehlenbeck *et al*. 2007). These home gardens have a multilayered vegetative structure and thus are important habitats for wild life, biodiversity while also acting as family farming units, providing food and products for consumption and sale (Berti et *al.* 2004; Chadha & Oluoch 2003; Midmore *et al*. 1991; Pandey *et al.* 2006, 2014). In addition, they provide forest cover to the environment, thereby helping to reduce the rate of depletion of national forest areas, while contribu-

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ting to the conservation of natural resources and maintaining biodiversity (Kabir & Webb 2008). Recent studies also identify these home gardens as potential carbon stocks due to the high populations of plants and their biodiversity (Kumar 2006; Mattson *et al.* 2013; Saha *et al.* 2009). However, due to the differences in climates of South Asia, there would be differences in these home gardens, but these have not yet been highlighted.

Traditional ecological knowledge (TEK) plays a part in managing smallholder farming systems (Ceccoloni 2002; Scaglion 2010). Although farmers do not identify the term TEK in their practices, their actions generally illustrate their awareness of the principles of maintaining soil fertility by composting and adding animal manures both in Asia and Africa (Scaglion 2010). Thus TEK also forms a useful component in sustainable home gardening, which has not yet been clearly identified across home gardens in different climatic regions of South Asia.

Sri Lanka, a South Asian island republic of 65,610 km^2, has a population reaching 20.5 million. Amongst this population that lives in some 4.5 million households, 22 % are in urban areas and the balance live in the rural regions (Dept. of Census & Statistics 2009). Food insecurity and rural poverty are still major problems in the country (FAO 2012). Over 65 % of the rural households engage in some form of agriculture either on a full time or part time basis for food production or for increased household incomes (Dept. of Census & Statistics 2009). Furthermore, as in all tropics, environmental degradation, especially in terms of soil through erosion and excessive exploitation due to non-sustainable practices is a major feature in Sri Lanka (Senanayake *et al.* 2009).

Sri Lanka, with its tropical South Asian Monsoonal climate is divided into 9 provinces and 25 administrative districts. Climatically, it has three regions based on mean annual rainfall, namely wet (> 2500 mm per annum), intermediate (1750 - 2500 mm per annum) and dry (< 1750 mm per annum) and 45 agro ecological zones, divided on the basis of elevation, soil types, rainfall expectancy and terrain (Punyawardena *et al.* 2003). Thus it has a diverse environment, as found in most South Asian nations. Home gardens in various forms have played a significant role in agricultural, social and cultural lives of the Sri Lankan people since ancient times (Hochegger 1998). Most of the earlier studies of these home gardens (Jacobs & Alles 1987; Nuberg *et al.* 1994; Perera & Rajapakse 1989; Sangakkara 1989) have concentrated on the species composition and role of trees within these agroforestry systems with little emphasis on vegetables and staple food crops. In contrast, two recent studies (Sangakkara & Frossard 2014; Senanayake *et al.* 2009) conducted in three districts in the wet zone and one district in the intermediate zone respectively, have illustrated that annual crops play an important role as sources of food in these home gardens.

Although there are differences in vegetation and management across climatic zones (Gunarathne & Perera 2014) there is no comparative study identifying the characteristics of the home gardens in different climatic regions in South Asia. The features of the farming families too have not been reported nor the contribution of these home gardens to family incomes. Thus the present study was carried out in 10 of the 25 administrative districts of Sri Lanka, located in the three climatic regions (4 districts in the dry, 3 in the intermediate and in the wet zones respectively) to determine the characteristic features of the households and the associated home gardens. The objective of the study was to determine on a comparative basis, the demographic and agricultural features of these households and the home gardens in the three zones, their contribution to family incomes and food baskets, differences in soil fertility and the annual and perennial crop species commonly grown in these systems as an example of differences found in different climatic zones of South Asia.

Material and Methods

This study selected 10 of the 25 administrative districts of Sri Lanka, namely Hambantota, Moneragala, Trincomalee and Polonnaruwa in the dry zone (where Hambantota and Moneragala are identified as the poorest regions of Sri Lanka), Matale, Badulla and Kurunegala in the intermediate zone and Kandy, Galle and Matara being the districts in the wet zone. The locations within the districts were identified on the basis of the presence of home gardens. Each location had over 50 home gardens, and from these 30 were selected on a random basis to represent each district. The study was carried out on 300 farmer families and their home gardens.

A structured questionnaire was used to obtain the required information on the households and home gardens. Visits were made to each of the 300 households over a period of four months to collect

their characteristics, list the most common food crop species (both perennial and annual species) grown in the home gardens, and analyze the contribution of these crops to household food basket and income. The responses were verified by visits to the home gardens. Filling of each questionnaire and the visits to the home gardens took several hours per household. When required, a second visit was made generally within two weeks of the first visit to confirm data and obtain missing information.

Soil sampling was carried out in 10 home gardens of each district, which added up to 100 samples in total. In addition, similar numbers of samples were collected from open cultivated fields in the vicinity for comparison of soil fertility determined on the basis of important chemical properties. Sampling was carried out using soil augers to a depth of 30 cm. From each home garden or open field, 5 samples were collected on a random basis, and mixed to form a composite sample of 1 kg for analysis at the University of Peradeniya and the soil testing Laboratory of CIC Agribusinesses Ltd, located at Pelwehera, Dambulla.

The soils were analyzed for: pH using a 1:2.5 mixture (weight)-water; total N using the Kjeldahl digestion method; exchangeable K extracted with 1N CH_3COONH_4 (pH 7) with a 1 g to 10 ml soil solution ratio and measured using Atomic Absorption Spectrometry; available P extracted with the Olsen method (Olsen *et al.* 1954); total organic matter measured by the Walkley and Black method (Walkley and Black 1934) and bulk density. Each soil sample was analyzed three times.

The data of the survey was analyzed on a descriptive basis using the Statistical packages SPSS and SAS (Version 6.0) to obtain frequencies, percentages and means of values, depending on the type of data. The Chi square test was used when required to determine the significance of the observed differences. The soil data was analyzed using SAS (Version 6.0) to determine the significance of observed differences in the measured parameters between the climatic regions, using an ANOVA and determining probability values.

Results and Discussion

Analysis of the data illustrated no significant differences in the determined parameters, between the different districts of a particular climatic zone. Thus the data is presented on the basis of totals and percentages for each climatic zone (3 districts each in the wet and intermediate and 4 from the dry zone).

Demographic features

In home garden management, productivity and production efficiency are influenced by the characteristics of the units and the operators (Schupp & Sharp 2012). Important parameters affecting productivity are age, gender ratios, education, experience, cooperation between householders and the farm size.

In this study, the age of the home gardeners ranged from 21 - 77 years, the oldest farmer and the most number of younger home gardeners were in the dry zone. As the ability to work in home gardens depends on age (Dawoe *et al.* 2012), the age classes were defined on the basis of 10 year intervals. In the wet zone, from a population of 90, the highest numbers of home gardeners were in the age category of 51 - 60 years (26 %), while the numbers in age classes of 21 - 30, 31 - 40, 41 - 50 and 61 - 70 were 16 %, 21 %, 19 % and 18 % respectively. The intermediate zone had the highest number of home gardeners (36 %) in the 41 - 50 year age group from a total of 90, while the numbers in the 21 - 30, 31 - 40, and 51 - 60 year age groups were 6 %, 25 %, 19 % and 8 % respectively. This feature was also seen in the dry zone, where the highest number (41 %) out of 120 was in the 41 - 50 year age category. The home gardeners in the 21 - 30, 31 - 40, 51 - 60 age groups in this zone were 14 %, 22 %, 17 % and 5 % respectively. These results illustrate that home gardeners were younger in the drier zones (intermediate and dry). However the dry zone also had two home gardeners over the age of 70 years, who had been on the units for their lifetime. The availability of land in the drier climates for expansion of agriculture, along with the governmental projects supporting settlements promoted the younger generations moving into new lands and settling down to pursue farming, and thus developing their home gardens.

The farm families of all districts in the three zones had both males and females, with the exception of 1 in Trincomalee, a war affected district of the dry zone, and where the male had been killed during the war and the home garden was managed by the widow. From the surveyed households in the wet and intermediate zones 51 % had 2 males while 44 % of the households in the dry zone had two males. However, in the dry zone, 25 % of the households had one male, and

22 % three males working in the home gardens. In contrast, the numbers of households with 1 or 3 males working in the home gardens were considerably lower in the other two zones (range between 11 - 21), as males sought external employment to supplement incomes. Unlike in the case of males, all households had at least one female, and most had two (33 %, 39 % and 48 % households in the wet, intermediate and dry zones respectively). The percentages of households with one female in the wet, intermediate and dry zones were 21 %, 27 % and 22 % respectively, while those with three or more females were significantly lower. These results indicated that most households had two males and females for work on home gardens, irrespective of the climatic region.

Education is a major determinant of successful home gardeners in the tropics (Mariano *et al.* 2012), and thus this parameters was determined among the home gardeners in the three climatic zones. Ten % of the total surveyed had no education (Fig. 1). The majority (46 %) had some schooling - of five years, while 36 % had 10 years of schooling. There were no graduates within the surveyed population, which was not surprising as most educated, even home gardeners', children tend to leave for white collar jobs, as reported for Nepal (Rahut & Scharf 2012).

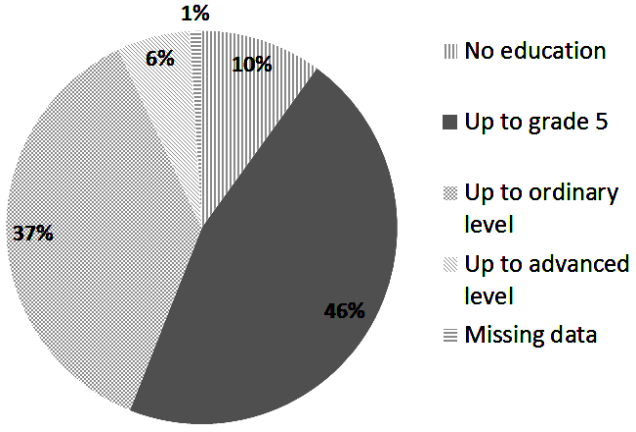

Fig. 1. Educational attainments of the Respondents.

The data education presents interesting results in terms of the three zones. The highest numbers of non-educated home gardeners (19 %) were in the dry region, and were older people, who depended upon their children for information. However they stated that their experience and local traditional knowledge helped in the processes of maintaining home gardens confirming earlier reports (*e.g.* Hermann & Tori 2009) for Asia and Latin America. The non-educated in the wet and intermediate zones, which are more developed in terms of infrastructure such as schools and roads, were significantly lower (3 - 4 %). The numbers of home gardeners who had education up to grade 5 were similar in all three zones (44 - 47 %) and those who had attended school for 10 years, until the first public school examination were 44 % and 41 % in the wet and intermediate zones, while it was 28 % in the dry zone, again due to two principal reasons, namely the need of human power for supporting farm work and the lack of high schools. The trend of home gardeners not studying further was clearly evident in data on numbers who had attended school up to the end, which is 12 years. In the wet zone, some 8 % had attended school until the end while in both other zones the percentage was only 4 %. The education levels of the spouses (females) were of a similar trend, with those in the dry zone being the least educated. Some 50 % of all spouses had been educated only up to grade 5, although the number that had no schooling was lower than of the male counterparts (16 %). Similarly more spouses had studied up to Grade 10 (the first public exam) (32 %, 45 % and 53 % in dry, intermediate and wet zones respectively) than males. Furthermore, the spouses had a greater awareness of TEK, which suggested their involvement in the home gardens, again a feature found in other units in South Asia (Hermann & Torri 2009).

The survey also presented an interesting phenomenon on the experience of the home gardeners in managing home gardens. Some 57 % of the total population had less than 5 years of experience in managing their own units, while 14 % had over 15 years of experience, principally in the dry zone. Furthermore, the greater percentage of home gardeners with over 5 years' experience in home garden management was also in the dry zone. This suggested that the dry zone, which is principally an agricultural region, had the most experienced home gardeners who had the most extended awareness of TEK. This awareness compensated for the lack of formal educating in managing the home gardens.

Home gardens and their characteristics

All home gardeners surveyed owned the lands of the home gardens in all climatic zones except for one each in the intermediate and dry zones, who were shareholder home gardeners. One farmer in

Table 1. Percentages of home gardens with different land surface in the three climatic zones of Sri Lanka.

Surface	1 - 20	21 - 40	41 - 80	81 - 120	121 - 160	161 - 320	> 320
Climatic zone	Surface in perches (1 perch = 25.3 m^2)						
Wet	64 %	24 %	9 %	1 %	2 %	0	0
Intermediate	21 %	24 %	26 %	26 %	2 %	1 %	0
Dry	5 %	39 %	38 %	3 %	6 %	9 %	0
P value (n = 300)	0.017	0.034	0.041	0.004	0.022	0.029	

the wet zone had leased the unit. This confirms earlier studies of home gardens in other parts of the wet zone of Sri Lanka (Wickramasinghe 1995) where home gardeners generally own their home gardens and develop them. However, the land extents varied significantly between the regions (Table 1). In the wet zone, which is the most populated region of Sri Lanka (Dept. of Census & Statistics 2009) the land available for home gardens was small, and 64 % of the units were between 1- 20 perches (25 - 500 m^2), 24 % were between 21 - 40 perches, and the percentages of other categories were much lower. In contrast, in the intermediate zone, the percentages of home gardens lying between the ranges of 1 - 20, 21 - 40, 41 - 60 and 61 - 80 perches were similar. Thus some 97 % of all home gardens lay within these categories. This is due to the greater dispersal of these gardens in both urban and rural regions of this climatic zone. The land extents in the dry zone were different; there were a very low number of small home gardens, in contrast to that of the wet and intermediate zones. The numbers of home gardens in the moderate categories (21 - 80 perches) were the highest in this zone, and it also had a significant number of large home gardens with more than 160 perches (4000 m^2 or 0.4 ha). This is due to the availability of land for home gardens in this zone, which is the least populated region of Sri Lanka.

Due to the smaller size of the farms and greater opportunities for off-farm work in the more urban environments, the number of respondents engaged in full time farming was lower in the wet and intermediate zones (Table 2). In contrast, 85 % of the home gardeners in the dry zone were engaged in their farming enterprises on a full time basis. They were not only managing their home gardens, but also their extensive fields of rice and other cereal or vegetable crops. Thus, the percentages of home gardeners engaged in part time farming in the dry zone was half of that in the other two zones. The survey examined the types of off-farm employment available (Table 3). There were some 35 % and 30 % self-employed home gardeners in the wet and intermediate zones when compared to the 24 % in the dry zone. The sources of self-employment were generally having small shops selling groceries in the more populated areas to offering catering services and some even having small three wheeler taxis, which brought in a regular income. There was a demand for these services in these two zones. However the numbers of respondents seeking work away from the farm or home gardens as paid labor in other lands, in the building or service industry were lower in the wet and intermediate zones. The land areas cultivated in the dry zone, especially with rice, were much larger, and required hired labor, which was provided by home gardeners. Furthermore, the numbers of home gardeners working full time away from the farms were the highest in the wet and intermediate zones. This again was due to the availability of positions in either the state or private sectors in the more developed regions of the nation. The home gardeners of the dry zone had a lower opportunity to secure full time employment, due to the lower numbers of positions and also due to the lower levels of education when compared to those of the wet and intermediate zones. Thus the percentage of home gardeners working full time on off-farm jobs was half of that of the wet and intermediate zones.

Table 2. Distribution of full and part time farmers in the climatic zones of Sri Lanka (values in parentheses indicate % of population in a zone).

	Full time farmers	Part time farmers	*P* value
Climatic zone			
Wet	58 (64%)	32 (36%)	0.018
Intermediate	63 (69%)	27 (31%)	0.035
Dry	77 (85%)	43 (15%)	0.004

Table 3. Types of other sources of income and percentages of farmers using these sources.

Other source of income	Self-employment*	Paid labor	Full time off-farm work
Climatic zone			
Wet	35 %	25 %	40 %
Intermediate	30 %	22 %	48 %
Dry	24 %	55 %	21 %

* Self-employment methods include maintaining shops, catering, provision of transport etc.

Of the 300 respondents surveyed, some 98 % stated that these units were indispensable, as they provide food, especially at times of scarcities as seen in Bangladesh (Ali & Muhammed 2005). This was clearer in the dry zone where 100 % of the surveyed home garden owners stated their indispensability. However, there were many reasons for the respondents to engage in home gardening, and the variability was highest in the intermediate zone (Table 4). In the wet zone, home gardens were maintained only for two purposes, firstly to produce food for the household, especially as vegetables are more expensive in the urban areas and secondly, to generate income, by selling the excess. In the intermediate zone, the variations in responses ranged from producing food for the households and sale of the excess, which was the highest (61 %), followed by producing only for home use and to derive an income. The income was derived principally from leafy vegetables, which were sold at village markets. There were a few who maintained home gardens as a hobby and for aesthetic value. A similar pattern was also observed in the dry zone, where most home gardeners (74 %) maintained home gardens for food and sale of produce, while 13% maintained them only to obtain food for the household. Interestingly there were a few (3 %) who also stated the value of home gardens to improve the environment by growing trees. Thus in terms of reasons for maintaining home gardens, there were greater similarities between the intermediate and dry zones, when compared to those of the wet zone, which were much smaller and maintained purely for economic reasons. However their value for household food security was very clearly evident from this study.

The home gardens contributed different percentages to the family monthly incomes (Table 5) both in terms of savings on purchased food and sale of excess, and again, there were significant variations between the three zones. The contribution was the smallest in the wet zone (72 % of home gardens contributed to less than 20 % of the monthly income), primarily because of the smaller extents, which sometimes could not produce sufficient food for the household. Some 24 % of the respondents stated that the home gardens contributed between 21 - 40 % of the monthly household income. A few households in this climatic zone (5 %) received more than 40 % of the household income from the home gardens, again primarily through the sale of leafy vegetables to the markets. In contrast, some 71 % of the households in the intermediate zone received between 21 - 40 % of their monthly income from the home gardens. This was significantly higher than in the wet zone. In this zone, some 26 % of the households derived less that 20 % of the monthly income from the home gardens. A contribution exceeding 40 % of the monthly income by the home gardens was only in 3 % of the households. The distribution of the contribution of home gardens to the household income was much wider in the dry zone, where 37 % and 32 % contributed either 41 - 60 % of the household income or less than 20 %. In addition 29 % of the households in this zone received between 21 - 40 % of their monthly income, again by the sale of vegetables. Only 2 % of the household received over 60 % of their income from the home gardens, and this in the dry zone was from the sale of timber and firewood from the larger units.

Soil fertility

Soil fertility is an important trait in home gardens, as it determines productivity (Pandey & Singh 2009). Therefore, farmer perception of soil fertility was determined based on observations and TEK. Of all home gardeners surveyed, some 71 % stated that the soils of their home gardens were not fertile; another 26 % stated that the soils of their home gardens were fertile; while a small percentage was undecided. The basis of perception of soil fertility was also further explored to cover soil color, growth of plants as determined by vigor and green color and crop yields, all based on TEK. All home gardeners surveyed stated that they determined soil fertility of the home gardens on the basis of yields, as it was the easiest parameter. Some 40 % in all climatic zones stated that they also checked soil color and if it was greyish,

Table 4. Percentages of farmers citing reasons for maintaining home gardens in the three climatic zones.

Climatic zone	Reasons for maintaining home gardens and percentages for each category								
	Produce food (A)	Hobby (B)	Derive an income (C)	Aesthetic value (D)	A + C	C + D	A + B + C	A + C + D	A + C and environment development
Wet zone	61				39				
Intermediate Zone	17	3	14	3	61	1	1		
Dry zone	13		3		74			7	3
P value (n = 100)	0.007		0.014		0.039				

considered it fertile. In contrast, only 20 % of the total population stated that they considered crop growth as an indicator of soil fertility and these home gardeners were in the intermediate zone. It was interesting to note that 94 % of home gardeners never got the soils of the home gardens tested to assess soil fertility, although the Sri Lanka Department of Agriculture offers this service at a nominal cost. Again, 6 % of home gardeners who got their soils tested were principally from the intermediate zone, indicating their keenness to improve their home gardens. Furthermore, some 66 % stated that the soil fertility was declining, especially in the dry zone, on the basis of lower yields, while 20 % stated that their soil fertility was being enhanced. This category was principally from the wet zone, which has lush vegetation. The balance stated that soil fertility was stable.

Home gardens are generally well managed by home gardeners, who add organic matter from the homesteads, compost and leaf litter to maintain soil fertility (Dawoe *et al.* 2012; Pinho *et al.* 2011). In the present study, as 66 % stated that soil fertility was declining, an assessment was made to determine the processes of maintaining this vital parameter. The responses varied between the climatic zones with an interesting trend of very few home gardeners in all zones maintaining soil fertility with mineral fertilizers alone (Table 6). Thus they had realized the importance of organic matter inputs, again through TEK. In the wet and intermediate zones, most home gardeners added a combination of household wastes and animal manures, followed by those who used household wastes only. The other categories of maintaining soil fertility were non-significant in this region. In the dry zone, where soil fertility was considered low by the respondents, a wider array of methods was used to maintain this parameter: 46 % of home gardeners used household wastes only, 20 % used this waste material with animal manures and 14 % used mineral fertilizers in combination with other methods. However in overall terms of the surveyed population, most used organic methods such as mixtures of household wastes and animal manures or household wastes alone to maintain soil fertility, as reported for other regions of Asia (Kehlenbeck & Maass 2005). This again was primarily through experience and TEK on the usefulness of these wastes and manures.

Table 5. Variations in the percentage contribution of the home garden to the monthly income of farm family.

Climatic zone	Percentage contribution to monthly income			
	0 - 20 %	21 - 40 %	41 - 60 %	> 60 %
Wet zone	72	24	3	2
Intermediate zone	26	71	3	0
Dry zone	32	29	37	2
P value (n = 300)	0.006	0.036	0.006	0.045

The analysis of soil samples from both home gardens and cultivated fields presented interesting results (Table 7). The soils of the home gardens had lower pH, higher organic matter and total N contents and higher CEC compared to the soils sampled from open fields. This was attributed to the greater use of organic matter in home gardens as also shown in other reports (Egodawatta *et al.* 2012; Kehlenbeck & Maass 2005). The soils of home gardens in the three climatic zones also presented

Table 6. Measures adopted to maintain soil fertility of home gardens by farmers in the three climatic zones.

Climatic zone	Percentage of farmers adopting different measures					
	Organic household wastes (A)	Mineral fertilizers (B)	Add animal manure (C)	A + C	A + B	A + B + C
Wet zone	37	1	2	59	1	0
Intermediate zone	28	2	2	68	0	0
Dry zone	47	0	16	20	3	14
P value (n = 300)	0.038	ns	0.009	0.037	0.048	0.004

ns: not significant.

Table 7. Selected soil parameters in home gardens and open fields in the climatic zones of Sri Lanka; ± indicates Standard Errors (n = 200).

Climatic zone	Sampling site	Soil parameters (0 - 30 cm)						
		pH (1:2.5 H_2O)	Organic Matter (%)	Total N (%)	Olsen P (mg/kg)	Exch. K (mg/Kg)	CEC (m.eq/100g soil)	Bulk density g/cm^3
Wet zone	Home garden	5.62±0.14	1.77±0.09	0.25±0.02	21.3±0.97	219.2±2.44	17.82±1.24	1.49±0.33
	Open field	6.04±0.20	1.24±0.21	0.19±0.04	22.8±0.56	225.8±3.01	15.44± 0.54	1.42±0.03
Intermediate zone	Home garden	6.41±0.17	1.32±0.09	0.22±0.02	11.3±1.06	195.3±3.20	16.43±0.33	1.53±0.08
	Open field	6.67±0.11	0.98±0.13	0.17±0.01	12.4±0.90	199.0±2.00	15.08±2.40	1.48±0.12
Dry zone	Home garden	6.71±0.27	1.01±0.27	0.18±0.03	37.4±1.11	184.4±4.07	11.52±0.66	1.59±0.07
	Open field	7.04±0.30	0.85±0.05	0.15±0.05	35.9±1.25	179.7±2.99	10.99±0.23	1.50±0.02

significant differences. The pH values of soils in the home gardens of the wet zone were the lowest, while those of the dry zone were the highest, due to the difference in rainfall. The greater organic matter content of the soils in the home gardens in the wet zone was also due to the higher rainfall allowing for a higher biomass production which is partly used as manure, and to the lower temperatures limiting organic matter mineralization. The higher organic matter content explained the higher total N, exchangeable K and CEC and the lower bulk density observed in the soils of the home gardens of the wet zone. The lower values of these parameters in the intermediate and dry zones could be attributed to the lower organic matter content controlled by the higher temperatures.

Plant species

The home gardens in the wet zone had 43 annual and perennial species, while 37 species were found in the home gardens of the intermediate and dry zones (Tables 8 and 9), highlighting their value in biodiversity and confirming earlier reports (Jacob and Alles 1987; Sangakkara 1989). Of these, 25 species were annual crops in the wet zone, 23 in the intermediate zone and 21 in the dry zone. Analyzing the data on annual crops, it is clear that the wet zone had both tropical and temperate species such as carrots and leeks. In contrast, the intermediate and dry zone home gardens did not have temperate species due to the higher temperatures and lower rainfall. However home gardens in these two zones had more plants of species such as bitter gourd, long beans and tomato, which are more adaptable to the drier and warmer climates. In terms of tuber crops, Colocasia species were the most predominant, followed by Dioscorea, which was more prevalent in the wet and intermediate zones. The wet zone also had more sweet potato and cassava cultivated than in the other two zones. All these contributed to the family food basket. The intermediate zone had three species of leafy vegetables

Table 8. Numbers of home gardens growing the most common annual crops in the three climatic zones.

Crops	Wet zone	Intermediate zone	Dry zone
	Numbers of home gardens		
Tuber crops			
Cassava	28	10	15
Colocasia	72	63	97
Dioscorea	48	62	25
Sweet Potato	46	30	27
Vegetable crops			
Beans	10	23	25
Bitter gourd	16	35	34
Aubergines	50	47	43
Cabbage	24	8	17
Capsicum	7	13	12
Carrot	7		17
Cucumber	6	7	
Leeks	6		
Luffa	29	35	30
Longbeans	37	49	51
Okra	24	3	26
Radish	29	30	33
Snake gourd	29	28	9
Spinach	6	12	
Tomato	39	54	68
Winged bean	17	29	33
Leafy vegetables			
Gotukola*	27	31	5
Kankun*	7	9	8
Mukunuwenna*		10	
Condiments			
Chilli	54	73	79
Turmeric	9	5	
Ginger	8		
Grain			
Maize			54

*Gotukola - *Centella asiatica*; Kankun - *Ipomoea aquatic*; Mukunuwenna - *Alternanthera sessilis.*

Table 9. The common perennial crops grown in home gardens of the three climatic zones.

Crop	Wet Zone	Intermediate Zone	Dry Zone
	Numbers of home gardens		
Fruits			
Amabarella*	15	8	
Avocado	12		
Banana	48	66	39
Bread fruit*	10		10
Cashew		10	33
Custard apple*			15
Guava		20	33
Jak*	46	34	17
Lime	17		35
Mango	36	51	52
Orange	25	21	
Papaya	20	17	40
Pomagranate		1	20
Rambuttan*	3		
Rose apple*	6		
Tamarind			7
Wood apple*			17
Nuts			
Arecanut	11		
Coconut	59	46	47
Beverages			
Tea	13		
Coffee	21	8	
Other			
Betel	4	13	7
Pepper	36	37	29
Tibbatu*	1	3	25

*Amberella - *Spondius dulcis;* Breadfruit - *Atrocarpus altilis*; Jackfruit - *Atrocarpus heterophyllus;* Custard apple - *Annona reticulata;* Rambutan - *Nephelium lappaceum;* Rose apple - *Syzygium jambos;* Wood apple - *Limonia acidissima;* Tibbatu - *Solanum torvum.*

which require moderate soil moisture, while the wet and dry zones had only two species. The numbers of home gardens in the dry zone with these leafy vegetables were lower than in the wet zone. Condiments form a part of the spicy Asian diet, and chillies (*Capsicum* spp.) which grow under warm dry conditions is an essential ingredient. Thus these species were grown in all home gardens, but were found predominantly in the intermediate and dry zones. In contrast, turmeric was grown in the wet and to a lesser extent in the intermediate zone, while ginger, was grown only in the wet zone, as these rhizomatous crops prefer moist conditions. Maize, the most important highland cereal grown in Sri Lanka was found only in the dry zone. This species prefers warm conditions and is cultivated in this region during the major season. This was an alternative cereal

for this region. This species was not found in any of the home gardens surveyed in the other two zones.

The dry zone had 16 perennial species, the intermediate zone 14 and the wet zone 18 (Table 9). The more drought adapted species such as pomegranate and wood apple were predominantly in the dry and to a lesser extent in the intermediate zones, while moisture loving perennial species such as orange, avocado and banana were found in greater abundance in the home gardens of the intermediate and wet zones. Coconut, another principal component of the Sri Lanka diet was found in all home gardens, the majority being in the wet zone, as this species prefers moist conditions due to its yielding patterns. Similarly, tea was found only in the wet zone as this species does not produce an economical yield under warm dry conditions. Coffee, especially the Robusta coffee which is more adaptable was found also prominently in the wet zone. The miscellaneous species such as betel, and pepper, which belong to the same family, were found in all zones. These bring in income, especially pepper. *Solanum torvum* which has a very high demand due to its medicinal value was found only in the dry zone, as it is a very drought hardy crop, and does not grow under wet conditions.

Overall there was a definite change in species when moving from the wet zone home gardens to those of the dry zone. The more conducive climate of the wet zone, with its more fertile soil could support a greater number of crops.

Livestock

Tropical home gardens contain some livestock (Snelder 2008). We report the presence of livestock for the first time for Sri Lankan units as earlier research concentrated only on plants (Jacob & Alles 1987; Perera & Rajapaksa 1989). A total of 51 % of the home gardens surveyed had some livestock although there were differences between the three zones. The least number of home gardens (23 %) having livestock was in the wet zone, which could be attributed to the small size of the units and the greater human population, which makes rearing animals difficult due to neighbor complaints. The intermediate zone had the highest number (76 % units) having livestock while 63 % of the dry zone units had some form of livestock. The most predominant form of livestock were poultry (layers) in 31 % of the units, especially in the intermediate zone, followed by a combination of goats and layer poultry in 5 % of the units, again in the intermediate zone. A few home gardens had cows (9 out of 300) alone while there were another 17 home gardens having a combination of cows, goats and layer birds. Livestock rearing was not a principal component of these home gardens, although their presence was very useful in terms of providing manure to the home gardens. Furthermore, the poultry was identified as a valuable contribution to the family food basket in terms of a protein supplement.

Productivity patterns

The final aspects of the survey identified labor use patterns and the overall productivity and sustainability of the units as perceived by the owners. The units primarily used family labor, as the extents were small. However in the dry zone a few home gardeners hired males for land preparation only. All other principal operations such as land preparation, planting, crop management and harvesting on these units were by family labor.

The respondents were asked about their perception on the overall productivity of the home gardens. Overall, 22 % of the 300 surveyed stated that the productivity was stable and sustainable, while some 19 % stated that productivity was increasing. The majority (59 %) stated that productivity was declining over the long term giving an indication of some loss in sustainability. An analysis of the three zones shows variations. Whereas some 40 % of the home gardeners in the wet zone stated that the productivity was stable, 3 % stated that yields were increasing. However, 57 % of the home gardeners in the wet zone stated that productivity was declining due to the lack of time dedicated to management of the units. In the intermediate zone, the reverse was observed as 5 % stated that their home gardens were stable units, and 59 % stated that productivity was increasing due to better management. Only 39 % stated that productivity was declining and these were principally part-time home gardeners. In contrast, there was a significantly higher proportion of home gardeners (78 %) in the dry zone who stated a decline in productivity; principally due to lack of maintenance when compared to 1 % who stated that productivity was increasing. The balance 21 % stated that productivity was stable. Thus it was evident that the perceived productivity and sustainability of these units varied between the zones.

Conclusions

This study, carried out on 300 households in Sri Lanka, is the first that reports on the diversity of home gardens and associated households in different climatic zones in South Asia. The diversity of characteristics observed, were explained by differences in both biophysical and socio-economics conditions prevailing in these zones. Whereas some of our results were valid for the 3 zones, significant differences were also observed between them.

The households of the three climatic zones of Sri Lanka managed their home gardens for food and/or income generation using mostly family labor. Soil fertility was managed in almost all gardens through organic matter addition using traditional ecological knowledge.

The climatic conditions of the wet zone allowed growing a high diversity of annual and perennial species and to obtain a high crop production and a high biomass production used as green manure to replenish soil fertility. This is also the zone where the human population density was highest, the land availability lowest, the infrastructure most developed, and the possibility for off-farm jobs highest. Our results suggest that in this zone home gardens were managed in first priority for economic reasons (saving on vegetables expenses, sale of surplus production).

Home gardens from the dry zone on the contrary were exclusively planted with tropical plants, some of them adapted to drought. The biomass production was constrained by the lack of moisture, leading to a weaker ability to replenish soil fertility by organic matter inputs. This region was less densely populated and had the largest home gardens. The first priority for managing home gardens in the dry zone was food security. The home gardeners in the dry zone were younger, managed larger units and had lower level of education than those of the wet and intermediate zones. The numbers of full time home gardeners were greater in the dry zone due to lower availability of off-farm employment opportunities.

Livestock was also often present in the home gardens (especially poultry and goats) contributing to the food basket of the households. The home gardens from the intermediate zone had the most livestock and the home gardens from the wet zone the least.

Although our results show that home gardens were indispensable units for household food security they were most probably not able to supply all the requirements of the households, especially in terms of cereal. Home gardens are and will remain an integral part of small holder sustainable agriculture and of the environment in nations of South Asia such as Sri Lanka. Home gardens therefore need to be maintained and improved through good management to meet household and national food security needs. The diversity of households and associated home gardens observed across different climatic zones however strongly suggests that any policies aiming at improving the productivity of home gardens will need to take into account the biophysical and socio-economic diversity of the context in which they are embedded.

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References

Ali, S. & A. Muhammed. 2005. Home gardens in smallholder farming systems: Examples from Bangladesh. *Human Ecology* **33**: 245-270.

Berti, P. R., J. Krasavec & S. Fitzgerald. 2004. A review of effectiveness of agricultural interventions in improving nutrition outcomes. *Public Health and Nutrition* **7**: 599-609.

Ceccolini, L. 2002. The homegardens of Soqotra island, Yemen: an example of agroforestry approach to multiple land-use in an isolated location. *Agroforestry Systems* **56:** 107-115.

Chadha, M. L. & M. O. Oluoch. 2003. Home based vegetable gardens and other strategies to overcome micronutrient malnutrition in developing countries. *Food Nutrition and Agriculture* **32**: 17-23.

Dash, S. S. & M. K. Misra. 2001. Studies of hill agro-ecosystems of three hills tribal villages on the Eastern Ghats of Orissa, India. *Agriculture Ecosystems and Environment* **86**: 287-302.

Dawoe, E. K., J. Quashie-Sam, M. E. Issac & S. K. Oppong. 2012. Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti region of Ghana. *Geoderma* **179-180**: 96-103.

Dept. of Census and Statistics, Sri Lanka. 2009. *The Statistics Yearbook*. Dept. of Census and Statistics,

Sri Lanka, Colombo, Sri Lanka.

Egodawatta, W. C. P., U. R. Sangakkara & P. Stamp. 2012. Impact of green manure and mineral fertilizer inputs on soil organic matter and crop productivity in a sloping landscape of Sri Lanka. *Field Crops Research* **129**: 21-27.

FAO. 2012. *Country Programming Framework 2013 - 2017 Sri Lanka*. December 2012. Rome, Italy.

Gunarathne, R. M. U. K. & Perera, G. A. D. 2014. Climatic factors responsible or triggering phenological events in *Manilkara hexandra* (Roxb.) Dubard., a canopy tree in tropical semi deciduous forest of Sri Lanka. *Tropical Ecology* **55**: 63-73.

Hermann, T. M. & M. Torri. 2009. Changing forest conservation and management paradigms: Traditional ecological knowledge systems and sustainable forestry: Perspectives from Chile and India. *International Journal of Sustainable Development and World Ecology* **16**: 392-403.

Hochegger, K. 1998. *Farming like the forests. Traditional Home Garden Systems in Sri Lanka*. Margraf Verlag, Weikersheim, Germany.

Jacobs, V. & W. Alles. 1987. Kandyan gardens of Sri Lanka. *Agroforestry Systems* **5**: 123-137.

Kabir, M. E. & E. L. Webb. 2008. Can home gardens conserve biodiversity in Bangladesh? *Biotropica* **40**: 95-103.

Kehlenbeck, K. & B. L. Maass. 2005. Crop diversity and classification of home gardens in Central Sulawesi, Indonesia. *Agroforestry Systems* **63**: 53-62.

Kehlenbeck, K., H. S. Arifin & B. L. Maass. 2007. Plant diversity in home gardens in a socio economic and agro ecological content. pp 297-319. *In:* T. Tscharntke, C. Leuschner, M. Zeller, E. Guhardja & A. Bidin (eds.) *Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Constraints of Land Use and Conservation*. University of Gottingen, Germany.

Kumar, B. M. & P. K. R. Nair. 2004. The enigma of tropical home gardens. *Agroforestry Systems* **61-62**: 135-152.

Kumar, B. M. 2006. Carbon sequestration potential of tropical home gardens. pp. 185-204. *In:* B. M. Kumar & P. K. R. Nair (eds.) *Tropical Home Gardens - A Time Tested Example of Sustainable Agro-forestry*. ICRAF. Nigeria.

Mariano, M. J., R. Villano & E. Fleming. 2012. Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems* **110**: 41-53.

Mattsson, E., M. Ostwald, S. P. Nissanka & B. Marambe. 2013. Homegardens as a multi-functional land-use strategy in Sri Lanka with focus on carbon sequestration. *Ambio* **42**: 892-902.

Midmore, D. J., V. Ninez & R. Venketaraman. 1991. Household gardening projects in Asia. Past experiences and future directions. *Technical Bulletin* **19**, AVRDC, Taiwan.

Nuberg, I. K., D. G. Evans & R. Senanayake. 1994. Future of forest gardens in the Uva uplands of Sri Lanka. *Environment Management* **18**: 797-814.

Olsen, S. R., C. V. Cole, F. S. Watanabe & L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939. U.S. Government Printing Office, Washington D.C.

Pandey, C. B. & L. Singh. 2009. Soil fertility under home garden trees and native moist evergreen forests in South Andaman, India. *Journal of Sustainable Agriculture* **33**: 303-318.

Pandey, C. B., K. Lata, A. Venkatesh & R. P. Medhi. 2006. Diversity and species structure of home gardens in South Andaman. *Tropical Ecology* **47**: 251-258.

Pandey, C. B., M. Begum, S. K. Singh & D. Saha. 2014. Coconut-based homegardens: mechanisms of complementarity in sharing of growth resources among homegarden trees in the South Andaman Islands of India. *Tropical Ecology* **55**: 339-348.

Perera, A. & N. R. M. Rajapaksa. 1989. A baseline study of Kandyan forest gardens of Sri Lanka. Structure, composition and utilization. *Forest Ecology and Management* **45**: 269-280.

Pinho, R. C., S. S. Alfaia, R. P. Miller, K- Uguen, L. D. Magalhaes, M. Ayers, V. Freitas, R. Trancoso. 2011. Islands of soil fertility: Soil improvement under indigenous home gardens in the savannas of Roraima, Brazil. *Agroforestry Systems* **81**: 235-247.

Punyawardena, B. V. R., T. M. J., Bandara, M. A. K. Munasinghe & N. J. Bandara. 2003. *Agro-ecological Regions of Sri Lanka*. Natural Resource Management Centre, Department of Agriculture, Peradeniya, Sri Lanka.

Rahut, D. B. & M. M. Scharf. 2012. Livelihood diversification strategies in the Himalayas. *Australian Journal of Agricultural and Resource Economics* **5**: 558-582.

Saha, S. K., P. K. R. Nair, V. D. Nair & B. M. Kumar. 2009. Soil carbon stock in relation to plant diversity of home gardens in Kerala India. *Agroforestry Systems* **76**: 53-65.

Sangakkara, R. 1989. Characteristics of tree smallholdings in the midcountry of Sri Lanka. pp 661-666. *In:* Shiek Ali Abod *et al.* (eds.), *Proceedings of Regional Symposium on Recent Developments in Tree Plantations of Humid/Sub humid Regions of Asia*. UPM, Malaysia,

Sangakkara, U. R. & E. Frossard. 2014. Home gardens

and Dioscorea species - A case study from the climatic zones of Sri Lanka. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* (JARTS) **115**: 55-65.

Scaglion, R. 2010. Local ecological knowledge in island Southeast Asia- Modern crises and traditional strategies. *Human Ecology* **38**: 175-176.

Schupp, J. L. & J. S. Sharp. 2012. Exploring the social bases of home gardening. *Agriculture and Human Values* **29**: 93-105.

Senanayake, R. L., U. R. Sangakkara, D. K. N. G. Pushpakumara & P. Stamp. 2009. Vegetation composition and ecological benefits of home gardens in the Meegahakiula region of Sri Lanka. *Tropical Agricultural Research* **21**: 1-9.

Snelder, D. J. 2008. Smallholder tree growing in Philippine backyards: Home garden characteristics in different environmental settings. pp. 37-74. *In:* Snelder, D. J. & R. D. Lasco (eds.) *Smallholder tree Growing for Rural Development and Environmental Services: Lessons from Asia*. Advances in Agroforestry **5.** Springer, Dordrecht, Netherlands.

Walkley, A. & I. A. Black. 1934. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science* **63**: 251-263.

Wickramasinghe, A. 1995. The evolution of Kandyan home-gardens. pp. 37-74. *In:* P. Halliday & D. A. Gilmour (eds.) *Conserving Biodiversity Outside Protected Areas*. IUCN, Geneva, Switzerland.

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