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Joshepkumara, Thamilini; Wekumbura, Chandima; Silva, Ruchira R.; Mohotti, Janaki; Kumara, Aruna; Kudagamma, Sanath T.; Frossard, Emmanuel

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Organized Homegardens Contribute to Micronutrient Intakes and Dietary Diversity of Rural Households in Sri Lanka

Joshepkumar Thamilini¹, Chandima Wekumbura², Anoma Janaki Mohotti³, Aruna Pradeep Kumara², Sanath Thushara Kudagammana⁴, K. D. Renuka Ruchira Silva^{1*} and Emmanuel Frossard⁵

¹ Department of Applied Nutrition, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, Gonawila, Sri Lanka, ² Department of Export Agriculture, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka, ³ Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka, ⁴ Department of Paediatrics, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka, ⁵ Department of Environmental Systems Sciences, Institute of Agricultural Sciences, ETH Zurich, Lindau, Switzerland

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*Correspondence:

K. D. Renuka Ruchira Silva
renuka.silva@wyb.ac.lk

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A greater diversity of crops grown in homegardens in Sri Lanka is thought to be positively associated with increased nutritional diversity of the diet of members of households and their improved nutritional status and health. However, no studies have been made to evaluate the quantitative contribution of homegardens to people's food and nutrient intake and security. Here we report three studies to test an improved homegarden production system, with agricultural and extension interventions, designed for the mid-country wet zone in Sri Lanka. The study assessed the impact of the improved system on crop type diversity, on dietary intake and diversity and food and nutritional security of the households. In Study 1, 100 households with homegardens were evaluated for their household characteristics and homegarden practices. Study 2 was on a sub sample of 20 households each with organized homegardens (OHG); households were provided with planting material, agricultural inputs and advice, and were regularly monitored by a field officer for methodical farming. These improved home gardens were contrasted with non-organized homegardens (NOHG; without intervention) to measure crop diversity through a simple species count. Study 3 assessed 25 sample households with OHG and 20 households with NOHG: dietary nutrient intake and diversity and household food security were quantified. Family food consumption was assessed using a 5-day diet diary. Perceived household food security status was determined using United States Department of Agriculture Food Security Module. Nutrient intakes, dietary adequacy, and contribution to dietary diversity from produce derived from homegarden were calculated. A total of 149 crop species were recorded in the homegardens with a 14% greater diversity in OHG than NOHG. Household food security was not significantly associated with organized or non-organized homegardens. The improved, organized home gardens provided diets with a greater contribution of energy, carbohydrates, fat,

calcium, iron, zinc, folate, thiamin, niacin, vitamin C, and vitamin A compared with NOHG. The study demonstrates that households with OHG had greater dietary diversity from homegarden produce compared with that of households with NOHG leading to better food and micronutrient intake and nutritional security.

Keywords: crop diversity, dietary diversity, dietary intake, homegardens, household food security, micronutrients, Sri Lanka

INTRODUCTION

Micronutrient deficiency associated with malnutrition is an important contribution to poor health of people globally. Deficiencies in many nutrients impair growth and physical and mental development at key stages in children, for example retarding intellectual capacity and causing blindness. These lead to general losses in human productivity and potential (Development Initiatives, 2018). In addition, nutrient deficiencies increase vulnerability to, or exacerbate the severity of, diseases. Sri Lanka is a lower middle-income country with a GDP per capita of USD 4,073 and a total population of 21.4 million people inhabiting its 65,165 km² land area (Central Bank of Sri Lanka, 2017). At present, its economy is transitioning from a predominantly rural-based economy, with 78% of the population living in rural areas, toward a more urbanized economy focused around manufacturing and services (Central Bank of Sri Lanka, 2017). Although extreme poverty is rare, a relatively large proportion of the population concentrated in some geographical pockets lives on only slightly more than the extreme poverty line (World Bank, 2019). Sri Lanka is experiencing the triple burden of malnutrition i.e., both over- and undernutrition, along with micronutrient malnutrition: diets are deficient in iron, zinc, calcium, folate, and vitamin A (Abeywickrama et al., 2018). Prevalence of underweight, wasting, stunting, and anemia among children under 5-year-old is 23.5, 19.6, 13.1, and 15.1%, respectively (Jayatissa et al., 2013).

The major causes for wider prevalence of undernutrition in Sri Lanka have been identified as lack of diversity and low nutritional quality of foods consumed due to household food insecurity and poverty (World Bank, 2007a; Rajapaksa et al., 2011). Several studies have identified the risk to children and women of living in households with food insecurity and deficient dietary intake of micronutrients such as vitamin A, iron, zinc, and calcium (Alaimo et al., 2001; Matheson et al., 2002; Schipani et al., 2002; Cook et al., 2006; Saha et al., 2009). Consumption of an adequate and diverse diet has been identified as the most sustainable intervention method to combat micronutrient deficiencies (Trowbridge et al., 1993).

In addition to expanding and diversifying food production generally on a commercial scale, homegardens have been recognized as an important source of food energy and nutritional security and also in providing livelihoods (Johnson-Welch et al., 2000; Krishna, 2004). A homegarden is described as a small portion of land that tends to be located close to or within walking distance from the family dwelling (Odebode, 2006), with a mixed cropping system that consists of vegetables, fruits, plantation crops, spices, herbs, and ornamental and medicinal plants, as well

as livestock, that can serve as a supplementary source of income and food primarily for domestic consumption. Definitions and characteristics of homegardens and their social, economic, and environmental contributions to communities in various socio-economic contexts have been reviewed elsewhere (Kumar and Nair, 2004; Galhena et al., 2013; Mattsson et al., 2018).

Promoting homegardening, along with awareness of human nutrition is commonly practiced in developing countries to encourage dietary diversity, allowing families to improve their food security and health and nutritional status (Schipani et al., 2002). Studies also indicate that homegardens benefit the nutrition of households in many ways: They provide better access to a diversity of plant and animal food items, leading to an overall increase in dietary intake (World Bank, 2007b; Galhena et al., 2013). They contribute significantly to dietary diversity (Gautam et al., 2009; Olney et al., 2009; Akrofi et al., 2010) and improve the bioavailability and absorption of essential nutrients (Talukder et al., 2000). Furthermore, homegardens improve micronutrient intake (Faber and Bernadé, 2003): increase fruit and vegetable consumption of preschool children (Cabalda et al., 2011); increase human intake of animal protein (De La Cerda and Mukul, 2008); contribution to household income (Chadha and Oluoch, 2003); improve household food security in terms of dietary diversity (Jacobs et al., 2016). Dietary diversity is important in countries where the staple food does not contain sufficient micronutrients (Faber and Bernadé, 2003; Johns and Sthapit, 2004). Several studies showed that homegardens play an important role by supplementing a staple-based diet (e.g., rice) with micronutrients obtained through intake of green leaves, vegetables, and fruits (Faber et al., 2002; Kumar and Nair, 2004) leading to an enriched and balanced diet (Abdoellah et al., 2001; Pulami and Poudel, 2004). Weerahewa et al. (2011) estimated that homegardens supplied a considerable proportion of vitamin A, vitamin C, calcium, and iron requirement of the household. These direct benefits are very applicable to Sri Lanka, as the typical diet consists of a large portion of rice along with few vegetable curries and very limited food from animal sources (Jayawardena et al., 2013).

Homegardening has been a long-standing practice in Sri Lanka, a country with more than 35% of the population engaged directly or indirectly in the agrarian sectors. The central hill region of Sri Lanka possesses special tree gardens called “Kandyan Forest Gardens” (KFG) (McConnell and Dharmapala, 1973). KFG consists of perennial and semi-perennial trees and shrubs (with spices, food tree crops, and cash crops prominent): they contain many crops, in different combinations, randomly planted and intimately mixed, with in excess of 1,700 species per ha (Jacob and Alles, 1987; Pushpakumara et al., 2010). Because of

the high agrobiodiversity in these homegardens, several essential nutrients (in particular, micronutrients) are provided by the produce in the daily diet of the household, enhancing the dietary diversity of the household (Pushpakumara et al., 2010; Weerahewa et al., 2011; Galhena et al., 2013).

Most farmers in rural hill areas of Sri Lanka utilize low-lying, more easily cultivated land in their homesteads for growing rice (*Oryza sativa*), and the uplands for tea [*Camellia sinensis* L. (O.) Kuntze] and other species as cash crops (Pushpakumara et al., 2010). They also grow a small amount of vegetables and fruits in homegardens, mainly for household consumption, not for income generation. Generally, the productivity of homegardens is low, due to insufficient knowledge of crop production and unavailability of good quality seeds and other agricultural inputs when needed. These improperly managed homegardens would be more effective at producing fruits, vegetables, and staples such as yams and thus improving nutrition of the family if the productivity could be improved and optimized. In addition, better production would improve income generation of smallholders as surpluses could be traded. A review that evaluated the effectiveness of agricultural interventions in improving nutritional status in participating households emphasized that home gardening projects had greater success in relation to improving human nutrition than other types of agricultural intervention (Berti et al., 2004).

In Sri Lanka, in order to address the issues with regard to household food insecurity and malnutrition, the Ministry of Agriculture initiated, during the last decade several programmes promoting Home gardening under the National Programme on Food Production (Anonymous, 2012, 2015, 2019). Many local non-governmental organizations, along with the Department of Agriculture, promoted homegardens in line with this national programme, by raising awareness, distributing planting materials, and providing training for farmers.

We hypothesized that these agricultural and extension interventions significantly improved homegardens, increasing their diversity, and resulting in greater food and nutrition security of the households. The impact of homegardens on improving food and nutrient availability, ecological benefits, increasing household income, and the quantity of the households' food production has been widely studied in Sri Lanka (Pushpakumara et al., 2010; Weerahewa et al., 2011; Galhena et al., 2013). However, scientific evidence of the value of the improved homegarden model for production of fresh vegetables, fruits and yams and of its ability to enhance nutrient intake for the family is still limited in Sri Lanka. Therefore, the overall objective of the study was to evaluate the improved homegarden production system designed for mid country in Sri Lanka on crop diversity, dietary intake, dietary diversity, and food and nutrition security of households.

MATERIALS AND METHODS

Survey Design and Sample

This study was conducted in Aluthgama village, Nawalapitiya of the Kandy District, Central Province, Sri Lanka, during May 2015 to December 2016. The village, with 200 households, is

situated in the mid country (range 300–900 m above mean sea level) wet zone (with >2,500 mm total annual rainfall). This area has the typical “KFG” type land use pattern (Figures 1, 2). These gardens were within the homestead and contained a highly diverse mixture of annual and perennial plant species, including food crops and tree species of different heights forming different strata.

Two types of homegarden were identified in this village: The first was supported by a non-governmental organization, as a community project, which provided selected homesteads with planting material, agricultural inputs and advice, and were regularly monitored by a field officer for methodical and effective farming. The participants were selected purely based on their willingness to participate in the programme. These homegardens will be referred to as “organized homegardens” (OHG) hereafter in this paper. The other type of homegarden was self-maintained by homesteads without any external support and hence will be referred to as “non-organized homegardens” (NOHG).

Study Methods

Three studies were conducted in this village.

Study 1: The local authorities of the area were contacted to obtain the list of households and 100 out of the total of 200 households were randomly selected to answer a survey questionnaire administered by an interviewer. Available literature, informal discussions with farmers in the area, and personnel experience of the researchers were used in preparation of the questionnaire. The questions related to details of the family members (e.g., age, education, income), to land use and cultivation details, and details about the homegardens (e.g., extent, cropping, and purpose), details of tea cultivation, inputs such as labor, and agrochemicals, soil conservation methods, and problems/issues with homegardening/tea cultivation. The questionnaire was prepared in English, translated to the local language (Sinhala) and pre-tested with a 10% of the population. Some questions were modified based on the responses. The data were collected by researchers using the native-language. Part of the information generated in this study has been published elsewhere (Wekumbura et al., 2017).

Study 2: A sub-sample of 20 each of OHG and NOHG (10% of the total households) were drawn randomly from the 100 household list. All selected households gave consent to participate and an inventory of the cultivated food and cash crop species (crops that had a direct influence on food or income) was compiled, where different species were documented. The crops were grouped into three categories with each having subgroups as follows: fruits [This category included fruit trees in the top canopy layer (>10 m in height), fruit trees in the medium canopy layer (5–10 m in height), fruit trees/plants in bottom canopy layer (<5 m in height) and fruit vines], vegetables and other crops (root and tuber crops, leafy vegetables, condiments, cereals, and other foods), income and utility crops (food and timber, only timber, food/ cash crops, food /cash /home consumption, non-timber/ non-food). Although not directly of food value, non-timber/ non-food crops were included since they had an economic value and were used for various purposes, hence had an indirect value on nutrition and income (e.g., *Gliricidia sepium*

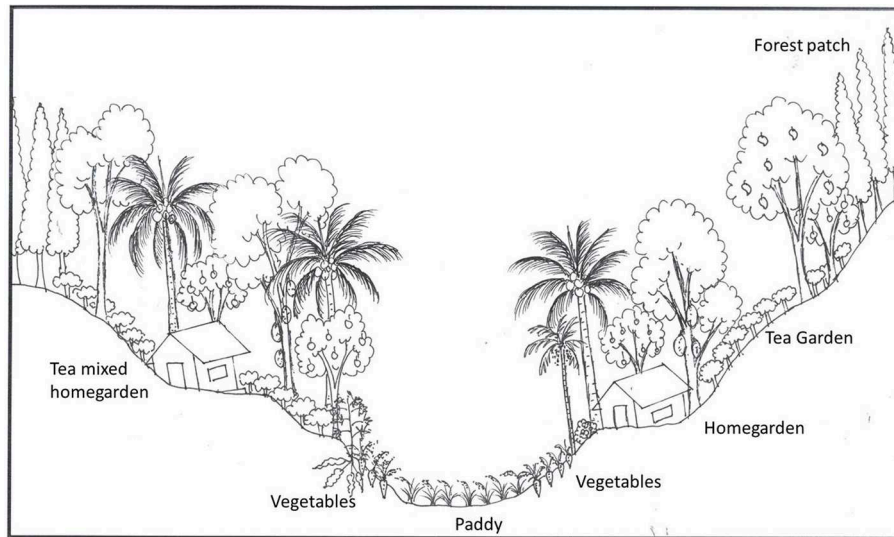


FIGURE 1 | Graphical representation of the typical land use pattern in the study area.



FIGURE 2 | Typical land use pattern in the study area including Kandyan Forest Garden.

is used as a shade tree, sticks used for fencing and as a support for vine crops, leaves used as a green manure). These species also occupied different layers of the canopy and therefore, represented and contributed to the diversity of homegardens in the study area.

The crop type diversity in each homegarden was quantified using the Shannon-Wiener index ($H = -\sum (p_i \log p_i)$), where p_i is the relative abundance of occurrence of the i^{th} crop sub category in the homegarden, calculated as the proportion of the number of species of the i^{th} crop sub category to the total number of species (Kent and Coker, 1992), Simpson's Index ($D = \sum n(n-1)/\sum N(N-1)$), where n is the total number of species individuals of a particular crop type and N is the total number of species of all crop types considered (Whittaker, 1972), the

Whittaker beta diversity ($\beta_w = (S/\alpha)-1$), where S is the total number of species/types and α is the mean number of species (Whittaker, 1960). These indices were also computed for different crop categories, i.e., fruits, vegetables and income, and utility crops. The different species of domestic livestock reared in each homegarden also were recorded.

Study 3: Another 25 households with OHG and 20 households with NOHG having at least one preschool age (< 5 years) child, one of the highly vulnerable age groups for malnutrition, were selected randomly to study the contribution of homegarden to the household food security, nutrient intake and dietary diversity. The sample size in this study was restricted based on the availability of families having at least one child <5 years

and need for detailed data collection. Demographic and socio-economic data (age, educational level of household members, household monthly income, total household expenditure, food ratio) and homegarden information (area of land used, number of plant species, and livestock reared) were collected using the survey questionnaire. Ethical clearance was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Peradeniya, Sri Lanka, and informed, written consent was obtained from household heads before collecting data. All households invited to participate in the study 2 and 3 gave consent to provide information and none of them refused to participate.

Food ratio was calculated as the share of expenditure on food out of total household expenditure. Household food security was determined using questions on perceptions regarding uncertainty and worry, inadequate quality, insufficient quantity, and social acceptability of food access of the households based on the modified version of 18-item United States Department of Agriculture's (USDA) food security survey module (Bickel et al., 2000), which was translated into the local language and modified for the Sri Lankan context (Malkanathi et al., 2007). Mothers of the children in the selected households were the respondents. Households were categorized into 4 levels of food insecurity: food secure, food insecure without hunger, food insecure with moderate hunger and food insecure with severe hunger.

Nutritional status of the children below 5 years in the households were determined by measuring height and weight using standard methods. All measurements were taken by the same investigator. When there were more than 1 child was present at a household, the youngest child <5 years was included in the study. Stunting (height-for-age Z-score <-2), wasting (weight-for-height Z-score <-2), underweight (weight-for-age Z-score <-2) and overweight/obese (weight-for-age Z-score > +2) was determined using World Health Organization reference values. Blood samples (3 ml) were collected by nurses. Hemoglobin level was measured immediately after the blood draw using a Hemocue Hb 201 system (HemoCue AB, Ångelholm, Sweden). The combined Sandwich ELISA technique was used to assess serum ferritin (Erhardt et al., 2004). Children were classified as anemic if they had hemoglobin concentrations < 110 g/L (World Health Organization, 2011a). Ferritin concentration <12 µg/L was used to define iron deficiency (World Health Organization, 2011b).

Household dietary intake was assessed using a 5-day diet diary, which is the "gold standard" to measure actual intake information throughout a specific period (Shim et al., 2014). Each respondent was given a printed diet diary booklet and asked to complete the intake of all foods and beverages consumed by all household members in cooked or raw form, for 4 days in the week and for 1 day of the weekend. The women were instructed how to record the time of food taken, food name, brands, type of cooking, fat, and oil sources used in cooking, portion sizes in household measures (e.g., spoons, cups etc) and the source of food (whether they purchased from market or shops or from the homegarden). All diet diaries showed acceptable compliance to instructions. The household daily intakes of energy, macro, and micronutrients were derived from portions of foods recorded in diet diaries using Foodbase 2000 software (Institute of Brain

Chemistry, UK) which has food composition database modified and updated for Sri Lankan food items (Thamilini et al., 2014). Energy and nutrient intakes of households were converted to adult male equivalents (Claro et al., 2010) for comparison between households.

To estimate the nutrient adequacy of the diet, a Nutrient Adequacy Ratio (NAR) was calculated for the intake of energy, protein and 9 selected micronutrients. The NAR for a given nutrient is the ratio of household intake to the summation of Recommended Daily Allowance (RDA) (FAO/WHO/UNU, 2001; World Health Organization, 2005, 2007; World Health Organization/Food Agriculture Organization, 2006) on the basis of age and sex for the household members. Adequacy was defined as $NAR > 80\%$.

Diversity of the diet of the households was assessed using the Dietary Diversity Score (DDS) and Food Variety Score (FVS) (Ruel, 2003). DDS was calculated as the number of food groups consumed by the members of the household over a period of 24 h using the following 12 food groups: cereals, white tubers and roots; vegetables; fruits; eggs; meat; fish, and other sea foods; legumes; nuts and seeds; milk and milk products; fats and oils; sweets and others. One point was given for each food group consumed during the study period with a maximum score of 12. DDS for household including $[DDS_{(+HG)}]$ and excluding home garden products $[DDS_{(-HG)}]$ was calculated. FVS is a simple count of food items eaten by an individual over a period of 24 h. FVS for household including $[FVS_{(+HG)}]$ and excluding $[FVS_{(-HG)}]$ homegarden products was calculated.

Statistical Analysis

Two types of home gardens were compared for their crop diversity indices by using the general linear model (PROC GLM) and count data of plant species were analyzed using CATMOD procedure in Statistical Analysis System (SAS) statistical package version 9.13 (SAS 9.0, SAS Institute Inc., Cary, NC, USA). The Statistical Package for Social Sciences (SPSS) version 22.0 (IBM SPSS 22.0, Chicago, IL) was used for the other statistical analyses. Descriptive analyses were used to summarize household and homegarden characteristics and household consumption of food groups. Student's *t* test and Fisher's exact test were used to identify statistically significant differences of mean values and proportions of different variables, respectively, between OHG and NOHG at $P < 0.05$ level of significance. Continuous variables that were not distributed normally were log-transformed before *t*-test. Binary logistic regression analysis was performed to determine the association between food security status and home gardening practice of the study sample. Odds ratios (OR) were reported with 95% confidence interval (CI). Food insecurity was considered as dependent variable. The other data collected included, family size (≤ 4 vs. > 4 persons), number of years of education of male and female heads of households (< 11 year vs. ≥ 11 year), DDS (≥ 8 vs. < 8), food ratio (≤ 80 vs. $> 80\%$), household income per month (\geq median vs. $<$ median) and having an organized homegarden (no vs. yes) as independent variables. In the presentation of data, continuous data are given as mean (SD) and categorical data as actual frequencies and percentages.

RESULTS

The area of land belonging to homesteads ranged between 0.2 and 0.8 ha. All households had a homegarden and a tea land, which were either closely integrated together or the tea land existed as an adjoining block to the homegarden. Only 28% of heads of the families (male) were formally engaged in farming. Others were employed either in the government and private sectors or were self-employed (carpenter, driver, etc.). Another 29% mentioned that they do not have a definite occupation.

Crop Diversity of Homegardens

Both types of homegardens were quite diverse in terms of the crops grown as shown by the maximum number of species per homegarden (Table 1). For example, some individual homegardens contained 43 species out of the recorded 50 fruit species, 68 out of the 72 in the group consisted of vegetables, leafy vegetables, root/ tuber crops, spices and condiments, and cereals, 38 out of the 46 income and utility crops recorded, and 135 out of 168 total species recorded.

The OHG had a higher diversity of crops compared to the NOHG as presented in Table 1. The mean numbers of fruit (24 vs. 19), and vegetable and other crops (43 vs. 33), and income and utility crops (24 vs. 20) were significantly higher in the OHG than in the NOHG. In the number of subgroups, a statistically significant difference was observed only in vegetables and other crops, which was higher in the OHG than in the NOHG, although the OHG consistently had a greater number of subgroups than in the NOHG. Similarly, the Shannon-Wiener and Simpson's Diversity Indices (1-D) for vegetables and other crops, and income and utility crops were significantly higher in the OHG than the NOHG indicating higher diversity of those crops in OHG. When all these crops were considered together without categorizing, all the indicators of crop diversity showed significantly greater values for OHG compared with NOHG. OHG in all the crop categories had lower beta diversity than the NOHG, indicating similarity in species composition of the community.

Both OHG and NOHG in the study area grew fruits, vegetables, tuber and other crops, together with income and utility crops. Most commonly grown vegetables in both types of homegardens were "thibbatu" (*Solanum torvum*), tomato (*Solanum lycopersicum*), "dara dambala" (*Psophocarpus tetragonolobus*), manioc (*Manihot esculenta*), "Naimiris" (*Capsicum frutescense*), brinjal (*Solanum macrocarpon* L.), pumpkin (*Cucurbita maxima*), beans (*Phaseolus vulgaris* L.), and raddish (*Raphanus sativus*). Sorghum (*Sorghum halappense*) was grown only in OHGs. Most commonly grown green leaves in this study area were "Gotukola" (*Centella asiatica*), "Japan gotukola" (*Apium* sp.), "Japan batu" (*Sauropus androgynus*), "Mukunuwenna" (*Alternanthera sessilis*), "Kurathampala" (*Amaranthus tricolor*), and "Koppa kola" (*Polyscias scutellaria*). Cassava (*Manihot esculenta*), "Kiri ala" (*Colocasia* sp.), "Wel ala" (*Dioscorea alata*) and sweet potato (*Ipomoea batatas*) were the most commonly obtained, starchy, root, and tuber crops from both types of household, while there were several other indigenous root and tuber species present in both homegarden

types. The majority of households grew guava (*Psidium guajava*), banana (*Musa* spp.), avocado (*Persea americana*), papaya (*Carica papaya*), "Rambutan" (*Nephelium lappaceum*), durian (*Durio zibethinus*), and mango (*Mangifera indica* L.) as fruits in their homegarden, but "Gaduguda" (*Baccaurea motleyana* Müll.Arg.), "Galsiyambala" (*Dialium ovoideum*), and Indian Gooseberry (*Phyllanthus emblica*) were found only in OHG. Donga fruit (*Sandoricum indicum*) was available only in NOHG. All homegardens had tea [*Camellia sinensis* L. (O.) Kuntze] as a cash crop integrated into the homegarden or as a separate plot adjoining the homegarden. In addition, betel (*Piper betle*), pepper (*Piper nigrum*) and cloves (*Syzygium aromaticum*) were also grown as cash crops in both types of homegardens. A complete list of crop species found in the two groups of homegardens is given in Annexure A. Only 5 out of 25 households reared livestock. They were cattle, goat, broiler chicken, and layer hens.

Household Food and Nutrition Security

Socio-demographic characteristics of the households with OHG and NOHG are presented in Table 2. Age of the father and mother, size of the household, educational level, monthly income and expenditure, and food ratio of OHG were not significantly different compared to NOHG. Monthly income and expenditure of households with OHG and NOHG showed high variation. In both groups, mean monthly household income (Sri Lankan Rupees-LKR 40958 and 34225 for OHG and NOHG, respectively) and expenditure (LKR 28838 and 34443 for OHG and NOHG, respectively) were lower than the mean national monthly income and expenditure of the rural sector (LKR 58137 and 51377, respectively) (Department of Census and Statistics, 2016). Food ratio of both OHG and NOHG was higher than the national figure for the rural sector (35.4%) (Department of Census and Statistics, 2016). Most families selected for the study 3 were nuclear families (except for 2 OHG and 1 NOHG) with a maximum of 3 children. There were no differences in adult/child ratio.

Household Food Security

Out of the four levels of food insecurity status classified by the USDA household food security survey module, only two levels, i.e., "food secure" and "food insecure without hunger" were observed in the studied households. Among the households, 88% ($n = 22$) with OHG and 65% with NOHG ($n = 13$) were food secure. However, there was no statistically significant association between organized or non-organized practice of homegardening, family size, number of years of education for male and female heads of the household, DDS, food ratio and food security. In contrast, households that had monthly income below the median of the study sample were 23% more likely to be food insecure compared with households that received monthly income above the median (Odds ratio 1.23; 95% CI 1.000–3.108).

Nutritional and Health Status of Children Under 5 Years

The prevalence of wasting and underweight was higher in children under 5 years in households with NOHG (30 and 30%, respectively) compared with those with OHG (16 and 20%,

TABLE 1 | Number of crop species and species diversity indicators for different groups of crops in OHG and NOHG.

Crop group		Number of species [†]	Number of sub groups [‡]	Shannon Weiner Index [#]	Simpson (1-D) [#]	Whittaker Beta Diversity
Fruits	Maximum	43	4			
	OHG	24	3.8	1.147	0.653	0.101
	NOHG	19	3.6	1.091	0.628	0.108
	<i>P</i>	0.001	0.16	0.20	0.14	<i>nd</i>
Vegetables and other crops ^a	Maximum	68	5			
	OHG	43	4.6	1.394	0.733	0.087
	NOHG	33	4.4	1.309	0.705	0.149
	<i>P</i>	0.001	0.001	0.007	0.01	<i>nd</i>
Income & utility crops	Maximum	38	5			
	OHG	24	5	1.554	0.777	0.008
	NOHG	20	4.8	1.49	0.757	0.042
	<i>P</i>	0.001	0.9	0.03	0.03	<i>nd</i>
All crops	Maximum	149	14			
	OHG	91	13.4	2.423	0.899	0.053
	NOHG	72	12.8	2.349	0.889	0.099
	<i>P</i>	0.001	0.001	0.01	0.01	<i>nd</i>

^aOther crops include leafy vegetables, pulses, root/ tuber crops, spices and condiments, and cereals.

OHG, Households with organized homegardens; NOHG, Households with non-organized homegardens.

[‡]Sub groups: fruits [fruit trees in the top canopy layer (>10 m in height), fruit trees in the medium canopy layer (5–10 m in height), fruit trees/plants in bottom canopy layer (<5 m in height) and vine fruits], vegetables, and other crops (root and tuber crops, leafy vegetables, condiments, cereals and other foods), income and utility crops (food and timber, only timber, food/cash crops, food/cash/home consumption, non-timber/non-food); Values for OHG and NOHG were compared using.

[†]Categorical data analysis (CATMOD procedure in SAS).

[#]Student's *t*-test.

nd: not determined.

TABLE 2 | Comparison of socio-demographic profiles of the households with OHG and NOHG.

Variables	OHG (n 25)	NOHG (n 20)	<i>P</i>
Mean (SD) age of the father (years)	37.2 (6.2)	35.8 (4.3)	0.062 [#]
Mean (SD) age of the mother (years)	34.2 (5.9)	33.1 (4.5)	0.352 [#]
Household size	4.5	4.4	0.785 [#]
Education level of the father			
Up to Grade 11 (%)	36	30	0.524 [*]
Below Grade 11 (%)	64	70	
Education level of the mother			
Up to Grade 11 (%)	50	40	0.085 [*]
Below Grade 11 (%)	50	60	
Household income (LKR per month)	40958	34225	0.120 [#]
Total household expenditure (LKR per month)	28838	34443	0.916 [#]
Food ratio (%)	49.6	50.1	0.645 [#]

OHG, households with organized homegardens; NOHG, households with non-organized homegardens; LKR: Sri Lankan Rupees; [#]Student's *t*-test for mean differences and ^{*}Fisher's exact test for difference between proportions (OHG vs. NOHG).

Values given in parenthesis are SDs.

respectively). Stunting was not observed among the children studied. Prevalence of overweight ranged from 4 to 5% in both types of households. In the study population, out of 45 children whose hemoglobin and serum ferritin were measured, 18 (40%) were anemic and 27 (60%) had low iron status. There was no statistically significant difference in prevalence

of anemia and iron deficiency between households with OHG and NOHG.

Dietary Energy and Nutrient Consumption

The intake of energy, macro and micronutrients of adult equivalent from all sources that provided food is given in **Table 3**. There was no significant difference in the energy and macronutrient intake between households with OHG and NOHG. However, there was a trend of greater contribution of fats and protein from OHG compared with NOHG. Intake of calcium, iron, vitamin C and vitamin A was significantly greater in households with OHG compared to NOHG.

Households with OHG obtained adequate (>80%) of energy, protein, iron, zinc, niacin, vitamin C and vitamin A (**Table 4**). Households with NOHG also reached the adequacy level of energy, protein, iron, zinc, niacin, and vitamin C. Households with OHG showed significantly higher adequacy level of iron, folate, vitamin C and vitamin A compared with that of NOHG.

Contribution From the Homegardens to Daily Energy and Nutrient Intake

Percentage contribution from the homegardens on daily energy and nutrient intake is given in **Table 5**. A significantly higher contribution of energy, carbohydrates, fat, calcium iron, zinc, folate, thiamin, niacin, vitamin C and vitamin A from the homegardens was observed in households with OHG compared with that of NOHG.

TABLE 3 | Comparison of mean energy and nutrient intake of the households with OHG and NOHG.

Nutrient	EAR	RDA	OHG (n 25)		NOHG (n 20)		P [#]
			Mean	SD	Mean	SD	
Energy (kcal)	na	2100	2277	568	2118	472	0.262
Carbohydrate (g)	na	na	355	90	352	78	0.910
Protein (g)	46	56	65	26	56	15	0.133
Fat (g)	na	na	75	21	63	18	0.065
Calcium (mg)	833	1000	632	257	470	109	0.004
Iron (mg)	6.0	13.7	19.7	7.8	14.5	4.2	0.003
Zinc (mg)	5.8	7.0	9.0	2.8	8.0	2.0	0.131
Folate (μg)	320	400	252	92	198	85	0.581
Thiamine (mg)	1.0	1.2	1.1	0.5	0.9	0.4	0.099
Riboflavin (mg)	1.1	1.3	0.9	1.5	0.4	0.5	0.050
Niacin (mg)	12	16	21	12	18	8	0.251
Vitamin C (mg)	37	45	64	39	31	14	<0.001
Vitamin A (RE μg)	429	600	542	304	284	106	<0.001

EAR, estimated nutrient intake; NOHG, households with non-organized homegardens; OHG, households with organized homegardens; RDA, recommended dietary allowance; SD, standard deviation.

[#]Student's t-test (OHG vs. NOHG).

na, not available.

TABLE 4 | Nutrient Adequacy Ratio (NAR) of selected nutrients of the households with OHG and NOHG.

Nutrient	OHG (n 25)		NOHG (n 20)		P [#]
	Mean	SD	Mean	SD	
Energy	97	24	89	20	0.311
Protein	116	35	111	26	0.188
Calcium	61	27	48	12	0.044
Iron	143	61	110	35	0.026
Zinc	130	43	112	31	0.103
Folate	63	23	50	21	0.048
Thiamine	74	30	74	32	0.953
Riboflavin	71	35	65	45	0.686
Niacin	175	100	151	64	0.419
Vitamin C	113	48	98	57	<0.0001
Vitamin A	88	69	44	18	0.004

OHG, households with organized homegardens; NOHG, households with non-organized homegardens; SD, standard deviation.

[#]Student's t-test (OHG vs. NOHG).

Dietary Diversity

Contribution of homegarden produce to dietary diversity was compared within and between the two groups of households and is presented in **Table 6**. There was no significant difference in $DDS_{(+HG)}$ and $DDS_{(-HG)}$ between two types of households. But there was a significantly higher $DDS_{(+HG)}$ compared to $DDS_{(-HG)}$ within the households with OHG. There was a significantly greater $FVS_{(+HG)}$ and $FVS_{(-HG)}$ in households with OHG compared with that of NOHG. $FVS_{(+HG)}$ was significantly higher than that of $FVS_{(-HG)}$ in both types of households.

TABLE 5 | Percentage contribution of homegarden to daily energy and nutrient intakes of the households with OHG and NOHG.

Nutrient	OHG (n 25)	NOHG (n 20)	P [#]
Energy	3.7	1.3	0.033
Carbohydrate	3.3	1.1	0.034
Protein	2.8	1.2	0.061
Fat	5.1	1.8	0.026
Calcium	13.1	3.8	0.022
Iron	13.5	3.8	0.013
Zinc	7.4	2.2	0.017
Folate	14.5	4.6	0.048
Thiamine	6.9	2.5	0.026
Riboflavin	2.4	2.3	0.110
Niacin	12.4	3.8	0.025
Vitamin C	25.0	8.5	0.045
Vitamin A	14.8	4.2	0.031

OHG, households with organized homegardens; NOHG, households with non-organized homegardens.

[#]Student's t-test (OHG vs. NOHG).

TABLE 6 | Contribution of homegarden produce to dietary diversity score and food variety score of the households with OHG and NOHG.

Dietary score	OHG (n 25)	NOHG (n 20)	P [#]
$DDS_{(+HG)}$	8.8 ^a	7.9	0.305
$DDS_{(-HG)}$	7.5	7.4	0.719
$FVS_{(+HG)}$	14.0 ^a	11.9 ^a	0.004
$FVS_{(-HG)}$	11.9	10.0	0.007
Contribution of homegarden produce to DDS (%) ¹	14.5	2.4	<0.0001
Contribution of homegarden produce to FVS (%) ²	15.1	2.9	<0.0001

OHG, households with organized homegardens; NOHG, households with non-organized homegardens; $DDS_{(+HG)}$, dietary diversity score including food items from homegarden; $DDS_{(-HG)}$, dietary diversity score excluding food items from homegarden; $FVS_{(+HG)}$, food variety score including food items from homegarden; $FVS_{(-HG)}$, food variety score excluding food items from homegarden.

¹Contribution of homegarden to DDS: $DDS_{(+HG)} - DDS_{(-HG)} / DDS_{(+HG)} \times 100$.

²Contribution of homegarden to FVS: $FVS_{(+HG)} - FVS_{(-HG)} / FVS_{(+HG)} \times 100$.

[#]Student's t-test: OHG vs. NOHG.

^aSignificantly different from $DDS_{(-HG)}$ or $FVS_{(-HG)}$ within the column.

Both DDS and FVS had a greater percentage of contribution from the homegarden in households with OHG (14.5%, 15.1%, respectively) compared to households with NOHG (2.4 and 2.9%, respectively).

DISCUSSION

The study evaluated the crop species biodiversity in the “Kandyan Forest Garden” type of homegardens with organized (referred to as OHG) and non-organized (referred to as NOHG) farming practices in a rural village in the Central Province of Sri Lanka. Households with OHG were previously supported by a non-government organization and were selected based on their

willingness to participate in the programme. Therefore, it can be speculated that the owners of OHG might be more enthusiastic in home gardening than those of NOHG.

The study assessed the contribution of food items from these gardens to household dietary nutrient intake and dietary diversity. This provided an insight into the contribution of homegarden produce to household nutrient intake, dietary diversity, and food security. To the best of our knowledge, this is the first study conducted in Sri Lanka to quantify the contribution of homegardens to dietary intakes, dietary diversity, and food and nutrition security of families.

Homegardens in the present study mainly had rain-fed crops (during the study period). In both OHG and NOHG, tea was grown as a cash crop. The OHG had more diverse vegetation than NOHG. The greater diversity was also evident for all categories of crops studied (fruits, vegetables and other crops, cash and utility crops, and the total number of species). In contrast, the NOHG contained a smaller number of species (lower diversity). Qualitative records of the food crop species also showed greater diversity in OHG compared with NOHG. It can be concluded that the agricultural intervention in the in OHG of present study contributed to the increased species diversity.

A majority of households studied was food secure, irrespective of the intervention on home gardening practices. We assessed the household food security using USDA Food security scoring module which is based on the perceptions of people on qualitative and quantitative supply and consumption of food, but not necessarily on the nutritional quality of the diet. In our study, we found that the households with greater income are more likely to be food secure.

When lower income and higher food ratio of the studied families were compared with the national average values, it indicated that these families are vulnerable to food insecurity unless they adopt some other coping strategies. The homegarden food produce had a relatively low contribution to the total diet of the household, hence the homegarden functions as a supplementary food source but not as a primary source of food for the household. This indicates the lack of difference in overall perceived household food security between OHG and NOHG. It has been shown that homegardens have potential to add to households' food supply and nutrition (Niñez, 1984; Mitchell and Hanstad, 2004), especially during "lean" seasons (Christanty et al., 1986; Karyono, 1990). For rural households, homegardens offer a free or low-price source of foods (Wezel and Bender, 2003). Homegardens are therefore considered as the most adaptable and accessible land resources for rural households and are an important component in reducing vulnerability and ensuring food security (Buchmann, 2009).

Although a majority of households was food secure in this study, greater prevalence of undernutrition (wasting and underweight) among children in households with NOHG implies that their diets were nutritionally inappropriate compared with OHG. In both types of households, prevalence of anemia was relatively high, which might have been related to inadequate iron intake. The households with both types of homegardens consumed adequate levels of energy and macronutrients. Although not statistically significant, there was a greater

contribution of fats and protein from OHG compared with NOHG. Households with OHG consumed a greater number of food items with or without considering homegarden. It can be suggested that when more food items are consumed fats (mainly coconut milk) and protein food sources are added to these foods which can increase the fat and protein intakes. In contrast, households with OHG consumed greater amount of micronutrients, especially calcium, iron, vitamin C and vitamin A compared with NOHG although the overall contribution from homegarden produce is modest (3.3–25%). Greater cultivation and consumption of vegetables, green leaves, and fruits, which contain micronutrients were reported among households with OHG compared with NOHG.

Dietary diversity, i.e., the number of foods consumed across and within food groups over a reference period, is widely recognized as a proxy indicator of nutrient adequacy of individuals and households. In the present study we used DDS and FVS (Kant et al., 2000; Ruel, 2003; Maxwell et al., 2014) to measure diet quality. Although the DDS and the FVS cannot give a full picture of the adequacy of the nutrient intake, such food scores can give a good indication of the nutritional adequacy of the diet, in particular when they are combined (Hatloy et al., 1998; Mirmiran et al., 2004; Steyn et al., 2006). The diversity of the diet in terms of food groups was not different between two types of households. However, the plant species cultivated in the homegarden offered an important source of micronutrients and had a higher contribution toward the dietary diversity of households with OHG than did in NOHG. A modest but higher contribution of homegarden produce to DDS in households with OHG is attributed to their relative higher consumption of number of food groups from the homegardens. Moreover, the households with OHG consumed, overall, a greater number of food items (FVS) compared with those with NOHG. The contribution of number of food items from homegarden was also higher in households with OHG. This implies that households with OHG not only cultivate a greater diversity of plant species, but also consume more of the food items (may be from the same food group as indicated by similar DDS) from the homegarden.

The typical Sri Lankan diet consists of a staple dish of rice, accompanied with one or a few vegetables, green leaves and pulses, prepared using coconut milk, or oil added with spices and condiments. The diet is often supplemented with some animal protein food source such as fish, chicken, or eggs. Usually, the household diets are not entirely composed of homegarden products. It is possible that households, especially the households with NOHG, had supplemented their diets with foods purchased from the market and the wild to compensate for low availability of homegarden food produce. This may be the reason for similar dietary diversity in terms of food groups between two types of households. Many food items in the daily diet of both households were purchased from the market according to their diet records.

In our study population, animal protein consumption was low. Only 5 out of 25 households have opted for animal husbandry. It was reported that the rearing of animals in homegardens of Sri Lanka is limited compared to other countries in the region (Marambe et al., 2012; Weerahewa et al., 2012). Only about 25% of the households had consumed meat.

Fish or fish products, especially dried fish, was consumed by most of the households within the given period as the major source of protein. Some households consumed eggs from homestead reared hens, but otherwise, animal sources of foods were purchased. Even though their protein and iron intakes were in satisfactory levels, there may be issues with quality of protein and bioavailability of iron. This could be the reason for relatively high anemia and low iron status observed in the pre-school aged children in this population.

The small sample studied from a single location is a limitation in generalizing the findings of this study to other locations and homegarden types in the country. The study sample had similar characteristics as they were residing in a particular area. Therefore, further studies with larger samples and diversities of homegardens from different geographical, agro-ecological locations, and socio-economic status are needed to understand the impact of homegardens on household food security, contribution to household food consumption and nutrient intakes. Alternatively, more convincing results on the contribution of homegardens might have been obtained if this study was conducted to compare home gardening and non-gardening households. The household members spent considerable time and allocated more family labor for tea cultivation, therefore home gardening was given less priority when there was a high labor demand for tea cultivation. During the data collection period, adverse weather conditions prevailed, so most of the households lost their crops. Since the study was not conducted during different seasons, drawing firm conclusions about the impact of homegardens and its sustainability in nutritional contribution throughout the year is prevented. Five-day diet diary method was considered reliable to determine dietary intakes, but more subject burden is unavoidable. Therefore, some under- or over-reporting may have occurred.

Despite these limitations, the study provides a strong indication that the homegarden model with organized agricultural practices contributed significantly to micronutrient intake and dietary diversity of the households. It has been hypothesized that the crop biodiversity could be positively associated with dietary diversity, which in turn could improve nutritional status of vulnerable population groups. Although the perceived household food security status is not influenced by homegarden practice *per se*, “nutrition security” of the household is directly affected by homegarden. The findings of the present study contribute to the rapidly growing evidence based on nutrition sensitive agricultural interventions that can best be used to improve family nutrition (Ruel et al., 2018).

Further, it can be suggested that motivating farmers to have improved and organized practices in homegardens coupled with effective awareness on nutrition would promote nutrition security of the family. The cultivation of fruits, vegetables, roots, and tuber crops in homegardens should be promoted as part of a nutrition-based intervention for rural communities with vulnerable groups. Moreover, the homegarden is a useful agricultural production system for

conservation of biodiversity in the long run, and to support household livelihoods by providing food, additional income and a wide range of products such as firewood, fodders, medicinal plants and ornamentals. The present homegarden promotion programmes conducted by the government have given very limited focus on nutrition promotion through homegardening. The agricultural support alone provided in such programmes may not be enough to achieve the broader goals of nutrition security of the households. Also, there is a need to develop holistic policies with multisectoral involvement to promote homegardens in Sri Lanka. It has been suggested that the recognition and integration of traditional knowledge and practices of the communities related to local food species is also important in planning and adapting sustainable homegardening systems (Singh et al., 2013). Therefore, further detailed studies examining the approaches of improving multifunctional nature of homegardens is needed to fully understand the roles of homegardens in improving human well-being.

CONCLUSION

The study concluded that improved home gardening practice *per se* is not associated with perceived household food security. However, households with more organized home gardening practices had greater and diverse crop combination compared to the households which practice non-organized agricultural practices. Those families with organized homegardens had greater intake of calcium, iron, vitamin C and vitamin A, achieved greater nutrient adequacy and higher dietary diversity from homegarden produce compared with that of households with non-organized homegardens leading to better nutrition security. The present study provides insight into the shortcomings in current homegardening policies and programmes conducted in Sri Lanka and emphasizes the need for integrating nutrition promotion into them in order to improve family nutrition outcomes.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Ethics Review Committee of the Faculty of Medicine, University of Peradeniya with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the name of committee.

AUTHOR CONTRIBUTIONS

JT and CW implemented the field research and drafted the manuscript with support from KS, AM, and EF. JT, CW,

and AK processed the experimental data and performed the statistical analysis. AM took the photographs and drew the illustration. KS, AM, SK, and EF conceived the study design, supervised the project, and contributed to the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2019.00094/full#supplementary-material>

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