



## Enhancing Household Food Security and Dietary Diversity through Homegardens: A Case Study in Selected Districts of Sri Lanka

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### ABSTRACT

Homegardens are resourceful ecosystems that provide essential services to the environment and mankind. Their contribution to secure household food requirement is among the provisional services of contemporary relevance. A study was conducted in 429 homegardens in Jaffna, Matale, Ratnapura, and Hambantota districts to assess the scope of utilizing homegarden resources on household food security. A questionnaire survey was conducted to gather information on the consumption frequency and the number of food categories that were purchased, produced, and shared. The mean food consumption score (FCS) was  $60 \pm 23$ , where 89% of the study population had an acceptable level of FCS ( $FCS > 35$ ). As per the dietary diversity score (HDDS), an average household consumed at least eight food categories per day. Coconut was the most common food commodity produced in homegardens, followed by jackfruit and other fruits (mango, guava, soursop and pomegranate). Households rely on the market-available foods as their primary food source. The study revealed that utilizing at least one food category as a homestead-resource produced, could improve FCS and assist to fulfil the household food demand significantly. However, the majority of the homestead-resources were identified as plant-based, except in Jaffna where the presence of livestock and poultry in homegarden was common. Many of the plant-based resources were from perennial fruit-bearing trees. Therefore, modifying and utilizing the tree composition and viable crops can be considered a timely option to avert household food insecurity. Further, incorporating livestock components (dairy, poultry) as a part of homegardens is beneficial in fulfilling the animal protein demand of the household.

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## INTRODUCTION

Homegardens are complex yet sustainable land-use systems that combine annual and perennial crops, livestock, and occasionally fish (Weerahewa et al., 2012). They can also be man-made traditional ecosystems, sometimes comparable to natural forests and secondary forests (Kumar, 2015; Ramli et al., 2021). These ecosystems provide environmental services, household necessities, employment, and income generation opportunities for households (Pushpakumara et al., 2012; Weerahewa et al., 2012). While there are various definitions for homegardens in literature, they can be considered as multilayered, viable land-use systems that combine crops, livestock, and sometimes aquaculture, offering environmental services, meeting domestic requirements, providing employment, and generating revenue for families and households (Pushpakumara et al., 2012). Ecosystems with diverse flora and other living forms exhibit high levels of productivity (Kumar, 2011), primarily due to the large stable carbon stock present in the system (Henry et al., 2009). Furthermore, the tree component within the homegarden improves the microclimate and helps buffer the interface with the external environment, making it resilient to critical climatic impacts (Mbow et al., 2014).

As the world population continues to rise, the increased demand for food and food insecurity pose major challenges. Many scientists argue for diverse approaches to mitigate these concerns by implementing different methods to enhance the food supply (Lopez-Ridaura et al., 2019; Mora et al., 2020). Rapid urbanization has led to the utilization of available arable lands for other human activities (Kumar, 2006; Mbow et al., 2014). Moreover, climate change adversely affects plant growth, biodiversity, and carbon storage in the biosphere, resulting in the breakdown of existing agricultural production systems (Linger, 2014). Agroforestry or homegardens, as viable and diversified ecosystems, present a timely and relevant option to address food insecurity and cater to the increasing food demand at the household level (Getachew, 2014; Vibhuti

et al., 2019). Thus, homegardens, which have proven to be adaptive to climatic hazards and extreme events (Galhena et al., 2013; Ninez, 1985; Pandey et al., 2017), can play a vital role in meeting household food requirements.

In terms of food security, homegardens and their various resources provide a variety of food items as supplements, including staple foods such as jackfruit, breadfruit, yams, sweet potatoes, and cassava, as well as vegetables, fruits, medicines, fodder, livestock, and occasionally fish (Pandey et al., 2017; Pushpakumara et al., 2012). Therefore, homegarden ecosystems can intervene to minimize food crises at the household level by offering a variety of food items as supplements and providing several food items at subsistence levels, including ready-to-consume and ready-to-trade products (Caballero-Serrano et al., 2016; Getachew, 2014; Mathewos et al., 2018). Properly maintained homegardens ensure relatively uninterrupted food production due to the proper combination and management of crops with different life cycles throughout the year (Lope-Alzina & Howard, 2012). Thus, researchers suggest that homegardens provide the best opportunity to overcome food crises and improve food security in the future at the household level (Kumar, 2006).

However, there is a need to clarify and better measure the influence of tree diversity and the contribution of other homestead resources, such as livestock, in achieving food security and satisfying domestic food demand (Mellisse et al., 2018). A research gap exists regarding the actual contribution of homegardens in ensuring domestic food security, considering the diverse scales of ground-level circumstances and compositional variations of homegardens in different sites in Sri Lanka. Therefore, the present study was conducted to assess the contribution of the homegarden ecosystem in satisfying household food demand, promoting dietary diversity, and enhancing food security in four selected districts of Sri Lanka. The study aimed to examine prevailing household food consumption patterns, assess dietary diversity, and explore the potential of different components of the homegarden in alleviating household food insecurity.

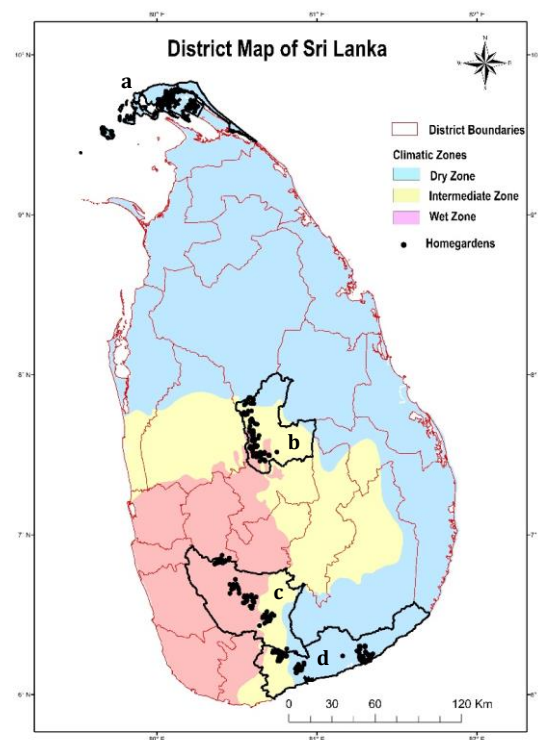
## METHODOLOGY

### Study sites

The current study aimed to assess the utilization patterns of homestead resources in order to support domestic food security by conducting a detailed examination of homegarden activities in four major districts located in different climatic and topographical zones across the island (Land Use Policy Planning Department, 2019). The selection of administrative units shown in Map 1 was based on expert opinions and previous studies, ensuring a significant diversity among the homegardens. The chosen districts were Jaffna (Northern Province), Matale (Central Province), Ratnapura (Sabaragamuwa Province), and Hambantota (Southern Province), known for their varying biodiversity and agricultural practices. The study encompassed 15 out of the 46 agro-ecological regions (AERs) identified in Sri Lanka (Punyawardena, 2009). The selection of sub-administrative units (villages) and homegardens was carefully conducted to capture the maximum diversity among homegardens within each district.

### Selection of homegardens

In each district, an approximate transect was established, encompassing urban, suburban, and rural areas to capture the distribution of agro-ecological regions (AERs) within the district. The transect was constructed along an elevation gradient to account for ecological and environmental variations. Along the transect, 4-5 specific locations were identified, taking into consideration the diversity among the different AERs. Using ArcGIS software, circular areas with a diameter of 10 km were demarcated at each location. Within these circular areas, a set of sub-locations (8-10) was identified based on covariates such as soil series distribution, elevation, proximity to the nearest forest, and distance to the road. The Conditioned Latin Hypercube sampling approach (Minasny & McBratney, 2006) was utilized to determine these sub-locations. These sub-locations served as guide points for selecting homegardens. The survey team visited these sub-locations with the aid of GPS navigation, and at each sub-location, 2-5 homegardens were selected for the study. The survey was conducted and completed between mid-2019 and mid-2020.



**Map 1.** Study sites; a: *Jaffna*, b: *Matale*, c: *Ratnapura* and d: *Hambantota*

## Homegarden survey

The selected homegardens underwent a comprehensive examination through a questionnaire survey, one-to-one interviews, and detailed observations conducted by the research team and trained enumerators. To facilitate convenient data recording, an e-questionnaire was developed as a mobile application, accessible on any mobile device using the commonly used open-source Android application called 'ODK\_Collect'. The digitized version of the survey eliminated the need for paper usage and expanded the range of different types of questions that could be included. The virtual questionnaire was filled out in real-time during the interview with the survey respondent. In total, 429 households were included in the survey. Upon completion of the survey, the survey form was saved on the device as a data file and then uploaded to Google Cloud Storage. The uploaded survey forms were subsequently downloaded to a computer as a compiled MS Excel file, organized according to a predefined arrangement.

## Survey questionnaire

The questionnaire aimed to collect information relevant to demographic details, income and expenditure, food consumption, and floral categories. Demographic information encompassed basic details of household members, starting from the head of the household, including their age and the size of the homegarden. It also captured information on their farming experience and contact details for further visits. Income and expenditure information comprised the income generated from farming and non-farming sources, household expenses, expenses related to the homegarden and other agricultural activities, the contribution of homegrown food items to household consumption, and the income generated from selling various products from the homegarden. The information collected on food consumption included different food categories and commonly consumed items in Sri Lankan households. It recorded the quantities consumed in the past week, purchased quantities, shared quantities, quantities produced within the homegarden,

and the number of days the food items were consumed. Floral data, which included perennial trees, non-woody trees, crops cultivated, animals reared in the homegarden, and their productions, were gathered through observations with the assistance of a family member. Additionally, each homegarden was photographed to obtain further details and document the arrangement of the garden. Multiple visits were conducted to most of the homegardens to fill any data gaps and verify the collected information.

All food items were classified into 15 groups namely; cereals, pulses, coconut, jack/breadfruit, vegetables, leafy vegetables, yams, fruits, meat, fish, dried fish, eggs, milk, and condiments, as outlined by Wiesmann et al. (2009). Data on the consumption patterns of individual food items within these categories were collected from each household to determine the extent to which homegardens contributed to domestic food consumption. Rice was included in the list despite not being cultivated in homegardens, as it is the staple food for Sri Lankans. The data on food consumption were collected from each household only once, at a single point during the survey. Therefore, in this study, each homegarden had an equal chance of being selected for a specific week, as the survey was conducted randomly. Further, data collection for each district was completed within a four-week timeframe.

## Analysis of data

The analysis was conducted using MS Excel and Minitab v15. Descriptive statistics were employed to describe and compare the various components of homegardens across districts, while ANOVA and t-tests were used to determine the significance of differences among groups and districts for different components. To enhance data interpretation, several biodiversity and food consumption indices and scores were calculated. These indices were computed using standard equations and procedures specified in the literature, which were based on similar studies conducted in Sri Lanka and other countries in the South Asian region.

### Food consumption score (FCS)

The Food Consumption Score (FCS) is an index developed by the World Food Program (WFP) in 1996. The FCS, as shown in Table 1, quantifies household food consumption data based on the diversity and frequency of food groups consumed over the previous seven days (1-week time period). The score is then weighted according to the relative nutritional value of the consumed food groups. For instance, food groups consisting of nutritionally-dense items (e.g., livestock produce) are given higher weights compared to those containing less nutritionally-dense food items (e.g., root crops). Using this score, a household's food consumption is classified into one of three categories: poor, borderline, or acceptable. The food consumption score serves as a secondary indicator of household caloric availability.

The maximum value for FCS is 112, representing the scenario where all the food groups are consumed every day for one week. The score ranges were defined as follows: 0 to 21 as poor, 21.5 to 35 as borderline, and greater than 35 as acceptable.

### Household Dietary Diversity Score (HDDS)

A Household Dietary Diversity Score (HDDS) was calculated to assess the accessibility of food items within households (USAID). The HDDS is a straightforward index computed by counting the total number of different food groups consumed within a specified time period and is considered a proxy indicator for food security. The HDDS utilizes the following

12 food groups for calculation: cereals, fish and seafood, root and tubers, pulses/legumes/nuts, vegetables, milk and milk products, fruits, oils/fats, meat, poultry, edible meat offal, sugar/honey, eggs, and miscellaneous items (INDDEx, 2019). The index was determined by counting the total number of food groups consumed within the last 24 hours of the day when the survey was conducted in the current study. The maximum value for the index is 12, indicating the highest diversity in domestic food consumption.

### Shannon-Wiener index (SWI)

Richness was determined by recording the total number of woody and non-woody perennial species observed within the homegarden. Abundance, on the other hand, was recorded by counting the number of mature trees present for each species observed. In these calculations, only tree species with diameters at breast height greater than 5 cm were considered, as the homegardens are predominantly tree-based farming systems and the tree component forms the permanent structure of the homegarden. The overall tree diversity, measured in terms of richness and abundance, was used to calculate the Shannon-Wiener index (SWI) (Eqn. 1) (Spellerberg & Fedor, 2003), which is a compiled diversity index.

$$H (SWI) = - \sum [(p)_i] \times \ln(pi) \quad (\text{Eqn. 1})$$

where,  $H=SWI$ ,  $p_i$ =Proportion of the total sample represented by species,  $i$ =proportion of species relative to the total number of species.

**Table 1. Food categories and food items with their weights to calculate the FCS**

Food Item	Food Group	Weight (A)	Days eaten in past 7 days (B)	Score (A×B)
Maize, Rice, Sorghum, Millet, Bread and other cereals	Cereals	2	7	14
Cassava, Potatoes and sweet potatoes	Tubers			
Beans, Peas, Groundnuts and Cashew	Root crops			
Vegetables and Leaves	Pulses	3	7	21
Fruits	Vegetables	1	7	7
Beef, Goat, Poultry, Pork, Eggs, Fish	Fruits	1	7	7
Milk & other Dairy products	Meat and Fish	4	7	28
Sugar and Sugar products	Milk	4	7	28
Oils, Fats and Butter	Sugar	0.5	7	3.5
	Oil	0.5	7	3.5
Composite score				112

(Source: INDDEx Project, (2019), *Data4Diets: Building Blocks for Diet-related Food Security Analysis*. Tufts University, Boston, MA. <https://inddex.nutrition.tufts.edu/data4diets>. Accessed on 6 November 2019).

Species density, which represents the number of tree species per hectare (Eqn. 2), and tree density, which represents the number of individual trees per hectare (Eqn. 3), were calculated by dividing the total recorded number of species and trees by the extent of the respective homegarden. The area of each homegarden, measured in acres, was recorded as a survey question.

$$\text{Species per ha} = \frac{\text{Total number of tree species recorded}}{\text{Extent of the homegarden}} \quad (\text{Eqn. 2})$$

$$\text{Trees per ha} = \frac{\text{Total number of trees recorded}}{\text{Extent of the homegarden}} \quad (\text{Eqn. 3})$$

### Summed Dominance Ratio (SDR)

The Summed Dominance Ratio (SDR) was calculated (Eqn. 4) using the relative density (RD) and relative frequency (RF) of the woody species in order to identify the most dominant species within a homegarden (Chen et al., 2014; Rahman et al., 2017; Whitney et al., 2018). The SDR, as explained by Chen et al. (2014), helps in understanding the growth patterns of different plant species and communities. It provides valuable insights into identifying the most valuable and useful species for a specific cluster, region, or area (Whitney et al., 2018a).

$$\text{Summed Dominance Ratio (SDR)} = \frac{RD+RF}{2} \quad (\text{Eqn. 4})$$

Where, SDR = Summed Dominance Ratio, RD = Relative Density (Total number of individuals of a crop/Total number of individuals of all crops) RF = Relative Frequency (Total count of homegardens in which a crop occurred/Sum of counts of all crop occurrences in all homegardens surveyed)

### Relative Importance Value (RIV)

Several different methods have been employed in various studies to determine the importance value of species (Razavi et al., 2012; Olorunmaiye et al., 2013; Taiwo et al., 2020). However, for the present study, the relative importance value (RIV) was calculated, as shown in Eqn. 5, by utilizing the relative frequency (RF) and relative dominance (RD'; Eqn. 6) of tree species.

$$\text{Relative Importance Value (RIV)} = RF + RD' \quad (\text{Eqn. 5})$$

$$\text{Relative Density (RD')} = \frac{\text{Total basal area of all individuals of a certain species}}{\text{Total basal area of all individuals of all species}} \quad (\text{Eqn. 6})$$

## RESULTS AND DISCUSSION

### General description of the homegardens

A total land extent of 61.23 ha of homegardens was surveyed, with small-scale homegardens (<0.2 ha) dominating the sample (75%), followed by medium-scale homegardens (24%), according to the categorization of Mattsson et al. (2015) (Table 2). Only 1% of large-scale homegardens were observed in the entire sample, specifically in Jaffna and Hambantota. This observation suggests that the practice of homegardening in Sri Lanka is predominantly carried out on smaller or medium-scale land sizes (less than 0.8 ha), where owners can effectively manage and sustain a subsistence level domestic production system. Furthermore, it indicates that small-scale operations are commonly observed in Sri Lankan homegardens. However, in terms of land size, more than 50% of the total studied land extent was attributed to medium-scale homegardens, while only 5% was covered by large-scale homegardens.

On average, each household consisted of four family members, including the household head, dependent children, and dependent or non-dependent elders. The majority (60%) of households in Hambantota reported that the main occupation of the household head was farming, which included homegardening as a part of their activities (Table 3). The age of the household head was similar across all study sites, regardless of gender or main occupation, and male-headed households were more prevalent in homegardens in all four sites. The dependency ratio was relatively higher, though not significantly, in Jaffna compared to other sites, due to a larger number of family members' dependent on the household's workforce. Monthly income ranged between LKR 35,000.00 and LKR 58,700.00, with a mean income of LKR 45,675.00 and mean expenditure of LKR 29,500.00.

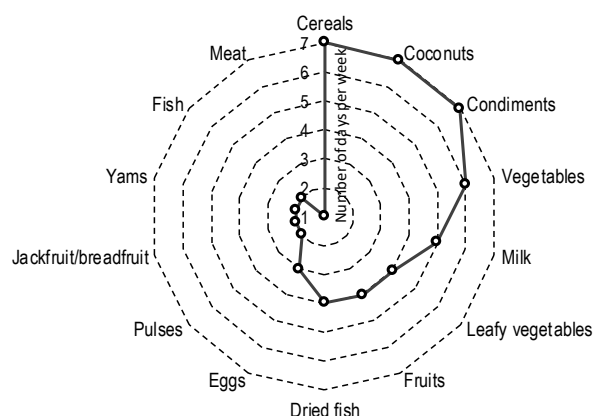
**Table 2. Description of the homegardens surveyed in all four districts**

Parameter	Jaffna	Matale	Ratnapura	Hambantota
Sample size (n)	139	122	90	78
Small-scale (<0.2 ha)	126 (91%)	96 (79%)	69 (77%)	35 (45%)
Medium-scale (0.2-0.8 ha)	11 (8%)	26 (21%)	21 (23%)	43 (55%)
Large-scale (>0.8 ha)	02 (1%)	NR	NR	01 (1%)
Extent ha (range)	0.02-1.21	0.02-0.61	0.01-0.61	0.03-0.81
Mean extent per homegarden (ha)	0.10±0.13	0.14±0.09	0.13±0.11	0.22±0.15

(NR: Not Recorded)

**Table 3. Summary of socio-economic description of an average household**

Parameter	Jaffna	Matale	Ratnapura	Hambantota
Main occupation farming (%)	37	38	31	60
Male as household head (%)	79	93	88	88
Dependency ratio (%)	87	72	69	72
Age of the household head (Years)	53±14	53±14	53±12	53±12
Family size (Number)	4±2	4±1	4±1	4±1

**Figure 1. Frequency of domestic consumption of predefined food categories**

During the study, a total of 178 tree species were recorded, representing 143 genera and 53 plant families. On average, each homegarden had a species density of  $91 \pm 69$  and a tree density of  $271 \pm 216$ . These values were relatively higher compared to the values reported for homegardens in Sri Lanka by Pushpakumara et al. (2012). When considering the uses of the recorded species, 84 species were classified as fruits, 111 as medicinal plants, 66 as timber species, 20 as fibers/leaves, 7 as ornamentals, 6 as pharmaceuticals, and 9 as oil-producing species. Among these, the most dominant species was coconut (*Cocos nucifera* L.), followed by mango (*Mangifera indica* L.), arecanut (*Areca catechu* L.), and jackfruit (*Artocarpus heterophyllus* Lam.).

### Food consumption pattern of households

According to Figure 1, cereals (rice), coconuts, and condiments were consumed consistently throughout the week, followed by vegetables. Meat was the least consumed food category throughout the study. On average, a household consumed eight coconuts and 7.6 kg of rice per week, with coconuts primarily used for extracting coconut milk. Additionally, approximately 6 kg of vegetables, including leafy vegetables and yams, were used in the preparation of daily meals throughout the week. The least consumed category was animal proteins, with an approximate total of 2 kg of meat and/or fish consumed, along with an average of seven eggs per week. However, milk and milk-based foods, totaling 1.7 L/week, were part of the daily meals for an average household in terms of food consumption

Among the four study sites, pulse consumption was noted at a higher frequency of 4 days per week in Jaffna, compared to the other sites where it was consumed 1-2 days per week. Despite being a peninsula, Jaffna had lower rates of dried fish and fresh fish consumption. On the other hand, households in Hambantota consumed fresh fish and dried fish an average of four and five days per week, respectively. Except in Jaffna where the average consumption was 3.5 kg per week, cereal consumption was relatively higher in the rest of the sites, ranging from 8-10 kg per week.

### Sources of different food categories

It was revealed that households obtain their food items for domestic consumption through three different sources: direct purchasing, production within their own garden, and receiving from another garden or neighbor. As shown in Figure 2, pulses, fish, and dried fish were always purchased from the market. This is understandable as domestic fish farming and the production of dried fish are not common in Sri Lankan homegardens. The most popular pulse was dhal/red lentil (dried and split), and the household's total requirement was purchased from the market. Red lentils are mainly imported from Australia, Canada, and India since they cannot be commercially grown in Sri Lanka. The most prominent food commodity produced within the homegardens was coconuts (68% of the study sample), as evidenced by their

abundance. Coconuts had a Summed Dominance Ratio (SDR) of 19% and Relative Importance Value (RIV) of 24.8%, making them the most abundant and prominent tree species in the study sample.

Jackfruit and breadfruit were the most commonly shared food items among neighboring households. Occasionally, fruits, yams, and leafy vegetables were also produced and shared among households. More than 20% of the households used rice from their paddy fields for domestic consumption, as it is the staple cereal (Figure 2). Additionally, vegetables and livestock products such as eggs, meat, and milk were produced at subsistence levels in homegardens. Condiments also played a vital role in Sri Lankan dishes, with various types used to prepare meals. However, it was observed that households purchased the most common condiments from the market for convenience. Nevertheless, the majority (68%) of households produced some condiments for domestic use, making them self-sufficient in those particular condiments. Curry leaf (*Murraya koenigii* L. Sprengel) and pandan leaves (*Pandanus amaryllifolius* Roxb.: *rampe*) were the most commonly grown condiments, while some households had plots of turmeric (*Curcuma longa* L.), ginger (*Zingiber officinale* Roscoe), and pepper (*Capsicum annum* L.) for domestic consumption.

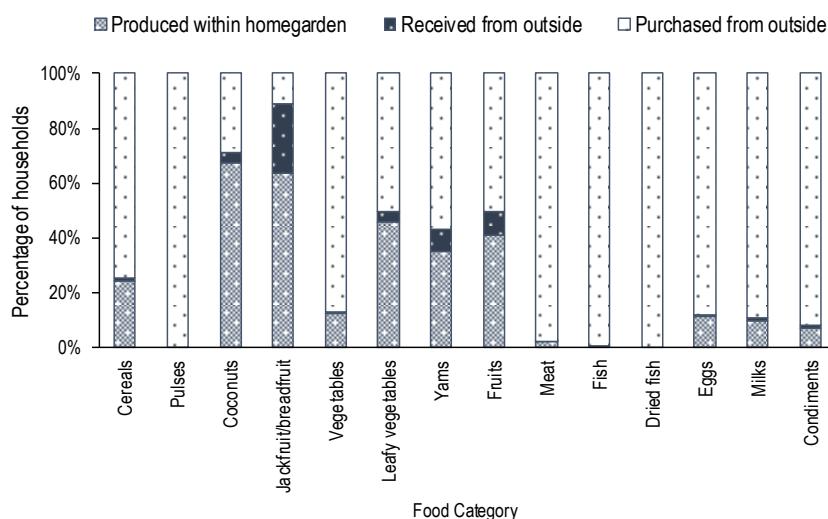


Figure 2. Sources of domestically consumed food items (n=429)



Even though most of the daily-consumed foods were acquired from markets, a homegarden study conducted in Bangladesh (Talukder et al., 2000) clearly stated that properly using homestead resources can significantly improve the diversity of daily meals. However, the contribution of homegardens to household food security is often considered an indirect aspect in the majority of studies (Mattsson et al., 2017). The current study aligns with these arguments, as households that did not utilize anything from their own homegardens had significantly lower food security levels (as measured by the FCS) compared to the rest (Figure 5). Yet, the food security of such homegardens could be easily achieved by effectively managing the garden to supplement with easily-grown vegetables and fruits, rather than relying on the market for such products. The results further revealed that some food commodities were shared among households, encouraging owners to utilize the homestead produce more effectively. All these food sources ultimately contribute to the cumulative FCS of the households.

### Food consumption score (FCS)

Food security is defined as ensuring that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life (Shaw, 2007). In the present study, two elements of food security were quantified using pre-defined indices: availability and access to different food items produced within homegardens, as well as those purchased or received from outside.

The primary measurement used was the Food Consumption Score (FCS). The mean FCS was  $60 \pm 23$  ( $n=429$ ), which fell into the acceptable category (FCS  $>35$ ) according to the classification of the World Food Program (INDEX project, 2018). Approximately 89% of the surveyed households were classified as having an acceptable FCS (mean FCS of  $65 \pm 18$ ;  $n=381$ ), regardless of the contribution of homestead resources. However, there were 29 households (7%) clustered in the borderline category with a mean FCS of  $31 \pm 3$ , and 19 households (4%) were classified as poor (FCS  $<21$ ; Table 4). This indicates that in terms of availability, domestic food supply for Sri Lankan households is generally secure. There may be exceptional situations occasionally, but these could be alleviated through simple approaches.

The FCS was used to assess domestic food security in a quantitative approach to food availability (Wiesmann et al., 2009). According to the INDDEX report (2019), the FCS is calculated by categorizing food items into five groups based on their caloric content; livestock products (scored 4), pulses (scored 3), cereals, tubers and root crops (scored 2), vegetables and fruits (scored 1), and fats/oils, and sugars (scored 0.5). Therefore, to increase the FCS, households should consume more food items with high caloric content (energy-dense) or increase the frequency of consuming low-caloric food (Lowe et al., 2021). A significant majority of homegardens (89%) had an acceptable level of FCS. The present study revealed a pattern of strategic food consumption, which included a combination of energy-dense foods and low-caloric food items at higher rates.

**Table 4. Categorization of the study sample based on FCS classes**

Site	Mean FCS	Poor %	Borderline %	Acceptable %	HDDS
JFN (n=139)	43±23	13	11	76	7±2
MTL (n=122)	72±18	1	2	97	9±2
RTN (n=90)	61±18	0	8	92	8±2
HMB (n=78)	72±20	0	5	95	8±1

JFN: Jaffna, MTL: Matale, RTN: Ratnapura and HMB: Hambantota

According to the results, the food consumption pattern exhibited substantial variation regardless of the Food Consumption Score (FCS) of the respective household (Figure 3). Cereals and tuber crops, which are staples in Sri Lankan domestic meals, showed a consistent contribution with slight variations. However, other major food items displayed significant variation. Interestingly, households with higher FCS values consumed more milk and milk-based foods compared to others. Additionally, the frequency of consuming meat, fish, and milk gradually increased as the FCS values increased. The consumption of dhal/red lentil, which is a primary pulse in daily meals, was observed to vary across the entire range of FCS. Oil (coconut oil) and sugar were identified as prominent food items in Sri Lankan daily meals.

Although condiments play a significant role in Sri Lankan daily dishes by adding flavor and aroma to the food, they were not included in the calculation of the FCS because they do not contribute to the caloric value (Lowe et al., 2021). According to Wiesmann et al. (2009), data on frequently consumed foods in relatively smaller quantities tend to inflate the FCS, resulting in a less accurate representation of the actual scenario. Therefore, foods consumed in smaller amounts, such as condiments, were deliberately neglected in the calculations. However, it is important to note that condiments are vital for providing daily micronutrient requirements (Spohrer et al.,

2013).

### Household dietary diversity score (HDDS)

According to INDDEX (2019), the Household Dietary Diversity Score (HDDS) is used as an indicator to measure household food access, which is one of the three dimensions of food security: availability, access, and utilization (Swindale & Bilinsky, 2006).

The mean HDDS was eight on a scale of 1-12, indicating that the studied households had a moderate diversity of domestically consumed food items. No households had HDDS values less than 4 (Figure 4). Fewer households had higher HDDS values, which suggests that the study sample had a normal distribution in terms of HDDS. Among the study sites, Matale had the highest HDDS ( $9 \pm 2$ ), while Jaffna had the lowest ( $7 \pm 2$ ). The cumulative HDDS was influenced by three visible sources: the market, homegrown produce, and sharing. As shown in Figure 4, the increase in HDDS was attributed to the utilization of resources from homegardens as a ready-to-eat food source. The findings indicate that higher HDDS values were achieved not only from the market but also through the proper exploitation of food sources within the homegarden (1-4 food sources). Interestingly, higher HDDS was associated with a higher number of food sources originating from the homegarden, which aligns with the findings of Thamilini et al. (2019) stating that greater crop diversity in homegardens leads to more diverse diets at the household level.

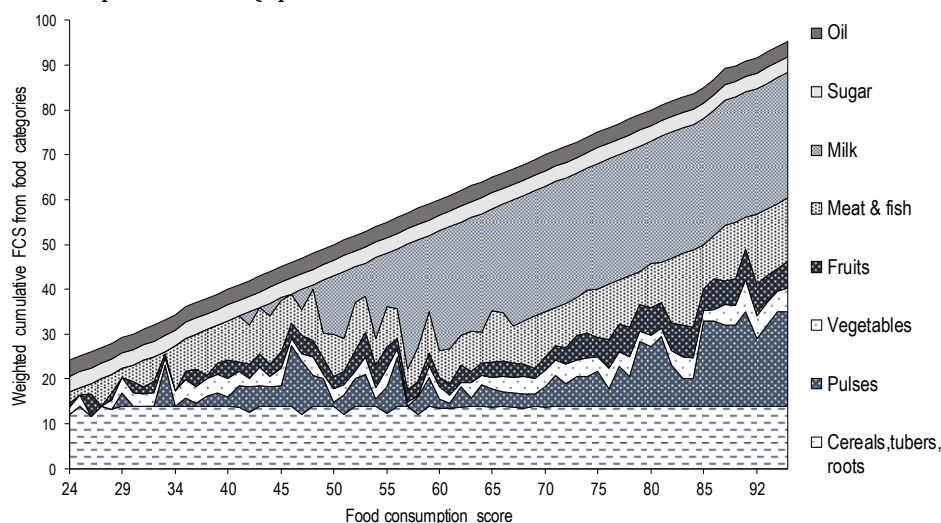


Figure 3. Weighted contribution of different food categories to the composite FCS

Thamilini et al. (2019) further mentioned that the HDDS was sustained by foods shared among households, which primarily consisted of the excess produce from donor homegardens. On average, one-third of the households received at least one food item through sharing, ultimately contributing to enhanced dietary diversity in the household. In this context, the shared foods, which were not readily available in the recipient homegarden, played a crucial role in improving the HDDS and indirectly the Food Consumption Score (FCS). The most commonly shared food items were jackfruit and breadfruit (*Artocarpus altilis* (Parkinson) Fosberg), which are typically considered auxiliary staple foods and consumed as supplements with rice. Other popular food commodities shared among households included yams, fruits, leafy vegetables, and coconuts. Regarding fruits, bananas, papayas, and mangoes were the most commonly consumed fruit species, which are considered major fruits in Sri Lankan households (Weerahewa et al., 2013). Additionally, condiments were occasionally shared among households as food additives.

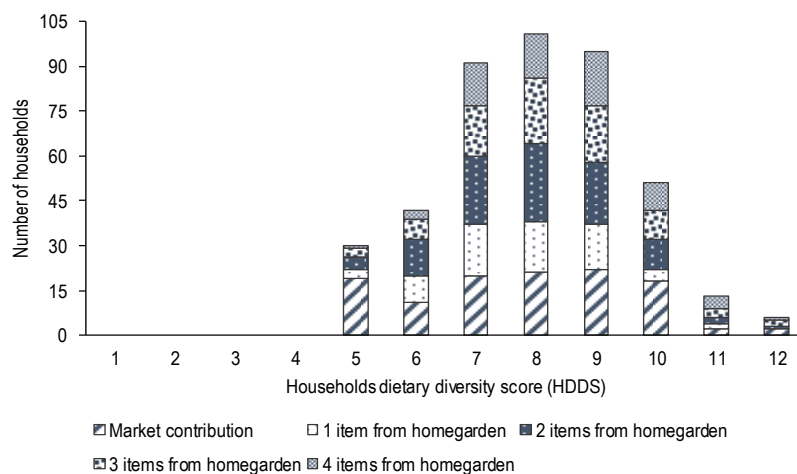
A validation study conducted by Wiesmann et al. (2009) confirmed that both the Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS) are associated with the caloric intake of households. However, it is important to note that both these indicators are often regarded as proxy indicators, intentionally assessing

the quality and quantity of the diet (Leroy et al., 2015).

### Contribution of homegardens on plant-based food demand

The concept of utilizing homestead resources to support domestic food supply can be assessed by properly addressing the aforementioned indicators. Daulagala et al. (2013) have defined two nutrient supply channels in homegardens: plant-based and animal-based foods. In the present study, it was observed that most food items produced within homegardens were plant-based, categorizing them as lower-weighted food items in the Food Consumption Score (FCS). While a variety of field crops are utilized to meet the energy requirements in rural households (Marsh, 1998), their contribution to caloric demand is relatively lower. Therefore, it is advisable to incorporate high-energy or energy-dense foods into daily meals to overcome nutrient deficiencies. Animal proteins and pulses are considered among the best and most convenient high-energy food items according to the FCS. Mitchell & Hanstad (2004) further argued that the proper utilization of these food sources at the household level plays a crucial role in mitigating malnutrition in lower-income families.

Interestingly, over 60% of households in the study sample produced coconut and jackfruit



**Figure 4. Utilization scope of resources from homegarden to enhance HDDS**

or breadfruit for household consumption, while only 12% supplemented their diet with vegetables. Furthermore, 41% of the homegardens produced ready-to-eat fruits for household utilization. These findings highlight the tree-dominating nature and long-term provision of services by fruit-bearing trees in homegardens. Perennial tree communities require less attention and inputs after reaching maturity, making them a convenient resource. However, tubers and root crops were also cultivated in over one-third of the study sample. The Species Wealth Index (SWI) showed a positive correlation with the FCS (adjusted  $R^2$ : 9.3%,  $p < 0.05$ ). Considering the diversity of fruit-bearing and other trees in homegardens, it was evident that higher tree diversity enhances both the FCS and the dietary diversity of households.

These findings suggest that households primarily rely on plant-based food items, including staple foods and easily producible foods like jackfruit, breadfruit, coconut, and fruits. These long-term perennial tree species bear fruits throughout the year. Additionally, non-woody perennials such as banana and papaya are commonly found in Sri Lankan homegardens (Lowe et al., 2022). The mean SWI of the studied homegardens was  $1.63 \pm 0.66$ , indicating moderate diversity based solely on perennial tree species. On average, a homegarden had  $9 \pm 6$  different species represented by  $32 \pm 30$  individual trees. It is evident that the tree community can be effectively utilized to supplement various food items for household food supply at subsistence levels. However, it is crucial to consider the households' requirements when deciding on the tree composition, as dominant and important species play a vital role.

As presented in Table 5, it was clear that an acceptable FCS is partially a result of diverse plant-based foods, as reflected by the SWI. The samples with acceptable FCS values showed a positive correlation with the SWI, explaining 6.8% of the variability in FCS ( $p < 0.05$ ). The association between the same factors in other categories (poor and borderline FCS) was not significant. The HDDS also showed gradual improvement as a

result of high tree diversity and the presence of fruit-bearing species.

The Species Dominance Ratio (SDR) and Relative Importance Value (RIV) analysis revealed that coconut (SDR: 19%) and mango (SDR: 8%) were the most dominant and important tree species in Sri Lankan homegardens. Coconut, as a multipurpose species, plays a vital role in domestic food security as it is used for food, timber, fuelwood, and thatching material (Lowe et al., 2021). Other highly dominating species based on the SDR included areca nut (8%), gliricidia (6.7%), jackfruit (5.5%), neem (4.6%), guava (3.2%), citrus (2.6%), teak (2.2%), sour sop (2.0%), drumstick tree (1.9%), pomegranate (1.8%), avocado (1.8%), rose apple (1.6%), and rambutan (1.5%). While breadfruit was less common in homegardens compared to jackfruit, it has the capacity to adapt to a wide range of environmental conditions, hence similar to jackfruit, and can serve as a staple food item (Ragone, 2006).

As suggested by Whitney et al. (2018), species with an SDR  $> 0.01$  are considered highly important. Furthermore, the ranking of the most important species in the homegardens closely aligned with the SDR. Consistent with the findings of Ramli et al. (2021), the present study also indicated that the majority of tree species in homegardens are fruit-bearing. This finding suggests that while homegardens may resemble secondary forests (Urquiza-Haas et al., 2007), only the important or valuable tree species are allowed to dominate within a given homegarden or living agroforestry system (Table 6).

Figure 5 clearly illustrates that households that did not produce anything ( $n=52$ ) in their homegardens consistently had a significantly lower mean Food Consumption Score (FCS) of  $40 \pm 32$  ( $p < 0.05$ ) compared to those who produced at least one food category, with an FCS of  $61 \pm 20$  ( $n=378$ ). This indicates that the utilization of homestead resources has a positive impact on the FCS of households and, consequently, on food security. It is worth noting that only one homegarden among the study sample managed to produce eight different food categories.

**Table 5. Classification of the calculated indices respective to FCS categories**

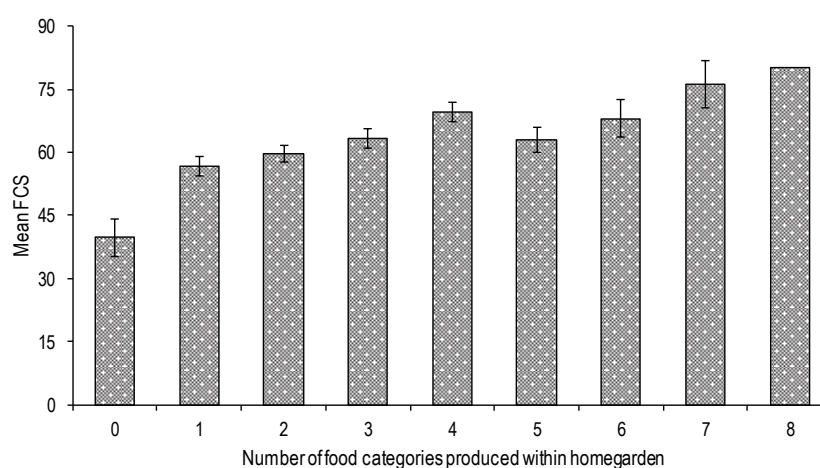
Parameter	Poor FCS (<21)	Borderline FCS (21.5-35)	Acceptable FCS (>35)
FCS vs SWI	R <sup>2</sup> =2.2% (p>0.05)	R <sup>2</sup> =0 (p>0.05)	R <sup>2</sup> =6.8% (p<0.05)
HDDS	5	6	8
Homestead Food categories	0 (0-3)	2 (0-7)	3 (0-8)
SWI	1.05 <sup>a</sup> +0.69	1.52 <sup>b</sup> +0.73	1.67 <sup>b</sup> +0.64
Species per ha	55 <sup>a</sup> +47	87 <sup>a</sup> +89	94 <sup>a</sup> +67
Trees per ha	78 <sup>a</sup> +54	262 <sup>b</sup> +245	281 <sup>b</sup> +216

Values with different superscripted letters along a single row are significantly different from each other

**Table 6. Most important species according to RIV (importance value)**

Common name	Botanical name	Family	RIV
Coconut*	<i>Cocos nucifera</i>	Arecaceae	24.8
Mango*	<i>Mangifera indica</i>	Anacardiaceae	10.2
Jack*	<i>Artocarpus heterophyllus</i>	Moraceae	8.1
Arecanut	<i>Areca catechu</i>	Arecaceae	4.8
Neem	<i>Azadirachta indica</i>	Meliaceae	4.8
Teak	<i>Tectona grandis</i>	Lamiaceae	2.8
Gliricidia	<i>Gliricidia sepium</i>	Fabaceae	2.5
Guava*	<i>Psidium guajava</i>	Myrtaceae	2.3
Avocado*	<i>Persea americana</i>	Lauraceae	1.9
Citrus*	<i>Citrus sinensis</i>	Rutaceae	1.9
Palmyra	<i>Borassus flabellifer</i>	Arecaceae	1.6
Mahogany	<i>Swietenia mahagoni</i>	Meliaceae	1.5
Drumstick tree*	<i>Moringa oleifera</i>	Moringaceae	1.4
Soursop*	<i>Annona muricata</i>	Annonaceae	1.4
Trincomalee wood	<i>Berrya cardifolia</i>	Malvaceae	1.4

\*Ready-to-eat fruit bearing tree species

**Figure 5. Effect of number food categories produced within homegarden to composite FCS**

### Animal-based foods from homegarden

A significant number of homegardens included livestock and poultry as part of their homestead resources. Compared to the districts of Matale, Ratnapura, and

Hambantota, the people in Jaffna showed a high level of interest in rearing domesticated animals both for subsistence and additional income. Approximately 50% of the homegardens evaluated in Jaffna had livestock animals, with chicken (*Gallus gallus*

*domesticus*) being the most common animal component, while cattle (*Bos* spp.) and goats (*Capra aegagrus hircus*) were found in smaller numbers (Jeyavanan et al., 2017; Lowe et al., 2021). In contrast, the other study sites had significantly fewer homegardens with livestock animals, with only about 2-3 households per district engaging in such rearing.

Chicken was the predominant animal component observed in the homegardens, probably due to the convenience of rearing and the low input cost associated with it. Only one homegarden in Matale had pigs (*Sus scrofa*), which were the least common type of animal found in homegardens across all four study sites. It is worth noting that homegardens with livestock animals in the Jaffna district had a significantly higher Food Consumption Score (FCS) of 45 compared to those without livestock animals (FCS 39) (Lowe et al., 2021). This finding aligns with the observations of Talukder et al. (2000) and highlights the benefits of including livestock as a component of the homegarden, as it provides nutrient-rich diets through animal-based foods such as meat, milk, and eggs

## CONCLUSIONS

According to the findings of the current study, it is clear that households in Sri Lanka primarily rely on food items available in the market as their main source of food. However, coconuts, jackfruit, and various fruits from homegardens significantly supplement the domestic food demand. With the exception of Jaffna, most households depend on animal protein sources available in the market to meet their meat, egg, and milk requirements. By incorporating high-caloric food items and livestock products from homegardens into daily meals, household Food Consumption Score (FCS) and food and nutrient security can be improved. More than 90% of the study sample had acceptable FCS estimations that fulfilled their caloric requirements. However, a few households had borderline FCS values, which could be addressed by adjusting daily diet plans, such as occasionally incorporating energy-dense foods or increasing the frequency of consuming low-caloric foods.

Homegardens were primarily utilized by households to obtain plant-based food products, except in Jaffna, where livestock and poultry played a substantial role in homegardens.

In terms of Household Dietary Diversity Score (HDDS), all households had moderate food diversity values, with at least four different food items (supplied from the homegarden and/or market) for daily consumption. Fruit-bearing trees played a vital role in assisting household food supply at the subsistence level in the long run. Furthermore, producing at least one food category within the homegarden could improve the food security of households by helping to meet their domestic food demand. Therefore, there is great potential in utilizing homegarden resources with appropriate interventions to meet household food demand and enhance dietary diversity.

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