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Ecosystem Services of Homegarden Agroforestry in Jaffna Peninsula

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Abstract: A study was carried out in Jaffna peninsula in dry zone area of Sri Lanka to assess the ecosystem services of homegarden agroforestry. Participant observation, interview of householders, measuring and collection of biodiversity data, photographing and sketching the structure of homegardens and focus group discussion were approached. In samples of 125 homegardens, a total of 5,920 individuals for flora were assessed from 58 families and 135 species. Mean value of Shannon diversity index (H), Simpson diversity index (D) and evenness (E) for the floristic component were 1.72 ± 0.04 (0.2-2.95), 0.78 ± 0.12 (0.27-1) and 0.81 ± 0.01 (0.12-1.19), respectively, revealed that the homegardens had medium, equally distributed floral diversity in Jaffna homegardens. A total of 825 individuals for domestic fauna were identified from 19 species and 12 families, H, D and E were 0.21 ± 0.03, 0.16 ± 0.03 and 0.22 ± 0.03, respectively, revealed that faunal component had low species diversity and not equally distributed among the homegardens. Mean above ground carbon stock was 40.51 ± 3.67 (235.71-0.33) Mg C ha^{-1}. Provision of fruits was high with mean of 2,996 kg ha^{-1} and nuts from coconut was 1, 444 nuts ha^{-1}. Mean production of milk from goat and cattle were 0.44 and 1.09 litre day^{-1} $animal^{-1}$, respectively. Mean volume of producible trees and poles were high accounted as 36.68 and 2.12 m^3 ha^{-1} $homegarden^{-1}$, due to high species density. Annual mean production of fodder for livestock was 875.99 ± 395.4 kg ha^{-1}, revealed that about 3.68 % of feed requirement could be met for livestock. There were more than 30 medicinal plants including trees, shrubs and vines used in ethno medicine. Mean value of income, expenditure and food ratio was Rs. 21,976, Rs. 18,802 and 0.56, respectively. Host per pollinator and pollinators per host were high in bees and mango, respectively. Effectiveness of the temperature and shade was medium-cool and medium-high, respectively in inside the homegardens, revealed that tree canopy play a key role to regulate the environment. Effectiveness of different conservation practices on soil, water, nutrient and biodiversity was medium, low-medium, medium and low, respectively.

Keywords: Agroforestry, Ecosystem Services, Homegarden, Jaffna Penisnsula

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1. Introductıon

Homegarden agroforestry system is the well planned and systematically managed cycles as a specialized way of farming and growing of high valued cultural trees, crops and animals together in appropriate manner and oldest and integral land use activity, next to shifting cultivation. It is suggested that all homegarden systems have evolved to provide food and other requirements of households and accounts 13.1 % of the total land area of the country (Pushpakumara *et al.,* 2012). Ecosystem services refer to the final benefits that are enjoyed or consumed by beneficiaries, including agroecosystems that are useful to humans or support human well-being (Gómez-Baggethun and De Groot, 2010). Ecosystem services are basically categorized into provisioning of goods, regulating services, cultural services and supporting services and plays a key role in production, protection, financial benefits and livelihood development to society (MA, 2005) Assessment of ecosystem services is the emerging option of agroforestry systems in scientific world. Attempts have been made to identify the ecosystem services of those four categories by several scientists (Mohri, 2013). However, ecosystem services of Sri Lankan agroforestry or any agriculture systems have not been properly identified/ analyzed. Development of homegarden is one of the way to rebuild the environmental, economic, social and food and nutritional secure community by providing the ecosystems services (Marambe *et al.*, 2014). But until recently the up scaling or improvement of homegarden agroforestry systems remains poor throughout the northern and eastern provinces due to prevailed war. As in other areas of the country, homegarden agroforestry has received little attention from policy makers and research institutes (Pushpakumara *et al.*, 2012). Jaffna peninsula is dominated by small holder agriculture and categorized as low country dry zone (DL_3 and DL_4). The total number of farm families in this peninsula is nearly 50 % of the total population which is accounted as 614,541 people (DSH, 2015). Total land available for cultivation is about 12,000 ha out of 102,500 ha. The total forest extent in this peninsula is around 2, 244 ha accounts 2.22 % of total land area in the district and 0.03 % of total land area of Sri Lanka. This result indicates the importance of agriculture and its land use practices and their contribution to ecosystem services of Jaffna peninsula. Thus, the objective of this study was to assess the ecosystem services of homegarden agroforestry in Jaffna peninsula.

2. Methods and Materials

The study was carried out in Jaffna district of the Northern Province of Sri Lanka. Jaffna is located between 09 °40′ N 80 °10′ E. Jaffna district consists of DL_3 and DL_4 agro-ecological regions (Punyawardena *et al.*, 2010). A total of 125 homegardens were assessed for ecosystems services out of identified homegardens during the period from 2014 to 2016. Questionnaire survey includes interview of householders, observation,

measuring and collection of biodiversity data, photographing of homegardens and sketching the structure of homegardens and focused group discussions. The number of species per sample was measured by the term of richness. Evenness was measured by relative abundance of the different species. Species diversity was measured by diversity indices such as Simpson's Diversity index and Shannon-Wiener Index (SWI). Tree height and diameter (DBH) of >= 5 cm) were measured using standard instruments clinometer and diameter tape, respectively. All sample homegardens n =125 were categorized into size of homegardens, namely small (<0.2 ha), medium (0.2-0.8 ha) and large (>0.8 ha). For the biomass, carbon stock and volume calculation, pan tropical allometric equations were used. Biomass of individual trees, banana and palm trees were used in different allometric equation developed by chave *et al.*, 2005 for dry forest, brown (1997) respectively (Table 1). Species specific wood density was followed by wood density database of world agroforestry center. Tree volume of the species were calculated by generic allometeric equation ($Vtree=0.4D^2H$, Where; Vtree = bio-volume of a tree in m^3, D = diameter in meter, H = height in meter, 0.4 is average form factor) followed by Pandya *et al.*, (2013).

Table 1: Generic allometric equation used to estimate the above ground biomass for individual trees, banana and palm in the dry zone homegardens of Jaffna District

Type of above ground biomass	Allometric equation	R^2	Source
Individual trees	$Y=\exp(-2.187+0.916\times\ln(D^2HS))$	0.99	Chave *et al.,* 2005
Banana	$Y=0.030D^{2.13}$	0.99	Hairiah *et al.,* 2010
Palms	$Y=\exp(-2.134+2.530\times\ln(D))$	0.97	Brown, 1997

Y = above-ground biomass density (kg $tree^{-1}$), D = diameter in cm, H = height in m, S = species-specific wood density in g cm^{-3}.

Qualitative data (gender, cultural services) and quantitative (height, dbh and yield) were statistically analyzed. The diversity, richness and evenness of species were computed using the Shannon Weiner and Simpson indices. Different tests were performed for non-parametric variables. Kruskal Wallis test was performed among the group such as small, medium and large sized homegardens. Spearman's Rho non parametric correlation was performed among the variables to find out the relationship. R-studio was used to develop the correlation plot among the variables. Goodness-of-Fit Test was performed to find

out significance of each practices followed by number of homegardeners. Wilcoxon signed rank test was performed to find out the significance within one variables. Analysis of variance (ANOVA) and LSD (p = 0.05) were conducted for parametric variables .Statistical Analysis Software of SAS, 1999 and Minitab 17 were used to analyze the data.

3. Results and Discussions

3.1 Provision services of Homegardens Agroforestry

A total of 5920 flora species were assessed from 58 families and 135 species. In 125 sampled homegardens, fruit crops had high frequency of occurrence followed by palm trees, vegetable crops and filed crops. Figure 1 (a) shows the floristic component in a homegarden. Mean value of Shannon diversity index and Simpson Diversity index were 1.72 ± 0.04 and 0.78±0.12, respectively. Mean value of evenness was 0.81±0.01, shows that the homegardens had medium diversity and species were more or less equally distributed in the Jaffna homegardens. Mean number of species per homegardens was high in small sized homegardens than medium and large sized homegardens. Kruskal-Wallis test shows that Shannon diversity index (H), Simpson diversity index (D) and evenness (E) were statistically significant in relation to size of the homegardens. ($P<0.004$, $P<0.013$ and $P<0.01$, respectively). Medium and large sized homegardens had high H, D and E than all category. Small size homegardens was statistically lower H, D and E. species richness and trees numbers were not statistically differed with size category (Table 2).

Table 2: Value of tree diversity indices in small, medium, large and all categories of Jaffna homegardens

HGs category extent wise	Shannon-diversity Index	Simpson diversity index	Evenness	Species richness	Mean number of tree species
Small *(<0.2 ha, n=100)*	1.65±0.05b 2.96-0.20	0.77±0.01b 1-0.33	0.76±0.02b 1.19-0.12	9.68±0.40a 26-2	48.34±5.72a 479-3
Medium *(0.2-0.8 ha, n=18*	1.89±0.13ab 2.64-0.56	0.80±0.04ab 0.93-0.27	0.80±0.03ab 0.96-0.40	11.11±1.05a 23-4	48.39±8.14a 149-7
Large *(>0.8 ha, n=7)*	2.13±0.07a 2.56-1.51	0.88±0.02a 0.95-0.79	0.88±0.03a 0.98-0.80	11.43±0.65a 13-9	30.71±4.81a 54-15
All categories	1.72±0.04 2.95-0.20	0.78±0.12 1-0.27	0.81±0.01 1.19-0.12	10.74±0.36 26-2	42.48±4.73 479-3

Note: Mean values shows with ± standard error (SE); significant test at $\alpha = 0.05$

(a) (b)

Figure 1: (a) Floristic component in a homgarden, b) a faunal component in a homgarden

A total of 825 domestic fauna were identified from 19 species and 12 family. About 72 homegardens have been growing faunal composition out of 125 homegardeners account 53.33 %. Chicken was the dominant species account 62.59 % (n=472) followed by goat and cattle (Figure 1.b). Galhena. (2012) reported that among the 167 gardens surveyed, 112 gardens contained some combination of livestock including cattle, goats, poultry, or swine, with 79 gardens having cattle, 74 with goats and 85 with chickens. Similarly for domestic fauna, Mean value of Shannon diversity index and Simpson diversity index for fauna were 0.21±0.03 and 0.16 ±0.03, respectively. These result shows that faunal diversity was low in Jaffna homegardens. Mean value of evenness and species richness of the homegardens for fauna were 0.22 ±0.03 and 1.05 ±0.13, respectively, shows that faunal species were not equally distributed among the homegardens (Table 3).

Table 3: Value of faunal diversity indices in small, medium, large and all categories in Jaffna homegardens

HGs category extent wise	Shannon-diversity Index	Simpson diversity index	Evenness	Species richness	Mean number of fauna species
Small *(<0.2 ha, n=100)*	0.19±0.03a 1.35-0.00	0.3±0.03b 1-0.00	0.22±0.04a 1-0.00	0.93±0.11a 4-0	5.73±1.21a 85-0
Medium *(0.2-0.8 ha, n=18)*	0.28±0.12a 1.56-0.00	0.3±0.07b 1-0.00	0.21±0.08a 0.87-0.00	1.39±0.41a 6-0	6.17±2.44a 40-0
Large *(>0.8 ha, n=7)*	0.31±0.16a 1.04-0.00	0.8±0.07a 0.61-0.00	0.33±0.16a 1-0.00	1.86±0.55a 5-1	10.00±3.90a 32-0
All categories	0.21±0.03 1.56-0.20	0.3±0.1 1-0.00	0.22±0.03 1-0.00	1.05±0.13 6-0	6.03±1.05 85-0

Note: Mean values shows with ± standard error (SE), Maximum-Minimum; Significant test at $\alpha = 0.05$.

Fruits was highly contribute to production of foods with mean total of 2995.92 kg ha^{-1} $homegarden^{-1}$. Coconut was dominant palm crops and widespread among the homegardens bring mean of 1, 444 nuts ha^{-1} $homegarden^{-1}$ followed by palmyrah with mean fruits of 832. Homegardens scattered in the country also constitute the most significant production system for fruits in Sri Lanka (Weerakkody, 2004). Galhena., 2012 reported that on an average, 140 kg of vegetables, 408 kg of fruits, and 118 coconuts were produced in homegardens. Average milk production of goat and cattle were 0.44 and 1.09 liter $animal^{-1}$ day^{-1}. Local chicken was dominant in egg production. About 88 % of chicken were in egg producing stage and mean egg production was 35 eggs hen^{-1} $week^{-1}$. Homegardens can capable to produce a mean of 35.68 ± 3.52 m^3 of tree volume ha^{-1} and 4.10 ± 0.40 m^3 of tree volumes $homegarden^{-1}$ (0.21 ha). FSMP (1995) revealed that homegardens produce about 0.95 m^3 of saw logs $year^{-1}$. There were 7 species have been contributing to pole production in JHGs, commonly found in the living fence of the homegardens. Mean pole production was 2.12 $m^3year^{-1}ha^{-1}$. According to FSMP (1995), homegardens produce 0.5 m^3 of $polesha^{-1}year^{-1}$, on average, revealed that pole production was somewhat high in Jaffna peninsula, due to its high population of living fence species. Mean fodder production of grass and trees were 4.82±2.72 and 953.39±273.33 $kgha^{-1}year^{-1}$, respectively. Average fresh fodder requirements of the cattle and goat in sample areas was 2,125.76 $kgyear^{-1}HGs^{-1}$. however, average production of fodder from both grasses and trees was 78.27 $kgyear^{-1}HGs^{-1}$, revealed that HGs was only satisfied 3.68 % of fodder requirements for rearing animals. There were more than 30 medicinally important species including trees (14), shrubs (12), herbs and vines (6), flowering plants (2) were identified in sampled areas. Mean total income of the homegardens per unit area per year was Rs.1, 34, 704.24 (> 1 million rupees in LKR). Fruit crops was contributed to high income of Rs. 107, 027.18 than palm and vegetable crops. Galhena. (2012) also reported that fruit was major income generator in the peninsula. It was generated from sales of milk and eggs as well as sales of individual's livestock (goat) and poultry (finches). Average income from the egg $homegarden^{-1}$ $week^{-1}$ was Rs. 52.09 ±1.91. This was higher than the average income of milk

3.2 Regulating Services of Homegardens Agroforestry

Mean carbon stock is given in Mg C ha^{-1}. Mean carbon stock of all homgerdens in sampled area was 40.51±3.67 ranges from 235.71-0.33 Mg C ha^{-1}. Mean above ground carbon stock was significantly higher ($p<0.05$) in small homegardens (45.47±4.12, n=100, <0.2 ha) followed by medium (27.27±8.76, n=18, n=0.2-0.8 ha) and large (3.68±1.56, n=7, <0.2 ha) sized homegardens (Table2). Small sized homegardens had significantly highest above ground carbon stock followed by medium and large sized homegardens shows that size of the homegardens was negatively correlated with above ground carbon (Table 4). Mattsson *et al.* (2015) reported that mean aboveground biomass

Table 4: Aboveground biomass and carbon stock in small, medium, large and all categories of Jaffna homegardens

HGs category extent wise	Aboveground biomass (AGB, Mg ha^{-1})	Aboveground Carbon (AGC, Mg ha^{-1})
Small *(<0.2 ha), n=100)*	90.93±8.28a (471.41-0.67)	45.47±4.14a (235.71-0.33)
Medium *(0.2-0.8 ha, n=18*	54.55±17.52b (291.58-2.35)	27.27±8.76b (145.79-1.17)
Large *(>0.8 ha, n=7)*	7.36±3.10c (24.00-1.27)	3.68±1.55c (12.00-0.63)
All categories	81.01±7.33 (471.41-0.67)	40.51±3.67 (235.71-0.33)

Note: Mean values shows with ± standard error (SE); significant test at $\alpha = 0.05$

stock of 13 Mg C ha^{-1} with a large ranges from 1–56 Mg C ha^{-1}, n = 45 due to a variation of tree diversity and composition between individual homegardens.

Kruskal-Wallis test result that AGC was statistically significant with size category of the homegardens ($p<0.0001$). Small size homegardens had high AGC from the average AGC for all categories than the medium and large sized homegardens. In sampled homgardens, small and medium sized homegardens had high number of species followed by large sized homegardens. Mean and total number of tree species was high in small sized homegardens followed by medium and large homegardens (Figure 2). Host range or host/pollinator was high in bees and butterflies (16 plants) followed by wasp and birds, revealed that foraging range was high and had an ability to search the food any time (Table 5). Kruskal-Wallis test shows that median practices of prevalence of fully organic practices was above the average rank (62 %) followed by mechanical (41 %) and indigenous or traditional knowledge (40 %), respectively at p value 0.000 (α=0.05) in Jaffna homegardens. Calvet-Mirr, (2012) reported that about 75 % of the studied homegardens received manure or organic products as main fertilizers and organic or manual management methods as main practices to control weeds and pests.

Inside of the homegardens, shade was higher level and temperature was lower level than outside of the homegardens, shows that, reduction of the temperature and increased shade level were mainly due to the tree species in the homegardens. Mean range of temperature were ranges from medium to cool and medium to hot in inside and outside of the homegardens, respectively, similarly, mean range of shade was ranges from medium to high and low to medium in inside and outside of the homegardens, shows that homegardens regulate the temperature and shade lead to reduction of temperature and increased the shade compared to outside of the homegardens (Table 6). Kruskal Wallis test shows that conservation practices conserve the soil and nutrient at medium level than water and biodiversity, revealed that homegardens regulates and enhanced the soil, nutrient, water and biodiversity by several conservation practices (Table 7).

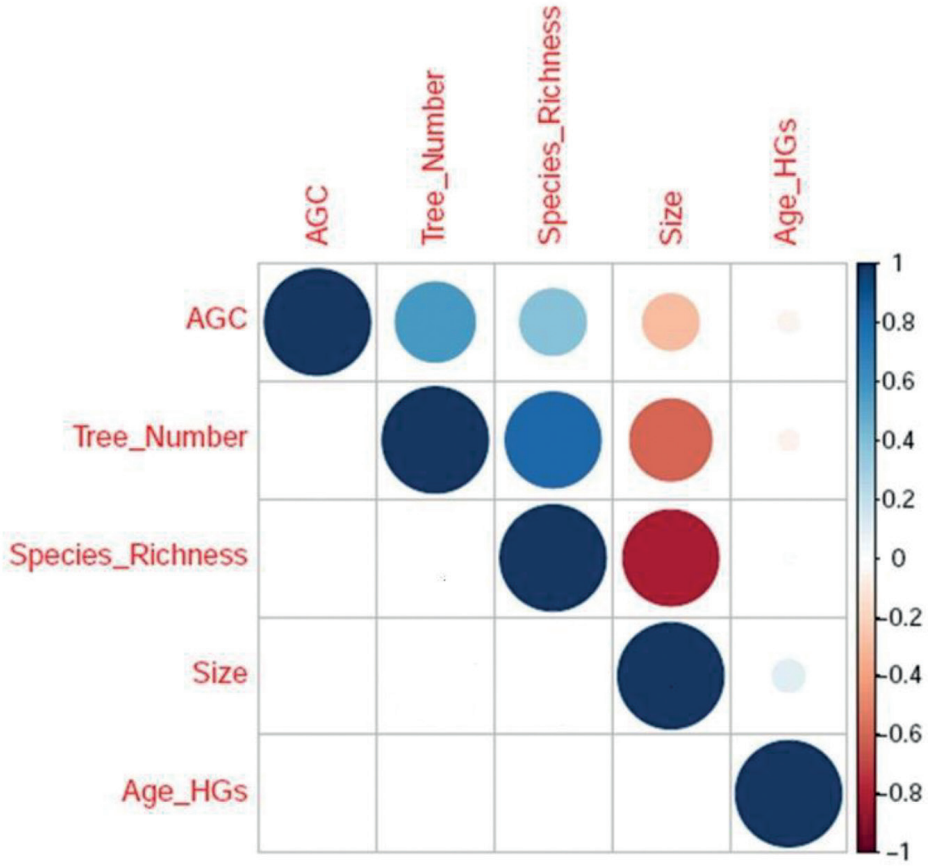

Figure 2: Correlation plot for the variables of age of the homegardens (years), size of the homegardens (ha), species richness (ha^{-1}), number of trees (ha^{-1}) and above ground carbon stock, AGC (Mg C ha^{-1}) in sampled homegardens (n=125); Note: Increasing trend of blue colour shows the increasing of positive correlation among the variables, similarly, brown colour shows the negative correlation of the variables.

Pushpakumara *et al.* (2012) reported that cover crops and mulching are rarely practiced to control soil erosion but a dense cover of dead litter is found on the floor of most homegardens providing the same function.

3.4 Cultural and Supporting Services

Some trees were not preferred within the homegardens with some religious belief of the people such as *Polyalthia longifolia* (Sonn.) Thw. and *Tamarindus indica* L. due to this, these are rarely found in the homegardens. Banana, coconut, arecanut and mango frequently used in all the religious events. *Erythrina variegata* L. (*Erythrina indica* Lam) and *E. subumbrans* (Hassk.) Merr were used in religious event and wedding. Kruskal Wallis test shows that grouping of lifestyle

Table 5: Pollinator-Plant in the homegardens

Host vs. pollinator	Bees	Butterfly	Wasp	Birds	Beetles	Bat	White ants	Moth	Flies	Pollinators/ host
Mango	√	√	√	√	√	√	√	√	√	9
Banana	√	√	√	√	√					5
Bitter gourd	√	√	√		√				√	5
Moringa	√	√	√	√						5
Jampu	√			√		√	√			4
String bean	√	√	√	√						4
Papaya	√	√		√	√					4
Citrus		√	√	√				√		4
Coconut			√	√	√					3
Shoe flower	√	√	√							3
Rose	√	√	√							3
Snake gourd	√	√	√							3
Brinjal	√	√	√							3
Pomegranate	√	√			√					3
Guava				√		√	√			3
Passion fruit		√				√				2
Pumpkin	√				√					2
Tomato	√	√								2
Ponnuchchi	√	√								2
Ixora		√					√			1
Neem	√									1
Hosts/pollinator	16	16	11	9	7	4	4	2	2	

Table 6: Spearman's Rho correlation for temperature and shade levels in inside and outside of the homegardens

Spearman's Rho	Temperature inside of the HGs	Temperature Outside of the HGs	Shade inside of the HGs
Temperature Outside of the HGs	1.00		
Shade inside of the HGs	-0.834**	-0.834**	
	p=0.001	P=0.001	
Shade Outside of the HGs	-0.834**	-0.834**	0.833**
	p=0.001	p=0.001	p=0.001

Result of Spearman rho correlation analysis and, **significant Mann Whitney test result at 0.05.

Table 7: Effectiveness of conservation practice on soil, water, nutrient and biodiversity in JHGs

Conservation methods	Soil	Water	Nutrient	Biodiversity
Hedgerow	Medium	Medium-high	High	High
Mulching	Medium	Low-medium	Medium	Medium-high
Strip cropping	Low-medium	Medium	Medium-high	Medium
Cover crops	Medium	Low	Medium	Medium
Drainage channel	--	Medium	Medium	Low
Ditches	Medium	Low	Medium	--
Organic fertilizer	Medium	High	High	Low
Bund	Medium	Low-medium	Medium	Low
Burning	Medium	--	Medium	--
Heap method	Medium	Low	Medium	Medium
Sprinkler	--	Medium	Low	--
Worm compost	--	--	Medium-high	--
Overall	Medium	Low-medium	Medium	Low
Number of HGs	76	43	29	27

and aesthetic based on the importance were rated significantly as somewhat important and very important for aesthetic and life style (p=0.001). People obtained the aesthetic and ornamental services by mind relax and fresh environment. Kruskal-Wallis Test, reveals grouping of each services shows that mean rank was high for lifestyle followed by aesthetic, health, pleasure and satisfaction among the services (Figure 3). Calvet-Mirr *et al.*, (2012) reported that home gardens provide a large set of ecosystem services, being cultural services the category most valued in the homegardens of Northeastern Spain. Dominant habitat for the seasonal fauna was trees (55 %) specially for birds, white ants, butterflies, snails and squirrel, shows that trees in the homegardens was major habitat for faunal compositions. Living fence was a structural demarcation of the boundary provides live support and *Commiphora caudata* was the dominant tree species followed by *Thespesia populnea* and *Delonix elata* in live fences in Jaffna district (Jeyavanan *et al.*, 2014).

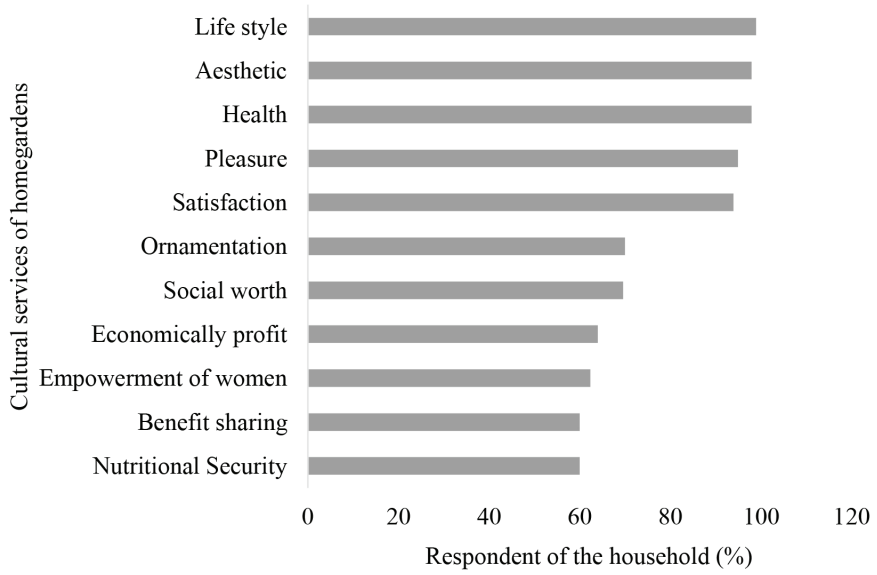

Figure 3: Percentage of household respondent for cultural services

Soil structure is enhanced through the activities of macro fauna such as earthworms, centipedes, millipedes, and isopods that aerate soil (Hendrix *et al.*, 1990) Homegardeners have been practicing several cultivation practices such as burning, harvesting of crop yield, planting, watering, pollarding and pruning of live fence startup the soil process. Abrupt environmental factors include wind, rainfall, flood and drought was recorded in the homegardens also leads to nutrient removal in the soil (Daily *et al.*, 1997). Enhancement of soil formation and nutrient cycling will leads to hasten the primary production through photosynthesis (Garbach *et al.*, 2014).

4. Conclusions

Jaffna homegardens provides all four category of ecosystem services namely, provisioning, regulating, cultural and supporting. Live fence structure and domestic animal rearing were the unique features of the Jaffna homegardens. Floristic diversity of the homegardens was equally distributed with medium species diversity and domestic faunal diversity was not equally distributed with low species diversity. Mean value of aboveground carbon stock was 40.51±3.67 Mg C ha^{-1}. Growing more number of fodder trees in the fence as living wall and grasses in the homegardens will meet the demand of fodder requirement for animals. Attractive landscape features, scientific advancement and research need to be addressed for cognitive development through the process of replacement, substitution, expansion and management in the peninsula.

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