DOI: https://doi.org/10.4038/jepsl.v15i1.7931

Journal of Environmental Professionals Sri Lanka: 2026 – Vol. 15 – No. 1

Evaluating Tree Diversity and Carbon Sequestration in Kandyan Home Gardens: Implications for Climate-Smart Agroforestry and Carbon Mitigation

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Abstract

Agroforestry systems are increasingly recognized for their dual capacity to sequester carbon and sustain biodiversity, yet fine-scale assessments of tropical home gardens remain limited. This study quantified species composition, above- and below-ground biomass, and carbon storage across four Kandyan home garden sites in Sri Lanka, encompassing 500 trees from 21 species. Total carbon (TC) ranged from 25,629 to 33,030 kg C per site. Smaller, structurally complex gardens (Bothota and Pallepola) exhibited higher carbon density (256–262 tC ha^{-1}) than larger, sparsely vegetated sites. Myristica fragrans (Nutmeg) dominated carbon stocks, contributing up to 9698.58 kg C per site, followed by Artocarpus altilis, Artocarpus heterophyllus, and Mangifera indica. Biodiversity indices indicated moderate to high diversity (H' = 2.736–2.973) and evenness (E = 0.91–0.98). Findings highlight the importance of integrating high-carbon species with diverse vegetation structures to support carbon storage, biodiversity, and sustainable home-garden management.

Keywords: *Kandyan home gardens, carbon sequestration, biodiversity, agroforestry, structural complexity*

I . Introduction

Climate change, driven primarily by increasing atmospheric concentrations of greenhouse gases, especially carbon dioxide (CO_2), has emerged as one of the most critical global environmental challenges of the 21st century. Among the various mitigation strategies, carbon sequestration through vegetation and soil offers a cost-effective and sustainable means of reducing atmospheric CO_2 (Lal, 2004). Within this context, agroforestry systems, particularly home gardens in tropical regions, are increasingly recognized for their potential to store substantial amounts of carbon due to their complex, multilayered vegetation structures and long-term biomass accumulation (Kumar & Nair, 2004).

In Sri Lanka, Kandyan home gardens (KHGs) are among the most prominent and traditional forms of tropical agroforestry. These systems can be described as multistrata agroforestry complexes, typically established on plots smaller than one hectare and composed of diverse combinations of tree and crop species (Perera et al., 1991). Over centuries, KHGs have evolved into ecologically and socially resilient production systems that integrate cereals, vegetables, fruits, spices, medicinal plants, timber-yielding species, and livestock (Pushpakumara et al., 2010).Extensive studies have documented the exceptional species diversity of KHGs, which conserve over 200 useful plant species and serve as repositories of traditional agro-biodiversity (Huston and Marland,2003). Characterized by high vertical stratification, species richness, and the integration of perennial and annual crops, these systems provide both socioeconomic and ecological benefits (Pushpakumara et al., 2010). Their multifunctionality not only sustains household food security and income generation but also supports essential ecosystem services such as carbon sequestration, nutrient cycling, and microclimate regulation.

Compared to monoculture systems of annual or perennial crops, home gardens with complex canopy structures exhibit moderate to high levels of above-ground biomass carbon, often comparable to that of secondary forests (Lowe et al., 2022). Ecosystems characterized by greater plant diversity typically maintain higher and more stable carbon storage over time, reflecting the positive relationship between biodiversity and ecosystem function (Henry et al., 2009). Agroforestry systems further contribute to climate change mitigation by enhancing biomass and soil carbon storage, conserving existing forest carbon stocks, and providing renewable biomass that substitutes energy-intensive materials (Kumar, 2006). Additionally, recent findings indicate that agroforestry systems accumulate higher soil carbon, especially in deeper soil layers, than treeless agricultural or pasture systems under similar ecological conditions. More than 50% of the carbon assimilated by woody perennials in such systems is allocated belowground through root growth, rhizodeposition, and litter decomposition, thus enhancing the soil organic carbon (SOC) pool (Kumar, 2006).

Despite extensive research quantifying carbon stocks in Kandyan home gardens using large-scale surveys, contemporary analyses capturing both carbon sequestration and biodiversity trends at smaller spatial scales remain limited. The present case study, conducted in two selected villages within the Kandy and Matale Districts, aims to assess current variations in tree composition, carbon sequestration potential, and species diversity in small-scale home gardens. Although KHGs are well-known for conserving a diverse range of plant species, recent socio-economic transitions have

led to a gradual decline in traditional diversity and balance, as households increasingly shift toward commercially oriented monocultures or abandon cultivation altogether (Landreth & Saito, 2014). These changes underscore the need for empirical evaluation of how species composition and management priorities are evolving within the KHG system.

By simultaneously evaluating carbon storage capacity and species diversity, this study provides new insights into the current ecological status and carbon dynamics of Kandyan home gardens. The findings aim to identify tree species with high carbon sequestration potential for climate change mitigation while highlighting the shifting socio-ecological dynamics influencing the resilience and sustainability of traditional home garden systems in Sri Lanka.

2. Materials and Methods

2.1 *Study Area Selection*

The study was conducted across four Kandyan home garden sites located within the Kandy and Matale Districts of Sri Lanka's Central Province. Two sites were selected from each district: Owilikanda (Site 1) and Pallepola (Site 4) in Matale, and Bothota (Site 2) and Katugasthota (Site 3) in Kandy. Collectively, the four sites encompass a total land area of 4.43 hectares, with individual site sizes ranging from 0.80 ha in Bothota to 1.41 ha in Katugasthota. Owilikanda and Pallepola cover 1.21 ha and 1.01 ha, respectively.

Matale District has diverse topography, climate and soils, with intermediate and wet-zone areas generally characterized by hilly to rolling terrain and elevations of about 300–900 m (National Science Foundation of Sri Lanka, n.d.). Pallepola and Owilikanda are rural to semi-rural areas dominated by residential land, home gardens and agriculture. Owilikanda is also recognized for soil-conservation importance, highlighting the potential influence of erosion and runoff on waste movement (Ministry of Plan Implementation, 1982).

Bothota in Harispattuwa, Kandy District, represents a relatively rural/semi-rural hill-country setting with undulating terrain, home gardens and mixed vegetation. In contrast, Katugastota is a densely settled suburban area with extensive residential, commercial and built-up land uses. It receives approximately 2,266 mm annual rainfall, with a mean annual temperature of about 23.5 °C (Climate-Data.org, n.d.).

These differences in terrain, vegetation, rainfall and land use provide contrasting settings for plastic-waste accumulation and transport.

These variations in land extent reflect differences in landholding size, vegetation structure, and management intensity, which can substantially influence species diversity, biomass accumulation, and carbon storage potential (Nair et al., 2009; Kumar & Nair, 2011). The selected sites represent the mid-country wet and intermediate climatic zones of Sri Lanka, lying at elevations between 400–800 m above mean sea level (MSL). The region experiences an average annual rainfall of 2000–2500 mm and a mean annual temperature of 24–26 °C, with a bimodal rainfall pattern dominated by the Southwest and Northeast monsoons (Chithranayana et al., 2008).

Soils in these areas are primarily Red-Yellow Podzolic and Latosolic, characterized by good drainage, moderate fertility, and organic matter accumulation that supports diverse tree-crop systems. The combination of favorable climatic and edaphic conditions provides an ideal environment for multi-structural vegetation growth, enhancing both biodiversity and carbon sequestration capacity within the home garden ecosystems.

2.2 Sampling Method

The study covered four purposively selected Kandyan home gardens in Sri Lanka's Central Province: Owilikanda and Pallepola in Matale District, and Bothota and Katugastota in Kandy District. The sites covered 4.43 ha in total, ranging from 0.80 ha (Bothota) to 1.41 ha (Katugastota). Selection was based on established tree vegetation and field accessibility. The entire available garden area, excluding household buildings, was surveyed to capture variation in species composition, tree size, stand structure, and biomass.

A total of 500 established living trees were inventoried, with 125 trees per site. Trees were included if they had measurable DBH at 1.3 m above ground and sufficient structural development for field measurements; dead trees and very small seedlings or saplings were excluded. Although purposive site selection limits generalization to all Kandyan home gardens, surveying the entire available garden area reduced spatial selection bias within each selected site and provided comprehensive coverage of the defined sampling areas.

2.3. Tree Measurements

2.3.1. Diameter at Breast Height (DBH)

DBH was measured at 1.3 m above ground level for each selected tree using a measuring tape, following standard forestry protocols (FAO, 2012). Trees with buttresses were measured above the buttress height to ensure accurate stem diameter representation. Multiple measurements per tree were taken and averaged to minimize observational errors.

2.3.2. Tree Height

Tree height was determined using a clinometer (Suunto PM-5/Vertex IV), which allows accurate estimation of tree height by measuring angles from a fixed distance. Multiple readings per tree were taken from different directions, and the mean value was used for analysis (Chave et al., 2005).

2.3.3. Tree Radius

Tree radius was calculated from girth (circumference) measurements taken at 1.3 m above ground. Since girth (CCC) represents the stem circumference, the radius (r) was derived using the standard geometrical relationship:

$$r = \frac{C}{2\pi} \tag{1}$$

- **r** = tree radius (m)
- **C** = girth/circumference of the tree at breast height (m)

Girth measurements were recorded with a flexible measuring tape held perpendicular to the stem. For irregular or buttressed stems, multiple measurements were averaged to improve accuracy. The derived radius was subsequently used for tree volume and biomass estimation.

2.4. Calculations

Tree volume (V) was estimated using a cylindrical approximation based on DBH and height:

$$V = \pi(DBH/2)^2 H \quad (2)$$

where d is DBH (m) and h is tree height (m).

Tree volume (V) was estimated using a cylindrical approximation based on DBH and height. This approach was adopted as a practical and consistent first-order approximation because species-specific allometric equations were not available for all species included in the study. However, the cylindrical assumption does not account for natural stem taper and may therefore overestimate actual stem volume, particularly for trees with strongly tapering stems. Species-specific or regionally validated allometric equations could provide more accurate biomass estimates in future studies (Chave et al., 2014).

Aboveground biomass was calculated by converting tree volume to wet biomass using species-specific wood density values (WD, kg m^{-3}) from global databases (Zanne et al., 2009):

Wet biomass (kg) = V x WD (3)

Dry biomass (DB) was calculated using an average moisture content of 27.5% (Bada et al., 2018):

Dry biomass (kg)=Wet biomass×0.725 (4)

A below-ground-to-above-ground biomass ratio of 0.26 was applied consistently across the sampled trees following Mithbavkar et al. (2022). This common ratio was adopted to maintain a consistent estimation approach across species in the absence of species-specific below-ground biomass data.

BGB (kg)= AGB x 0.26 (5)

Total Biomass (TB) in kg/tree= AGB+BGB (6)

Total carbon stored (C) was then estimated by applying a carbon fraction of 0.5 to total biomass, consistent with the approach of Mithbavkar et al. (2022)

Carbon stored (kg C)=Dry biomass×0.5 (7)

Finally, CO_2 equivalents were derived using the standard molecular weight ratio:

$$CO_2 \text{ eq (kg)} = \text{Carbon stored} \times 3.67 \quad (8)$$

This approach allows quantification of aboveground carbon storage and CO_2 mitigation potential for each tree and home garden.

2.5. Species Diversity and Evenness

Species diversity of the tree communities in the home gardens was quantified using the Shannon–Wiener Diversity Index (H′), which accounts for both species richness and relative abundance of individuals. The index was calculated using the formula:

$$H^i = -\sum_{i=1}^{s} p_i \, lnp_i \quad (9)$$

where S is the total number of species, and p_i is the proportion of individuals of species *i* relative to the total number of individuals ($p_i = n_i/N_i$), with n_i representing the number of individuals of species *i* and N the total number of individuals across all species.

To evaluate the evenness of species distribution, the Shannon Evenness Index (E**)** was calculated as:

$$E = \frac{H^i}{lnln\,(S)} \quad (10)$$

Where; S = *Species richness*

4. Results and discussion

4.1. Species Composition and Functional Types

A total of 500 trees representing 21 species were inventoried, including 16 exotic and five native species. Fruit trees were the dominant group, with species such as *Persea americana*, *Elaeocarpus serratus*, *Durio zibethinus*, *Syzygium samarangense*, and *Psidium guajava* particularly abundant in Sites 1 and 3 (Pushpakumara et al., 2016). Staple food species such as *Artocarpus altilis*, *Artocarpus heterophyllus*, and *Cocos nucifera* were moderately abundant, while economic species including *Syzygium*

aromaticum, *Theobroma cacao*, *Myristica fragrans*, and *Tamarindus indica* showed site-specific dominance. *M. fragrans* reached 24% and 23.2% relative abundance in Sites 2 and 3, respectively. Timber, woody, shade, and ornamental species also contributed to the vegetation structure, with *Tectona grandis* reaching 7.2% in Site 4.

The high abundance of *M. fragrans* agrees with Mihiranga et al. (2025), who found *Myristica fragrans* (Nutmeg) in 78% of surveyed Kandyan home gardens, contributing 17% of tree abundance and 19.75% of total basal area. They also identified *Myristica fragrans* (Nutmeg) dominance as an important determinant of species composition. Similarly, Egodawatta and Waransooriya (2014) reported differences in tree composition between inherited and settled Dry Zone home gardens, with economically valuable timber species and multipurpose food species varying according to household needs and economic objectives. Consistent with these findings, the present Kandyan home gardens comprised diverse functional groups, including fruit, staple food, economic, timber, shade, and ornamental species. Overall, the tree communities were dominated by multipurpose and economically valuable species, particularly spice, food, and timber species (Figure 1), reflecting the multifunctional nature of Kandyan home gardens.

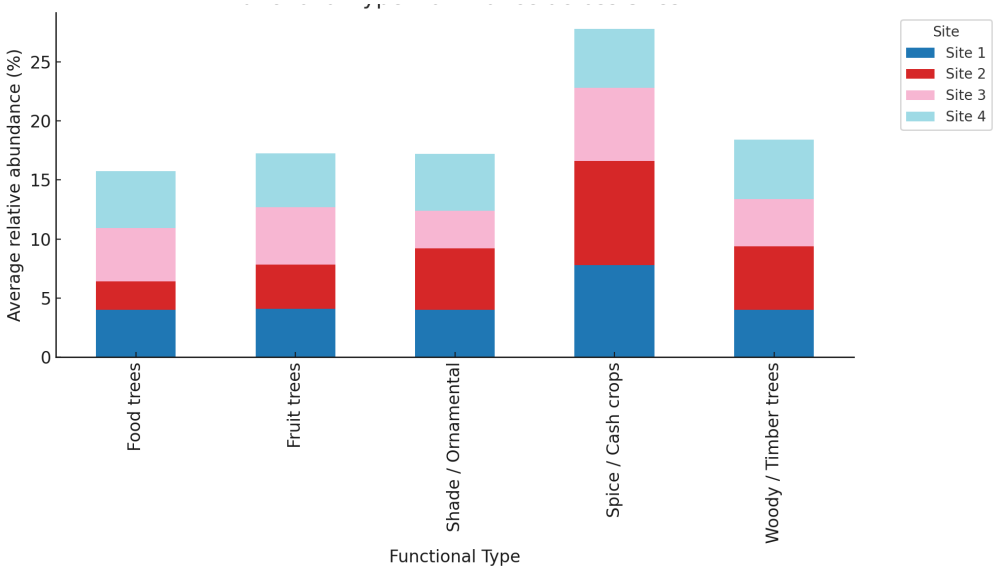

Figure 1: Species distribution among the sites

This dominance reflects local priorities for food security, income generation, and ecological functionality. The higher abundance of spice and cash crops across all four

sites is closely linked to livelihood strategies that prioritize economic sustainability. In Kandyan home gardens, high-value spice species such as *Cinnamomum verum*, *Myristica fragrans* (Nutmeg), *Piper nigrum*, and *Syzygium aromaticum* are widely cultivated as reliable income sources due to their strong market demand and relatively low management requirements. The favorable climatic conditions in the mid-country wet and intermediate zones further promote the growth of these species, reinforcing their prevalence. Moreover, the integration of spice and cash crops aligns with the traditional multifunctional design of Kandyan home gardens, which balance subsistence needs with commercial benefits. This management approach enhances household resilience by diversifying income sources, supporting year-round productivity, and contributing to ecological stability through increased biodiversity and carbon sequestration potential (Mattsson et al., 2013).

4.2. Total Carbon Content and Spatial Variation

Figure 2 presents the boxplot of total carbon content (Tc), illustrating the overall distribution.

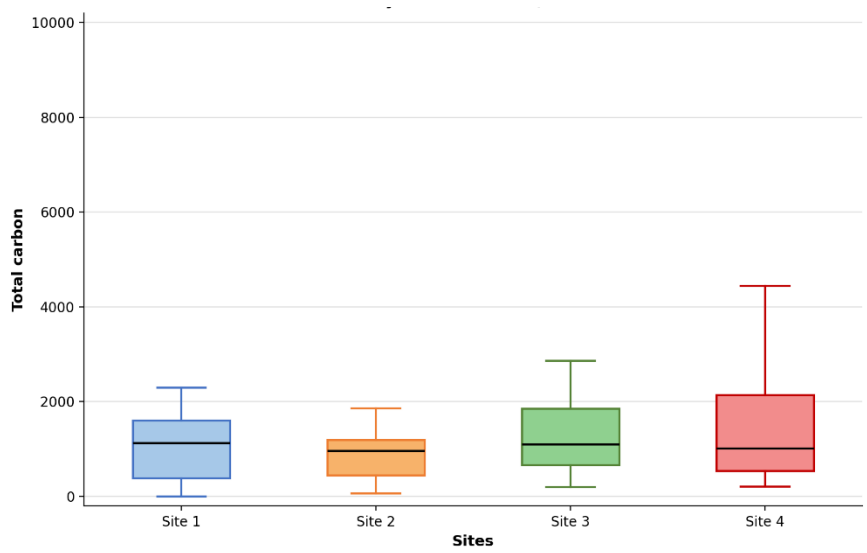

Figure 2: Variability of carbon stocks across the four Kandyan home garden sites.

Total carbon content varied substantially among the four sites. Site 4 showed the widest distribution (IQR: 534–2,138 kg C ha^{-1}; maximum ≈4,438 kg C ha^{-1}), while Site 1 had the second-highest median (≈1,132 kg C ha^{-1}) with a major *Myristica fragrans* outlier (≈9,825 kg C ha^{-1}). Site 3 had a similar median (≈1,100 kg C ha^{-1})

with one outlier (≈4,129 kg C ha^{-1}), whereas Site 2 had the lowest median (≈957 kg C ha^{-1}) and a relatively compact distribution, but two high-carbon outliers (≈2,830 and 7,759 kg C ha^{-1}).

Total carbon stock and density also varied spatially, reflecting differences in site area, vegetation composition, density, and management. Bothota (Site 2), despite being the smallest site (0.80 ha), recorded relatively high carbon stock (28,438.83 kg) and density (256.29 t C ha^{-1}), associated with high-biomass species such as *Myristica fragrans*, *Caryota urens*, and *Tectona grandis*. Pallepola (Site 4) recorded the highest total carbon (33,030.24 kg) and carbon density (261.63 t C ha^{-1}), likely reflecting dense and mature vegetation. In contrast, Owilikanda (Site 1) had 28,405.73 kg and 203.01 t C ha^{-1}, while the larger and more urbanized Katugastota (Site 3) recorded the lowest values (25,629.10 kg; 160.03 t C ha^{-1}), potentially due to lower vegetation density and greater anthropogenic disturbance.

The higher carbon density of Pallepola compared with Katugastota (approximately 63% higher) further suggests that vegetation structure and land-use intensity strongly influence carbon storage. Similarly, Kassa et al. (2022) reported 22.02–39.96 Mg C ha^{-1} across 93 Ethiopian home gardens and found positive relationships between carbon stocks, woody species richness, and plant density. These findings are broadly consistent with Roshetko et al. (2002), who reported that species-rich, tree-based home gardens can function as important carbon reservoirs. Their study found that 13-year-old home gardens stored 35.3 Mg C ha^{-1} in above-ground biomass, with projected time-averaged carbon stocks ranging from 30 to 123 Mg C ha^{-1} depending on species composition and management. Overall, the findings indicate that dense, structurally diverse home gardens can achieve high carbon storage efficiency regardless of total garden size, highlighting their potential as important carbon reservoirs and multifunctional agroforestry systems.

4.3. Species-Specific Carbon Contributions

Myristica fragrans (nutmeg) made the highest carbon contribution, likely due to its large canopy, dense wood, and long lifespan, which enhance biomass accumulation. Its total carbon peaked at 9,698.58 kg C at Site 2 and remained high across other sites (4,152.63–8,119.88 kg C). *Tectona grandis* and *Artocarpus altilis* also showed high carbon accumulation, particularly at Site 4 (4,394.28 and 4,183.55 kg C, respectively). In contrast, *Tamarindus indica* and *Annona muricata* recorded the lowest carbon contents, while *Syzygium aromaticum*, *Garcinia mangostana*, and *Artocarpus heterophyllus* showed moderate and relatively stable values. Overall,

species-level variation in carbon storage was more pronounced than site-level variation, indicating that species composition is an important determinant of carbon sequestration in the studied Kandyan home gardens.

4.4. Mean Carbon Content and Stand Characteristics

The mean carbon content of tree species varied considerably among the four Kandyan home garden sites—Owilikanda (Site 1, 1.21 ha), Bothota (Site 2, 0.8 ha), Katugasthota (Site 3, 1.41 ha), and Pallepola (Site 4, 1.01 ha)—reflecting differences in vegetation structure, stand age, and management intensity. In general, Pallepola and Katugasthota exhibited higher mean carbon accumulation compared with Owilikanda and Bothota. The higher above-ground biomass and carbon density observed in larger and structurally diverse home gardens in the present study may be partly attributed to the greater number and diversity of woody vegetation retained within these systems. This is consistent with Subba et al. (2020), who reported that plant biomass carbon was highest in large home gardens, reaching 60.38 Mg C ha^{-1}.

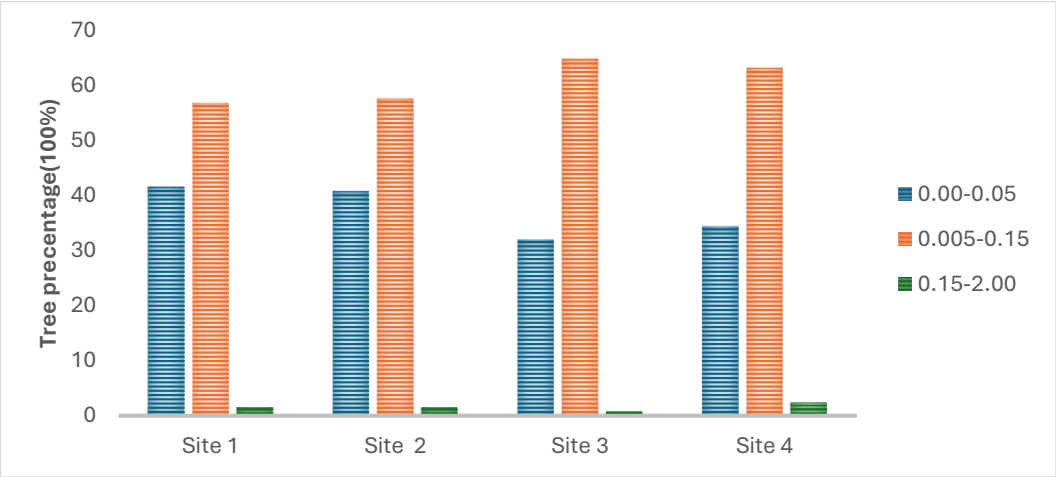

Figure 3: DBH class distribution among trees in selected sites

The DBH class distribution (Figure 3) further illustrates these structural differences across sites. In all home gardens, most trees fall within the 0.005–0.15 m DBH range, accounting for more than 60 % of total individuals, indicating dominance of small- to medium-sized trees. A substantial proportion of trees also occurred in the 0.00–0.05 m DBH class (approximately 30–40 %), representing younger and regenerating individuals that contribute to stand renewal. Only a minor fraction (< 5 %) of trees belonged to the 0.15–2.00 m DBH class, reflecting the scarcity of mature, large-

diameter trees. However, Pallepola (Site 4) and Katugasthota (Site 3) exhibited a slightly higher proportion of these large-diameter individuals, aligning with their greater mean carbon content and structural maturity.

Among dominant species, *Artocarpus altilis* showed a progressive increase in mean carbon content from Owilikanda (283.85 ± 152.39 kg C) to Pallepola (603.63 ± 112.84 kg C), indicating enhanced growth performance and carbon assimilation in well-managed, less-disturbed gardens. Similarly, *Artocarpus heterophyllus* and *Mangifera indica* maintained consistently high carbon stocks, particularly at Pallepola, reinforcing their contribution as dominant carbon-rich taxa in mixed-canopy systems. In contrast, *Cocos nucifera* and *Theobroma cacao* exhibited low mean carbon values (< 80 kg C), consistent with their smaller structure and lower wood density.

Overall, the observed DBH distribution and species-level carbon content collectively suggest that Pallepola and Katugasthota function as the most carbon-dense home garden systems, driven by the presence of mature, large-canopy species and diversified stand structure. Conversely, Bothota, characterized by a high share of small-diameter individuals, reflects a relatively young stand with limited carbon storage potential. These findings emphasize the ecological importance of stand structure, management intensity, and species composition in determining the carbon sequestration capacity of Kandyan home gardens.

4.5. Biodiversity Indices and Species Evenness

The Shannon–Wiener diversity index (H′) and Shannon evenness (E) values indicate relatively high and uniform biodiversity across all four home garden sites. The H′ values ranged from 2.736 to 2.973, reflecting moderate to high species diversity within the studied agroforestry systems. The home gardens in Bothota and Katugasthota (Sites 2 and 3) in Kandy District recorded H′ values of 2.736 and 2.764, respectively, and identical evenness values (E = 0.91), indicating similar diversity and species distribution within the two sampled gardens. In both sites, *Myristica fragrans* (Nutmeg) showed the highest relative abundance (0.240 and 0.232, respectively), indicating greater dominance of this species within the sampled tree communities. The home gardens located in Owilikanda and Pallepola (Sites 1 and 4) in Matale District recorded H′ values of 2.968 and 2.973 and evenness values of 0.980 and 0.976, respectively. The relative abundance of *Myristica fragrans* was lower at these sites (0.096 and 0.088, respectively).

The observed variation between the selected sites may be associated with differences in management intensity, land-use objectives, and socio-economic priorities. In the selected Kandy home gardens (Bothota and Katugasthota), the relatively higher dominance of *Myristica fragrans* (Nutmeg) may reflect differences in species selection and management practices at these sites. Conversely, the selected home gardens in Matale (Owilikanda and Pallepola) recorded greater species diversity and evenness, which may be associated with differences in management practices and species composition. However, these potential explanations were not directly evaluated in the present study and should therefore be interpreted cautiously. Overall, these results underscore the potential of home gardens as multifunctional land-use systems that integrate livelihood needs with biodiversity conservation, while highlighting variation in species composition and ecological characteristics among the selected sites.

Cultivating *Myristica fragrans* (Nutmeg)as the dominant species in home gardens may initially seem beneficial for carbon sequestration due to its capacity for biomass accumulation. However, research indicates that ecosystems dominated by a single-species monoculture often have lower overall carbon storage and reduce ecological resilience compared to more diverse systems. A study by Ma et al. (2020) also indicated that biomass carbon content in mix species-based agroforestry systems was substantially higher in multiple-species systems (~60 Mg C ha^{-1}) than in single-species based agroforestry systems (~30 Mg C ha^{-1}), with a significant difference ($p < 0.05$).Similarly, a study in Malaysia by Besar et al(2020) found a significant difference in biomass carbon between natural ecosystems, agroforestry systems with mix species and monoculture, indicating highest biomass carbon in natural forestry ecosystems with 287.29 Mg C ha^{-1}. Collectively, these findings indicate that species composition, diversity and vegetation structure can play important roles in determining carbon storage, supporting the higher carbon storage observed in the more diverse Kandyan home gardens in the present study.

5. Recommendations for Optimizing Carbon Sequestration and Biodiversity in Kandyan Home gardens

The study confirms that carbon sequestration in Kandyan home gardens is highly species-specific, with significant contributions from a few high-biomass trees, while overall ecosystem resilience depends on maintaining native species diversity and structural complexity. Based on our results, the following recommendations are proposed:

5.1 Prioritize High Carbon-Storing Species

Myristica fragrans (Nutmeg) consistently recorded the highest total carbon across sites (up to 9698.58 kg C in Site 2). *Artocarpus heterophyllus*, *Artocarpus altilis*, and *Mangifera indica* showed high mean carbon values (up to 603.63 kg C per tree in Pallepola), making them excellent candidates for maximizing above-ground carbon storage while providing food and economic benefits.

5.2 Incorporate Native Ecologically Functional Species

Although exotics dominate most home gardens, native species recorded in the study such as *Artocarpus nobilis* and *Caryota urens* should be prioritized for enrichment planting. These species contribute to structural diversity, habitat provision, and soil carbon enhancement, strengthening ecological resilience and complementing high-carbon exotics.

5.3 Maintain Functional and Structural Diversity

Multi-layered canopies combining tall timber species (*Tectona grandis*, *Swietenia macrophylla*), mid-canopy fruit and spice species (*Artocarpus*, *Mangifera*, *Myristica*), and shade or nitrogen-fixing species such as *Gliricidia sepium* can enhance carbon storage, soil fertility, microclimate regulation, and livelihood benefits. The higher carbon density observed in smaller, densely vegetated gardens (Bothota and Pallepola) further highlights the importance of canopy density and vertical layering.

5.4 Balance Carbon Goals with Biodiversity Conservation

Home gardens in Matale (Owilikanda and Pallepola) had higher species diversity ($H' = 2.968–2.973$) and evenness ($E = 0.976–0.98$) compared with Kandy sites, which were dominated by *Myristica fragrans*. Monocultures may increase short-term carbon but reduce resilience. We recommend a target composition of ~60–70% native species, ~20–30% high-carbon exotics, and ~10% nitrogen-fixing or medicinal species to balance carbon storage, biodiversity, and livelihood benefits.

5.5 Limitations of the study

The study has several limitations. Only four sites, with two each from Kandy and Matale Districts, were sampled; therefore, the findings may not fully represent district-level or wider Kandyan home-garden variation. Comparisons between

districts should consequently be interpreted cautiously and primarily as descriptive rather than statistically representative. Biomass estimation using cylindrical volume approximations may also introduce uncertainty because tree forms are often irregular and tapering. In addition, common carbon fractions and above-ground-to-below-ground biomass ratios were applied across species, although these parameters vary with species characteristics and wood density. Future studies should include more sampling sites and use species-specific biomass parameters and methods that account for tree form to improve the accuracy, statistical reliability, and generalizability of biomass and carbon-stock estimates.

Conclusion

This study demonstrates the considerable carbon sequestration capacity of Kandyan home gardens, with total carbon stocks ranging from 25,629 kg C in Katugasthota (Site 3) to 33,030 kg C in Pallepola (Site 4), and corresponding carbon densities of 160.03 tC ha^{-1} and 261.63 tC ha^{-1}, respectively. Smaller but dense gardens, such as Bothota (28,438 kg C; 256.29 tC ha^{-1}), exhibited high carbon accumulation efficiency per unit area, highlighting the importance of vertical stratification and multi-layered vegetation. Species-level contributions were highly variable, with *Myristica fragrans* (Nutmeg) showing the highest total carbon per site (up to 9,698.58 kg C in Site 2), followed by *Artocarpus altilis*, *Artocarpus heterophyllus*, and *Mangifera indica*, reflecting their dominance in aboveground biomass. The Shannon–Wiener diversity index ($H' = 2.736–2.973$) and evenness ($E = 0.91–0.98$) indicated moderate to high species diversity and relatively uniform individual distribution across sites, suggesting ecological resilience in these traditional home gardens. Collectively, the findings underscore that Kandyan home gardens serve as multifunctional agroforestry systems that integrate carbon storage, biodiversity maintenance, and livelihood support, providing a scalable model for climate-resilient land-use in tropical regions.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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