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The *Owita* agroecosystem: a promising traditional land management system for sustainable farming in Sri Lanka

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Abstract The *Owita* agroecosystem is a unique peri-urban land-use system. Typically it is a narrow strip of land with vegetation located between lowland paddy fields and the uplands of the Wet zone in Sri Lanka. Despite its potential to develop as a sustainable agricultural ecosystem, it has largely been ignored, underutilized and lesser-known. The main objective of this study was to assess the present status of *Owita* agro-ecosystem, with a focus on its plant species diversity, socio-economic aspects and ecosystem services. The study identified and evaluated thirty-five *Owita* systems located in the Wet zone of Sri Lanka through conducting vegetation and socio-economic surveys. The study reported a total of 115 plant species belonging to 49 families and 99 genera, of which, the family Fabaceae was found to be the most dominant, with a total of 11 species. Field observations and farmer feedback revealed that *Owita* provides numerous environmental benefits in the peri-urban landscape, including flood control, biodiversity conservation, and temperature regulation in the surrounding areas. Apart from the ecosystem services, *Owita* opens up new business ventures for subsistence farmers in peri-urban areas, and products from the system possess high demand due to their freshness and minimal usage of agrochemicals. Although the traditional *Owita* agro-ecosystem is primarily an annual-based cropping system, findings of the present study indicate that, it has been gradually transformed into a perennial tree-based agroforestry-type cropping system where plant species are spatially arranged in three vertical layers. Thus, the *Owita* system can be considered as a promising and sustainable agroecosystem that provides numerous benefits to the subsistent farmers in peri-urban environments.

Keywords Agroforestry · Subsistence cropping systems · Ecosystem services · Sustainable land-use · Peri-urban agriculture

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Introduction

Sri Lanka is predominantly an agricultural country dominated by historically evolved agricultural systems with an extraordinary level of biodiversity. These systems were organic farming systems which were closely related to natural ecosystems (Bandara 2007). Besides, those were more elegant and shaped up with the indigenous knowledge of the local farming community, especially in terms of resource management. Additionally, the unique indigenous irrigation water management systems have significantly contributed to the productivity of national agriculture and those systems remain unharmed due to their sustainable management structure (Abeywardana et al. 2018, 2019). The wisdom and the traditional knowledge used in agriculture and the livelihood style of Sri Lankan farmers have not evolved within a few decades but are a long-time-tested knowledge which has created an environmentally adapted, disaster tolerant and sustainable living system (Dharmasena 1995, 2010, 2020).

The indigenous farming systems of Sri Lanka were a close integration of livestock, especially cattle and goat mixed homegarden systems, upland dry farming of rice, other grains, oil crops and vegetables as a component of *Chena* (shifting cultivation), and lowland paddy cultivation with a very well organized centrally planned watershed and water management system (Bandara 2007). Among these traditional agricultural systems *Chena* cultivation, homegardens and rice-based farming systems are continuing to integrate modern technologies, making them commercially viable. The traditional *Chena* cultivation system is the oldest form of farming practice in the uplands of Dry zone using direct rainfall (Dharmasena 1993). Bandara (2007) claimed that the traditional *Chena* farming system is not haphazard and follows ecological principles and soil conservation strategies. However, despite the numerous studies already published on various aspects of *Chena* farming system (Agalawtte and Abeygunawardena 1994; Wickramasuriya et al. 2009; Gunasena and Pushpakumara 2015) information is scanty on its potential to transform towards a more productive and sustainable farming system. Home garden is also considered as a dynamic sustainable food production system, and presumably the oldest land-use activity, next to shifting cultivation (Pushpakumara et al. 2012). It remains as one of the major forms of land-use systems in Sri Lanka and evolved to suit the socio-economic, cultural, and ecological needs of Sri Lanka's diverse communities and landscape (Pushpakumara et al. 2010, 2012). As a staple food, the traditional rice-based farming system has been significantly improved and contribute to the country's economy. At present, rice-based farming is a well-established agricultural system and has become the back born of Sri Lankan agriculture. Since its utmost importance as the main cash crop, it has gained attention and extensively studied over the past few decades.

Apart from the above-stated commercially established, crop-based agroecosystems, some other neglected farming systems exist in Sri Lanka which have long been practiced by different farming communities but remains underutilized due to the undervaluing of their economic, social and environmental benefits. *Owita*, *Deniya,* and *Bada-wetaya* are some such agroecosystems that remain active in some parts of the country without adequate attention. Of which, the *Owita* ecosystem is remarkable due to its unique positioning in the landscape, cropping pattern and adaptability to transformation. The O*wita* agroecosystem is a unique peri-urban land-use system with specific soil types and is found between lowland paddy fields and upland rubber, coconut, cinnamon or mixed homegarden predominant Wet zone of Sri Lanka. Moreover, the area is characterized by rolling and hilly terrain landscape and major soil groups are red-yellow podzolic and low-humic gley (Wijesekara and Hunter 2010). Due to its position between lowland and upland farming systems, water table in an *Owita* is subjected to fluctuate annually.

Though characteristically *Owita* system is an annual cropping system, in some areas it has transformed into fully perennial-based cropping system. However, the status of *Owita* system is yet unclear due to the lack of information on the biological, environmental, cultural, and socio-economical values. Wijesekara and Hunter (2010), are the only researchers who have paid attention and studied on this hidden yet important ecosystem so far. Their findings are based on a case study conducted at a couple of subsistence farms in villages in *Colombo, Kaluthara*, and *Galle* districts of Sri Lanka. According to them, the *Owita* ecosystem characteristically has a high groundwater level throughout the year and always a shallow perennial stream flowing through it or alongside.

Apart from its contribution to ensure household food security, its biological and environmental values are at utmost importance for the well-functioning of agrobiodiversity and to sustain natural equilibrium in peri-urban areas. Wijesekara and Hunter (2010) highlighted that mostly the lower-middle-class dwellers and peasants practice the *Owita* systems to supplement their day-to-day food requirements. Since it is a subsistence-level cultivation system, this system operates as a small family business. As Wijesekara and Hunter (2010) further explained, most of the activities occur during the afternoon, starting around 3:00 pm when the entire family has free time after attending to other day-to-day work. It includes land preparation, planting, watering, weeding and fertilizer application. In addition to cultivation and management practices, some ingredients for the day's meal are collected from *Owita*. Cash crops like betel leaves, root and tubers, and extra produce are periodically sold in the local market or to produce collectors, or shared with neighbors.

To address the challenges in today's agriculture sector such as land limitation, maximum land utilization, productivity enhancement and achieving environment sustainability, the exploration and introduction of novel and sustainable agricultural ecosystems are a need of the hour. Moreover, the exploration and utilization of such hidden resources will open new income-generating avenues for most of the underprivileged groups within such farming communities. In this background, it is urgent and important to understand the biological value, socio-economic aspects, and environmental services lying along with this unique but neglected agroecosystem to be developed as a highly productive and sustainable system in peri-urban areas. Thus, this study was specifically designed to investigate the potential of the *Owita* system as a promising traditional land management approach for sustainable farming in Sri Lanka.

In this context, the objectives of this study were to answer the following questions, aiming to enhance this distinctive and site-specific agricultural system.

(a) What is the level of plant species diversity in *Owita* system, their classification, and spatial arrangement?
(b) Do the studied *Owita* systems differ from each other in terms of plant species diversity, and their arrangement?
(c) How does the *Owita* system contribute to improving the socio-economic aspects of peri-urban farmers?
(d) What are the ecosystem services provided by the *Owita* systems?

Materials and methods

Areas of study and sampling

As the *Owita* system is highly specialized and site-specific, it is confined to only a few administrative districts in the Wet zone of Sri Lanka. Due to rapid transformations in land-use over the past few decades, traditional *Owita* systems are now scarcely found. Following preliminary field surveys, 35 well-functioning *Owita* systems were identified across the Wet zone of Sri Lanka. Considering factors such as accessibility, level of cultivation, land use, and cropping patterns, all 35 *Owita* systems were purposively selected for detailed analysis (Fig. 1).

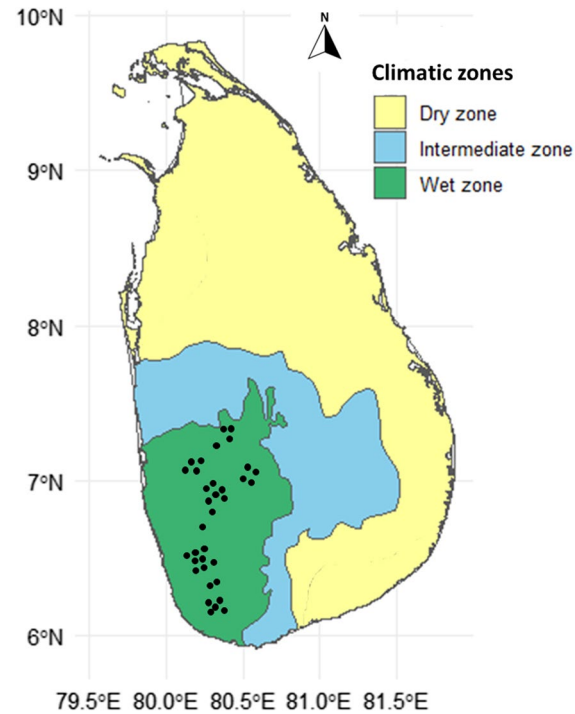

Fig. 1 Locations of the studied *Owita* systems in the Wet zone of Sri Lanka

Field survey

A field survey was carried out to understand the level of plant species diversity and their spatial arrangement (i.e. horizontal and vertical distribution patterns) of different plant species. Given that the *Owita* system is neither a monoculture nor a purely cultivated mixed cropping system, its plant component comprises both commercially cultivated introduced and native crop species, as well as other plant species found in nearby landscapes. Additionally, owing to its proximity to homegardens, occasionally it mirrors traditional homegardens in terms of plant species diversity, life and growth forms, as well as their spatial distribution, particularly in vertical and horizontal patterns of distribution and stratification. Consequently, a field survey was conducted to investigate all of the aforementioned features of plant species in the 35 selected *Owita* systems. The size of an *Owita* system was in the range of 0.2–0.4 ha. In order to make a fair comparison among *Owita* systems, only 0.2 ha of an *Owita* system was selected to obtain measurements. When selecting a sample from an *Owita* system with the size > 0.2 ha, the central 0.2 ha of that system was sampled.

Since many traditional *Owita* systems are situated near homegardens, the presence of three common strata is a typical characteristic of both systems. After referring number of research evidences on vegetation surveys of Wet zone home gardens (Kumari et al. 2009; Pushpakumara et al. 2016; Kadupitiy et al. 2018; Lowe et al. 2022), the recorded species were classified and identified according to three vertically arranged layers: the ground layer (0–1 m), the mid-layer (1–4 m), and the dominant layer (> 4 m), with species diversity estimated within each layer. Additionally, the average height of all recorded mature plant species was measured and categorized them into seven groups based on their height. Moreover, to comprehend the horizontal distribution of plant species within each *Owita*, we examined the common distribution patterns across each system and grouped them into major crop categories. The species were botanically identified using Standard Herbarium Techniques (Forman and Bridson 1989).

Questioner survey

A questionnaire survey was conducted to identify the socio-economic aspects, ecosystem services, constraints and farmer perspectives of *Owita* systems. The owners of 35 selected *Owita* systems were considered as respondents and they were interviewed using direct, indirect, open-ended and closed-ended questions. During the interview information related to following key aspects were obtained.

(a) Plant species diversity and arrangement: In addition to our on-site investigation at each *Owita*, we gathered information from respondents about the plant species, encompassing both native and introduced, present in the system. This included details about their spatial arrangement and any changes in crop diversity and arrangement over time. Such information proved invaluable for validating our findings concerning all aspects of the plant community within the *Owita* system. We combined such information with our plant diversity assessment at the each *Owita* system.
(b) Cultivation practices: Since *Owita* is a traditional and unique site-specific system, our focus was specifically on farmer cultivation practices. These include seasonal or year-round cultivation, crop rotation or intercropping patterns, the utilization of traditional knowledge or modern techniques, and input usage (fertilizers, pesticides and labor), as highlighted in the questionnaire survey.
(c) Socio-economic aspects: Information pertaining to the socio-economic aspects, with a primary focus on cultivation purposes (subsistence or commercial), income derived from *Owita* products, challenges encountered (such as labor shortages, land ownership issues, and wild animal attacks), and future cultivation plans were collected. This data aims to elucidate how this agroecosystem contributes to the well-being of peri-urban farmers. Due to the absence of record-keeping practices among the farmers, information collected was entirely reliant on qualitative data.
(d) Ecosystem services: Given that this agroecosystem is not entirely commercialized, its role in maintaining environmental balance within the urban landscape is noteworthy. As such, interviews were conducted to gauge whether the per-

ceived benefits of the *Owita* system, such as flood control, soil conservation, habitat provision, and contributions to biodiversity conservation (including indigenous species and crop wild relatives), align with general ecosystem services.

(e) Constraints, limitations, and farmers' perspectives: Information was collected to grasp the constraints and limitations they encounter in engaging with *Owita* cultivation. These include factors such as the impact of seasonal flooding or waterlogging, availability of planting materials, access to technical support or extension services, and market access challenges. Additionally, we sought their perspectives, including reasons for continuing or abandoning *Owita* cultivation, interest in adopting sustainable practices or organic farming, willingness to participate in conservation or development programs, and suggestions for enhancing *Owita* cultivation.

Data analysis

The statistical analysis of the data was made using SAS statistical package (version 9.0). The observed frequencies among the levels of a given variable were compared using Chi-square test i.e. species abundance among *Owita* systems, number of species present among vertical layers, number of species present among height categories, number of species present among families, number of plants among growth/plant habits, number of plants between annual and perennial categories were compared using a chi-square test at 95% significance.

Results

Crop diversity and abundance

This study recorded 115 species belonging to 49 families and 99 genera (Figs. 2 and 3) of which the family Fabaceae was the most dominant family with 11 species ($P < 0.05$). Banana, coconut, areca nut, cassava and gliricidia were the commonly occurring species in the *Owita* system. Moreover, the number of species found in an *Owita* system ranged between 2 and 24 ($P < 0.05$), with a median number of twelve species (Fig. 2). These species could be categorized into various groups, including vegetables, fruits, cereals, root and tuber crops, medicinal plants, timber, and spices.

According to the observations made during the study, we noticed that only a few *Owita* ecosystems were based on annual cropping, with vegetables being the most dominant crop category ($P < 0.05$). Even though *Owita* system was dominated by exotic vegetables, the earlier system was mostly occupied by indigenous vegetables and some root and tuber crops. However, results of the present study revealed that perennials were more prominent than annuals in all tested *Owita* systems, except in three *Owita* systems ($P < 0.05$) (Fig. 4). It depicts that the annual-based traditional *Owita* system has gradually transformed into a perennial-based system. According to our observations, some systems have been totally converted into perennial cropping systems such as cinnamon, coconut, tea and rubber implemented as mitigation measures to overcome the seasonal flooding. As the farmers revealed, seasonal folding has not been experienced much frequently during the last two to three decades. Hence, the system could have easily transformed into a perennial-based system. Also,

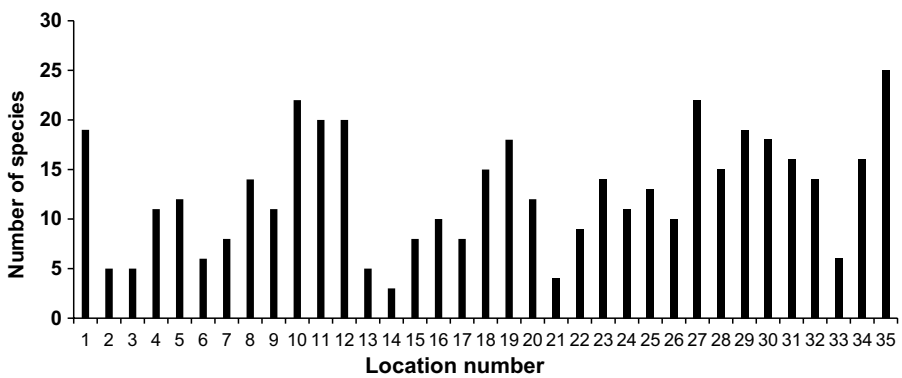

Fig. 2 Number of plant species recorded in each *Owita* system

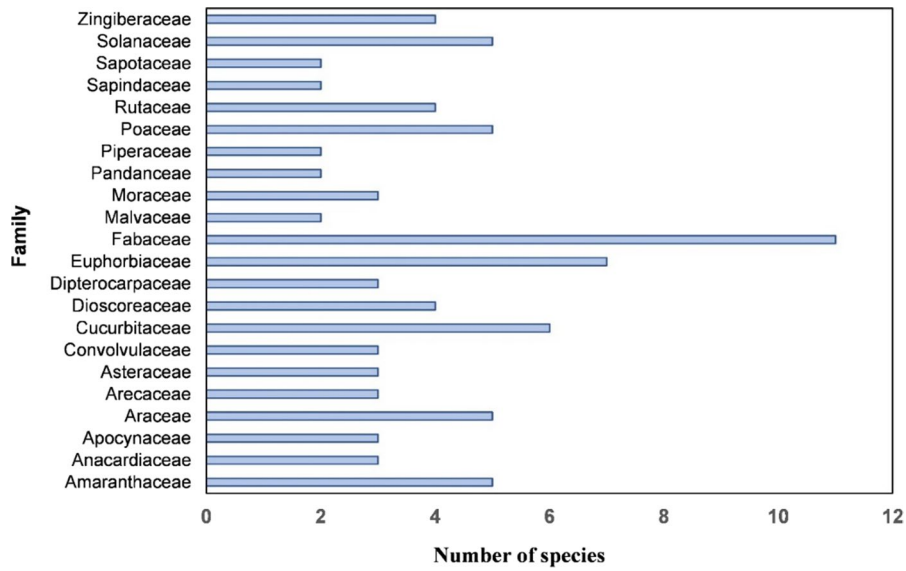

Fig. 3 Number of species belonging to major plant families encountered in 35 *Owita* systems in Sri Lanka. (27 other plant families which comprised only one species are not shown in this graph)

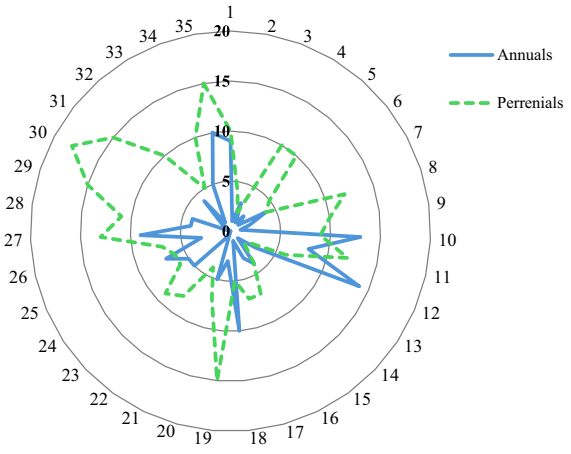

Fig. 4 Graphical representation of the number of annual and perennial species observed in 35 *Owita* systems in the Wet zone of Sri Lanka

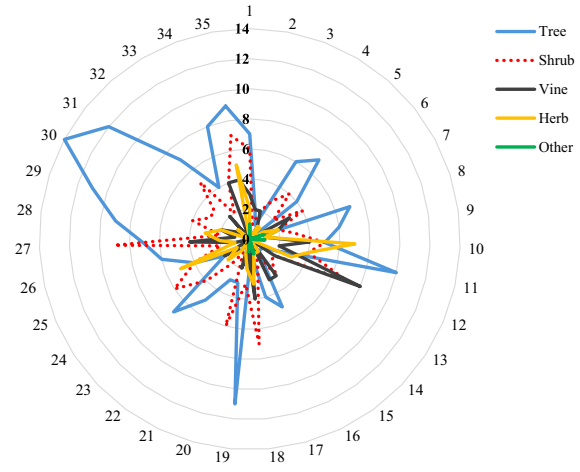

Fig. 5 Graphical representation of the number of different plant habits observed in 35 *Owita* systems in the Wet zone of Sri Lanka. *Note*: The category "other" represents the sedges and grasses

majority of the farmers have not shown interest in dealing with annual crops, mainly due to the lack of time for cultivation, as they require close attention and high inputs. During the study, it was noted that some *Owita* systems have merged with the adjacent homegarden and thereby both systems were functioning as a single unit.

It was observed that trees and shrubs were more frequent than other annual herbs and vines ($P < 0.05$) (Fig. 5). Since *Owita* was located just adjacent to the homegarden, most of the homegarden crops were shared with the *Owita* system as well. Even though trees were dominant in the system, vegetables represent an essential component of the *Owita* system (Table 1 presents the high diversity of crop and plant species found in 35 *Owita* systems. In the present study, we were able to further expand the plant species list developed by Wijesekara and Hunter (2010) adding more species belonging to various plant categories (Table 1). Figure 6 shows a few of the surveyed *Owita* systems and their plant compositions.

Table 1 Different crop and tree species recorded from 35 sampled *Owita* systems

Plant group	Species recorded
Vegetables	*Abelmoschus seculentus* (Okra), *Capsicum annuum* (Chilli), *Capsicum frutescens* (Kochchi), *Cucumis melo* (Cucumber), *Cucurbita maxima* (Pumpkin), *Lagenaria sicerria* (Bottle gourds), *Luffa acutangular* (Luffa), *Momordica charantia* (Bitter gourd), *Phaseolus vulgaris* (Bean), *Psophocarpus tetragonolobus* (Winged bean), *Sauropus androgynus* (Japan batu), *Solanum melongena* (Brinjal), *Solanum insanum* (Elabatu), *Solanum torvum* (Thibbatu), *Vigna unguiculata* (Ma- karal)
Fruits	*Ananas comosus* (Pine apple), *Annona muricata* (Sepathiila), *Antidesma alexiteria* (Ambilla), *Artocarpus heterophyllus* (Jack), *Atlantia ceylanica* (Yaki-naran), *Averrhoa carambola* (Kamaranga), *Carica papaya* (Papaya), *Citrus aurantifolia*, *Citrus grandis* var. *grandis* (Jambola), *Citrus* spp., *Mangifera indica* (Mango), *Musa*×*paradisiaca* (Banana), *Nephelium lappaceum* (Rambutan), *Psidium guajava* (Guava), *Spondia dulcis* (Ambarella)
Leafy vegetables	*Achyranthes aspera* (Karalheba), *Alternanthera sessilis* (Mukunuwenna), *Amaranthus viridis* (Thampala), *Basell alba* (Nivithiya), *Cassia alata* (Aththora), *Celosia argentea* (Kirihanda), *Centella asiatica* (Gotukola), *Commelina diffusa* (Girapala), *Ipomoea aquatica* (Kankun), *Lasia spinosa* (Kohila), *Sesbania grandiflora* (Kathurumurunga), *Syngonium angutatum* (Wel-kohila), *Trianthema portulacastru* (Sarana)
Cereals	*Zea mays* (Maize)
Legumes	*Gliricidia sepium* (Gliricidia), *Vigna radiata* (Mung bean), *Vigna unguculata* (Cowpea)
Root and Tuber	*Alocasia cucullata* (Habarala), *Colocasia esculenta* (Kalu-ala), *Diascorea alata* (Angili-ala), *Diascorea esculanta* (Kakulala), *Diascorea pentaphylla* (Katu-ala), *Dioscorea alata* (Raja ala), *Ipomoea batatas* (Sweet potato), *Manihot esculanta* (Cassava), *Xanthosoma sagittifolium* (Kiri-ala)
Medicinal Plants	*Asparagus racemosus* (Hathavariya), *Cardiosprmum halicacabum* (Penala), *Costus specious* (Thebu), *Erythrina variegate* (Erabadu), *Kaempferia galangal* (Inguru-piyali), *Madhuca longifolia* (Mee-tree), *Murraya koenigi* (Curry leaves), *Osbeckia octandra* (Bowitiya), *Pandanus amaryllifolius* (Rampe), *Pongamia pinnata* (Karada), *Ricinus communis* (Endaru), *Vitex negundo* (Nika)
Timber	*Alstonia macrophylla* (Ginikuru), *Alstonia scolaris* (Rukkaththana), *Dipterocarpus zeylanicus* (Hora), *Lannea coromandelica* (Hik tree), *Sweteria mahogany.* (Mahogani), *Syzygium paniculatum* (Bata domba), *Tectona grandis* (Teak)
Plantation Crops	*Cocus nucifera* (Coconut), *Coffea arabica* L. (Coffee), *Saccharum officinarum* (Sugarcane), *Camellia sinensis* (Tea), *Hevea brasiliensis* (Rubber)
Other	*Agrostistachys coriacea* (Beru), *Areca catechu* (Arecanut), *Artocarpus altillis* (Breadfruit), *Argyreia populiolia* (Ginithilla), *Bambusa vulgaris* (Bamboo), *Barringtonia asiatica* (Midella), *Calphyium inophyllum* (Domba), *Canarium zelanicum* (Kakuna), *Caryota urens* (Kithul), *Codiaeum variegatum* (Croton), *Ceratopteris thalictroides* (Gona-an), *Cerbera manghas* (Wel-kaduru), *Cymbopogan nardus* (Mana), *Dicranopteris linearis* (Kakilla), *Dillenia retusa* (Godapara), *Ficus racemose* (Attikka), *Isachne globose* (Batadal), *Lagenandra ovata* (Ketala), *Macaranga peltate* (Kanda), *Mikania cordata* (Wathupalu), *Mimosa pudica* (Nidikumba), *Moringa oleifera* (Murunga) *Pandanus kaida* (Watakeiya), *Piper betel* (Betel), *Schoenoplectus grossus* (Thunhiriya), *Terminalia catappa* (Kottamba), *Symplocos cochinchinensis* (Bombu),*Thespesia populnea* (Gansuriya), *Tithonia diversifolia* (Wal sooriyakantha), *Vateria copallifera* (Hal), *Vernonia cinereal* (Monarakudumbiya)

Common names are given in parentheses

Categories of plants species used in *Owita* system

According to the results of the study, there was no specific spatial arrangement of crops planted in an *Owita* system. Therefore, it was difficult to develop a realistic model to represent the crops, crop combinations and their arrangement within the *Owita* system. However, according to the outcomes of the present study, and using the only scientific information given by Wijesekara and Hunter (2010), we could identify ten major categories of plants within the *Owita* cultivation system. The identified ten categories of plants are listed below.

1. *Hedgerow plants*: Hedgerows are used to demarcate the upper boundary or lower boundary of the *Owita* system. It is referred to as "*bada-wetiya*" by the local community and is mostly dominated by woody perennials. When the hedgerow consists of only *Areca catechu,* it is locally referred to as "*puwak-aramba*". Usually, *Giliricidia sapeium* is common in upper

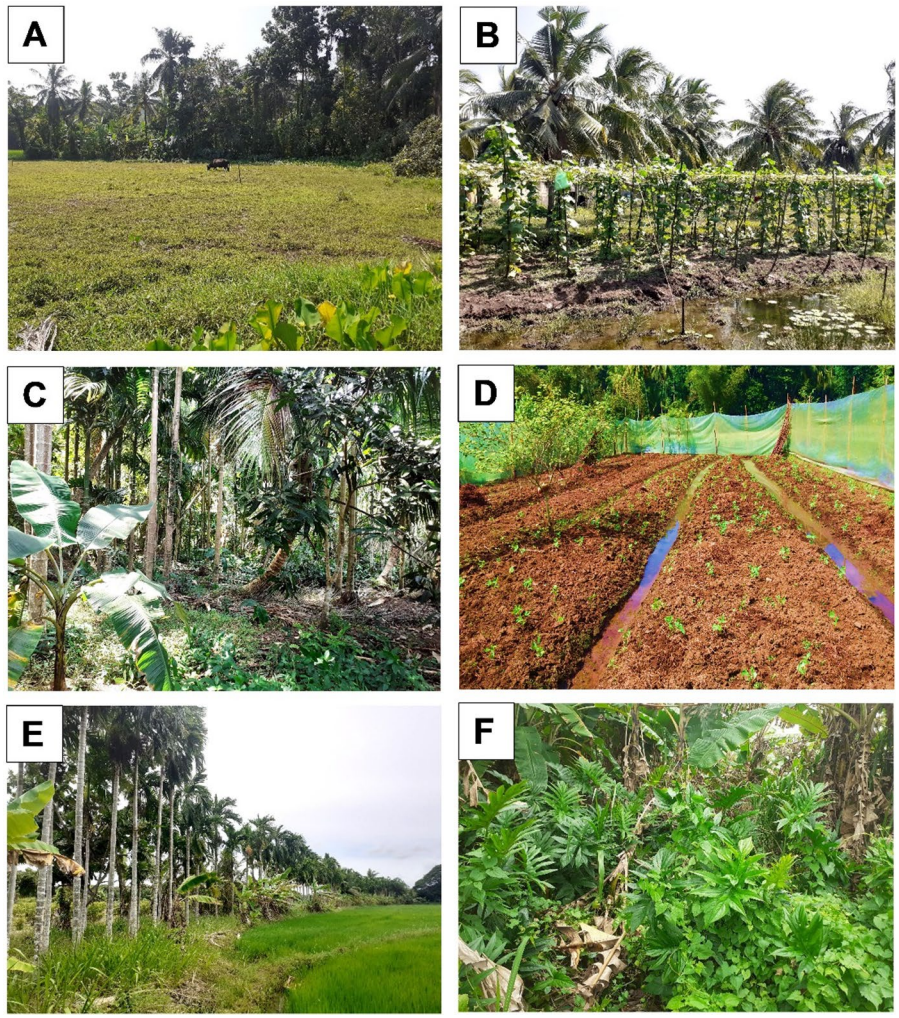

Fig. 6 A few of the surveyed *Owita* systems and their plant compositions. **A** An abandoned *Owita* land over the last 10–15 years. **B** A successfully cultivated land with snake gourd and bitter gourd. **C** A transformed *Owita* system into perennial-based mix cropping system. **D** Just after the transplanting of vegetable seedlings. **E** A well-established hedgerow of areca nut and banana. **F** *Lasia spinosa* cultivation in *Owita* land

boundary hedgerows whereas the lower boundary comprises *Annona glabra*, *Cerbera mungha* and other species which can tolerate submerging conditions. In common, *Areca catechu was* found in both boundaries.

2. *Cyperus bed*: It is locally referred as "*pan-wila*" which is dominated by *Cyperus corymbosus*, a perennial grass-like plant in which, dried culm is used in making basketry, hats, matting and making ropes. Though it appeared as an essential crop in the traditional *Owita* system in some areas of the Wet zone, it has been disappeared from the modern *Owita* system. Apart from *Cyperus corymbosus, Eleocharis dulcis* is also grown for the same purposes.
3. *Betel trellis*: Usually betel trellis (*Piper betel*) is located close to the upper boundary of *Owita* and grown in raised beds to minimize the damage from seasonal flooding. Betel leaves, which are known as "Green gold" traditionally have been used for chewing with areca nuts by the local community.
4. *Clumps of Banana*: *Musa x paradisiac* (Banana) is one of the common species found in *Owita* system and usually grows near the upper boundary. Banana shows a wide range of genetic variation within agricultural ecosystems and are consumed either as fresh fruits or in cooked form.
5. *Clumps of Sugarcane*: *Saccharum officinarum* (Sugarcane) is a ratoon crop that is consumed as a refreshing dessert. The clump of sugarcane was a main candidate in traditional homegardens or *Owita* systems in the earlier days. Cur-

rently, it can rarely be found in either homegarden or *Owita.*

6. *Lasia cultivation*: *Lasia spinosa* is a spiny aroid and is commonly consumed as a leafy vegetable. Due to its amphibious nature, it has become an essential component in both traditional and improved *Owita* systems. *Lasia* cultivation is locally known as "*kohila wala*" or "*kohila kotuwa*".
7. *Fruit and vegetables*: Usually vegetables are commonly cultivated in *Owita.* Of which, *Abelmoschus esculentus*, *Solanum melongena*, *Solanum insanum*, *Lagenaria sciceraria*, *Cucumis sativus*, *Momordica charantia, Vigna cylindrical*, and *Musa x paradisiac* were mostly found.
8. *Leafy vegetables*: Leafy vegetables play a key role among crops of traditional *Owita* cultivation and currently some *Owita* systems are transformed into a monoculture of high-demanding leafy vegetables. However, most of the *Owita* are occupied by *Alternanthera sessilis*, *Amaranthus dubinus* and *Sesbania grandiflora* as leafy vegetables. Apart from that some of the indigenous and underutilized leafy vegetables are also cultivated by some farmers.
9. *Root and tuber crops*: *Xanthosoma sagittifolium*, *Plectranthus rotundifolius*, *Dioscorea* sp., *Ipomoea batatas* and *Manihot esculenta* are the commonly cultivated root and tuber crops. Cultivation of root and tuber crops is challenged due to frequent flooding and wild animal attacks in *Owita* system of peri-urban areas.
10. *Medicinal plants*: A few numbers of medicinal plant species are been cultivated in *Owita* which are used as home remedies (*Bacopa monnieri*, *Hygrophila schulli*, *Eclipta prostrata*) by the local community. Apart from their medicinal use, they are used in various traditional cuisines as well. Also, some medicinal plant species are found naturally occurring in the *Owita* system.

The 115 recorded species showed clear stratification and are vertically arranged in three distinct layers (ground layer, 0–1 m; mid layer, 1–4 m; and dominant layer, > 4 m). The dominant layer (> 4 m) encompasses higher diversity as compared to the other two layers. Figure 7 shows the plant species found at different plant height levels in *Owita* systems.

Ecosystem services

While no formal assessment has been conducted to evaluate the ecosystem services provided by the *Owita* system, our observations and information gathered directly from farmers indicate that, apart from its economic potential, *Owita* offers numerous environmental benefits within the evolving peri-urban landscape. Farmers have emphasized its significant contribution to flood control, citing their long-term experiences. Given *Owita*'s resemblance to inland freshwater marsh, its water storage capacity appears relatively high. As they further mentioned, the present-day reclamation of some *Owita* land and its conversion into different landscapes will create numerous problems regarding controlling flood situations in urban areas.

Owita provides habitats for a wide array of plant and animal species. The current study reported 57 native, 7 endemic, and 9 naturalized exotic species within *Owita* systems, including underutilized fruits, vegetables, and wild relative of cultivated crops. Thus, the conservation of plant genetic resources and associated traditional knowledge are also major services provided by this agroecosystem. Although this

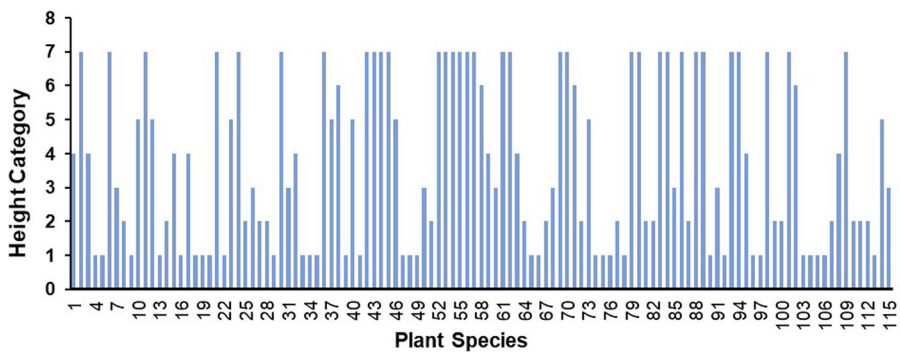

Fig. 7 Number of species under seven height categories (1: 0–0.5 m, 2: 0.5–1.0 m, 3: 1.0–2.0 m, 4: 2.0–3.0 m, 5: 3.0–4.0 m, 6: 4.0–5.0, 7: 5.0 <). *Note*: The scientific names, families, common names, plant habits, life forms, average plant heights, and types of crops for the 115 species shown in Fig. 7 are provided in supplementary file 1

study did not focus on faunal diversity, during our assessment, we observed that *Owita* serves as a resting place and breeding ground for a number of animal species, particularly birds and insects. However, within the urban setup, having such a traditional landscape is vital due to its unique role in conserving both flora and fauna.

It is also important to understand the contribution of the *Owita* ecosystem in controlling heat and creating a cooling environment for the community living there. Some respondents emphasized that despite a significant increase in temperature over the last few decades, they feel much more comfortable due to managing both the homegarden and *Owita* together. We also observed that as *Owita* gradually transforms into a perennials based system, their justification becomes more valid. However, conducting a comprehensive and long-term assessment is essential to fully understand the contribution of the *Owita* system in managing and balancing environmental stability and providing services.

Socio-economic aspects

Owita cultivation is focused on the production of food plants, particularly vegetables and leafy vegetables. Moreover, the cultivations are directly aimed at financial outcomes. In comparison to other modes of cultivation, minimum usage of agrochemicals is a unique feature of this *Owita* system. Hence products of the *Owita* system have a high potential to create a niche market and high demand compared to fruits and vegetables which come from other commercially oriented food production systems. In contrast to homegardens, it does not show diversification in terms of products and services. It is a site-specific model and can cultivate a narrow range of crops, particularly crops with high adaptability for water lodging or flood-prone conditions. Currently, flooding is not frequent in *Owita* and is gradually transforming towards perennial-based cropping systems in many areas. Moreover, in some areas, traditional *Owita* has transformed to highly commercialized leafy vegetable cultivations which are locally known as "*Keera kotu*". Currently, the traditional *Owita* systems have encroached on various development activities, especially other cultivations and numerous constructions. In some areas, it has merged to either homegarden or paddy field, thus it appears as an extension of the homegarden or paddy field. However, the economic potential and social value of this lesser-known system need to be properly understood and required to be developed as a sustainable cropping unit while paving new avenues for subsistence farmers in peri-urban areas.

Limitations and constraints

Traditional and lesser-known farming systems are disappearing gradually due to water deficit, incompatibility with modern agricultural knowledge and technology, loss of interest in farming continuity and natural disasters. The present study also encountered several issues related to *Owita* systems. Seasonal flooding is one of the major problems they face. During the monsoonal rains, flooding is a frequent event in some areas of the Wet zone. As a result, fluctuating groundwater levels are one of the characteristic features of *Owita* systems. Hence, the land will inundate and create submerging conditions even due to a little change in the water table. Usually, vegetables and leafy vegetables grown in the *Owita* are highly sensitive to water lodging conditions. Moreover, due to the seasonal flooding, crop diversification is less possible in *Owita* system as compared to the adjacent homegarden system and therefore, it is restricted to a limited number of vegetables.

Usually, the owners of the *Owita* systems are subsistence farmers and they are engaging with farming as an alternative income source. Hence, they are not fully committed to the cultivation of *Owita* with much interest and attention. The study encountered it as a major impediment to develop and manage this unique system as a highly productive farming system. In some areas, farmers need to make additional efforts to protect their cultivation from wild animals such as wild boar, rats, porcupines and peacocks. Apart from that, issues related to land ownership, labor shortage and availability of planting materials, and poor financial status have been identified as other related problems of *Owita* cultivation. Since this is a lesser-known cultivation system, farmers do not have the support and guidance from government and private sector organizations as for the other popular cultivations.

Discussion

Despite its characteristic small land size, Sri Lanka is rich in biological diversity and home to a wide range of agricultural ecosystems with over 80% of its food producers being small-scale farmers (Gunaratne et al. 2021). Unarguably, such agro-ecosystems encompass diverse and unique agro-biodiversity including important crop genetic resources and indigenous knowledge associated with traditional farming. Such ecosystems have been identified as hotspots for wild, neglected and underutilized food plants (Ratnayake et al. 2023). From the current study, it was also confirmed that *Owita* system is rich in agricultural diversity and it significantly contributes to the conservation of crop genetic resources. Having 115 plant species in urban agroecosystems is significant, showcasing the potential for developing this neglected system to uplift the economic status and wellbeing of the peri-urban community.

Although all the *Owita* systems studied were distributed across three adjoining districts within the agroclimatic zone of the Wet Zone Low Country, the soil and climate conditions were largely similar across these districts. These administrative boundaries did not correspond to distinct agro-ecological or climatic differences. Due to the shared similarities in soil, climate, and ecosystems among the districts, we did not observe significant differences in plant species diversity and their distribution patterns across the 35 Owita systems studied. Nevertheless, the results of vegetation analysis will serve as valuable baseline information for future research on this often overlooked agroecosystem.

While this study aimed to demonstrate the impact of the *Owita* system on improving farmers' livelihoods, it faced challenges in providing concrete facts and figures regarding the increase in farmers' income levels. Despite this limitation, the study made a substantial contribution to enhancing their living standards. Through interviews, it became evident that farmers lacked sufficient knowledge to provide quantitative data on income and expenditure. Many were unable to accurately report their earnings and expenditures related to cultivation and other farming practices. However, it was observed that the *Owita* system significantly contributed to improving their economic status.

Furthermore, it was noted that many farmers had limited education and struggled to answer some questions. The majority of them came from traditional backgrounds and belonged to underprivileged segments of society. Nevertheless, the study acknowledged the future potential of the *Owita* system in developing a more sustainable framework that supports the upliftment of peri-urban communities in specific areas. Therefore, a comprehensive study including economic analysis is warranted as the next step. In this context, we provide baseline information to facilitate future research, particularly in conducting cost–benefit analyses of this vital agroecosystem.

Most of the Sri Lankan agricultural systems are principally based on two cultivation seasons which are decided by the annual rainfall distribution pattern which governed by the monsoonal rains. Rice-based cropping systems, low-country vegetables and other field crops (grain legumes, cereals, and oilseed crops), and shifting cultivation are some of the well-known examples of such systems. However, the homegarden system and *Owita* ecosystem are the best examples of a well-adapted year-round cultivation system in Sri Lanka (Pushpakumara et al. 2010; Wijesekara and Hunter 2010). Regardless of the seasonal effect, both systems can successfully maintain throughout the year as a sustainable farming unit. From the present study, it was also evident that despite the major cultivation seasons, farmers attend to cultivate *Owita* system throughout the year. As per the information collected from farmers during the study, unlike in the past, the present-day *Owita* system is not frequently exposed to continuous flooding due to the measures that have been taken to mitigate flooding in urban areas. Hence, cultivations are not frequently interrupted due to seasonal floods. Therefore, farmers can successfully maintain the *Owita* as a sustainable year-round cultivation with low or minimum inputs. However, *Owita* ecosystems in *Kaluthara*, *Ranthnapura* and *Galle* are vulnerable to the unfavorable effects of the south-west monsoon. Hence, special attention is needed to minimize crop damage due to seasonal flooding in these areas. To overcome such situations, farmers are advised to follow an appropriate cropping calendar and select appropriate crop combinations to maintain the system as a year-round cultivation.

Undoubtedly, the most important service provided by agriculture is the provision of food, fuel, and fiber. Grain, livestock, fuel, forage, and other products are

used to meet subsistence or market needs, usually disregarding the provision of other services (Swinton et al. 2007). Apart from that, several other direct or indirect services are also provided by the tropical agricultural ecosystems. Characteristically, the *Owita* system closely resembles the wetland ecosystem. Due to the high water table and frequent flooding, it creates an amphibious environment where it provides food and habitat for the wildlife in urban areas. Moreover, relatively less usage of agrochemicals in this unique farming system makes a healthy environment for many macro- and micro-organisms.

Apart from that, *Owita* system also has a potential to provide numerous services given by other agricultural ecosystems, such as carbon sequestration and storage, erosion prevention, air and water pollution control, nutrient recycling, protection from natural disasters, pollination and, pest and disease management (Swinton et al. 2007). Since the traditional *Owita* system transforms towards a perennial-based system, it will significantly contribute to maintaining the natural balance of the ecosystem. However, a proper evaluation or estimation of the actual value of ecosystem services provided by this important *Owita* system has not yet been carried out. Hence more systematic and comprehensive assessment is required for the valuation of this lesser-known biological asset in Sri Lanka.

The importance of tropical agricultural landscapes to global conservation is widely appreciated due to the rapid conversion of natural ecosystems for agriculture and the limitations of protected areas for conserving biological diversity (Rodrigues et al. 2004; Foley et al. 2005; Chandler et al 2013). Being a tropical island with unique climatic and topographical characteristics, Sri Lankan agricultural ecosystems are home to rich agrobiodiversity and are known to provide a wide range of ecosystem services. The current study also reported 57, 7 and 9 native, endemic and naturalized exotic species in *Owita* systems, respectively. It includes underutilized fruits, vegetables and crop wild relatives as well. Ratnayake et al. (2023) also highlighted the importance of the Owita system in conserving wild and indigenous food crops and their contribution to future food and nutritional security. The Wet zone of Sri Lanka is highly vulnerable to loss of biodiversity in natural ecosystems as well as loss of crop genetic resources in agricultural ecosystems (Gunawardene et al. 2007; Gunatilleke et al 2008). Hence, preserving lesser-known and underutilized tropical agricultural systems is of paramount importance in terms of the conservation of biological diversity in urban and semi-urban areas. Moreover, such ecosystems provide food and habitats for wildlife while maintaining the natural balance of elements and services of agricultural ecosystems. By considering all the facts, unarguably, the *Owita* system can be identified and defined as a natural refugium for plant genetic resources in urban areas of the wet zone of Sri Lanka.

Conclusions and recommendations

Owita system has the potential to improve as a sustainable agricultural system. Since it is a site-specific model, it is vital to understand and identify the suitable crops or crop combinations for cultivation in each agro-ecological region. Moreover, because of fresh products and the minimum use of agrochemicals, it is not a challenge to find a market for crops produced in *Owita* systems. This agricultural system can be easily promoted to organic crop production units to cater to the existing demand for organic food mostly among urban communities or in the international markets. It may result in an additional income source for urban communities those who are not involved in full-time farming. Further to that, there is a high potential for *Owita* to develop as a perennial-based cropping system or agroforestry system. Hence, it is important to adequately understand the environmental, economic and social values of *Owita* system to popularize it as a sustainable agricultural ecosystem, particularly in peri-urban areas of Sri Lanka.

The current study also evident that *Owita* system is home to rich agricultural diversity including indigenous and underutilized crops, wild relatives of cultivated crops and other commonly cultivated species. The record of 115 different plant species belonging to 49 families is a considerable number found within a agricultural ecosystem. It was ranged from native wild species to highly commercialized crop species. Results further revealed that despite its economic potential, it significantly contributes to the sustainable utilization and conservation of crop genetic resources in peri-urban areas. Since this unique system is mainly found in peri-urban areas, such areas are much benefit from the *Owita* system

to maintain the natural balance of the ecosystem, wildlife conservation, control seasonal flooding and mitigate extreme climatic conditions.

Apart from its ecosystem services, it opens up new business ventures for subsistence farmers in peri-urban areas. Moreover, the products from the system possess high demand and high value due to freshness and minimum usage of agrochemicals. We propose conducting a detailed and comprehensive assessment of cost–benefit analysis to understand how this system contributes to uplifting the economy of peri-urban communities. Furthermore, understanding the marketing channels is crucial for enhancing its commercial viability.

The study identified labor shortage, seasonal flooding and ownership of land as major limitations associated with *Owita* cultivation. Despite the above constraints, many farmers expressed their willingness to continue with *Owita* cultivation using modern farming techniques and high-yielding crop varieties. Hence, *Owita* system should not be neglected or isolated and needs to be further investigated to understand its socio-economic potential, environmental and agricultural values. Based on the results of this study, the *Owita* system can be identified as a high-potential and sustainable agroecosystem that provides multiple benefits to the subsistence farmers and contributes to maintaining the natural balance of the ecosystems in peri-urban environments.

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Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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